7-15-1999

Exotic Policy: An IJC White Paper On Policies for the Prevention of The Invasion of the Great Lakes by Exotic Organisms

Eric Reeves
U.S. Coast Guard

Exotic Policy

An IJC White Paper
On Policies for the Prevention of
The Invasion of the Great Lakes by Exotic Organisms

July 15, 1999
Eric Reeves

§ 1. Introduction: Coming to terms with the issue

About ten years ago, the Great Lakes environmental community initiated the first action to counteract the worldwide spread of exotic organisms in ballast water. In 1988, in response to the discovery of the ruffe and the zebra mussel in the Great Lakes, the Great Lakes Fishery Commission and the International Joint Commission called upon the Canadian and United States Governments to act. In 1989, Canada issued the first voluntary ballast exchange guidelines. In 1990, the United States passed the first major piece of legislation on aquatic nuisance species, mandating consultations and studies on all pathways for aquatic invasions. And in 1993, the US Coast Guard issued the first set of mandatory regulations for controlling ballast water in the Great Lakes. The issue is now on the global agenda. The International Maritime Organization, under pressure from Canada, the United States, and Australia, has issued similar guidelines and begun to consider a mandatory international convention. The United States enacted a second major piece of legislation in 1996, making it a national issue, and Canada enacted legislation authorizing national mandatory regulations to control ballast water in 1998.

This paper has been prepared as part of the International Joint Commission Workshop on "Exotic Policy" on September 23, 1999, in Milwaukee, Wisconsin. The workshop and the white paper are cosponsored by the Great Lakes Fishery Commission and the Michigan Department of Environmental Quality Office of the Great Lakes (MDEQ OGL). Some of the research supporting the white paper was conducted as part of a project previously funded by MDEQ OGL. The author served for five years as a senior US Coast Guard staff officer responsible for oversight of Coast Guard environmental programs in the Great Lakes, including the Great Lakes regime for control of exotic species in ballast water. He has a JD and an MA in political science (and is about to begin doctoral studies in international affairs and environmental policy at Carleton University in Ottawa). His works on the subject of exotics include M. Eric Reeves, "Techniques for the Protection of the Great Lakes from Infection by Exotic Organisms in Ballast Water," in Frank M. D'Itri, ed., *Zebra Mussels and Aquatic Nuisance Species* (Chelsea, MI: Ann Arbor Press, 1997) 283-299, and Eric Reeves, *Analysis of Laws & Policies Concerning Exotic Invasions of the Great Lakes*, a report commissioned by MDEQ OGL (Lansing, MI: MDEQ OGL, March 15, 1999).

Significant assistance in the preparation of this paper was provided by Ms. Margaret Dochoda, a biologist on the staff of the Great Lakes Fishery Commission, who has published a number of papers on the subject of fisheries management in the Great Lakes, including Margaret Dochoda, "Meeting the Challenge of Exotics in the Great Lakes: The Role of an International Commission," *Canadian Journal of Fisheries and Aquatic Sciences* (1991), vol. 48 (Supplement 1), pp. 171-176.

All opinions and errors are those of the author, and this paper does not constitute a policy statement of the IJC, the GLFC, or the MDEQ OGL. The purpose of this paper is to provide a basis for discussion.

With support from the Great Lakes environmental community, and with valuable assistance from distant allies in Australia, a Great Lakes regional coalition of binational, federal, state, and provincial agencies seems to have made considerable progress on the problem of exotics in these last ten years. In terms of public education and political rhetoric, the effort has been a great success. We have seen the transformation of what was an arcane and poorly understood issue – an issue which was somewhat "exotic" in political terms even within the special culture of the environmental community – into an issue accepted as worthy of attention, even if still sometimes poorly understood, by the mainstream public and their political leadership. Moreover, the enactments of the first major pieces of legislation in the US and Canada, even if largely tentative and inchoate, have come relatively quickly in comparison to the history of legislative efforts on other forms of pollution.

But there are two reasons to be cautious about this apparent success. First, the nature of the problem is inherently acute. As a matter of biological reality, exotic invasions are irreversible. This is a form of pollution that can never be cleaned up, and new invasions compound the damage already done to a stressed ecosystem. Second, much of the progress in developing legal regimes is illusionary – or worse. Although the Great Lakes mandatory regulations issued in 1993 were an essential first step, they are fundamentally flawed. So is the design of the national regime being developed in the United States, especially because of an alteration in the terms of that legislation obtained by the shipping industry as it was rewritten from a Great Lakes to a United States regime. The international convention being negotiated at the International Maritime Organization in London sounds as though it would be a good thing. But it contains the same flaws – and one more. Under some versions of the convention under negotiation, it would prohibit the enforcement of stronger provisions enacted by national and subordinate governments. These are matters that require close attention.

Also, ballast water is not the only pathway for invasion. Although the state and provincial governments in the Great Lakes region have a wide array of legal authorities and programs for the control of exotics, they are far from being uniformly strong or consistent in their terms. There are substantial issues about some major vectors – aquaculture, bait transportation, and the aquarium trade – which beg for attention. There is an obvious need for better coordination of strategies and enforcement policies at the federal, binational, and regional levels.

Those are some of the points addressed in this paper. The purpose of this paper is also to provide a common body of facts and ideas to assist in the discussion of "exotic policy" – the public policy for dealing with the invasion of the Great Lakes by exotic organisms – at an IJC workshop to be held with the 1999 Great Lakes Water Quality Forum.[1] I attempt to sum up the essential biological, technical, legal, economic, and political aspects of this complex, newly emerging environmental issue. I try to do that in an objective and analytical

[1] Information on the 1999 Great Lakes Water Quality Forum, September 23-26, 1999 in Milwaukee, Wisconsin, is available on the IJC web site at http://www.ijc.org./milwaukee/index.html.

manner. But I also try to be honest about my point of view, which is distinctly biased in favor of environmental conservation and the proposition that our current policies for the prevention of exotic invasions are inadequate. All that might be impossible. But I hope that this will, at least, provide a basis for stimulating discussion.

It is basic to the nature of most environmental problems, and certainly true of the problem of exotic invasions, that they involve disparate social communities. There is often a wide gulf between the "public interest groups" or the "environmental community" concerned with the damage being done to natural resources and the "economic interests" or the "business community" who are equally concerned about the cost of regulatory programs. Both claim, with some justification, to represent the wider "public interest." Both are in fact legitimate "special interests" appealing to a wider public interest in very different terms, based on different values. One of the major problems to be dealt with, analytically and politically, is the problem of evaluating these competing claims on the general interest. It is not helped by the fact that these opposing communities often speak in different terms, almost different languages. The need to preserve "priceless resources" and a "vision of the future" is countered by the need to avoid "increasing costs" and undermining "economic development." Nor does it help that the government bureaucrats who are supposed to fairly balance the two interests seem to speak an entirely different language of "regulatory process" and "cost/benefit analysis."[2] It is almost as bad when they get down to concrete details and bring in their experts. Aquatic biologists look at ballast water as an environment for limnetic and benthic organisms which alter the energy balance or competitive characteristics of native ecosystems. Marine engineers look at ballast water in terms of metric tonnes and flow rates which alter safety parameters and competitive cargo rates. The lawyers (you cannot forget about them, no matter how much you might want to) look at it in terms of statutory definitions of "pollution," questions of "preemption," enforcement standards, and exemptions.

I will attempt to bridge these divides – to provide a guide to the perplexed and a means to translate among these groups. In the course of doing so, however, I will introduce another language not normally used by any of them, but one which is essential to understanding what it all means. This is the language of political economics. This is the perspective which sums up all human problems in the terms of "markets," "externalities," "values," "optimality," "rational choice," "institutional structures," "transaction costs," and "game strategies." To some, this sort of talk is the most offensive of all. To some environmentalists, this is pseudoscientific jargon for selling out on fundamental human

[2] Some environmentalists feel that cost/benefit analysis (or "risk/benefit analysis") "is the invention of those who do not wish to regulate, or to be regulated, and…its primary use in governmental decision-making is to avoid taking action which is necessary or desirable in order to protect the health of the public or the integrity of the environment." Burke Zimmerman, "Risk-Benefit Analysis: The Cop-out of Government Regulation," *Trial* (February 1978), p. 14, quoted in Steven E. Rhoads, *The Economist's View of the World: Government, Markets, & Public Policy* (New York: Cambridge Uni. Press, 1985), p. 132. The business community, on the other hand, usually views the cost/benefit analyses, or "economic impact statements," attached to regulatory proposals with the same skepticism with which environmentalists view environmental impact statements. They seem to be no more than ad hoc justifications for policies already decided upon for political purposes.

values. To some industrialists, this is the babble of a bunch of ivory tower intellectuals telling them how to manage a business they know nothing about. It should, in fact, be language which is quite understandable by biologists and other environmental scientists, because it is built upon the same principles which govern natural selection and evolution.[3] Despite that, however, there is a regrettable divide between the way that a biologist and a political scientist (such as myself) look at the world. I hope to convince you that there is a basis for translating between these communities, and that there is a potential for meaningful dialogue here. Dialogue, however, is not the same as agreement. Because of the difference in the interests of the opposing groups, there will be, inescapably, vehement disagreements on the primary policy questions. I will not attempt to paper over that whatsoever. But I will try to provide a basis for dealing with those disagreements in a rational way.

My primary focus is on the predominant vector for new invasions of the Great Lakes – ballast water. But I also review the threat from certain "commercial uses" of exotics – aquaculture, bait, and aquaria. The following sections provide a biological threat assessment, a description of the relevant industries, a review of legal regimes in the Great Lakes region, the United States, Canada, and the world, and then, finally, a suggested framework for analysis of the economics and politics of exotics. This paper is organized so that you do not need to read all of it, or read it in any particular order. As much as possible, each main section stands by itself, and I have included an appendix on terms and acronyms to help translate the language from various disciplines. Some of it is very concrete and detailed. Some of it is rather philosophical. It is an attempt to lay out all relevant aspects of the issue. And some of it is wrong. There will no doubt be places where I have misstated something from the literature outside my own areas of expertise, or where my interpretations could benefit from contrary views. I hope to receive those corrections and hear those contrary views at the IJC workshop.

I begin by reciting the basic facts, familiar to many, about the damage done by exotics. But let me also warn the reader that this misses the main point of the problem. Too much of our current effort in the environmental community, in terms of actual research dollars[4] and intellectual capital, is spent on continuing refinement of the diagnosis of the disease. That is entirely valid scientific work as far as it goes. But it has too often been an excuse for the lack of action on curing the disease. There seems to be an assumption that one more study documenting the ecosystem effects or economic costs of the zebra mussel will finally prompt the necessary action. But any assumption that we have failed to take effective action

[3] See Geoffrey M. Hodgson, *Economics and Evolution: Bringing Life Back into Economics* (Ann Arbor, MI: University of Michigan Press, 1996).

[4] A survey conducted by the Great Lakes Commission Panel on Aquatic Nuisance Species found that less than 5% of the money spent on research related to exotics in the Great Lakes was focused on prevention of new invasions. Projects were divided into 6 general categories, (1) biology and life history, (2) control and mitigation, (3) ecosystem effects, (4) prevention of introductions, socio-economic considerations and analysis, and (6) spread of established populations. "Forty percent of all projects fall within the Ecosystems Effects research category, with zebra mussel research accounting for 58 percent of total research expenditures. Projects in the Prevention of Introduction category account for only four percent of total research expenditures." GLC ANS Panel, *Aquatic Nuisance Species Research Relevant to the Great Lakes Basin: Research Guidance and Descriptive Inventory* (Ann Arbor, MI: GLC, June 18, 1997), p. 5.

because of a lack of information – even though better information would certainly help – is mistaken. We have failed to act because the industries which are the vectors for invasions, and which have no incentive to support meaningful action, have claimed ownership of the issue and captured the attention of the government agencies responsible for promoting the public interest. The general environmental community has remained more concerned with other pressing issues, such as toxics, habitats, and extinctions – and has failed to incorporate the synergistic interactions of exotics into their thinking about those other issues. Some specific sectors of the environmental community, or perhaps groups that we might call more traditional conservationists, have claimed ownership of the problem. But too many of them are more concerned with invasions which have already taken place, and they are noticeably absent at the councils in the higher levels of government, at the national and international forums, where critical decisions are being made. Understanding the biological threat is the first step, but only the first one.

On the whole, the problem of exotic species should be a relatively easy environmental problem. Unlike global warming, this does not require changes in life styles. Unlike toxic chemicals, this does not require significant changes in industrial infrastructure. This does not require massive expenditures or the invention of new technologies. With respect to the problem of exotics in ballast water – the vector which presents the greatest cost problem, but the one which also promises the highest payoff for preventative measures – the technologies for dealing with the problem already exist and the costs of implementing them are relatively low. That does not mean that the costs are inconsequential, or that they might not have significant effects on some sectors of the shipping industry. You will see many dollar signs in this paper, because I spend a great of time talking about costs. In the end, however, I submit that they are quite manageable. The double-hull requirement in the US Oil Pollution Control Act of 1990, alone, added 10%–20% to the cost of new tankers. We are talking here about costs more in the range of 1% of the cost of new construction. That is the good news. The bad news is that the problem of exotics in ballast water is especially time-sensitive. Every new invasion is irreversible. Yet, every year that we go on without incorporating some simple design changes in new vessel construction, we lose the opportunity to make those changes in vessels which will be in service 20 to 30 years – and which will be much more expensive to correct with later retrofitting.

Dealing with the other vectors of concern – aquaculture, baitfish, and aquaria – should be of minimal cost. It certainly does not require new technologies or limitations on the ability of those businesses to thrive. In fact, better coordination of policies among the multitude of jurisdictions already regulating those activities, and use of logical points in the stream of commerce to establish better quality control, are things which may benefit some of those businesses. That is the good news. But the bad news is that it is not being done.

Ten years is not a long time. But exotic invasions are for a very long time. The critical question for the reader of this paper or the participant in the IJC workshop is ask is whether or not the Great Lakes will really be any better protected ten years from now. In the end, I submit, the answer to that question lies not in biology and technology but in economics and politics.

§ 2. The continuing history of invasions: What they are, the damage they do, and where they come from

Not all exotics are detrimental. Only about 10% of the exotics introduced into the Great Lakes have been, but these "have had a significant impact on ecosystem health."[5]

§ 2.1. Exotic, ANS, NIS, or what?

What I am referring to generally as "exotics" are also commonly called "aquatic nuisance species" or "ANS." That term, although cumbersome, has the virtue of making clear that we are mostly concerned with undesirable aquatic invaders of the Great Lakes ecosystem. It is slightly misleading. The detrimental exotics are much more than just a "nuisance," and we sometimes have reason to be concerned about strains within species. They are also referred to in various places as "nonindigenous species" or "NIS," "non-native species," "harmful exotic species," "ecologically harmful species," or "unwanted aquatic organisms and pathogens," among other things. The most recent addition to the collection, deliberately chosen for the title of recent legislation in order to better mobilize political support, is "invasive species." Also, the term "biological pollution" has been floated lately. It has not yet caught on, but it has already been strongly objected to by some representatives of the shipping industry sensitive to the policy implications of such a term. This is exactly why it is used, and the debate about how ballast water should be regulated may well result in this term becoming more popular. I will speak of detrimental exotics as a form of "pollution," because that is exactly what they are in terms of both the technicalities of law and the theory of economics,[6] as well as common sense.

§ 2.2. Bad things in the water

The sea lamprey. One of the first invaders of the Great Lakes was the sea lamprey (*Peromyzon marinus*), a primitive but highly predacious parasitic fish, resembling an eel, anadromous, which was apparently introduced through the canal systems in the 1830s. In

[5] Edward L. Mills, Spencer R. Hall, and Nijole K. Pauliukonis, "Exotic Species in the Great Lakes: From Science to Policy," *Great Lakes Research Review* (February 1998), vol. 3, no. 2, pp. 1-7, 1. On the overall history of invasions of the Great Lakes, see also Edward L. Mills, Joseph H. Leach, James T. Carlton, and Carol L. Secor, "Exotic Species in the Great Lakes: A History of Biotic Crises and Anthropogenic Introductions," *Journal of Great Lakes Research* (1993), vol. 19, no. 1, pp. 1-54; and E.J. Crossman, "Introduced Freshwater Fishes: A Review of the North American Perspective with Emphasis on Canada," *Canadian Journal of Fisheries and Aquatic Sciences* (1991), vol. 48 (Supplement 1), 46-57.

[6] Re the legal definition of "pollution" as something including "biological material" or doing damage to "biological integrity," see the detailed review of US and Canadian statutes in Eric Reeves, *Analysis of Laws & Policies Concerning Exotic Invasions of the Great Lakes*, a report commissioned by MDEQ OGL (Lansing, MI: MDEQ OGL, March 15, 1999). Re the economic theory, see § 10 of this paper.

the 1940s, it devastated native populations of whitefish and lake trout which were worth $14 million a year back then in commercial takes,[7] and which probably would be at least a billion dollars per year in commercial and recreational value to the Great Lakes today.[8] Almost all of the other large fish species in the upper Great Lakes were also significantly affected by lamprey predation.[9] As bad as the sea lamprey has been, it has actually been much more susceptible to control than most other exotics. But control of the sea lamprey costs over $15 million per year,[10] and requires the introduction of tens of thousands of pounds of biocide into the lakes each year, as well as other control measures which are being developed to reduce that.[11]

The zebra mussel. The best known invader, detected in 1988, and the one that finally prompted the first political action to prevent new invasions, is the zebra mussel (*Dreissena polymorpha*). It was originally from the Black and Caspian seas, and was apparently introduced from Europe through the ballast water of oceanic shipping sometime before 1988.[12] It fouls industrial water systems, smothers and starves out other benthic organisms,

[7] William Ashworth, *The Late Great Lakes: An Environmental History* (Detroit, MI: Wayne State University, 1987), p. 120.

[8] The current Great Lakes fisheries, made up in large part of artificially stocked salmonids (and other fish) to compensate for the loss of the native whitefish and trout, are worth several billion dollars per year. Christopher I. Goddard, Executive Secretary, Great Lakes Fishery Commission, circular letter (July 8, 1997). One can argue that this replaces the original resource, and that the true cost of the lamprey is therefore only the cost of lamprey control measures plus the cost to the various agencies around the lakes of the stocking programs. It is unlikely, however, that these actually replace the abundance of the original populations. Despite the control measures, the lamprey continues to do substantial damage in some areas. The artificially stocked populations may be inherently fragile. And there are long-term costs in terms of disruptions of the ecosystem from the artificially stocked fish, no matter how good they are for fishing. See § 2.4, below, re intentional releases.

[9] The burbot (not a valuable commercial species) declined along with the whitefish and lake trout. High sea lamprey scarring rates on catostomids (suckers), walleye, and rainbow trout were reported frequently and fisheries for these species were also drastically reduced. After the lake trout and burbot were largely gone, the lamprey was forced to turn to the larger cisco species. By 1960–1961, the two largest species, *Coregonus johannae* and *C. nigripinnis*, were reduced to extinction or nearly so. Four other cisco species were seriously depleted. The bloater, *C. hoyi*, smallest of the cisco species, became abundant as the predators disappeared. In the late 1940s, another exotic from the Atlantic Ocean, the alewife, entered Lakes Huron and Michigan, and flourished because of the absence of large predators. The alewife soon affected the species composition of those lakes, greatly reducing the abundance of many species, including the bloater, lake herring, yellow perch, and emerald shiner. B.R Smith and J.J. Tibbles, "Sea lamprey (*Petromyzon marinus*) in Lakes Huron, Michigan and Superior: History of Invasion and Control, 1936–78," *Canadian Journal of Fisheries and Aquatic Sciences* (1980), vol. 37, pp. 1780-1801.

[10] Christopher I. Goddard, Executive Secretary, Great Lakes Fishery Commission, circular letter (July 8, 1997).

[11] The biocide is 3-trifluormethyl-4-nitrophenol, or TFM. The average annual use of TFM during 1980-89 was 52,000 kilograms and for 1990-96 was 40,000 kilograms. Target use for the year 2000 is 26,000 kilograms. Gerald T. Klar, *Integrated Management of Sea Lampreys in The Great Lakes 1996: 1996 Annual Report to the Great Lakes Fishery Commission* (Marquette, MI: US Fish & Wildlife Service, 1996). The Great Lakes Fishery Commission is working to reduce the use of biocides, hopefully by as much as 50%, by use of alternative control measures such as river barriers and release of sterile males. Goddard, *ibid*.

[12] Edward L. Mills, Joseph H. Leach, James T. Carlton, and Carol L. Secor, "Exotic Species in the Great Lakes: A History of Biotic Crises and Anthropogenic Introductions," *Journal of Great Lakes Research* (1993), vol. 19, no. 1, pp. 1-54.

dramatically alters nutrient balances and lower food chains, and may play a significant role in making toxics more bioavailable. The zebra mussel is the "poster child" which led directly to both the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA 90)[13] as it impacted the Great Lakes, and to the National Invasive Species Act of 1996 (NISA 96)[14] as it spread through the Mississippi Basin and threatened the rest of the United States. It has been notable for the amount of direct economic cost it causes by clogging industrial water piping and almost anything else that touches the water. Estimates of the direct costs vary, but they range from hundreds of millions to a few billion per year. One of the most recent estimates puts the total cost of the zebra mussel to the United States (mainly the US Great Lakes and the Mississippi Basin) at $3 billion per year.[15] (One can assume comparable costs, relative to population and industry, to the Canadian side of the Great Lakes Basin.) These are "nuisance" costs. Although they are substantial (and have been responsible for the political attention), the damage in disruption of the native ecosystems of the Great Lakes may be much worse.

It is difficult to be precise. No invader, except perhaps the sea lamprey, has been studied as well as the zebra mussel. But the exact nature of its ecosystem effects is still being sorted out. It has certainly had a dramatic effect on other mollusks, and could well be leading to their extirpation or extinction. "The Lake St. Clair-Western Lake Erie corridor once had the richest and most diverse assemblages of large freshwater clams in North America. Within six years of the discovery of the zebra mussel in this region, freshwater clam populations in the region had declined to almost zero. Biodiversity has declined sharply as the functional community has shifted from a stable, slow-growing, multi-species clam community to a single-species population of zebra mussels with a relatively high turnover rate of energy that strongly affects ecosystem dynamics."[16] Other benthic organisms (things on the bottom) are impacted by the amazing ability of the zebra mussel to physically cover the bottom of shallow areas – some parts of Lake Erie appear to be carpeted by the things – which squeezes out habitats for a variety of other native organisms, including fish eggs. Limnetic organisms (things floating or swimming in the water column) are impacted by their consumption of nutrients.

More generally, the fact that zebra mussels are highly active filter feeders, who then spit out the end product of this process on the bottom as "pseudofeces," changes the whole "energy balance" or food distribution in the system. In the course of doing so they clarify the water column. They may have some desirable effects. Among other things, they may

[13] US Public Law 101-646 (November 29, 1990), codified at 16 USC §§ 4701 *et seq*.

[14] US Public Law 104-332 (October 26, 1996), making amendments to the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, US Public Law 101-646 (November 29, 1990), codified at 16 USC §§ 4701 *et seq*. Technically, the act is still "NANPCA" after the amendments by "NISA" in 1996. But "NISA" is being rapidly adopted as the popular name of the current law, if for no other reason than the fact that it is much easier to remember and pronounce.

[15] David Pimentel, "Environmental and Economic Costs Associated with Non-indigenous Species in the United States," unpublished paper presented to the American Association for the Advancement of Science, Anaheim, California, January 24, 1999.

[16] US Environmental Protection Agency (EPA) and Environment Canada, *State of the Great Lakes 1997* (Chicago, IL, and Burlington, ON: EPA and EC, 1997), p. 22.

help increase the production of native mayflies, which are important to desirable fish in the Great Lakes,[17] and they can make the water look cleaner. However, there are some distinctly undesirable side-effects of this "cleaning." The effect may be to concentrate toxic contaminates and make them more bioavailable. Sudden changes in light available to the bottom can cause blooms of submerged vegetation. And there is some indication that the mussels select out the more desirable algae, giving a competitive advantage to toxic algae. Overall – although research continues – the general consensus in the scientific community seems to be that, whatever benefit might be expected from zebra mussels cleaning up the water column is more than counteracted by the starvation of beneficial fish, concentration of contaminates in the food chain, and possible preferential selection of toxic algae.[18]

The ruffe. The ruffe (*Gymnocephalus cernuus*), referred to as either "European" or "Eurasian" ruffe (and pronounced "rough"), is another invader detected in 1988, just before the zebra mussel. It is a garbage fish from Europe and Asia, introduced through the ballast water of oceanic ships sometime before 1986, which has a high potential to displace native species. It illustrates the great difficulty of determining the precise nature of the economic and ecosystem effects. It has been largely confined for the time being to waters on the western end of Lake Superior, after being deposited there by the ballast water of international shipping calling on the Port of Duluth-Superior. (This is the largest Great Lakes port for shipping grain overseas, and therefore is also the largest recipient of overseas ballast water, which is pumped off when the vessel takes on cargo.) In 1993, the population of ruffe plateaued, and it has not yet broken out of Western Superior except for a small number discovered in Thunder Bay, Michigan, in 1995. The good news is that the ruffe, which does better in warmer water, has had difficulty migrating past the natural barrier of the cold waters in the central part of Lake Superior. The bad news, however, is that it is likely to eventually work its way along the shoreline, and make significantly faster progress once it breaks through the Kewennaw Peninsula. It is unclear whether the few ruffe found in Thunder Bay, probably brought there by internal Great Lakes shipping, are representatives of an established population.

The ruffe threatens to displace native fish because it has high rates of reproduction, is an efficient bottom feeder (eating a wide variety of foods, including the eggs of other fish), is tolerant of poor water conditions, and has few natural predators. Protective spiny fins make it an unsavory meal for the higher level-predators in the Great Lakes. Because the ruffe is still confined to a small area of cold water (despite its complete success in establishing itself there) it is difficult to predict its effect when it eventually breaks out to the rest of the Great Lakes. "Experience in Scotland and Russia, however, points to serious problems for North American fisheries if ruffe escapes from its limited range in western Lake Superior. In Loch Lomond, Scotland, native perch populations declined dramatically when the ruffe was introduced. In some Russian waters, the ruffe has harmed whitefish populations by preying heavily on whitefish eggs. Movement of the ruffe to the lower Great Lakes, or to inland

[17] EPA and EC, *ibid*., p. 23.

[18] See Glenn Zorpette, "Mussel Mayhem Continued: Apparent Benefits of the Zebra Mussel Plague are Anything But," *Scientific American* (August 1996), vol. 275, no. 2, pp. 22-23.

lakes and rivers, could have devastating consequences."[19] Valuable warm water fisheries in the lower lakes, such as the Ohio Lake Erie fishery worth about $600 million per year, could be significantly affected.[20]

Attempts to conduct an objective threat evaluation, a difficult exercise in prediction when dealing with any biological problem, have been complicated by a vehement policy dispute among fellow environmentalists about whether or not to try blocking the slow progress of the ruffe along the shoreline with biocides. When the Ruffe Control Committee of the US Aquatic Nuisance Species Task Force met to approve a cost-benefit analysis of the overall Ruffe Control Program, some committee members thought that "the projections were so unrealistic as to be useless." One participant was of the opinion that "arguments over economic impacts seemed to reflect policy interests; those opposed to aggressive ruffe control also opposed projecting impacts of ruffe."[21] Ironically, the shipping industry was able to play an entirely constructive and non-controversial role in the control program. The Canadian Shipowners Association and the US Lake Carriers' Association put together a voluntary program for the exchange of ballast water in the cold depths of Western Superior, by vessels leaving the ports of Duluth-Superior and Thunder Bay, in order to help slow down the spread. At this point, however, "prospects for controlling their spread in the Great Lakes are poor…."[22]

Other invaders. Other invaders of the Great Lakes which biologists believe to have had "significant impacts" include purple loosestrife,[23] the alewife,[24] furunculosis,[25] Eurasian watermilfoil,[26] and *Glugea hertwigi*.[27] This is the short list of the worst, out of more than 140 documented introductions to the Great Lakes since the 1800s.[28] (Others may make the

[19] Mike McLean, Minnesota Sea Grant Communications Coordinator, Minnesota Sea Grant web site at http://www.d.umn.edu/seagr/areas/exotic/ruffe.html (accessed July 14, 1999).

[20] L. J. Hushak, "Economics of Ruffe in the Great Lakes," Proceedings of the International Symposium on Biology and Management of Ruffe, March 21-23, 1997.

[21] Thomas R. Busiahn, "Ruffe Control: A Case Study of an Aquatic Nuisance Species Control Program," in Frank M. D'Itri, *Zebra Mussels and Aquatic Nuisance Species* (Chelsea, MI: Ann Arbor Press, 1997), p. 80.

[22] Busiahn, *ibid*., pp. 84-5.

[23] *Lythrum salicaria*, a robust aquatic weed which squeezes out other plants and animals, first recorded in 1869, apparently introduced by railroads or canals. Edward L. Mills, Joseph H. Leach, James T. Carlton, and Carol L. Secor, "Exotic Species in the Great Lakes: A History of Biotic Crises and Anthropogenic Introductions," *Journal of Great Lakes Research* (1993), vol. 19, no. 1, pp. 1-54.

[24] *Alosa pseudoharengus*, a garbage fish, prone to cataclysmic blooms and dieoffs, but with some use as feed stock, recorded in 1873. Like the lamprey, this may have been native to Lake Ontario, but apparently was introduced from the Atlantic by canals. Mills, *et al*. (1993), *ibid*.

[25] *Aeromonas salmonicida*, a bacterium pathogenic to fish, introduced to the Great Lakes, perhaps from Germany, by an unknown vector, sometime before 1902. Mills, *et al*. (1993), *ibid*.

[26] *Myriophyllum spicatum*, a robust aquatic weed which squeezes out other plants and animals, and also alters water temperature, spread from the Atlantic sometime before 1952, apparently by either aquarium release or transport in vessels. Mills, *et al*. (1993), *ibid*.

[27] A protozoan fish parasite, discovered in 1960, apparently introduced with its host, rainbow smelt, which was intentionally stocked in 1912. Mills, *et al*. (1993), *ibid*.

[28] Mills, *et al*. (1993), *ibid*., especially Figure 6, p. 43. On the overall history of invasions of the Great Lakes, see also E.J. Crossman, "Introduced Freshwater Fishes: A Review of the North American Perspective

short list after we get to know them a little better.) Note that this list includes more than just the larger organisms such as the sea lamprey and the zebra mussel. Those are the easiest to identify and study. But exotic species which may be of real threat include every form of flora and fauna up and down the taxonomic scale.[29]

§ 2.3. Dollars and damage

A 1993 study by the Congressional Office of Technology Assessment (OTA) attempted a comprehensive survey of all invasions of the United States – over 4,000 species, including 2,000 plants, 2,000 insects, 239 plant pathogens, 142 terrestrial vertebrates, 91 mollusks, and 70 species of fish. OTA reported in 1993 that the damage from those which are harmful runs anywhere from hundreds of millions to billions of dollars per year, but declined to offer precise estimates of the economic damage, or to put a value on what the OTA called "profound environmental consequences."[30] A more recent study at Cornell University in 1999 counted more than 30,000 exotics in the United States and totaled up the economic costs of the harmful ones at about $123 billion per year.[31] (This does not mean that the number increased so much during that time.) The accounting for specific categories of aquatic species is less impressive, but still amounts to real money. In addition to the zebra mussel's cost of $3 billion per year, the study found that the Asiatic clam costs the US about

with Emphasis on Canada," *Canadian Journal of Fisheries and Aquatic Sciences* (1991), vol. 48 (Supplement 1), 46-57.

[29] "Despite recent advances in our understanding of ballast-mediated transfer and invasion for marine species, microbial organisms have been virtually ignored in all ballast water and invasion research to date. In contrast to research on macro-plankton (organisms >60-80 microns): (1) patterns of microbial abundance and diversity associated with ballast water have not been measured; (2) we know virtually nothing about the dynamics, risk of invasions, or actual patterns of invasion for micro-organisms entrained in ballast tanks; (3) the impacts or potential impacts associated with invasions of micro-organisms have only been considered for a few species, although key information is still lacking; and (4) the efficacy of currently favored ballast management practices (to reduce the introduction of macro-plankton) has not been evaluated for micro-organisms. Yet, it is micro-organisms that are most abundant in the environment, arrive in the greatest numbers in ballast tanks, and probably have the greatest chances of survival. In addition, these organisms can have significant ecological and economic impacts on invaded communities." Smithsonian Environmental Research Center (SERC) Marine Invasions Research Laboratory "Chesapeake Bay Research Overview Chesapeake Bay Research Overview" at http://www.serc.si.edu/invasions/chesoverview.htm (accessed July 15, 1999).

[30] Office of Technology Assessment, *Harmful Non-Indigenous Species in the United States* (Washington DC: US Government Printing Office, 1993), p. 3, Table 1-1, and p. 5.

[31] David Pimentel, "Environmental and Economic Costs Associated with Non-indigenous Species in the United States," unpublished paper presented to the American Association for the Advancement of Science, Anaheim, California, January 24, 1999. Some of these figures need to be read with caution. For example, the Cornell study included the costs from domestic cats, which can certainly carry serious diseases and kill birds, but which have historically served a valuable economic function (quite aside from their considerable aesthetic value) in controlling human diseases and damage to grains caused by rats and other pests. (Economic costs of exotic rats came in at $19 billion per year.) However, few such compensatory qualities can be claimed for zebra mussels, the Asiatic clam, nuisance fishes, and aquatic nuisance plants.

$1 billion per year, fish cost another $1 billion per year, and aquatic plants cost $110 thousand per year.[32]

More importantly, exotic species are a threat to the survival of native species in the areas they invade and the long-term biological heritage of the human species. The Convention on Biodiversity identifies exotics and genetically modified organisms as major threats to global biodiversity.[33] Exotics "cause fundamental, irreversible alterations in the structure of communities through predation, competition, disturbance and the introduction of disease and parasites. No introduced marine organism, once established, has ever been successfully removed or contained…."[34] A recent study by the Environmental Defense Fund was one of the few attempts at a quantitative assessment of environmental threats. It found that invasions by exotics in general are second only to destruction of habitats as a cause of extinctions – although aquatic species are third, behind destruction of habitats and pollution, as a cause of aquatic extinctions.[35] (The study includes changes in aquatic habitat characteristics as a form of pollution. That, in fact, is one of the effects of some exotics.) A study by the American Fisheries Society found that 40 North American freshwater fishes have become extinct over the past century, and that exotics were a contributing factor in 68% of these extinctions. They also found that exotics are implicated in the decline of 42% of those species listed as threatened or endangered by the US Fish and Wildlife Service.[36] Mention of endangered species helps to put the problem into perspective, because what we are really talking about here is protecting endangered ecosystems. The damage may not be as immediate and dangerous to human health as toxic contaminants, but it is forever.

It might help to put the problem in perspective by comparing the damage done by exotics (and our political response to it) with oil spills. More than 10.8 million gallons of crude oil spilled into the waters of Prince William Sound when the tanker *Exxon Valdez* ran aground in 1989. This was the worst oil spill in US waters, and led directly to major new programs for prevention and response under the Oil Pollution Act of 1990 (OPA 90),[37] which are far more comprehensive (and expensive) than any of the analogous measures for the control of ballast water under NISA 96. Although the impact on life in the sound was devastating, it was temporary. It does not appear that any species was driven to extinction

[32] Pimentel, *ibid*. Cost of "aquatic plants" via personal communication from Dr. Pimentel.

[33] Convention on Biological Diversity adopted at Rio by the UN Conference on Environment and Development, "Earth Summit," June 5, 1992, article 8, §§ (g)-(h). The convention has been ratified by Canada, December 4, 1992, and signed for the United States, June 4, 1993, but not yet ratified by the US Senate. The text is available from the Secretariat of the Convention on Biodiversity, Montreal, at www.biodiv.org.

[34] James T. Carlton, "Biological Invasions and Biodiversity in the Sea: The Ecological and Human Impacts of Nonindigenous Marine and Estuarine Organisms," in *Nonindigenous Estuarine & Marine Organisms (NEMO)*, proceedings of workshop at Seattle, Washington, April 1993 (Washington DC: National Oceanic and Atmospheric Administration, April 1993), p. 8.

[35] David S. Wilcove, David Rothstein, Jason Dubow, Ali Phillips, and Elizabeth Losos, "Quantifying Threats to Imperiled Species in the United States," *Bioscience* (August 1998), vol. 48, no. 8, pp. 607-615.

[36] Bruce A Stein and Stephanie R. Flack, eds., *America's Least Wanted: Alien Species Invasions of U.S. Ecosystems* (Arlington, VA: The Nature Conservancy, 1996).

[37] US Public Law 101-380 (August 18, 1990), which made amendments to the Clean Water Act (Federal Water Pollution Control Act), 33 USC §§ 1251 *et seq*., and other places.

by the spill. Many of the affected populations have not fully recovered. Some have, including the salmon that is so important to the economy of the area. The Exxon Valdez Oil Spill Trustee Council, which oversees ongoing monitoring and restoration, predicts that "Complete recovery from the Exxon Valdez oil spill will not occur for decades," but also observes that "Based on results gathered to date, through restoration monitoring studies, it appears that affected systems and their constituent populations may regain normal species composition, diversity, and functional organization through natural successional processes."[38] Without minimizing the scope of that disaster, or discounting the possibility of unpredictable long-term impacts on some of the affected species, I would suggest that the long-term damage to aquatic ecosystems is far less than what is being done by the zebra mussel as it continues to spread through the Great Lakes and the Mississippi Basin. There will never be any recovery of "normal species composition, diversity, and functional organization" in this huge area of natural aquatic resources in the heartland of North America.

§ 2.4. Changing pathways for invasion over time

The primary vectors for exotic invasions of the Great Lakes have changed over time.[39] Whereas it was once canals and intentional releases which were the predominant vectors (or pathways), it is now ballast water and "unintentional releases." Ballast water is very likely to remain the predominant vector in the near future. (Other shipborne vectors, such as hull fouling, may also be a problem.) "Unintentional releases" from aquaculture, bait, and aquaria may be a significant problem in the future, but this is more debatable.

Canals. The sea lamprey and the alewife are characteristic of an older type of introduction. They were native to the Atlantic seaboard, perhaps even native to Lake Ontario, but spread upward into the whole Great Lakes ecosystem via the canals developed around the turn of the century. Purple loosestrife may have originally invaded the Atlantic seaboard via solid ballast in shipping, and then also followed the canals and railroads into the lakes around the turn of the century. That vector has declined in importance over recent decades, perhaps simply because the railroads and canals are already built and most of those organisms which could make use of the opportunity to spread around the continent on human transportation systems have already done so.

Intentional and "Unintentional" Releases. Furunculosis, a fish pathogen, and Eurasian watermilfoil are representative of another vector, or group of vectors. Furunculosis came along with trout and salmon which were deliberately introduced around the turn of the

[38] The Exxon Valdez Oil Spill Trustee Council web site, at www.oilspill.state.ak.us (accessed June 28, 1999).

[39] This discussion is based on the seminal work in Edward L. Mills, Joseph H. Leach, James T. Carlton, and Carol L. Secor, "Exotic Species in the Great Lakes: A History of Biotic Crises and Anthropogenic Introductions," *Journal of Great Lakes Research* (1993), vol. 19, no. 1, pp. 1-54, and Edward L. Mills, Spencer R. Hall, and Nijole K. Pauliukonis, "Exotic Species in the Great Lakes: From Science to Policy," *Great Lakes Research Review* (February 1998), vol. 3, no. 2, pp. 1-7.

century. Eurasian watermilfoil was probably introduced in aquariums, if not transported by recreational boats or shipping, and became established in the lakes around 1960. This sort of introduction is sometimes called an "unintentional release," defined to include "escape from cultivation, aquaculture and aquaria, and accidental releases due to fish stocking and from unused bait."[40] But the distinction between an "intentional" and "unintentional" introduction is fuzzy. For example, the US Aquatic Nuisance Species Task Force defines "escapes from aquaculture or aquarium facilities and activities such as dumping of baitfish and home aquarium species," along with deliberate fish stocking, as "intentional" introductions.[41] The difference is whether there is a focus on the initial introduction of the organism in a controlled setting, which is intentional, or the consequent escape of the organism into the natural environment, which is usually unintentional (but often easily foreseeable and negligent[42]).

Also, the Great Lakes are filled with exotic salmonids deliberately stocked by public authorities. This began in the 1870s and became accelerated with advances in culturing technology in the 1960s. Although they were selected for their beneficial characteristics, and are valuable to many people, they have detrimental long-term effects on native species and the integrity of the Great Lakes.[43] Some biologists hope that "the era of widespread, intentional introduction of salmonids and other fish species as a fishery management activity justifiably is drawing to a close."[44]

Ballast water. The zebra mussel and the European ruffe, most probably carried by the ballast water of transoceanic shipping and introduced sometime before 1988, are characteristic of most current introductions. Shipping was always a major vector, but it became more so, and has now significantly overtaken all other vectors, since the opening of the Saint Lawrence Seaway in 1959.[45] Before then, transoceanic ships could not enter the Great Lakes. Now they do, in numbers varying between four and six hundred or more per year, and a large number of them travel all the way in to Duluth or Chicago. Ships have become faster over the years, thus increasing the probability that organisms will survive on board during the voyage. They come to Great Lakes ports from all over the world, including many tropical ports, but about 70% participate in a "triangle trade" between the Great Lakes,

[40] Mills *et al*. (1998), *ibid*., pp. 1-7, 3.

[41] Aquatic Nuisance Species Task Force, *Findings, Conclusions, and Recommendations of the Intentional Introductions Policy Review*, report to Congress (Washington, DC: U.S. Fish and Wildlife Service, March 1994), p. i.

[42] See W.L. Shelton and R.O. Smitherman, "Exotic Fishes in Warmwater Aquaculture," in W.R. Courtenay, Jr. and J.R. Stauffer, Jr., ed., *Distribution, Biology, and Management of Exotic Fishes* (Baltimore, MD: Johns Hopkins University, 1984), pp. 262-301.

[43] C.C. Krueger and B. May, "Ecological and Genetic Effects of Salmonid Introductions in North America," *Canadian Journal of Fisheries and Aquatic Sciences* (1991), vol. 48 (Supplement 1), pp. 66-77; David O. Evans and Campbell C. Willox, "Loss of Exploited, Indigenous Populations of Lake Trout, *Salvenlinus namaycush*, by Stocking of Non-Native Stocks," *Canadian Journal of Fisheries and Aquatic Sciences* (1991), vol. 48 (Supplement 1), pp. 134-147; Paul J. Wingate, "US State's View and Regulations on Fish Introductions," *Canadian Journal of Fisheries and Aquatic Sciences* (1991), vol. 48 (Supplement 1), pp. 167-170.

[44] C.C. Krueger and B. May, *ibid*., p. 74.

[45] Mills, *et al*. (1993), and Mills, *et al*. (1998).

the Mediterranean, and Northern European ports. (See § 3.3 below.) Those areas, both ports of commerce in the times of the ancient Greeks, may be the most badly infected, "cosmopolitan"[46] waters in the world. (The zebra mussel was originally native to the Black and Caspian Seas. It first invaded the trade ports at the mouth of the Rhine in 1820-1830 before eventually being carried across the Atlantic to the Great Lakes in the 1980s.[47] The Mediterranean is currently being impacted by a "mutant seaweed," *Caulerpa taxifolis*, which seems to be as aggressive and as deadly to other benthic life as the zebra mussel.[48] Also, both North Atlantic and Mediterranean waters have been infected by exotics from North America.) The structure of this triangle trade, moreover, could not be much better designed for the transport of exotic pathogens. They are most likely to be present in large concentrations in warm waters, such as the Mediterranean. But they are more likely to survive the transoceanic voyage if refrigerated and made inactive by cool water, picked up in the North Atlantic. Exotics may be thought of as a form of plague. Unfortunately, shipping has always been an efficient means for spreading plague.

In sum, the great preponderance of introductions, throughout the whole history of the lakes, has been through two vectors, "unintentional releases" and shipping.[49] Along with a steady flow of introductions via unintentional releases, the increase in shipping introductions is responsible for a dramatic increase in overall introductions in recent decades. Biologists count 141 invasions of the Great Lakes during the 188-year span of 1810–1997. Of those, 43 (30% of the total number) have occurred in the 38-year period of 1960–1997 (20% of the time span) since the opening of the St. Lawrence Seaway, almost entirely from shipping and unintentional releases.[50] Introductions of exotics are on the rise.

§ 2.5. Future invasions

In both ecology and economics, it is a mistake to assume that a trend will continue at current rates of increase (that, in other words, the curve will continue to bend in the same direction[51]). It is perhaps dismal, but relevant, to ask whether or not the Great Lakes are

[46] "Cosmopolitan," which many of us think of as a good thing when referring to human societies which are more open and varied because of global influences, is an implicitly pejorative term of art in biology for the contamination of a local ecosystem to the point where it has lost its unique character. It also refers, without any positive or negative implication, to a species which is wide-spread around the world from either natural or anthropomorphic causes.

[47] Brian Morton, "The Aquatic Nuisance Species Problem: A Global Perspective and Review," in Frank M. D'Itri, *Zebra Mussels and Aquatic Nuisance Species* (Chelsea, MI: Ann Arbor Press, 1997), pp. 1-54, 16.

[48] Marlise Simons, "Mutant Seaweed Threatens Mediterranean Marine Life," *The Globe and Mail* (August 19, 1997).

[49] Edward L. Mills, Spencer R. Hall, and Nijole K. Pauliukonis, "Exotic Species in the Great Lakes: From Science to Policy," *Great Lakes Research Review* (February 1998), vol. 3, no. 2, p. 1-7, 4, figure 2.

[50] Mills, *et. al* (1998), *ibid*., p. 2, figure 1.

[51] Indeed, in both environmental studies and economics (as well as other fields) one usually expects to see the classic "bell curve" of distributions or "S-curves" of expansion and stabilization, both due to natural limits to growth and negative feedback mechanisms – systemic tendencies toward equilibrium. But that does not give one any basis for predicting ahead of time where that decline or point of inflection will occur. "In the long run, it will all work out," economists were once found of saying, and the paleontologist Stephen J. Gould

already so significantly impacted that the worst has already happened and there is little to be accomplished by future preventative efforts? Probably not. What little science there is to provide a threat assessment of future invasions seems to tell us that there is still a lot out there that could be harmful. And it is particularly relevant that even some of the most heavily infested waters around the world, such as the Mediterranean and the Northern European ports, continue to discover new invaders which could well be on their way to the Great Lakes.[52] For example, a review of the literature in 1998 identified 17 freshwater aquatic animals from the basin of the Black, Caspian, and Azov Seas which are prime candidates for invasion of the Great Lakes because they have recent invasion histories, are likely to be transported overseas in ship ballast water, and have broad salinity tolerance which could allow them to survive an incomplete ballast water exchange.[53] I trust the biologists will not be offended if we assume that there is much more out there that has yet to be identified. Moreover, the future potential for global warming and climate change in the Great Lakes may have totally unpredictable effects on the vulnerability of the Great Lakes to new invasions.[54]

The overwhelming importance of ballast water as the primary vector for current invasions is fairly well accepted. Aside from the obvious association of shipping with identified invasions in time (increases corresponding to the opening of the St. Lawrence Seaway) and space (Duluth-Superior Harbor), and the lack of other plausible vectors to explain many introductions, a number of actual studies of ballast water arriving in the Great Lakes have confirmed the presence of live organisms able to colonize a fresh water system.[55]

---

certainly agrees with that. But, as the economist John Maynard Keynes pointed out, and Gould emphasizes today with regard to environmental recovery, "In the long run, we are all dead." Keynes quoted in Robert L. Heilbroner, *The Worldly Philosophers: The Lives, Times and Ideas of the Great Economic Thinkers* (New York: Touchstone, 6th ed., 1986), p. 263. Gould makes the point about the likelihood of the long-term recovery of the planet Earth, and the irrelevance of that to the fate of the human species, in Stephen Jay Gould, *Eight Little Piggies: Reflections in Natural History* (New York: W.W. Norton, 1993), pp. 50-51. Moreover, the response to a disturbance, the way that the system finds a new equilibrium, can be decidedly "catastrophic" in both a mathematical and common sense. See illustrations from both biology and economics in Alexander Woodcock and Monte Davis, *Catastrophe Theory* (New York: Avon, 1978).

[52] The US Coast Guard "Shipping Study" on ballast water, conducted under mandate from NANPCA 90 and published in 1995, identified 6 various creatures, both salt and freshwater, around the ports of the world, which are prime candidates for future invasion of North America via ballast water precisely because they have already demonstrated an ability to invade other ecosystems. James T. Carlton, Donald M. Reid, and Henry van Leeuwen, *The Role of Shipping in the Introduction of Nonindigenous Aquatic Organisms to the Coastal Waters of the United States (other than the Great Lakes) and an Analysis of Control Options*, Shipping Study I, USCG Report No. CG-D-11-95 (Springfield, VA: National Technical Information Service, April 1995), p. 102, Box 5-2.

[53] Anthony Ricciardi and Joseph B. Rasmussen, "Predicting the Identity and Impact of Future Biological Invaders: A Priority for Aquatic Resource Management" *Canadian Journal of Fisheries and Aquatic Sciences* (July 1998), vol. 55, no. 7, pp. 1759-65.

[54] See *Adaptations*, Newsletter of the Binational Great Lakes-St. Lawrence Basin Project (1996), vol. 1, issue 1, on line at www.glerl.noaa.gov/pubs/other/glslb/adaptations.v1.1.html.

[55] Among others, A. Locke, D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen, *Effectiveness of Mid-Ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water*, Fisheries and Aquatic Sciences Report 1822 (Burlington, ON: Great Lakes Laboratory, 1991); and Aquatic Sciences,

Things are less clear when we look at other vectors. Some of the environmental agencies are particularly concerned about potential introductions from commercial aquaculture, baitfish transportation across watersheds, and imports of aquarium fish and plants. These are all potential vectors for the sort of "unintentional releases" mentioned above, although they do not exhaust the general category. They can be lumped together (and sometimes overlap a bit in actual practice) as "commercial uses" of live aquatic organisms. The commercial nature of the activities has two important aspects (aside from simply making them an attractive target for government regulation, in the opinion of some of the people in these businesses).

First, because they are commercial activities, they have a potential to transport a large number of aquatic organisms across wide ecological boundaries. Some purely private or recreational activities, such as private collection of baitfish or simple movement of recreational boats around the country, also move exotics around. On the whole, however, the scale of that transport, in terms of both quality and distance, is less by orders of magnitude. Private recreational fishers and boaters, moreover, do not introduce genetically modified organisms.

Second, because they are legitimate and useful activities, they will tend to expand. (In fact, there is a strong government policy of promoting the development of aquaculture, in both the US and Canada, at both federal and state and provincial levels.) The legitimate special interests who engage in this commerce will naturally exert constant pressure to widen the use of exotics – including the use of genetically modified organisms.[56] On the other hand, some of these businesses also have a strong interest, within certain limits, in preventing unintentional introduction of exotics and diseases associated with them. They should also have an enlightened self-interest in maintaining some diversity in the genetic stock.[57] More generally, there are naturally some control measures used in these businesses as a matter of quality control for their own purposes, and there are sometimes natural concentrations of storage or transport facilities in large-scale commerce. This offers some natural targets of opportunity, "critical control points," at which government regulators might interdict exotics in cooperation with the businesses concerned.[58]

Examination of Aquatic Nuisance Species Introductions to the Great Lakes through Commercial Shipping Ballast Water and Assessment of Control Options, Phase II Final Report, ASI Project E9225/E9285 (St. Catherines, ON: Aquatic Sciences, August 1996).

[56] Re aquaculture, one critic has said that "The pressure exerted by this industry to have the right to farm any species regardless of possible negative outcomes is awesome." Paul J. Wingate, "US State's View and Regulations on Fish Introductions," *Canadian Journal of Fisheries and Aquatic Sciences* (1991), vol. 48 (Supplement 1), pp. 167-170, 168. Wingate expresses specific concerns about disease and genetic changes. See also the discussion in § 4 of this paper below.

[57] See R.W. Doyle, N.L. Shackel, Z. Basiao, S. Uraiwan, T. Matricia, and A.J. Tolbot, "Selective Diversification of Aquaculture Stocks: A Proposal for Economically Sustainable Genetic Conservation," *Canadian Journal of Fisheries and Aquatic Sciences* (1991), vol. 48 (Supplement 1), pp. 148-154.

[58] This is the focus of a study currently being conducted by Dr. Douglas Jensen, Minnesota Sea Grant, and Dr. Ron Kinnunen, Michigan Sea Grant.

In the following sections, I present a closer look at the major technological and economic issues specific to these major vectors of concern.

§ 3. The shipping industry and ballast water: Metric tonnes, dollars, and things getting through the cracks

Because the ballast water of transoceanic shipping is the major vector for current invasions of the Great Lakes, the following subsections provide a detailed review of the global shipping industry, the characteristics of ships which affect the water they carry, how much they carry, what comes into the Great Lakes, where it comes from, the Great Lakes and Seaway system, the costs of shipping, the overall threat from ships, the current Great Lakes exchange regime, and technological options for managing ballast water.

§ 3.1. The global business of shipping

About 98% of world trade, 4.5 billion metric tonnes per year,[59] and 80% of world commodities,[60] are carried by sea. The major bulk cargoes are coal, iron ore, crude oil, grain, rice, steel, timber, bauxite, phosphates and refined products of oil. These relatively "low value" cargoes are fuel and raw materials for industry, and food for people. In addition, all variety of higher value manufactured products are carried by ships, many of these in the newer form of containerized cargo which is "intermodal" between sea and land. Shipping is a truly global trade, with vessels of a multitude of nations calling at most ports around the world. The international character of shipping is also reflected in the fact that it is not uncommon to see a vessel owned by a company in one nation, registered in another, chartered for use by a company in another, and actually sailed by officers and crewmembers from several other nations. Many vessels operate under "flags of convenience," which simply means that they register with nations which offer economical terms and conditions, but which sometimes also have doubtful regulatory standards. (There has been a long-term decline in the number of US-owned or controlled vessels actually registered in the United States.) It is a highly sophisticated, but also highly varied industry. Some vessels are operated by major companies with large fleets, long-term international reputations to uphold, and high internal standards for maintenance and safety. Other vessels are "bare boat" chartered to temporary owners with little interest in the maintenance of the vessel or owned by one-vessel corporations which anticipate bankruptcy. Some vessels, "liners," operate on regular routes and schedules. Others are "tramps," which does not necessarily mean that they are poorly maintained, chasing the cargo wherever it takes them.

Shipping is one of the most highly regulated industries in the world. Nations control shipping both as "flag states," exercising legal authority over vessels registered under their

[59] The Baltic Exchange, London, at www.balticexchange.com (accessed July 1, 1999).

[60] Marine Board, National Research Council, *Stemming the Tide: Controlling Introductions of Nonindigenous Species by Ship's Ballast Water* (Washington, DC: National Academy Press, 1996), p. 1.

flag wherever in the world, and as "port states," exercising legal authority over vessels of any nation operating in their waters. In both Canada and the United States, shipping is considered a matter of special concern to the federal governments and has been subject to regulation long before other areas of the national economy. In addition, shipping is regulated by international organizations, both governmental and commercial. The International Maritime Organization in London, an agency of the United Nations, provides a central forum for negotiation of "conventions" or treaties on safety and environmental protection. International insurance consortiums such as Lloyds of London and "classification societies" such as the American Bureau of Shipping and Det Norske Veritas set industry safety standards which are often adopted by government agencies. International commodity exchanges, such as the Baltic Exchange (which operates in London), and other international "conferences" (standing industry consortiums) negotiate standard cargo rates for liners, subject to some governmental controls.[61]

Many governments (including both the United States and Canada) have policies to promote shipping under their flag for purposes of both national security and economic protectionism. These may include cabotage protection (restricting domestic coastal trade to the ships of the coastal nation), cargo preferences (requiring government or government subsidized cargo, such as cargo paid for by foreign aid, to be carried on flag vessels), and outright subsidies. Despite both industry and governmental efforts to create market stability and promote the shipping of flag states, the prices for ships, charter rates, and freight rates are strongly affected by changes in economic conditions around the world and are highly volatile. (For example, the "Asian crisis" of 1998 drove down the prices of ships by 8% to 10%, and even more for new construction, depending on type. Some of that many have been due to the fact that currencies fell in Japan and Korea, where many ships are built. During the same time, however, daily charter rates for certain classes of bulk carriers declined by halves and thirds, and freight rates for carrying grain on some vessels declined by almost half.[62]) Some industry representatives argue that they are losing economic viability due to excessive governmental regulation, and they particularly object to the long-term trend of industry standards being replaced by legal conventions and domestic legislation.[63] Generally, however, the shipping industry is characterized by oversupply of ships and declining profits to vessel owners and operators, due to government policies

[61] See Paul S. Clyde and James D. Reitzes, "Market Power and Collusion in the Ocean Shipping Industry: Is a Bigger Cartel a Better Cartel?" *Economic Inquiry* (April 1998), vol. 36, pp. 292-304; Senate Committee on Commerce, Science and Transportation, Report No. 105-61 on S. 414, Ocean Shipping Reform Act [Public Law 105-258 (October 14, 1998), amending 46 USC App. § 1701 *et seq*.] (July 31, 1997).

[62] Barry Rogliano Salles, *Annual Review of World Shipping and Shipbuilding: 1998 Mid-Year Update*, (Paris: BRS, November 4, 1998).

[63] See Dr. Nikos Mikelis, Director, Lyras Shipping Ltd, "Merchant Shipping Into The Next Millennium," speech to the London Maritime Association & Royal Institution Of Naval Architects Joint Seminar, at the Baltic Exchange, October 22, 1996, available at www.shipshape.net (accessed July 1, 1999).

subsidizing shipping, increases in efficiency through containerization,[64] and perhaps also the market power of the shipping conferences.[65]

§ 3.2. Ships and the water they carry: A quick taxonomy of ship species

Bulkers, tankers, and container ships. The main categories of major commercial vessels are bulk carriers ("bulkers"), tankers, and container ships. More than 70% of the vessels entering the St. Lawrence Seaway and the Great Lakes from foreign ports are bulkers.[66] The bulkers are still the most efficient way to carry large "low value" dry bulk cargoes such as grain and ore. However, the fact that these cargoes gather relatively little money for each tonne makes the trade sensitive to relatively small variations in freight rates and other costs.

Ships great and small. How much ballast a ship carries varies with its type and size. Ship sizes are most often identified by "deadweight tons" (DWT), in English long tons in the US and in metric tonnes[67] in the rest of the world. This is a rough measure of their cargo

[64] Senate Committee on Commerce, Science and Transportation, Report No. 105-61 on S. 414, Ocean Shipping Reform Act [Public Law 105-258 (October 14, 1998), amending 46 USC App. § 1701 *et seq*.] (July 31, 1997), pp. 1-3.

[65] The conference agreements, which have special immunity from anti-trust laws, create a partial monopoly or limited "market power" (power to control prices, among other things) mitigated by the lack of exclusive control of the trade by the conferences and the ability of members to defect from the conferences, subject to certain rules. One economic analysis has found that the evidence for strong market power exercised the shipping conferences is "at best, mixed." Paul S. Clyde and James D. Reitzes, "Market Power and Collusion in the Ocean Shipping Industry: Is a Bigger Cartel a Better Cartel?" *Economic Inquiry* (April 1998), vol. 36, pp. 292-304, 302. However, they add that "one should not conclude from our results that liner carriers behave competitively." *Ibid*., p. 303. Part of the apparent lack of ability to control prices indicated in that study may be due to the considerable over-capacity of world shipping, due to other national policies promoting and subsidizing shipping. Shipping rates vary dramatically over relatively short periods of time, despite both government and private policies to control competition, because there are so many ships chasing available cargo. See discussion in Clyde and Reitzes, *ibid*.; Senate Committee on Commerce, Science and Transportation, *ibid*. In other words, it may be that there is a strong market power effect, but that effect is manifest in the oversupply rather than control over prices. From the point of view of shippers, that is the more rational place to exert market (and political) power. Getting rich is great. But staying in business is even better.

[66] Michael G. Parsons, Russell Moll, Thomas P. Mackey, and Rendall B. Farley, *Great Lakes Ballast Demonstration Project -- Phase I* (Ann Arbor, MI: Cooperative Institute for Limnology and Ecosystem Research, University of Michigan, 1997), p. 18, table III-2 (1995 statistics). About 10% are tankers, and about 10% are "general cargo carriers," which includes container ships and break bulk carriers.

[67] The shipping industry speaks in terms of English "long tons" or metric "tonnes" of cargo and water, and also of cubic meters (m^3) of water. Tons or tonnes are most relevant to cargo carrying capacity, because cargo is usually limited by weight, which in turn affects the weight of ballast needed, and the weight of ballast affecting stability and hull integrity. Quantity, on the other hand, is more directly related to pumping or treatment capacity. The most useful shorthand for both cargo and ballast is the metric tonne, a mass of 1,000 kilograms (2,205 pounds), which is a rough approximation of a volume of one cubic meter (m^3) of water because the metric system relation between mass and volume was originally based on the weight of water, although that varies with temperature and salinity. (Just to confuse the issue, a cubic meter of seawater, which is heavier, is closer to an English long ton.) A metric tonne of mass is equal to 1.102 English short or net tons

carrying capacity (after deduction for fuel, stores, *etc*.). The tankers and bulkers are commonly grouped in rough size categories which relate to where they are small enough to operate, although that is also determined by their specific physical dimensions. The "handysize" tankers and bulkers which are small enough to fit through the St. Lawrence Seaway,[68] also sometimes called "small handys," are anywhere from 10,000 to 35,000 DWT. Other ships in world trade include a somewhat larger "handymax" ship from 35,000 to 50,000 DWT, a "Panamax" ship which can just fit through the Panama Canal from 50,000 to 80,000 DWT, a "Capesize" bulker which must go around Cape Horn from 80,000 to 150,000 DWT, a "Suezmax" tanker for the Suez Canal at about 140,000 DWT, a "very large crude carrier" (VLCC), a tanker over 300,000 DWT, and an "ultra large crude carrier" (ULCC) or "mammoth" tanker at 500,000 DWT.[69]

Ballasting up. Ships use ballast water to maintain the essential operational and safety parameters for overall immersion, trim, stability, and hull integrity. It is dangerous for a ship to be either too low or too high in the water. Regulatory "load lines" or "marks" (literally welded-on marks on the outside of the hull) control the commercial tendency to load on as much cargo as possible. When running without cargo, or a light load, ballast is taken on to compensate according to the judgement of the master and loading guidance for the specific ship. The master is often balancing commercial profit and safety. A ship not ballasted sufficiently is unsafe. But one ballasted too much is slowed down and uses more fuel. Ballast may be carried in either dedicated or "segregated" ballast tanks, used exclusively for that purpose or in the cargo tanks of tankers or bulkers. Ballasting cargo tanks is less common than it once was, and is now typically to be found only when the vessel is putting on extra "heavy ballast" or "storm ballast" in order to deal with bad sea conditions. A vessel reports itself as "BOB" for "ballast on board," meaning that it is either "in ballast" (full up) or "with ballast" (partially ballasted), or "NOBOB" for "no ballast on board," meaning that it has pumped down the ballast tanks as far as possible. But "NOBOB" is almost never literally true, because most ships carry unpumpable slop and sediment in the range of a few hundred tonnes on the bottom of the tanks. For the obvious commercial reasons, ships will run with maximum cargo and minimum ballast as much as possible. Container ships generally carry less ballast and, unlike the tankers and bulkers, some container ships may carry a substantial portion of their ballast water as permanent or semi-permanent ballast which does not need to be discharged, because it is used to trim a loaded vessel for purpose of stability (to offset the relatively high weight of containers on deck). Through careful planning, some of the newer container ships can significantly minimize the

(2,000 pounds) and 0.98 English long or gross tons (2,240 pounds). US civil engineers (such as those dealing with water in waste water treatment plants) tend to speak in terms of gallons or cubic feet of water. A cubic meter (m^3) equals 264 gallons or 35 cubic feet.

[68] The maximum Seaway dimensions are 225.5 meters (740 feet) length by 23.7 meters (78 feet) beam by 8.0 meters (26 feet, 3 inches) draft by 35.5 meters (116.5 feet) "air draft" (clearance under bridges). Some of the "handymax" bulkers around 35,000 DWT just squeeze in by offloading some of their cargo at or below Montreal in order to come up on draft.

[69] See Everett C. Hunt and Boris S. Butman, *Marine Engineering and Economics Cost Analysis* (Centreville, MD: Cornell Maritime Press, 1995), pp. 1-4, 1-11, figure 1-4.

total amount of ballast that they need to discharge in port.[70] Most tankers and bulkers, however, must discharge large quantities of ballast in order to take on their cargo.

Typical loads. Getting an idea of the amounts of ballast water to be dealt with is important to understanding the practicalities of various management options. Unfortunately, this is not as straightforward as one might think. Keeping in mind that it varies according to the specific type, size, and design of a vessel, one rough rule of thumb is that the basic ballast capacity of a bulker or tanker, using only dedicated tanks, runs around one third of its DWT.[71] The ballast *capacity* of dedicated tanks on a handysize bulker or tanker coming into the Great Lakes through the Seaway runs from about 1,000 to 10,000 metric tonnes.[72] The typical ballast *carried* by a vessel running "in ballast" or "with ballast," depending on sea conditions, is less than this, anywhere from 15% to 30% of DWT.[73] Estimates of average or typical loads on the BOB vessels entering the St. Lawrence Seaway and the Great Lakes from overseas ports – mainly bulkers – vary quite a bit from a low of 3,115 metric tonnes[74]

[70] See Carlton *et al*. (1995), *ibid*., pp. 68-9.

[71] Christopher J. Wiley, "Aquatic Nuisance Species: Nature, Transport, and Regulation," in Frank M. D'Itri, *Zebra Mussels and Aquatic Nuisance Species* (Chelsea, MI: Ann Arbor Press, 1997), pp. 55-63, 59. One survey of vessels calling on US coastal ports found that ballast water capacity was 0.38 of DWT for all classes of large commercial vessels, 0.32 for container ships, 0.38 for tankers, and 0.43 for bulkers. James T. Carlton, Donald M. Reid, and Henry van Leeuwen, *The Role of Shipping in the Introduction of Nonindigenous Aquatic Organisms to the Coastal Waters of the United States (other than the Great Lakes) and an Analysis of Control Options*, Shipping Study I, USCG Report No. CG-D-11-95 (Springfield, VA: National Technical Information Service, April 1995), p. 75. A study using marine engineering models to estimate ballast capacities used an average ballast capacity of 49% of DWT, but found on the basis of actual samples that this overestimated capacity by about 20%, and would thus indicate a figure of 40% of DWT. The study noted, further, that "the overestimation is further amplified by the assumption of universal ballasting for heavy-weather." Rendall B. Farley, *Analysis of Overseas Vessel Transits into the Great Lakes through Commercial Shipping and Resultant Distribution of Ballast Water*, University of Michigan College of Engineering Department of Naval Architecture and Marine Engineering paper No. 331 (Ann Arbor, MI: University of Michigan, October 1996), pp. 12, 19, and Michael G. Parsons, Russell Moll, Thomas P. Mackey, and Rendall B. Farley, *Great Lakes Ballast Demonstration Project -- Phase I* (Ann Arbor, MI: Cooperative Institute for Limnology and Ecosystem Research, University of Michigan, 1997), p. 21.

[72] See estimate of 1,500–8,500 mt range in Parsons, *et al*., *ibid*., p. 16, table 1, and sampling of specific vessels running from 1,181–9,608 mt in Pollutech Environmental Limited, *A Review and Evaluation of Ballast Water Management and Treatment Options to Reduce the Potential for the Introduction of Non-Native Species to the Great Lakes, Technical Appendix A, Ballast Water Characterization*, report prepared for the Canadian Coast Guard (Sarnia, ON: March 31, 1992), p. 11, table 2.1.4. I am rounding off to widen the range here.

[73] The survey of coastal ships noted above found that actual ballast carried when operating "in ballast" or "with ballast" was 0.16 of DWT for all classes, 0.15 for container ships, 0.05 for tankers, and 0.23 for bulkers. Carlton, *et al*., *ibid*. An analysis of foreign vessels entering the Great Lakes found that "Ballast tonnage at 25% [of DWT] is considered the norm, 20% for short trips and good weather, and 30% for heavy weather. In severe conditions, a master may decide to use 40% ballast." Pollutech Environmental Limited, *A Review and Evaluation of Ballast Water Management and Treatment Options to Reduce the Potential for the Introduction of Non-Native Species to the Great Lakes, Technical Appendix A, Ballast Water Characterization*, report prepared for the Canadian Coast Guard (Sarnia, ON: March 31, 1992), p. 8.

[74] A. Locke, D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen, *Effectiveness of Mid-Ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water*, Fisheries and Aquatic Sciences Report 1822 (Burlington, ON: Great Lakes Laboratory, 1991), p. 10 (mean average, based on 1990 samples).

to highs of 7,013[75] and 7,500[76] metric tonnes. Most of the vessels, however, are running with cargo in a NOBOB status, with tanks pumped down as far as possible. These have varied between 75% and 95% of the vessels entering the system in recent years,[77] but a study conducted in 1990 estimated the NOBOBs to be only 52% of the total number.[78] They carry some amount of unpumpable slop and sediment, estimated to range from 59 to 468 metric tonnes and average 157.7 metric tonnes per vessel.[79]

Moving the water around. Ballast pumping rates – which also bear directly on the costs of many of the technological options for managing exotics in ballast – tend to vary according to the basic category of the vessel and the purpose for which the ballast is used. Bulkers (such as the third party foreign vessels entering the Great Lakes), which are using ballast to replace cargo, have typical rates of 2,000 to 10,000 m^3/hour. Tankers, which use it for the same purpose, have typical rates of 5,000 to 20,000 m^3/hour. Container ships, which are often using it for trim and stability in both unloaded and loaded conditions, and are therefore moving less total water around, have typical rates of 1,000 to 2,000 m^3/hour.[80] (These are combined rates, including more than one pump, and smaller vessels with less total ballast tend to be on the lower end of the scale.)

Speeds. The speed of vessels, which affects the survivability of the organisms in the tank, the scouring action of fouling on the outside of the hull, and the time available for exchange in the open ocean, has been slowly increasing over the years. Typical maximum speeds for modern vessels (which require maximum fuel consumption) range from 12 to 14

[75] Pollutech, *supra*, p. 8 (mean average, out of a range of 3,167–7,013 metric tonnes, based on the 25% rule given above). An average figure of 10,084 metric tonnes was used in Farley, *supra*. But, as noted above, that was found to be an overestimate based on samples of capacity, and was also based on "heavy-weather" ballasting.

[76] Daniel Gauthier and Deborah A. Steel, *A Synopsis of the Situation Regarding the Introduction of Nonindigenous Species by Ship-Transported Ballast Water in Canada and Selected Countries*, Fisheries and Aquatic Sciences report 2380 (Mont-Joli, Québec: Fisheries and Oceans Canada, 1996), pp. 2-4.

[77] This is probably typical of vessels, or at least bulk traders, around the world. They have their ballast tanks pumped down as far as possible because they are loaded with cargo, which is, from the point of view of the commercial operations, the ideal state for vessels to always be in. Percentages based on US Coast Guard Ninth District Marine Safety Analysis and Policy Branch figures from boardings of large transoceanic commercial carriers over the years 1993-1997, which varied from a low of 77.4% NOBOB in 1995 to 93.8% NOBOB in 1993, two of the years which are reported in M. Eric Reeves, "Techniques for the Protection of the Great Lakes from Infection by Exotic Organisms in Ballast Water," in Frank M. D'Itri, *Zebra Mussels and Aquatic Nuisance Species* (Chelsea, MI: Ann Arbor Press, 1997), pp. 283-299, p. 288, table 1. Please notice the qualification of "recent years." It does not appear safe to make any long-term predictions about the highly variable trade of the Seaway.

[78] A. Locke, D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen, *Effectiveness of Mid-Ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water*, Fisheries and Aquatic Sciences Report 1822 (Burlington, ON: Great Lakes Laboratory, 1991), p. 10.

[79] Locke, *et al*., *ibid*., p. 9.

[80] Marine Board, National Research Council, *Stemming the Tide: Controlling Introductions of Nonindigenous Species by Ships' Ballast Water* (Washington, DC: National Academy Press, 1996), p. 24, table 2-1, and Michael G. Parsons, Russell Moll, Thomas P. Mackey, and Rendall B. Farley, *Great Lakes Ballast Demonstration Project -- Phase I* (Ann Arbor, MI: Cooperative Institute for Limnology and Ecosystem Research, University of Michigan, 1997).

knots (14 to 16 miles per hour), with older and larger vessels tending toward the low end of the range. The passage from Rotterdam to Montreal is 3,138 nautical miles (3,612 statute miles and 5,805 kilometers), or 10 days at 13 knots. (Passage up through the St. Lawrence Seaway and the Great Lakes to the western end at Duluth or Thunder Bay is slower going and may take another 7-9 days.) During the crossing, a handysize vessel may come up in weight from its original loading (typically right "down to the marks," the regulatory loadlines on the outside of the hull showing the maximum safe immersion for the sea and season) due to burning off something around 40 tonnes of fuel per day.[81] (Larger vessels would burn correspondingly larger amounts.) Some vessels will make intermediate stops at ports along the North American coast before entering the Great Lakes, during which they may mix North American coastal water with unpumpable slop and sediment they carried across the Atlantic while loaded with cargo (and therefore unable to exchange ballast).

Counting metric tonnes. The total amount of overseas ballast entering US coastal ports (non-Great Lakes) each year has been estimated at 44.7 million metric tonnes (or 11.5 billion gallons).[82] For Canada, one set of somewhat mixed estimates puts the corresponding figure for overseas ballast entering Canadian coastal ports each year at 49.7 million metric tonnes (or 13.1 billion gallons).[83] There have been a number of attempts to estimate the amount of overseas ballast water entering the Great Lakes. Unfortunately, different methods and assumptions have resulted in widely different estimates. There is a significant difference between what the vessels are carrying when they enter the St. Lawrence Seaway and what they eventually discharge, with lake water added in along the way, at Great Lakes ports. The first amount is relevant to what has to be exchanged or treated aboard the ship before it shows up in the Great Lakes. The second amount is relevant to what would have to be treated in port upon arrival – which also varies significantly between different ports inside the Great Lakes. Both figures will also vary with changes in the trade, ranging from about 400 to 600 vessels each year, and how many vessels have ballast on board (BOB) because they are not loaded with incoming cargo.

Based on a comparison of the studies, I would suggest a round figure of 720,000 metric tonnes being carried upon entry into the Seaway in an average year. This figure is based on two of the studies, one conducted in 1990 and another in 1995. Both estimates in those studies may be slightly high for different reasons, but are probably reasonably close to current years, during which trade has increased somewhat.[84] A notional profile of the vessel

[81] Based on a sample vessel in Parsons, *et al.*, *supra*, at p. 74.

[82] James T. Carlton, Donald M. Reid, and Henry van Leeuwen, *The Role of Shipping in the Introduction of Nonindigenous Aquatic Organisms to the Coastal Waters of the United States (other than the Great Lakes) and an Analysis of Control Options*, Shipping Study I, USCG Report No. CG-D-11-95 (Springfield, VA: National Technical Information Service, April 1995), p. xix.

[83] Daniel Gauthier and Deborah A. Steel, *A Synopsis of the Situation Regarding the Introduction of Nonindigenous Species by Ship-Transported Ballast Water in Canada and Selected Countries*, Fisheries and Aquatic Sciences report 2380 (Mont-Joli, Québec: Fisheries and Oceans Canada, 1996), p. 4, table 1.

[84] A careful review of the literature indicates that this issue has been subject to confusion in interpretation, which I must also plead guilty to in some of my previous reports on this subject.

Some actual samples of vessels entering the St. Lawrence Seaway in 1990 put the amount for that year at 719,473 metric tonnes. A. Locke, D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen,

traffic upon entry through the Seaway, averaging out several assumptions in the various studies, and not reflecting any one actual year, might be:

500 Transoceanic entries		Total ballast	=	720,000 MT
100 BOBs (20%)	x	6,560 MT/BOB	=	656,000 MT
400 NOBOBs (80%)	x	160 MT/NOBOB	=	64,000 MT

Both the BOBs and NOBOBs engage in considerable cross-ballasting and movement of additional water in the course of stopping at an average of 2.3 ports inside the Seaway and the Great Lakes.[85] The amount of overseas water ending up at the ports, mixed with water from intermediate ports, has been separately estimated to be as much as 4,406,498[86] to 5,700,000[87] metric tonnes, although both of these estimates are likely to be somewhat high.[88] According to the study producing the lower estimate, "nearly 45% of all ballast loading

Effectiveness of Mid-Ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water, Fisheries and Aquatic Sciences Report 1822 (Burlington, ON: Great Lakes Laboratory, 1991), p. 10. That figure is based on a relatively high proportion, 48%, of the vessels entering BOB, but uses a relatively low average, 3,115 metric tonnes, of ballast carried on the BOBs.

One quick calculation based on reports of vessel numbers in 1991 and an average vessel load of 7,500 metric tonnes put the annual input at 1,400,000 metric tonnes, but that estimate was based on a large number of total vessel entries not consistent with other figures, and did not take account of the fact that most of the vessels actually enter in an unloaded NOBOB condition. Daniel Gauthier and Deborah A. Steel, *A Synopsis of the Situation Regarding the Introduction of Nonindigenous Species by Ship-Transported Ballast Water in Canada and Selected Countries*, Fisheries and Aquatic Sciences report 2380 (Mont-Joli, Québec: Fisheries and Oceans Canada, 1996), pp. 2-3.

An analysis of the *capacity* of representative vessels surveyed in 1994 produced an estimate of 5.7 million metric tonnes as the potential input of overseas ballast, but this estimate did not take account of typical loads on BOB vessels and also ignored the fact that most vessels enter NOBOB. Aquatic Sciences, *Examination of Aquatic Nuisance Species Introductions to the Great Lakes through Commercial Shipping Ballast Water and Assessment of Control Options, Phase II Final Report*, ASI Project E9225/E9285 (St. Catherines, ON: Aquatic Sciences, Inc., August 1996), p. 13.

Finally, a statistical study of 1995 trade based on assumed correlations between cargo and ballast came up with an estimate of 4,406,498 in total metric tonnes discharged by foreign vessels inside the Great Lakes, but pointed out that only 16.3% of this, or 716,462 metric tonnes, was originally ballast of foreign origin on BOB vessels. (This estimate is actually stated in cubic meters, m^3, rather than "metric tonnes.") This estimate is also somewhat high due to the fact that the study uses a relatively high estimate of the typical load on a BOB. Rendall B. Farley, *Analysis of Overseas Vessel Transits into the Great Lakes through Commercial Shipping and Resultant Distribution of Ballast Water*, University of Michigan College of Engineering Department of Naval Architecture and Marine Engineering paper No. 331 (Ann Arbor, MI: University of Michigan, October 1996), p. 22.

The rounded figure of 720,000 metric tonnes used here is probably still just a little bit high, even accounting for the recent increase in trade (which probably reduces the BOB percentage, because much of that is due to increased imports) but it thereby represents an estimate which may appropriately err a little on the high end in terms of estimating the cost of dealing with the water on board the vessels.

[85] Farley, *ibid*., p. 1.

[86] Farley, *ibid*.

[87] Aquatic Sciences, *ibid*.

[88] See the discussion of these studies in the long footnote above.

[inside the system] occurred in Hamilton and Cleveland…while almost 41% of all deballasting occurred in Duluth-Superior and Thunder Bay. Additionally, results indicate that of the 4.4 million tonnes of ballast discharged during 1995, vessels entering NOBOB accounted for nearly 3.7 million (84%)."[89] This last point is of considerable significance because the NOBOBs do not exchange their water on the open ocean under the current regime.

§ 3.3. The Great Lakes and Seaway System

In terms of the biological material in the water, the exact amount of the water is less important than where it comes from and how it gets here. It is primarily a problem with what are called the "third party" foreign vessels – vessels which are neither US nor Canadian – entering the Great Lakes through the St. Lawrence Seaway from transoceanic ports, although some Canadian vessels also participate in this trade. There is no bar to US transoceanic vessels entering the Great Lakes. But it happens to be very rare, perhaps in part because of the limitations on the size of a vessel which can fit through the Seaway.

The Erie Canal. There are two physical connections between the Great Lakes and the Atlantic Ocean. The Erie Canal (or "New York State Canal System," as it is now called) opened in 1825 and connected the Hudson River and New York to Lakes Ontario and Erie through a 524-statute mile system of interlocking canals and locks. (The Welland Canal, connecting Lakes Ontario and Erie, bypassing Niagara Falls, was also opened in 1829.) Although the Erie Canal was commercially significant at the time, it is much less so now after the opening of the St. Lawrence Seaway. The Erie Canal can accommodate barges and small vessels, but the locks limit it to vessels within the dimensions of 325 feet in length by 45 feet beam by 12 feet draft by 15.5 feet air draft (clearance under bridges). Although it is still used by recreational and fishing vessels from the open ocean, it is not used by major transoceanic commercial carriers.

The St. Lawrence Seaway. The St. Lawrence Seaway System was opened in 1959, as a joint project of Canada and the United States, to open up the Great Lakes to modern transoceanic trade. It is administered by the Canadian St. Lawrence Seaway Management Corporation (a non-profit corporation which replaced the Canadian Seaway Authority in 1998) and the US St. Lawrence Seaway Development Corporation. The Seaway Management Corporation and Canadian government agencies exercise authority over the entrance to the system via the Canadian waters of the Gulf of St. Lawrence, the St. Lawrence River, five Seaway locks from Montreal to Lake Ontario, and the Welland Canal. The US St. Lawrence Seaway Development Corporation and other US government agencies exercise authority over two locks between Massena, New York, and Lake Ontario. Each nation has exclusive territorial jurisdiction over the waters of the St. Lawrence within their boundaries (as a matter of international law, these are "internal waters," not "high seas" or "territorial seas" subject to rights of innocent passage) and vessels transiting the system must

[89] Farley, *supra*, p. 12.

comply with the domestic laws of both nations as they pass through. The similarity of the maritime laws and traditions of the two nations, the close working relationship between the maritime agencies on the Great Lakes, and joint boarding programs set up in cooperation with both the maritime agencies and the two national Seaway administrations, all make this much less burdensome and confusing to vessel operators than it might otherwise be. The maximum Seaway dimensions are 225.5 meters (740 feet) length, by 23.7 meters (78 feet) beam, by 8.0 meters (26 feet, 3 inches) draft, by 35.5 meters (116.5 feet) "air draft" (clearance under bridges). This opens up the Great Lakes to major transoceanic vessels, but only to the relatively smaller and older handysize vessels in the world fleets.

The Great Lakes and Seaway maritime industry. Like Caesar's Gaul, the Great Lakes and Seaway maritime industry is divided into three distinct tribes, (1) US domestic "lakers," (2) Canadian "lakers" and "salty lakers," and (3) third party "salties," which are our primary concern. The largest, although not the most numerous, ships sailing the lakes belong to a fleet of about 70 large US domestic bulk carriers called "lakers," (of which, perhaps 60 or so are actually sailing in a typical year), most of which belong to companies who are members of the US Lake Carriers' Association (LCA). These are restricted to the inside of the lakes, and therefore are not a source of transoceanic ballast, although they may contribute (along with more than 2.2 million US recreational vessels operating on the Great Lakes) to the spread of exotics already introduced. There is a comparable Canadian fleet of about 70 vessels, generally smaller in size, operating both inside and outside the Great Lakes, most of which are members of the Canadian Shipowners Association (CSA).[90] These are also called "lakers," but they are more difficult to define because a good number of them are "salty lakers" which operate on the ocean as well, sometimes seasonally, often making regular runs through the St. Lawrence Seaway. Although these vessels operate on the ocean, they are primarily in Canadian coastal and Great Lakes trade. Those among them that do make transoceanic voyages become subject to the same requirements for ballast exchange applicable to the third party transoceanic fleet.

The third party salties. And then there is a "third party" fleet, neither US nor Canadian, of transoceanic vessels, "salties," trading between the Great Lakes and the rest of the world. This includes a wide variety of vessels, anywhere from 200 to 300 ships running under 35 to 45 different flags, making 400 to 600 round trips (or a little more) per year. Of this, there is a core group of about 25 vessels which make regular runs into the Great Lakes. These are "liners" if they publish definite schedules. Many of the core group are owned and managed by major corporations in North America.[91] Some of the other vessels in the overall lot are what the public associates with the term "tramp" vessel (which technically just means a vessel without a regular repeat cargo run). That is to say that some of them are vessels frequently changing ownership or charter, operating under "flags of convenience" from countries with doubtful enforcement of marine safety laws, sometimes under "bare boat

[90] There are currently 88 vessels in the CSA companies, but not all of these operate inside the Great Lakes.

[91] See Michael G. Parsons, Russell Moll, Thomas P. Mackey, and Rendall B. Farley, *Great Lakes Ballast Demonstration Project -- Phase I* (Ann Arbor, MI: Cooperative Institute for Limnology and Ecosystem Research, University of Michigan, 1997), p. 15.

charter" for only one specific cargo run, sometimes owned by a "shell corporation" whose assets are little more than the one vessel.

The only thing the vessels of this third party fleet have in common is that almost all of them are handysize bulkers. On average, these handysize bulkers are old. Vessels in the area of 25 years of age are quite common, and they are becoming older. (That is not old in comparison to US lakers, which have a median age of just about 25 years. But the fact that lakers run in fresh water, which is much less corrosive, and the very high standards of maintenance on both US and Canadian lakers, make that a meaningless comparison.) There were 13,000 handysize vessels in the world in 1996,[92] but there had been only 89 new vessels of this class built in a ten-year span from 1984 to 1993.[93] More recent market reports indicate the size of the handysize fleet is continuing to decline.[94] Some of the third party vessels coming into the lakes are in fact "rust buckets" on their last legs, and with little remaining capital value.

They generally carry steel and high value cargoes such as heavy machinery and other manufactured goods into the Great Lakes. Steel, weighing in at about 5 million metric tonnes (about 10% of total tonnage) is valued at about $2 billion per year.[95] Although the foreign steel is of great concern to those in the domestic raw steel industry, such as the US lakers, this high quality feed to US and Canadian industries helps them to remain competitive in world markets. Also, despite the objections by domestic suppliers and vehement complaints about dumping of foreign steel, these imports are actually subsidized by a discount of 50 cents per tonne on the toll for steel, granted by both Seaway agencies in 1994.[96] The most important outgoing cargo is low value grain (low value only in the sense of a low price per tonne) from the North American heartland. Most of this is shipped out of Duluth and Thunder Bay, the major US and Canadian ports on the western end of Lake Superior.

Vessel operators always try to run with cargo both ways. Anywhere from 75% to 95% of them, more towards 95% in a typical year, if there is such a thing for this trade, run "in cargo" rather than "in ballast" on the way in. These report themselves as "no ballast on

[92] Kevin O'Malley, "Seaway Fleet Study," *DOT Today* (Washington, DC: US Department of Transportation, May 1996), reporting results of SLSDC study, *State of the St. Lawrence Seaway Vessel Fleet*.

[93] US St. Lawrence Seaway Development Corporation (SLSDC), *Log Book* (Washington, DC: SLSDC, March 1994), p. 2. Also, the 1996 study by the SLSDC found that 14,500 commercial vessels, or 41% of the world's merchant fleet in excess of 300 gross registered tons (including vessels below the handysize class) were capable of transiting Seaway locks and channels, that the existing Seaway-sized ocean and Great Lakes bulk fleet was rapidly aging, and that by 2005, the number of Seaway-sized ships 20 years old or younger would shrink substantially. SLSDC web site at www.dot.gov/slsdc/about/exthist.html (accessed July 3, 1999).

[94] Intercargo (International Association of Dry Cargo Shipowners), *Bulletin* (February 1999), no. 160, p. 1.

[95] Canadian Shipowners Association and Chamber of Maritime Commerce, *A Competitive Vision for the Great Lakes – St. Lawrence Seaway: An Initiative of Canada's Marine Industry* (Ottawa: CSA, October 1997), § III.

[96] See the St. Lawrence Seaway Development Corporation (SLSDC) web site at www.dot.gov/slsdc/about/exthist.html (accessed July 3, 1999). A variety of discounts are granted to other categories of cargo as well.

board" or "NOBOB" upon entry, but they actually carry a substantial amount of slop in the bottom of their tanks. Some of these also discharge part of their cargo at Montreal before proceeding to the first lock of the Seaway System, often because they have to lighten up to meet the Seaway draft limits of 8.0 meters (26 feet, 3 inches). After discharging that partial cargo in Montreal, they may then have ballast back on a few hundred or thousand metric tonnes to adjust trim.

The triangle trade. The third-party ships come into the lakes from every continent and climatic zone in the world. In 1994, when US and Canadian marine safety officers combined forces to prevent the illegal discharge of a load of freshwater ballast from the motor vessel *Pal Wind* (which has since changed ownership and name at least twice), they discovered from the ship's log that the fresh water was from the mouth of the Congo River. However, the major overseas markets are Western Europe, the Baltic, the Mediterranean, and the Middle East.[97] (The Mediterranean, Black, and Baltic Seas have also been heavily impacted by invasions of exotics, including organisms from North America.[98]) Perhaps 70% of the vessels follow a typical pattern of "triangle trade," carrying grain from the Great Lakes to ports in the Mediterranean, then to ports in Northern Europe, often with Mediterranean ballast in their tanks, to pick up steel, machinery, and other high value cargoes for the Great Lakes.[99] Transit time across the North Atlantic, sometimes with intermediate stops on the US or Canadian seaboard, may run from around ten days to two weeks. That relatively short transit time, from the heavily contaminated waters of Europe, increases the probability that exotics will survive the voyage.[100] Although the Seaway is only open from late March to late December, the North Atlantic in their operating area of latitudes is frequently cold and stormy, especially during the last runs before the end of December. Exchange of ballast on the open ocean, under the limitations of current tank and piping designs, can be dangerous. That was very well illustrated when the *Flare*, a typical old handysize bulker, broke in half off Newfoundland on January 16, 1998.

Tonnage carried. Total cargoes carried through the Seaway (both ways, including Canadian and third party vessels, and both the St. Lawrence and Welland Canal sections) ranged from 40 to 50 million metric tonnes per year in recent years. While the recent average annual variance in US and Canadian tonnage is in the area of 2%, the average

[97] Canadian Shipowners Association and Chamber of Maritime Commerce, *A Competitive Vision for the Great Lakes – St. Lawrence Seaway: An Initiative of Canada's Marine Industry* (Ottawa: Canadian Shipowners Association, October 1997), § III.

[98] See a number of articles in *Nonindigenous Estuarine & Marine Organisms (NEMO)*, proceedings of workshop at Seattle, WA, April 1993 (Washington, DC: National Oceanic and Atmospheric Administration, April 1993).

[99] Analysis by Dr. Al Ballert, Great Lakes Commission, Ann Arbor, MI, reported in Rendall B. Farley, *Analysis of Overseas Vessel Transits into the Great Lakes through Commercial Shipping and Resultant Distribution of Ballast Water*, University of Michigan College of Engineering Department of Naval Architecture and Marine Engineering paper No. 331 (Ann Arbor, MI: University of Michigan, October 1996), p. 23.

[100] Smithsonian Environmental Research Center (SERC) Marine Invasions Research Laboratory "Chesapeake Bay Research Overview" at http://www.serc.si.edu/invasions/chesoverview.htm (accessed July 15, 1999).

annual variance for the Seaway is double that at about 4%.[101] (Actual changes in individual years are sometimes much more dramatic.) Although cargo levels have improved in recent years, they are still significantly below the historic high level of 74 million metric tonnes in 1979.[102] Overall cargo topped 51 million metric tonnes in 1998 for the first time in a decade.[103]

Paying for the Seaway. Although it was originally supposed to be self-supporting, the Seaway has never paid for itself. In the words of a supporter, "The early high expectations for the Seaway have not yet been realized."[104] It has instead become another publicly supported transportation system (not in principle different from subsidies to airports and trains, or to other marine transportation infrastructures provided by US and Canadian navigation projects and marine services). The approximate cost of the original navigation project was just over $470 million, of which Canada paid $337 million and the US about $134 million. (Associated US projects to deepen interior Great Lakes navigation channels to accommodate Seaway traffic, which also benefited domestic shipping, added $257 million to that original bill.)

The US spent nearly $14 million, in 1979–1980, to conduct the Seaway Navigation Season Extension Demonstration Program, in order to prove the concept of all-winter navigation. That was a failure, and there is no serious advocacy for all-winter navigation in either the US or Canada at the present time. In fact, both nations, and their marine industries, are struggling with the need to reduce or reimburse government expenditures on current icebreaking (which are funded separately from the Seaway appropriations). The US Merchant Marine Act of 1970 relieved the US SLSDC of the requirement that it pay interest on its construction debt, and the US Department of Transportation Fiscal Year 1983 Appropriations Act cancelled the SLSDC's remaining $110 million construction debt. The US Water Resources Development Act of 1986 established a Harbor Maintenance Trust Fund, funded by a tax on foreign cargoes handled at all US ports, which now supports 90% of the SLSDC's operations. The SLSDC continued to collect tolls, but they were then rebated to users by the US Treasury. US tolls were completely cancelled in 1994.[105]

Canada has raised its tolls in recent years in an attempt to recover costs. In 1986, however, Canada appropriated $175 million from general revenue for a seven-year project to rehabilitate the Welland Canal. The Canada Marine Act of 1998[106] replaced the St.

[101] Based on my analysis of 1992-1996 tonnage reports from the Seaway and the lakers.

[102] See David L. Knight, "Continuing a pattern of Stability: Great Lakes/Seaway System and its Ports Seem to Have Found a Sustainable Level," Seaway Review (January-March 1997), vol. 25, no. 3, pp. 5-17, p. 9, table.

[103] St. Lawrence Seaway Management Corporation web site at www.seaway.ca (accessed July 3, 1999).

[104] Donald R. Vonnahme, Chair, Great Lakes Commission, form letter to members of Congress (May 1997).

[105] On the basic figures and history of the Seaway, see the St. Lawrence Seaway Development Corporation (SLSDC) web site at www.dot.gov/slsdc/about/exthist.html (accessed July 3, 1999). Characterizations, especially the statement that the winter navigation program was a "failure," are my own opinion, based on my experience as a Coast Guard officer in the Great Lakes.

[106] Canada Statutes, Chapter C-6.7, 1998, c. 10.

Lawrence Seaway Authority with the St. Lawrence Seaway Management Corporation, a nonprofit corporation.[107] The Canadian Management Corporation is continuing to collect tolls, and announced at the beginning of 1998 that "Toll revenues were the highest in Seaway history, at $80 million, thanks to the substantial increase in steel movements."[108] However, the Canadian government still owns the assets of the Seaway and has committed to pay for all renewal and maintenance of the 40-year old infrastructure beyond $15 million per year.[109] It does not appear that the system will ever pay for itself on the Canadian side either.

§ 3.4. Buying and renting ships

In order to put the discussion of the costs of technological options for handling ballast water into context, the following figures are offered as general parameters. Each vessel's value is affected not only by type, size, and age, but also by its design, special features such as cargo handling equipment, history of maintenance, and changing market needs. Markets are highly volatile. New construction prices slumped from 15% to 30% in 1998, in part because of the decline of currencies in the Asian countries where almost all bulkers and tankers are built, but also because of real declines in raw materials and decline in demand due to general over-capacity.[110] It costs tens of millions of US dollars for a new ship, depending on size and design. A new handysize tanker may go for around $20 million. It is rather difficult to find public reports of typical prices for new handysize bulkers of the size which fit through the Seaway because very few of them are being built, but a current new construction price for a rather small handysize bulker of $13 million[111] suggests that prices for average range handysize bulkers would be a little less than that $20 million benchmark for tankers if there were a current market for them. Average new prices for the next largest ships, the handymax bulkers, ranged from $26 to $19 million from the third quarter of 1997 to the third quarter of 1998 (a decline of 27%).[112] The ranges for larger ships during the same period were as follows: Panamax bulkers, $27 to $20 million. Panamax tankers, $36 to $30 million. Capsize tankers, $42 to $35 million. Suezmax tankers, $51 to $45 million. VLCC tankers, $82 million to $70 million.[113] Older ships can be had for much less. A handysize or handymax bulker around 10 to 20 years old may go for something in the range

[107] St. Lawrence Seaway Management Corporation web site at www.seaway.ca (accessed July 3, 1999).

[108] St. Lawrence Seaway Management Corporation, "St. Lawrence Seaway Opens for 40th Anniversary," press release (Cornwall, ON: March 31, 1999).

[109] A.J. Donaldson, Vice-Chairman, Upper Lakes Group Inc, "Commercialization of the St Lawrence Seaway," remarks to the Canada Grain Council reported at http://www.canadagrainscouncil.ca/donald~1.htm (undated, accessed July 3, 1999).

[110] Barry Rogliano Salles, *The BRS Annual Review of World Shipping and Shipbuilding: Developments in 1998 and Prospects for the Coming Months* (Paris: BRS, 1998), on line at http://www.brs-paris.com/research/index.html.

[111] See a public advertisement for a 12,000 DWT bulker at $12,900,000 by China Marine Industries Corporation, at www.asiaonline.net (accessed July 2, 1999).

[112] Barry Rogliano Salles, *supra*, "Shipping and Shipbuilding Markets 1999," and table.

[113] *Ibid*.

of $4 million to $10 million.[114] (Old ships at the end of their useful life, anywhere from 20 to 30 years, may obtain something around $1 million in scrap value.) A statistically average size bulker in the world fleet is around 49,500 DWT and is 14.5 years old.[115] This "average" large handymax (or near small Panamax) would be near the upper end of that $4 to $10 million range. According to an index of average values in a "representative fleet," the mean average value of a bulker in world trade is currently $8.6 million, down from $9.7 million one year ago, and $13 million for a tanker, down from $20.5 million one year ago.[116]

Ships are commonly chartered for 6-12 months or voyages, with rates calculated by the day. Depending on the same variables of size, age, etc., charter rates run anywhere from $5000 to $30,000 per day, with extreme fluctuations due to markets. Handymax bulker charter rates ranged from $8,000 to $7,000 per day in 1997–1998.[117] Rates for the smaller handysize bulkers fitting inside the Seaway would be a little less. For a typical Capesize bulker, it ranged from $15,000 to $10,000 in 1997–1998.[118] Tanker charters depend on type of cargo and route as well as size. Charter rates for Suezmax crude carriers varied from $22,000 to $17,000, and for very large crude carriers (VLCC), $33,000 to $27,000, during 1998.[119] According to an index of average rates in a "representative fleet," the mean average rate for a bulker in world trade is currently $6,700 per day, down from $7,044 one year ago, and $14,983 for a tanker, down from $18,350 one year ago.[120]

To this one must also add thousands of dollars per day for crew, fuel, other operational expenses, and in-port fees. Visits to a drydock can add tens of thousands to a hundred thousand or more per visit, not counting the actual repair or maintenance costs.

§ 3.5. The threat from ships: The biological island

Although ships have been subjected to extensive regulation for safety for about a century, and have been regulated to prevent spills by oil and chemicals for several decades, there are still no international legal controls on exotics in ballast water and other shipborne sources for aquatic organisms. This is odd, in a sense, because ships have long been

[114] See Portship Sale & Purchase Report at www.portship.com. and Shipping Intelligence, Inc. ship sales reports at www.marinelink.com.

[115] Intercargo (International Association of Dry Bulk Cargo Shipowners), *Bulletin* (April 1999), no. 162, p. 2.

[116] Shipping Intelligence, Inc., "Current Index Fleet Rate and Price Valuations" (New York, NY: July 12, 1999), available on line at http://anansi.panix.com/userdirs/spl/ifleet.htm.

[117] Barry Rogliano Salles, *The BRS Annual Review of World Shipping and Shipbuilding: Developments in 1998 and Prospects for the Coming Months* (Paris: BRS, 1998), on line at http://www.brs-paris.com/research/index.html.

[118] *Ibid*.

[119] *Ibid.*

[120] Shipping Intelligence, Inc., "Current Index Fleet Rate and Price Valuations" (New York, NY: July 12, 1999), available on line at http://anansi.panix.com/userdirs/spl/ifleet.htm.

recognized as vectors for the transmission of diseases and terrestrial pests.[121] Some of the marine biologists have pointed out that a ship can well be thought of as a "biological island" carrying its organisms around the world.[122] The variety of means by which ships can spread organisms include ballast water, fouling on the outside of the hull, poorly maintained marine sanitation devices, water on decks, water in anchor lockers, or fouling on anchors or chains. ("Bilge" water, commonly confused with ballast water, is small quantities of water forming by condensation or leaking from decks into lower interior spaces, and is not a significant threat.) Ballast water remains the greatest concern because of the huge quantity of water transported and the wide variety of organisms it carries.

Ballast. Ballast water began to be commonly used in ships with the introduction of steel construction in the mid 1800s.[123] Since that time, the threat of transport of exotics has grown as (a) total world trade has increased, (b) ships have become larger, and (c) ships have become faster. Large transoceanic vessels could not enter the Great Lakes until after the opening of the St. Lawrence Seaway in 1959, although some much smaller traffic from ports around the world could make it in from the Hudson River after the opening of the Erie Canal in 1825. Since 1960, however, introductions attributable to transoceanic ballast water have accounted for both a clear majority of all recent introductions (perhaps 60% of introductions between 1960–1997) and a dramatic surge in introductions since that time. "In fact, almost one-third of the exotic species in the Great Lakes have been introduced in the last 30 years, and this surge corresponded with the opening of the St. Lawrence Seaway."[124] The sea lamprey may have come up the Erie Canal. Most of the more recent invaders of note, the zebra mussel, the European ruffe, the round goby, the tubenose goby, and the spiny water flea, are attributable to ballast water.[125] Some of the researchers have calculated that, at any given time, there may be "somewhere in excess of 3,000 species" (presumably not

[121] During the negotiations of the first International Convention for the Prevention of Pollution from Shipping in 1973, the International Maritime Organization in London asked the World Health Organization to conduct research on epidemic disease bacteria in ballast water, but that research seems to have never been carried out. Daniel Gauthier and Deborah A. Steel, *A Synopsis of the Situation Regarding the Introduction of Nonindigenous Species by Ship-Transported Ballast Water in Canada and Selected Countries*, Fisheries and Aquatic Sciences Report 2380 (Mont-Joli, Québec: Fisheries and Oceans Canada, 1996), § 5.0, pp. 13-14. Customs and agricultural agencies in both the US and Canada inspect cargo and dunnage (packing material) under a wide variety of statutes and regulations for the control of animal and insect pests. Similar authority is exercised in Australia by the Australian Quarantine and Inspection Service (AQIS) which, unlike the agricultural agencies in the US and Canada, has been the lead federal agency for dealing with ballast water in Australia.

[122] James T. Carlton, Donald M. Reid, and Henry van Leeuwen, *The Role of Shipping in the Introduction of Nonindigenous Aquatic Organisms to the Coastal Waters of the United States (other than the Great Lakes) and an Analysis of Control Options*, Shipping Study I, USCG Report No. CG-D-11-95 (Springfield, VA: National Technical Information Service, April 1995), p. 19.

[123] Christopher J. Wiley, "Aquatic Nuisance Species: Nature, Transport, and Regulation," in Frank M. D'Itri, *Zebra Mussels and Aquatic Nuisance Species* (Chelsea, MI: Ann Arbor Press, 1997), pp. 55-63.

[124] Edward L. Mills, Spencer R. Hall, and Nijole K. Pauliukonis, "Exotic Species in the Great Lakes: From Science to Policy," *Great Lakes Research Review* (February 1998), vol. 3, no. 2, pp. 1-7, 2. See also Edward L. Mills, Joseph H. Leach, James T. Carlton, and Carol L. Secor, "Exotic Species in the Great Lakes: A History of Biotic Crises and Anthropogenic Introductions," *Journal of Great Lakes Research* (1993), vol. 19, no. 1, pp. 1-54.

[125] Mills, *et al*. (1993), *ibid*.

including bacteria and viruses) "in motion in the ballast water of ocean-going ships around the world."[126] Recent studies in the Great Lakes have documented a wide variety of organisms, including pathogens, in ballast water and sediment.[127] (Because of the low water quality in various ports around the world where international shipping ballasts up, they may also contain toxic chemicals, although the total levels of discharge are likely to be much less than discharges from terrestrial sources in the Great Lakes.) Somewhere around 720,000 metric tonnes of foreign ballast, most of it an organic soup, are discharged into the Great Lakes each year.[128] Although other vectors from both ships and terrestrial sources need to

[126] James T. Carlton, "Biological Invasions and Biodiversity in the Sea: The Ecological and Human Impacts of Nonindigenous Marine and Estuarine Organisms," in *Nonindigenous Estuarine & Marine Organisms (NEMO)*, proceedings of workshop at Seattle, WA, April 1993 (Washington, DC: National Oceanic and Atmospheric Administration, April 1993), p. 7.

[127] A. Locke, D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen, *Effectiveness of Mid-Ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water*, Fisheries and Aquatic Sciences Report 1822 (Burlington, ON: Great Lakes Laboratory, 1991); Aquatic Sciences, *Examination of Aquatic Nuisance Species Introductions to the Great Lakes through Commercial Shipping Ballast Water and Assessment of Control Options, Phase II Final Report*, ASI Project E9225/E9285 (St. Catherines, ON: Aquatic Sciences, August 1996). Re pathogens, in particular, a recent study of ballast water in vessels entering the Great Lakes by Dr. Ivor Knight at James Madison University, not yet published but presented to the 9th Zebra Mussel Conference on April 28, 1999, found fecal indicators in 88% of the samples and other pathogens in 40% of the samples, including cholera in 15% of the samples.

Exotics are a form of plague, and ships have always been carriers of plague. In the Fourteenth Century of Medieval Europe, a growing network of shipping connecting the Mediterranean and the North Atlantic ports with faster and more seaworthy ships played a significant role in spreading the black rats and fleas which carried the Black Death. Similarly, the development of steam-powered ships in the latter part of the Nineteenth Century resulted in a global outbreak of what was probably the same epidemic. William H. McNeill, *Plagues and Peoples* (New York: Anchor, 1976), p. 165. Ships ballast up in crowded ports near urban centers, where they discharge their cargo, in ports all around the world. Most of those communities have poor to nonexistent water treatment facilities. The waters in almost all ports of the world (including those of the United States and Western European nations, as well as those of underdeveloped nations) have been described by biologists as "microbial soup," or "veritable stews of viruses, plasmids, transposons, and bacteria," and there is evidence that algae provides a protective packaging for the transportation of bacteria and viruses. Lauri Garrett, *The Coming Plague: Newly Emerging Diseases in a World Out of Balance* (New York: Farrar, Straus and Giroux, 1994), Chapter 16, especially pp. 560-561.

It is often presumed that the Great Lakes are not likely to suffer ill effects from exotic pathogens because (1) the lakes are cold and (2) the lakes do not have any of the shellfish industries which commonly function as the medium for transmittal of pathogens to humans in warm-water areas. Those two factors are likely to have provided considerable protection, but may sometimes have only masked the chain of transmission. Although there are no outbreaks of human disease linked to foreign shipborne pathogens in the Great Lakes, we know the following two things: (1) The lakes are in fact quite warm enough in summer months (also the height of the shipping season, when ballast and marine sanitation device effluent is being discharged into ports very near public beaches) to require frequent closings due to documented outbreaks of *E. coli*. (2) Swimmers, particularly children who tend to ingest more water when swimming, are subject to more (usually undocumented) infections than the rest of the population. Greg Steele, "The Old Swimming Hole: An Epidemiological and Bacteriological Paradox," in Leslie Dorworth, ed., *A National Healthy Beaches Symposium: Research, Monitoring and Cooperative Efforts*, proceedings of conference at Indiana Dunes State Park, August 7, 1997 (Hammond, IN: Purdue University Calumet Illinois-Indiana Sea Grant Program, 1997), pp. 15-19; and other articles in the same proceedings. There is no evidence of a linkage between shipborne pathogens and disease in North America. But that evidence has not been looked for.

[128] See the detailed discussion of ships, ballast, and metric tonnes above.

be more closely examined, it is clear that prevention of ballast water invasions takes the highest priority.

Hull fouling. In addition to ballast water, which has been well documented as a threat, the next most likely shipborne source of exotics is probably hull fouling. This became less of a problem with the common use of steel construction and anti-fouling paints. Unfortunately, the most common anti-fouling paints use organotin tributyltin (TBT), which is toxic to marine organisms (and depends on that toxicity for its effectiveness). These are likely to be banned in the near future, in favor of copper-based coatings and silicon-based paints, which make the surface of the ship slippery so that sea life will be easily washed off.[129] (Copper is also toxic to marine life, but the idea is that it will work mainly by denying the organisms an easy surface to attach to rather than by dissolving toxins into the water.) It is generally believed that the increased speeds of ships (which adds to the ballast water threat) also decreases the threat from hull fouling by helping to wash off creatures not firmly attached, and it may also be much less of a potential vector for the transmission of freshwater organisms.

Marine sanitation devices (*MSDs)*. Marine sewage is a potential source for exotic pathogens. All ships which operate in Canadian or US waters are required to use shipboard marine sanitation devices (MSDs) which are designed to treat the sewage to basic land-side standards. However, perhaps in part because these vessels are not require to use MSDs in international waters, many of these MSDs on third party foreign vessels entering the Great Lakes and other Canadian or US waters are very poorly maintained.

Environmental benefits from shipping. It is also worth noting that world trade also creates intangible social benefits, and that shipping generally is far less damaging to the environment, per ton of cargo moved, in terms of use of fuel and generation of combustion byproducts.[130]

---

[129] "Antifouling paints are used to coat the bottoms of ships to prevent sea life such as algae and mollusks attaching themselves to the hull – thereby slowing down the ship and increasing fuel consumption. In the early days of sailing ships, lime and later arsenic was used to coat ships' hulls, until the modern chemicals industry developed effective antifouling paints using metallic compounds. The compounds slowly 'leach' into the sea water, killing barnacles and other marine life that have attached to the ship – but studies have shown that these compounds persist in the water, killing sea life, harming the environment and possibly entering the food chain. One of the most effective antifouling paints, developed in the 1960s, contains organotin tributyltin (TBT), which has been proven to cause deformations in oysters and sex changes in whelks." IMO Marine Environment Protection Committee (MEPC), IMO Fax 04/98, 41st session: 30 March (London: IMO MEPC, April 3, 1998).

[130] This is, ironically, relevant to the protection of Great Lakes water quality and the protection of the health of citizens in the region because airborne deposition of heavy metals and persistent toxic chemicals is a source of significant contamination of the Great Lakes food supply, along with less persistent but damaging ozone and acid aerosols. See US EPA and Environment Canada, *The Great Lakes: An Environmental Atlas and Resource Book* (Chicago: US EPA Great Lakes National Program Office, 3rd Ed. 1995), p. 31; and US EPA and Environment Canada, *State of the Great Lakes 1997* (Chicago: US EPA Great Lakes National Program Office, 1997), pp. 39-42. A study by the Great Lakes maritime community found that, if the same cargoes carried by domestic Great Lakes shipping were to switch from vessel to rail, trains would burn an additional 14 million gallons of fuel and generate an extra 4,321 net tons of emissions. Lake Carriers' Association, *1996 Annual*

§ 3.6. Ballast exchange: Making do and putting ships at risk

The exchange requirement. The primary defense against exotics in all current ballast water regimes, both voluntary and regulatory, is the requirement for an open ocean exchange. Under the US mandatory regime establishing the exchange requirement for the Great Lakes in 1993, the shipping industry is invited to submit alternative measures to the US Coast Guard for approval, but no one has yet done so. Exchange was something that mariners had done on their own in the past, occasionally, for the purpose of cleaning excessive loads of sediment out of their tanks. Exchange was therefore seized upon by those who developed the first voluntary guidelines in Canada and Australia as a practical measure which could be immediately adopted at very little cost to the industry.

The US mandatory regime which went into effect in the Great Lakes in 1993,[131] generally based on voluntary guidelines previously developed by Canada,[132] requires that the exchange (1) is carried out beyond the exclusive economic zone (EEZ, extending 200 nautical miles from the "baseline" which approximates the shoreline of a nation) in a depth of at least 2000 meters, and (2) achieves a resulting level of salinity in the ballast water equal to or exceeding 30 parts per thousand (ppt). Neither the selection of the EEZ 200-mile line nor the regulatory standard of 30 ppt salinity were based on hard science, and there are problems with both of these regulatory standards.

Defining "open ocean." The 200-mile line only roughly approximates defining the distinction between the coastal and open ocean environments, and may be a particularly poor line to use over the wide continental shelf of Canada off the Gulf of St. Lawrence. The additional requirement of 2000 meters is intended to assure that the vessel is off the continental shelf, but it may allow a vessel to exchange in an area where currents carry the contaminated water into the coastal environment. On the other hand, it could well be that the 200-mile and 2000 meter requirement is too restrictive, depending on the actual currents

Report (Cleveland: LCA, 1997), p. 25. A similar analysis has not been done on the foreign cargoes entering through the Seaway, which do compete against trains for internal regional trade, but the same basic point very well applies. Great Lakes shipping, both foreign and domestic, has also been environmentally friendly in terms of accidental spills. There have been no major spills from commercial vessels in the Great Lakes since 1990 (a fire on a gasoline tank ship, which actually resulted in very little direct pollution of the water) and spills of oil and chemicals into the Great Lakes from shipping sources generally account for less than 1% of total load. Melville Shipping, *Assessment of Pollution from the Great Lakes from Vessel Sources in Comparison to Other Sources*, Canadian Coast Guard contract T1878-5-0147 (Ottawa: Canadian Coast Guard, March 1995), p. 58.

[131] US Coast Guard regulations at 33 CFR Part 151, Subpart C, §§ 151.1500 *et seq*., first promulgated in 1993, at 58 *Federal Register* 18334 (April 8, 1993), under the authority of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA 90), US Public Law 101-646 (November 29, 1990), codified at 16 USC §§ 4701 *et seq*. These mandatory regulations cover only the Great Lakes and, by later amendment, waters of the Hudson River connecting to the Great Lakes through the Erie Canal.

[132] See Daniel Gauthier and Deborah A. Steel, *A Synopsis of the Situation Regarding the Introduction of Nonindigenous Species by Ship-Transported Ballast Water in Canada and Selected Countries*, Fisheries and Aquatic Sciences report 2380 (Mont-Joli, Québec: Fisheries and Oceans Canada, 1996), § 3.2, p. 7.

and coastal environments. A report just submitted to the US ANS Task Force seems to indicate that, with a more precise evaluation of actual currents along the coastline, areas much closer to shore may be safe for exchange.[133] Unfortunately, this analysis does not include Canadian waters. The issue is important, because ships often need more time during the transoceanic passage, or more sheltered waters, in order to conduct their exchange safely.

Salinity. Salinity has proven to be a convenient standard for enforcement purposes, but a poor standard for ensuring that an effective exchange has actually taken place. The salinity of seawater varies in various parts of the ocean from 30 to 39 ppt, but stays fairly close to a mean of 35.3 ppt in the middle of the North Atlantic.[134] Thus, a reading of 30 ppt or more from an exchange in the North Atlantic nominally indicates that 84.98% (30/35.3) or more of a tank previously carrying fresh water has been exchanged. However, an analysis of salinity readings[135] taken by the US Coast Guard indicated that a substantial number of vessels begin with high salinity water (probably from the Mediterranean, a common area for the delivery of grain from the Great Lakes). This clearly undermines the validity of the salinity standard as a guarantee of exchange. Also, it should be kept in mind that a 100% exchange, not 85%, is the goal. The regulatory level of 30 ppt, or a nominal 85% exchange, was purely a practical accommodation for the shipping industry because of the difficulty that many vessels have in accomplishing a 100% exchange, and not because of any scientific basis for saying that 30 ppt salinity, or 85% exchange, provides a critical level of protection.

The logic of exchange. What is the purpose of requiring an exchange of ballast in the open ocean? Contrary to what is often assumed, the main idea is not to salt up the tanks to kill or inhibit the reproduction of fresh water organisms in the ballast. Salting up the tanks is undoubtedly a useful attack against some freshwater organisms. But that is not an effect

[133] Alfred M. Beeton, James T. Carlton, Bridget A. Holohan, Glen H. Wheless, Arnoldo Valle-Levinson, Lisa A. Drake, Gregory Ruiz, Linda McCann, William Walton, Annette Frese, Paul Fofonoff, Scott Godwin, Jason Toft, Lisa Hartman, and Elizabeth von Holle, *Ballast Exchange Study: Consideration of Back-Up Exchange Zones and Environmental Effects of Ballast Exchange and Ballast Release*, report to National Sea Grant, NOAA, and EPA (Ann Arbor, MI: Cooperative Institute for Limnology and Ecosystems Research, November 1998). The report indicates, for example, that exchange may be appropriate as close as 100 kilometers (54 nautical miles) off the approach to Boston. *Ibid*, p. v., par. 16.

[134] A. Locke, D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen, *Effectiveness of Mid-Ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water*, Fisheries and Aquatic Sciences Report 1822 (Burlington, ON: Great Lakes Laboratory, 1991), p. 26.

[135] I conducted this examination of readings, based on a sample of most of the vessels boarded during the 1997 navigation season, while the staff officer responsible for the program at the Ninth US Coast Guard District. It was cited by US Coast Guard Headquarters as evidence that "salinity cannot be relied upon alone as an indicator of an effective exchange, and should only be one factor in providing evidence that a performance standard has been met" as part of a notice of proposed rulemaking which would have established a performance standard of 90% exchange by volume, based on all available evidence, in place of the 30 ppt standard. Notice of proposed rulemaking at 63 *Federal Register* 17782 (April 10, 1998), p. 17785. Unfortunately, the US Coast Guard retreated from this position under pressure from the shipping industry in the following rulemaking action, but is still studying the problem. Interim rule with request for comments at 64 *Federal Register* 26672 (May 17, 1999), pp. 26677-8.

which can be relied upon, and is at best a secondary purpose of the exchange requirement. There are many organisms in a variety of taxa – the sea lamprey[136] and the cholera bacterium[137] come immediately to mind – which can make the transition from salt to fresh water quite nicely. Moreover, many exclusively freshwater organisms can live in a dormant form while exposed to salt water and become active again when exposed to fresh water. "A surprisingly diverse group of [freshwater] taxa, representing protozoans and 11 animal phyla, possess resting stages which may be capable of surviving extended saltwater immersion (although experimental data for most of these taxa are lacking)."[138] One of the seminal researchers in the field, Dr. James Carlton of Williams College, christened this the "Malinska Effect" after finding the freshwater calanoid copepod *Eurytemora affinis* still doing quite nicely after living for two weeks in the 30 ppt exchanged water of the motor vessel *Malinska*.[139] The sediments in the ballast tanks give many organisms a place in which to find shelter.[140]

It does appear, however, that the small pelagic organisms peculiar to the highly saline, high ultraviolet, and highly oligotrophic environment in the open ocean are not suited to reproduction in the low saline, low ultraviolet, and less oligotrophic environment of coastal areas – which *are* subject to invasion by creatures across the ocean from other coastal areas. (One might presume, this simple sailor would think, that anything floating around live for

[136] The sea lamprey (*Petromyzon marinus*) is an anadromous species originally living in the Atlantic Ocean and spawning in the Northeastern rivers. It is not a ballast introduction. It may have come up the Erie Canal System, or may even have been native to Lake Ontario, and spread later to the upper lakes. See Edward L. Mills, Joseph H. Leach, James T. Carlton, and Carol L. Secor, "Exotic Species in the Great Lakes: A History of Biotic Crises and Anthropogenic Introductions," *Journal of Great Lakes Research* (1993), vol. 19, no. 1, pp. 6, 9.

[137] Cholera, caused by the bacterium genus *Vibrio*, is a particularly instructive example of the adaptability of simple organisms. It has various species and strains, some of which are not pathogenic to humans, some of which thrive more in salt or fresh water. But some of the pathogenic forms can certainly make the transition. A 1961 pandemic of cholera in Peru was caused by the El Tor strain, *Vibrio cholerae* 01, which "was particularly well equipped, genetically, for long-term survival inside algae…." Also, "The El Tor strain was capable of shrinking itself 300-fold when plunged suddenly into cold salt water. In that form it was the size of a large virus, very difficult to detect….add nitrogen, raise the temperature, decrease the salinity, and bingo! instant cholera." It is believed that the El Toro strain infected Peru via water carried by a Chinese freighter from the Asian seas. Lauri Garrett, *The Coming Plague: Newly Emerging Diseases in a World Out of Balance* (New York: Farrar, Straus and Giroux, 1994), p. 564.

[138] James T. Carlton, Donald M. Reid, and Henry van Leeuwen, *The Role of Shipping in the Introduction of Nonindigenous Aquatic Organisms to the Coastal Waters of the United States (other than the Great Lakes) and an Analysis of Control Options*, Shipping Study I, USCG Report No. CG-D-11-95 (Springfield, VA: National Technical Information Service, April 1995), p. 161. See also Australian Quarantine and Inspection Service (AQIS), *Ballast Water Treatment for the Removal of Marine Organisms*, AQIS Ballast Water Research Series Report No. 1 (Canberra, Australia: Australian Government Publishing Service, June 1993), pp. 8-9; and A. Locke, D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen, *Effectiveness of Mid-Ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water*, Fisheries and Aquatic Sciences report 1822 (Burlington, Ontario: Great Lakes Laboratory, 1991), p. 39.

[139] James T. Carlton, Williams College Maritime Studies in Mystic Seaport, letter to Jonathan Burton, US Coast Headquarters, Washington, DC (February 12, 1993).

[140] A. Locke, D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen, *Effectiveness of Mid-Ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water*, Fisheries and Aquatic Sciences Report 1822 (Burlington, ON: Great Lakes Laboratory, 1991), p. 39.

long periods on the surface of the open ocean which is going to thrive in the coastal areas has already had thousands of years to move in on ocean currents.) Although there can be a good number of organisms in the open ocean, marine biologists have advised that "the probabilities of reciprocal introductions" between the open ocean and coastal environments "are virtually non-existent."[141] So exchange is in fact "contrary ballasting" between two distinct ecological zones, using the fact that open ocean is a natural barrier to invasion (to anything that has not already had plenty of opportunity via natural causes).

Effectiveness of the exchange regime. Compliance with the Great Lakes regime has been generally good. US Coast Guard enforcement statistics collected since the beginning of the regime in 1993 have indicated a steady decline in the number of "problem vessels" having difficulty meeting the regulatory standard of 30 ppt salinity.[142] In essence, the marine community has easily adapted to the regulatory requirement. But the problem, discussed above, is that the salinity standard does not mean much in terms of actual effectiveness of the regime. In addition to the problem of the regulatory salinity standard, there are three substantive limitations to the current exchange regime. These are (1) safety, (2) the problem of residual slop and sediment in the "empty" tanks of "NOBOB" vessels, and (3) the lack of effectiveness of exchange in actually flushing out the organisms. All three of these defects are directly related to the fact that ballast tanks on vessels currently in service were simply not ever designed for the purpose of exchange.

The design of ballast tanks. Conventional ballast systems are built with only one two-way pipe end in the bottom of each ballast tank. Unless some other provision is made for flushing the water through the tank, the only way it can be exchanged is by pumping down a full tank and refilling it. When conducting a pump-down and pump-up or "sequential" exchange, the vessel operators typically do one set of side-by-side (port and starboard) tanks at a time in order to avoid endangering stability. (Even if it were feasible within the limits of the pumping system to pump down all tanks at once, lightering the whole ship at once

[141] James T. Carlton, Donald M. Reid, and Henry van Leeuwen, *The Role of Shipping in the Introduction of Nonindigenous Aquatic Organisms to the Coastal Waters of the United States (other than the Great Lakes) and an Analysis of Control Options*, Shipping Study I, USCG Report No. CG-D-11-95 (Springfield, VA: National Technical Information Service, April 1995), p. 153. That statement was recently reaffirmed in Alfred M. Beeton, James T. Carlton, Bridget A. Holohan, Glen H. Wheless, Arnoldo Valle-Levinson, Lisa A. Drake, Gregory Ruiz, Linda McCann, William Walton, Annette Frese, Paul Fofonoff, Scott Godwin, Jason Toft, Lisa Hartman, and Elizabeth von Holle, *Ballast Exchange Study: Consideration of Back-Up Exchange Zones and Environmental Effects of Ballast Exchange and Ballast Release*, report to National Sea Grant, NOAA, and EPA (Ann Arbor, MI: Cooperative Institute for Limnology and Ecosystems Research, November 1998). "Experimental studies conducted on the survival of oceanic organisms under lowered salinity regimes indicate the effectiveness of this barrier. These experiments suggest that few organisms of oceanic origin in exchanged ballast water are likely to survive upon release to low salinity coastal habitats." *Ibid*., p. ii, para. 7.

[142] The number of "problem vessels," relative to the number of vessels entering with ballast, declined from 7.4% to 1% over the five years from 1993 to 1997. (And all these were required to take remedial action.) In addition, the ratio between the number of vessels entering with ballast and retaining their water throughout the voyage and those entering with ballast after conducting an exchange at sea declined, from almost an equal ratio (.933) in 1993 to about one in eighteen (.057) in 1997, thus indicating that vessel operators are getting in the habit of conducting an exchange instead of resorting to retention. Based on figures I collected while Chief of the US Coast Guard Ninth District Marine Safety Analysis and Policy Branch, Cleveland, Ohio.

would create a dangerous instability. That is why the ballast tanks are there in the first place.) Recent stress studies by one marine engineering firm indicate that some ships should instead bracket the tanks port and starboard (pumping one tank in the middle of the vessel on one side and two tanks near the ends on the other side) in order to reduce overall hull stress.[143] But these are all make-do measures to compensate for the limitations in existing tank and pumping design. The tanks could be fitted with a second set of pipes allowing water to be discharged and refilled simultaneously in what is called a "flow-through" or "flush" exchange. The International Maritime Organization has recommended that some existing vessels conduct a flow-through exchange by pumping water up out the top of the tank through the manholes or the vent pipes on the deck.[144] However, while preserving overall hull integrity, this make-do procedure can create dangerous over-pressurization of the tanks.[145] In order to be done safely, it requires some change in the existing piping. There is no general principle of marine engineering or naval architecture which requires there to be only one pipe end connecting to each tank.[146] Before exotic species became an issue in the late 1980s, there was simply no need for another pipe end to be built into the ballast system for each tank.

In addition, getting a good flush of the tank is impeded by a large number of structural members typically lining the sides and bottoms of a ballast tank.[147] This *is*, to a large extent, a constraint of naval architecture. The hull the of vessel must be supported by a semi-rigid internal structure of steel framing in order to supply overall strength to the hull and prevent the tendency of tubular shells to buckle. The exact design of that internal structure – and thus the degree to which it impedes cleaning out the tanks – varies somewhat among types and specific designs of vessels. Some vessels could accomplish much more effective exchanges, whether sequential or flow-through, with relatively small modifications. Others would require major work or could not be safely modified for that purpose.[148]

These two design problems interact. The structures inside the tanks serve to trap water and sediment when the water rises and falls during a pump-up pump-down cycle. How

[143] Robert Tagg, Herbert Engineering Corp., presentation to a conference on ballast water at the California Maritime Academy, Vallejo, California, June 16, 1999.

[144] Resolution A.686(2), IMO 20th General Assembly (London: IMO, November 27, 1997), especially Appendix 2, § 1.3.2 re flow-through exchange.

[145] Tagg, *ibid*.

[146] In fact, almost all large commercial vessel ballast piping systems have a set of multiple main pipes, either running down the centerline of the vessel or in parallel port and starboard, connected to two or more main pumps in the flow between the internal system and the seachests for taking on and discharging water, with lots of valves and controls for moving water in different directions. There is considerable independent pumping capacity and piping already built in. There just are not any outflow pipe ends put in at the tops of the tanks.

[147] The complexity of the internal structure of vessels (which goes far beyond this basic discussion of some of the main points of ballast tanks) can be seen in basic references such as Robert Taggart, ed., *Ship Design and Construction* (New York: Society of Naval Architects and Marine Engineers, 1980).

[148] The Marine Board of the National Research Council recommends consideration of "structural and piping designs that trap less sediment and are easier to clean" at the time of "construction or major alteration to existing vessels." Marine Board, *Stemming the Tide: Controlling Introductions of Nonindigenous Species by Ships' Ballast Water* (Washington DC: National Academy Press, 1996), Appendix D, p. 106.

efficient a process can be created by the addition of piping for a flow-through exchange depends a great deal on the specific configuration of the tank and whether or not the piping dictating the pattern of flow is strategically located. Computer modeling conducted by Brazil indicates that relatively slight variations in the placing of inlets and outlets can cause significant differences in the effectiveness of the flushing action.[149] In addition, there is no design or safety constraint which prevents the installation of small, relatively cheap plastic or non-marine steel piping systems inside the tank for the purpose of cleaning off the internal structure.

Those are only a few of the technical changes which could be made. There is a whole range of available technologies for treating ballast water, including filtering, heat, ultraviolet light, biocides, and shore side treatment of water, some of which may well be economically feasible for particular types of vessels and trades. (See § 3.7 below.) None of them require invention of new technology. However, in the absence of a legal regime requiring such changes, and thus creating a level playing field, there is little incentive for any shipping company to make the required investment.

Breaking ships in half. The sequential method of exchange, dictated by the piping systems on most existing vessels, creates some amount of unavoidable hull stress because of the change in buoyancy in one section of the vessel at a time. The degree to which this creates a safety problem varies with the general design of the ship, the strength of the structural members, the size of the ship, the length-to-breadth ratio, the age of the ship, its maintenance history, and other stresses which may be created by high seas or distribution of the weight of the cargo in the vessel. It is important to understand that hull stress is a chronic problem, particularly with older bulk carriers – related to age, maintenance, cargo loading, and sea conditions – regardless of whether or not those vessels are required to conduct ballast exchanges. Figures from the International Association of Classification Societies (IACS), which has expressed strong concern about hull stresses incurred by improper cargo loading practices, show that around the world from 1983 to 1997 there were 73 bulk carriers lost or written off due to structural failure, and another 40 suffering serious damage.[150] During that same period, there were no losses associated with vessels conducting ballast exchange on the way into the Great Lakes. In 1998, however, a handysize vessel named the *Flare*, bound for Montreal after the Seaway was closed for the season (and thus not subject to the US mandatory exchange regime), broke in half with the loss of most of the crew. It was an older vessel with a history of prior problems, and was lost in high seas. But it appears that a ballast exchange may have contributed to the disaster. We know that hull stress is a problem. What we do not know is how much, and under what specific circumstances, ballast exchange will contribute to that problem.[151] Most

[149] Submission to IMO MEPC Ballast Water Working Group by the representatives of Brazil, "Harmful Aquatic Organisms in Ballast Water: Results of Ballast Water Exchange Tests Using the Dilution Method," MEPC Document 40/10/4 (London: IMO, July 18, 1997).

[150] International Association of Classification Societies, *Bulk Carriers: Handle with Care* (London: IACS, undated, *circa* 1998), p. 3.

[151] Some engineering analyses have been conducted on a small number of vessels in order to obtain a picture of the problem. That picture, unfortunately, is confused. The University of Michigan Department of

importantly, it does not appear that the masters of the individual vessels are always aware of their safe parameters. The better-managed shipping companies are working to correct that

Naval Architecture and Marine Engineering analyzed three sample ships – a dry bulk carrier, a tanker, and a containership – taken as typical of smaller ships trading to US ports, although only the bulker was a handysize that fit inside the Seaway. That study found that "ballasting/deballasting can be done at sea with safety as long as wave heights are below a maximum value. From [the] small sample of three ships it appears that this maximum lies between 10 and 20 feet." J.B. Woodward, M.G. Parsons, and A.W. Troesch, "Ship Operational and Safety Aspects of Ballast Water Exchange at Sea," *Marine Technology* (October 1994), vol. 31, pp. 315-326, 324. On the other hand, a similar study conducted by Melville Shipping for Transport Canada concluded that two sample vessels would not be able to safely conduct an exchange due to bending moment and sheer force limitations. Melville Shipping, *Ballast Water Exchange Study: Phase I*, Transport Canada Contract T8080-4-6801 (Ottawa: Melville Shipping Ltd., March 1995). Both of the vessels used in the Melville study were larger than the upper physical limits of what can fit through the St. Lawrence Seaway. However, one of those vessels, a bulk carrier 225 meters in length and 32 meters in beam, just a bit too wide, was uncomfortably close to the Seaway limits of 226 meters by 24 meters.

It had often been assumed that hull stress was primarily a big boat problem, with the rule of thumb sometimes given as being that it is of concern with vessels of more than 40,000 deadweight tonnes (DWT). A typical handysize bulk carrier small enough to fit through the St. Lawrence Seaway might run anywhere from around 10,000 to 35,000 DWT. It was therefore assumed by many that hull stress from ballast exchange was not an issue for the Great Lakes. A 1996 Canadian report warned that this might not be a good assumption, particularly for the smaller but narrower vessels in the Seaway: "While the safety implications of ballast water exchange continue to be debated internationally the emphasis appears to be placed on larger ships, bulk carriers over forty thousand tonnes deadweight, which are too large to enter the Great Lakes. However, the bulk carriers built specifically for the lakes trade and designed to a length to breadth ratio of 10:1 have a history of structural cracking on North Atlantic passages. This condition could be further aggravated by the exchange of water ballast, particularly as these ships age, and change ownership and/or management. The program [the voluntary Canadian ballast water exchange program beginning in 1990] has been in effect for seven years without serious incident, which would tend to indicate it can continue. However, over a period where the majority of entries have been in a loaded condition [NOBOB], it is easy to be lulled into a false sense of security." Aquatic Sciences, *Examination of Aquatic Nuisance Species Introductions to the Great Lakes through Commercial Shipping Ballast Water and Assessment of Control Option, Phase II*, ASI Project E9225/E9285 (St. Catherines, ON: Aquatic Sciences, Inc., August 1996), pp. 34-35.

Those words were prophetic. On January 16, 1998, the motor vessel *Flare* broke in half off Newfoundland while on its way in ballast from Rotterdam to Montreal. (Information on the *Flare* case from Transport Canada and Canadian Department of Fisheries and Oceans.) There were 25 in the crew, of which 21 drowned and 4 were rescued. The *Flare* was a bulk carrier, 181 meters long and 23 meters wide (approximately 8:1 length to breadth ratio), of 29,222 DWT, and built in 1972 (26 years old). The St. Lawrence Seaway was closed at that time and Montreal was the final destination, so the *Flare* was not subject to the US mandatory regulations, but it apparently conducted a pump-down pump-up ballast exchange in accordance with the 1990 voluntary Canadian guidelines. Seas were reported to be as high as 4 meters (13.2 feet) at the time of the hull failure. (The ship may have been manipulating ballast in a tank for another purpose. Unfortunately, it seems that any of the ship's officers who could have explained exactly what was done did not survive.) The failure was catastrophic in nature, occurring without any advance warning. The phrase "broke in half" is not a salty metaphor. There was, literally, only one half of the vessel on the surface of the ocean when Canadian rescue forces arrived.

At 26 years, this was a relatively old vessel, but not uniquely so. It was flagged under Cyprus, owned by a Greek company, and crewed with a mixture of nationalities. In 1993, it had been temporarily abandoned because of problems with shifting steel in the holds. The case is still under investigation by the Canadian Transport Safety Board and there are no conclusions about the cause of the hull failure at this time. In particular, it cannot yet be said whether or not a pump-down ballast exchange contributed to the hull failure. It can be said, however, that this is dramatic and tragic confirmation of the systemic problems discussed in the 1996 Canadian report.

problem.

The fundamental problem to be dealt with, as far as ballast exchange is concerned, is that this is something the ships, ballast tanks, pumps, and piping systems were simply not designed for.[152] In order to make exchange both safe and effective, there must be some changes in those systems.

The infamous NOBOBs. The "NOBOBs" are vessels entering the lakes reporting "no ballast on board" because they contain no pumpable ballast in their tanks, but which carry a considerable amount of unpumpable slop still in these tanks. This is a gaping hole in the protection provided by our current regulatory regime, and is likely to be just as large a problem for any expansion of an exchange regime to areas where vessels make more than one port stop along the coast.[153] Although the concept was suggested some time ago,[154] little serious consideration has been given to the idea of requiring some sort of partial exchange, what is known informally as a "swish and spit," to help clean the slop out of the bottom of the NOBOBs. The NOBOBs typically come across the ocean at or close to their marks (literally, the marks on the outside hull which designate the safe loading limits), with some cargo that is offloaded at Montreal or an earlier Canadian port in order to come up to the Seaway draft limits. They do come up a little along the voyage as they burn off fuel during transit, typically about ten days long. This may provide a few hundred metric tonnes of clearance, but only near the end of the transit. However, a ship would not necessarily have to forego a great deal of cargo in order to add enough margin for a swish and spit, particularly when that is compared to the total cargo being carried.

The effectiveness of exchange. A 1990 study conducted for the Canadian Government[155] after the promulgation of the voluntary guidelines in 1989 confirmed the feasibility and relative effectiveness of mid-ocean exchange as a control measure for vessels entering the St. Lawrence Seaway, but warned that it was far from completely effective. Based on a sampling of 12 vessels following the voluntary Canadian guidelines for exchange, the Canadian Government found that:

> Although the absence of live freshwater zooplankton from most saltwater ballast

[152] "Complete exchange of ballast water in mid-ocean as a regular practice in an operation that was not foreseen, nor designed for in any exiting ships." Alex Bilney, International Chamber of Shipping, US Coast Guard NPRM Docket USCG-98-3423, Comment #54 (August 6, 1998), p. 2.

[153] Recent studies of ballast in US coastal trade indicate that "Domestic ballast water may have actually originated from a foreign port in a ship that picks up partial loads in each of several US ports before transiting back to a foreign port. Thus, even ships defined as domestic traffic may be carrying large quantities of foreign ballast and NIS." Smithsonian Environmental Research Center (SERC) Marine Invasions Research Laboratory "Chesapeake Bay Research Overview Chesapeake Bay Research Overview" at http://www.serc.si.edu/invasions/chesoverview.htm (accessed July 15, 1999).

[154] A. Locke, D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen, *Effectiveness of Mid-Ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water*, Fisheries and Aquatic Sciences Report 1822 (Burlington, ON: Great Lakes Laboratory, 1991), p. 43.

[155] A. Locke, D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen, *Effectiveness of Mid-Ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water,* Fisheries and Aquatic Sciences report 1822 (Burlington, ON: Great Lakes Laboratory, 1991).

> samples indicated ballast exchange to be very useful, their presence in a few cases indicates exchange to be less than 100 percent effective. We calculated effectiveness of ballast exchange using ships originating in foreign freshwater ports and exchanging ballast water in mid-ocean.... Four vessels (33%) carried zooplankton that could live in the Great Lakes. Thus effectiveness of ballast water exchange was 67 percent.[156]

The Australians have found exchange to be less effective on the larger vessels calling at their ports, especially for removal of the dinoflagellate cysts which are of great concern to them. Some of their tests "showed that among 32 vessels which explicitly claimed to have exchanged ballast water in mid ocean, 14 were still found to contain significant amounts of sediments, including dinoflagellate cysts."[157] In other words, to make the same calculation, although the basis is not exactly the same, the effectiveness on these larger vessels is 56%. A follow-up study on vessels entering the Great Lakes conducted by the Canadians in 1996, after the promulgation of the 1993 US mandatory regime, confirmed that a large range of invertebrates and bacteria are carried in both exchanged water and NOBOB slop.[158]

The bottom line. The bottom line on the effectiveness of the current exchange regime is whether or not exotic species are getting through. This is difficult to judge, because of the delay between the introduction of an exotic and its detection. But the available evidence does strongly suggest that the existing regime is not effective. The Canadian voluntary guidelines for exchange on vessels entering the Great Lakes, supposedly observed by most of the industry, were first put out in May 1989.[159] In the nine years before then, 1979–1988,

---

[156] Locke, *et al*., *supra*, p. 34.

[157] G.R. Rigby, I.G. Steverson, C.J. Bolch, and G.M. Hallegraeff, "The Transfer and Treatment of Shipping Ballast Water to Reduce the Dispersal of Toxic Marine Dinoflagellates," *Toxic Phytoplankton Blooms in the Sea* (Amsterdam: Elsevier, 1993), pp. 169-176, 173.

[158] Aquatic Sciences, *Examination of Aquatic Nuisance Species Introductions to the Great Lakes through Commercial Shipping Ballast Water and Assessment of Control Options, Phase II Final Report*, ASI Project E9225/E9285 (St. Catherines, ON: Aquatic Sciences, August 1996). The organisms included Mollusca (mussels), Bivalia (mussels), Rotifera, Copepoda, Cladocer (water fleas), Diptera (flies), Oligocha (worms), Polychae (worms), Nematoda (worms), *E. coli*, *V. alginoliticus*, *V. fluvialis*, *A. hydrophila*, *Pseudemonas sp*, *Providencia rettgeri*, *Ps. Aeruginosa*, *A. sobria*, and *A. caviae*.

[159] The initial Canadian guidelines are described in Daniel Gauthier and Deborah A. Steel, *A Synopsis of the Situation Regarding the Introduction of Nonindigenous Species by Ship-Transported Ballast Water in Canada and Selected Countries*, Fisheries and Aquatic Sciences report 2380 (Mont-Joli, Québec: Fisheries and Oceans Canada, 1996), § 3.2, p. 7. These were followed up in 1993 by the promulgation of almost identical US Coast Guard mandatory regulations in 58 *Federal Register* 18334 (April 8, 1993), adding 33 CFR Part 151, Subpart C, §§ 151.1500 *et seq*. A Canadian study conducted in 1990 reported 89% compliance with the Canadian voluntary guidelines. A. Locke, D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen, *Effectiveness of Mid-Ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water*, Fisheries and Aquatic Sciences Report 1822 (Burlington, ON: Great Lakes Laboratory, 1991), p. 8. That level of compliance increased with the US Coast Guard mandatory regime. Compliance was well above 90%, and "problem vessels" found to initially be not in compliance were required to take remedial measures, such as treatment of the water, to correct the problem. M. Eric Reeves, "Techniques for the Protection of the Great Lakes from Infection by Exotic Organisms in Ballast Water," in Frank M. D'Itri, *Zebra Mussels and Aquatic Nuisance Species* (Chelsea, MI: Ann Arbor Press, 1997), pp. 283-99, 288-9, table 1 and notes. However, it is important to understand that all of these statistics apply to BOB vessels with "ballast on board," and not to the NOBOB vessels carrying unpumpable slop and sediment.

there were six new invasions documented.[160] In the nine years since, 1989–1998, there were also six new invasions documented, exactly the same number.[161] Four of these were detected during the period 1990–1991, and it is certainly conceivable that they could have been introduced before 1989 but not detected for several years. That is less likely for the last two introductions documented in 1995 and 1998. (With respect to both sets of statistics, one should remember that many other organisms, especially small ones, may have been introduced but have not yet been detected.) Even more revealing, there are two fresh-and-salt water exotics, the Chinese mitten crab[162] and the European flounder,[163] which were discovered in the Great Lakes in 1994. Because these two species live in fresh water, but require salt water to reproduce, they had to be relatively recent introductions. A careful evaluation of the age of the crab put its introduction to the lakes at no earlier than "late 1989,"[164] after the promulgation of the first Canadian guidelines in May of 1989 (and it may, of course, been much later). The flounder was younger, and "was probably released into Thunder Bay either at the end of the first year (autumn 1993) or at the beginning of the second year of life (spring 1994), probably the later,"[165] either of which was after the beginning of the US Coast Guard mandatory regulations in April 1993. This, combined with the documentation of live organisms in tanks which have been exchanged (and the problem of the NOBOB tanks), makes it clear that much is slipping through the cracks in the current exchange regime.

§ 3.7. Technical options for managing ballast water

There is no lack of known technical means to deal with the problem of exotics in ballast water. (In fact, it is beginning to appear that the great variety of technical options is an impediment to selection and implementation of something.) The problem, however, is that it costs something to install those means on ships, especially if they are to be retrofitted on old vessels.[166] Most of the following options are not exclusive. There are many logical combinations and permutations on the theme. All of the following cost estimates should be regarded as very rough, and there are a number of debatable assumptions that go into them.

[160] These were (1) the oligochaete *Ripistes parasita*, 1980, (2) the oligochaete *Phallodrilus aquaedulcis*, 1983, (3) the spiny water flea, *Bythotrephes cederstroemi*, 1984, (4) the European ruffe, *Gymnocephalus cernuus*, 1986, (5) the four-spine stickleback, *Apeltes quadracus*, 1986, and (6) the zebra mussel, *Dreissena polymorpha*, 1988. Compilation by Ms. Margaret Dochoda, biologist, Great Lakes Fishery Commission.

[161] These were (1) the tubenose goby, *Proterorhinus marmoratus*, 1990, (2) the round goby, *Neopobius melanostomus*, 1990, (3) the quagga mussel, *Dreissena bugensis*, 1991 (4) the NZ mud snail, *Potamopyrgus antipodarum*, 1991, (5) the amphipod *Echinogammarus ischnus*, 1995, and (6) the cladoceran water flea, *Ceropagis pengoi*, 1998. *Ibid*.

[162] *Eriocheir sinensis.*

[163] *Platichthys flessus*.

[164] J.H. Leach, Research Scientist, Ontario Ministry of Natural Resources Lake Erie Fisheries Station, letter to James Carlton, Maritime Studies Program, William College – Mystic Seaport (May 18, 1994).

[165] John M. Casselman, Senior Scientist, Ontario Ministry of Natural Resources Research, Science, and Technology Branch, letter to P. Furlong, Lake Superior Management Unit (December 9, 1994).

[166] The mean average age of international shipping over 100 gross registered tons is 15.8 years for bulkers and 17.8 years for tankers. The Chamber of Shipping, December 31, 1997 data at www.british-shipping.org (accessed July 1, 1999).

Much more lengthy and detailed discussion of technological options may be found in other sources.[167] Many assumptions go into any cost estimate, and all of the following estimates are debatable. They should be taken as indications of orders of magnitude and benchmarks. Another problem is that many of the estimates bandied about in the literature and informal discussions fail to specify the size and type of the vessel being considered, and are therefore comparing apples and oranges. A study conducted by Pollutech Environmental for the Canadian Coast Guard[168] is one of the few to put the estimates in terms of dollars per metric tonnes, and thus provide a consistent standard for comparison. (The figures given here are in US dollars, rounded off, from these estimates made in 1992.)

Open ocean exchange. It is important to clearly distinguish between open ocean exchange as a current practice, without any retrofitting or redesign of vessels, and open ocean exchange as it could be conducted, in top-down flow-through mode, with such changes.

(a) Advantages: Open ocean exchange is the only general method of ballast management currently in use. It is relatively cheap at about $300 per 1,000 tonnes[169] without any retrofitting (depending on the flow rates of existing pumps), or less, because this figure assumes some lost time in transit.

(b) Disadvantages: Under the current limitations of the design of tanks and piping systems (which were, for the most part, never designed for this purpose) exchange is (1) unsafe for many vessels, primarily because of hull stress during the pump down of loaded tanks at sea, (2) incomplete, because most piping systems are not designed to remove all the slop and sediment on the bottom of the tanks, and (3) not an option for the removal of slop and sediment on the bottom of "empty" tanks or "NOBOB" vessels (vessels with "no ballast on board" and loaded with cargo) unless some amount of cargo is sacrificed in order to reduce weight, allowing water to be taken on for a partial exchange or "swish and spit."

[167] I provide a more comprehensive survey of the literature in M. Eric Reeves, "Techniques for the Protection of the Great Lakes from Infection by Exotic Organisms in Ballast Water," in Frank M. D'Itri, ed., *Zebra Mussels and Aquatic Nuisance Species* (Chelsea, MI: Ann Arbor Press, 1997) 283-299. The leading national scoping studies on ballast water technology are: (1) Canada: Pollutech Environmental Limited, *A Review and Evaluation of Ballast Water Management and Treatment Options to Reduce the Potential for the Introduction of Non-Native Species to the Great Lakes, Technical Appendix B, Ballast Water Treatment*, report prepared for the Canadian Coast Guard (Sarnia, ON: March 31, 1992). (2) United States: Marine Board, National Research Council, *Stemming the Tide: Controlling Introductions of Nonindigenous Species by Ships' Ballast Water* (Washington, DC: National Academy Press, 1996). (3) Australia: Australian Quarantine and Inspection Service (AQIS), *Ballast Water Treatment for the Removal of Marine Organisms*, AQIS Ballast Water Research Series Report No. 1 (Canberra, Australia: Australian Government Publishing Service, June 1993).

[168] Pollutech Environmental Limited, *A Review and Evaluation of Ballast Water Management and Treatment Options to Reduce the Potential for the Introduction of Non-Native Species to the Great Lakes, Technical Appendix B, Ballast Water Treatment*, report prepared for the Canadian Coast Guard (Sarnia, ON: March 31, 1992).

[169] Pollutech, *ibid*., p. 21, table 2.2.6.1. This estimate assumes a flow rate of 2,500 m^3/hour and extra transit time due to exchange.

(c) Variations on the theme: Relatively minor changes to the piping systems on existing vessels could allow for a top-down flow-through exchange which would address all the disadvantages listed above. Costs of similar retrofitting of piping systems for a bottom-up flow-through exchange (which may be more expensive, although less effective) range from $200,000 to $1,000,000 in capital costs "for existing large vessels."[170] Costs for the necessary design changes in new construction would be much lower. The costs of current ballast systems (which would probably increase by something less than one times the current cost) are less than 1% of the total costs of new vessel construction.[171] (The double-hull requirement for new oil tankers, required by OPA 90, is adding about 10% to 20% to new construction costs.[172])

Filtering. This includes a number of different filtering technologies, including (1) screen filters, (2) media filters (probably only practical for shoreside use), and (3) hydrocyclones.

(a) Advantages: Filtering is completely safe for the ship and crew. It is relatively simple in concept. Screen or mesh strainer filtering systems, with footprints small enough for shipboard installation, are a proven technology for large industrial facilities on land. It would provide some unknown cost payback to the ship in the form of reduced sediment load and corrosion in the tanks. Also, filtering may be a necessary first stage for other treatment options, such as ultraviolet light or biocides.

(b) Disadvantages: It is currently difficult to effectively filter high-volume and high-speed flows below the 50 micron level, and that still allows a significant number of organisms of concern into the tank. Under the prevailing concept, filtering would be conducted at the ballasting port so that the dirty backwash can be discharged directly back to its origin. This requires consistent maintenance of reliable filtering systems and a "virgin tank" throughout all voyages between shipyard cleanings. Many vessels and crews are unlikely to maintain their filters and tanks in such a condition. The capital cost of retrofitting a filtering system on the handysize vessels sailing the St. Lawrence Seaway, the smallest class in the world's fleets, has been estimated to be about $1,080,000 per vessel.[173] (Installation on new construction would be much less.) Another estimate puts the total capital and operating cost at $2,370 per 1,000 tonnes of ballast.[174]

---

[170] Michael G. Parsons, "Flow-Through Ballast Water Exchange," a background paper for the Society of Naval Architects and Marine Engineers (SNAME) Ad-Hoc Panel on Ballast Water Exchange, SNAME Annual Meeting, San Diego, California, 1998.

[171] Everett C. Hunt and Boris S. Butman, *Marine Engineering and Economics Cost Analysis* (Centreville, MD: Cornell Maritime Press, 1995), appendix C, page C-3, table 12-3, account number 918.

[172] Hunt and Butman, *ibid.*, p. 1-6.

[173] Michael G. Parsons, Russell Moll, Thomas P. Mackey, and Rendall B. Farley, *Great Lakes Ballast Demonstration Project -- Phase I*. (Ann Arbor, MI: Cooperative Institute for Limnology and Ecosystem Research, University of Michigan, 1997), p. 69. Also, in personal communications since that time, Dr. Parsons has said that additional experience with the demonstration project would lead him to revise that estimate upward somewhat.

[174] Pollutech Environmental Limited, *A Review and Evaluation of Ballast Water Management and Treatment Options to Reduce the Potential for the Introduction of Non-Native Species to the Great Lakes,*

(c) Variations on the theme: Many proponents of filtering propose a second-stage system to attack organisms below the size of the filters, usually around the 50 micron level (but perhaps lower to about 25 microns, which might then remove the need for a second stage if bacteria and viruses are not a significant concern). The ones most mentioned are ultraviolet light and biocides, both of which usually require pre-filtering in order to be effective. Heat has also been considered as a second-stage treatment, but it is unclear why there is any purpose in filtering before heating. Any second-stage treatment will add significantly to the total cost, depending on the system used. Another form of filtering, unproven but interesting, is a hydrocyclone system which may be able to reach lower levels of microns and which may tend to clump particles together rather than break them up. Both screen and hydrocyclonic filters may also assist in suppression of reproduction via stress and shearing of the organisms which slip through the system, but this is an unproven effect.

Ultraviolet light (UV). This is electromagnetic radiation in wavelengths between 4,000 angstroms (near visible) and 40 angstroms (near x-rays), typically produced by lamps which either illuminate a transparent tube, through which the water flows (and may re-circulate), or are set closely together to form a barrier which the water must pass through. Effective penetration is usually measured in fractions of an inch.

(a) Advantages: If the systems are properly maintained, UV can be highly effective at killing small organisms, and, compared to biocides, do not create any concern about collateral damage on discharge. They are a proven technology in large-scale water treatment and industrial systems on land, with footprints small enough for shipboard installation. The power requirements can probably be met by most shipboard generating systems. Treatment could be conducted at port of ballasting, during the voyage, or at the port of deballasting. (UV could also be, thereby, a backup for a "pregnant tank" contaminated by a filtering breakdown.)

(b) Disadvantages: Most UV systems require pre-filtering. The effectiveness of UV is highly sensitive to maintenance of the system and the filtering of the water. Much smaller UV systems commonly used onboard vessels for treatment of sewage have often *not* been adequately maintained by the crews and companies, particularly those of smaller fleets operating under flags of convenience. Incomplete penetration by UV might cause genetic mutations. Depending on the amount of filtration, pumping rates, the point of application, and the effective dosage to be administered, a UV system with the necessary pre-filtration, including both capital and operating costs, has been estimated to range between $3,290 and $126,350 per 1,000 tonnes.[175]

Technical Appendix B, Ballast Water Treatment, report prepared for the Canadian Coast Guard (Sarnia, ON: March 31, 1992), p. 115, table 2.7.6.1.

[175] Estimate of 1992 US dollars present value cost, including both capital and operating costs, per 1,000 cubic meters in Pollutech, *ibid.*, pp. 128-130, tables 2.8.6.1-2.8.6.3. One can obtain a slightly lower cost for filtering plus UV, compared to filtering alone, by combining a very coarse filter with a UV system. But this lowers the likely effectiveness of the UV system, and may also increase breakdowns.

Biocides. This includes a large range of chemicals with very different effects.

(a) Advantages: A number of biocides are proven technologies in large-scale water treatment and industrial applications on land.

(b) Disadvantages: If applied aboard the vessel, biocides can create serious health risks for untrained crews. Some biocides also create a corrosion hazard. The relatively cheap biocides, such as chlorine compounds ($245 to $1,950 per 1,000 tonnes, depending on concentration[176]) create collateral damage to the environment. Those biocides which seem to have less environmental impact, such as ozone or certain nonoxidizing biocides such as glutaraldehyde (GA), tend to be very expensive ($2,470 to $14,745 per 1,000 tonnes for ozone, depending on concentration,[177] $600 to $6,000 per 1,000 tonnes for glutaraldehyde, depending on concentration and whether or not there was pre-filtering, which is not included in these figures[178]). Most biocides are less effective against large organisms and require pre-filtering.

(c) Variations on the theme: Some of the environmentally safe but expensive biocides such as glutaraldehyde may be appropriate for use in treating the relatively small quantities of slop and sediment (in the range of only a few hundred tonnes on most vessels) in the bottom of the NOBOBs. This sort of application of biocides may also be appropriate to treat the same slop and sediment in a vessel which is exchanging dirty water for clean water during an intermediate stop at a shoreside treatment facility. In both of these scenarios, the biocide would be administered by separate trained technicians while the vessel is tied to shore, allowing the crew to stay away and avoiding any need to store the chemicals onboard.

Heat. Target temperatures of anywhere from 35° to 70° C (95° to 158° F) have been proposed. But there is no consensus on how hot is hot enough.

(a) Advantages: Some heat may be captured as a waste byproduct of the ship's engines, although this is certainly not enough to do the job. Heat is a proven technology onboard ship in that some chemical and petroleum tankers already have heated tank capability. It presents little shipboard hazard (on new construction) or collateral damage to the environment (although there is some concern about thermal pollution). At sufficient temperatures, it can provide a very broad-spectrum kill. It does not require pre-filtering.

(b) Disadvantages: It may be very difficult to retrofit a system to penetrate all the necessary areas on existing vessels. Application of heat to existing vessels, without tanks and structural frames designed for that purpose, may create a serious safety problem because

[176] Estimate of 1992 US dollars present value cost, including both capital and operating costs, per 1,000 cubic meters in Pollutech, *ibid.*, pp. 57-60, tables 2.5.1.6.1-2.5.1.6.4.

[177] Estimate of 1992 US dollars present value cost, including both capital and operating costs, per 1,000 cubic meters in Pollutech, *ibid.*, pp. 71-73, tables 2.5.2.6.1-2.5.2.6.3.

[178] Larissa M. Lubomudrov., Russell A. Moll, and Michael G. Parsons, *An Evaluation of the Feasibility and Efficacy of Biocide Application in Controlling the Release of Nonindigenous Aquatic Species from Ballast Water* (Ann Arbor, MI: University of Michigan, November 1997), p. 90, table 10.1.

of the unknown effects of local expansion or corrosion. Cost estimates have not been developed because there is very little agreement on the temperatures which might be required, and cost is highly dependent on temperature, but the cost for large quantities of ballast water is likely to be high unless it can be reduced by a relatively complex system of heat exchangers (which presumes in-stream rather than in situ treatment).

(c) Variations on the theme: As in the case of the expensive biocides, heat may be quite economical for treatment of relatively small amounts of slop and sediment in the NOBOB or shoreside exchange scenarios. Heat might also be a particularly useful technology in a "treat alongside" scenario in which a specialized ship or barge would take on ballast water for heat treatment, using heat exchangers to reduce the needed energy, and discharge the water after natural cooling.

Ultrasound. Although theoretically interesting, this is not a proven technology in any large-scale application, and therefore neither data on effectiveness nor cost estimates are available. It may also create safety concerns aboard ship, in the form of both crew exposure and increase in the corrosion of steel (caused by the same cavitation effects that kill organisms). I note it here mainly because there has been a recent revival of interest in ultrasound, which was fairly well dismissed by early scoping studies. I suggest that it also serves as a good example of many other ideas which periodically resurface, but are then dismissed again as something which obviously "needs more work."

Shoreside treatment. This is not a separate technology except to the extent that shoreside treatment allows for the use of media filtration and settling tanks which cannot be fitted aboard vessels. But it does create a significantly different management scenario.

(a) Advantages: This is a proven technology, in that large municipal waste water treatment facilities currently treat water in quantities sufficient to absorb the discharge from vessels (depending on the specific port and municipality). Operating cost of treatment in an existing municipal system has been estimated to be around $240 per 1,000 tonnes,[179] the lowest of any cost estimates. The capital cost of retrofitting a discharge system to the central lines of the ballast system aboard the vessels should be minimal, and has been estimated to be from $8,000 to $16,000 per vessel.[180]

(b) Disadvantages: The primary problem is mating up the ships with the facilities. In order to be feasible, there must be a high concentration of traffic to a specific area where treatment is available. In some situations, a vessel may need to take on new, clean ballast before moving on to a cargo transfer point. This will create additional costs due to (1) delay, and (2) the need to treat the slop and sediment on the bottom of the tanks, probably with chemicals or heat, with those associated costs, before loading on the clean water. Also,

[179] Estimate of 1992 US dollars present value cost in Pollutech Environmental Limited, *A Review and Evaluation of Ballast Water Management and Treatment Options to Reduce the Potential for the Introduction of Non-Native Species to the Great Lakes, Technical Appendix B, Ballast Water Treatment*, report prepared for the Canadian Coast Guard (Sarnia, ON: March 31, 1992), p. 162.

[180] Estimate of 1992 US dollars present value cost in Pollutech, *ibid.*, p. 163.

there has been some concern about (3) salinity, or (4) unknown hazardous chemicals picked up in foreign ports, but both of these problems are manageable.

(c) Variations on the theme: Special-purpose treatment of ballast ashore could also be quite economical, if there is a sufficient concentration of user traffic to a specific location, because ballast water should actually be easier to treat than the typical waste from city sewers. It begins with a lower overall biological and particulate load, and simple media filtration (sand filters) could be highly effective for first-stage treatment. Second stage treatment would then likely be either chlorine (with third-stage dechlorination in some areas) or UV, either in the specialized facility or in the municipal system. This might be a way to avoid the concern over contamination of the municipal system with salt or hazardous chemicals. (It should be kept in mind that those hazardous chemicals are currently being discharged in our ports, along with the biological pollution, without any restriction.)

Getting serious about the options. It should be obvious, from this quick review of the leading options, that questions of effectiveness and cost depend on what the standard is. How good does the exchange have to be, how low a number of microns must be filtered, how high does the dose of chemicals or UV have to be, or how high does the temperature have to be? Without a performance standard (which should be improved over time) it is difficult to compare these options in a meaningful way. All of the cost estimates are very rough, and should be qualified with two general observations: (1) Costs for installation of systems in new construction will always be significantly lower than for retrofitting existing vessels, sometimes by as much as an order of magnitude. (2) Costs are likely to decline, in general, as systems come into commercial production and the natural forces of competition come into play. In order to encourage such competition, however, it is important that government policy prescribe standards for bottom-line performance rather than particular technological approaches.

The fact that there is still some work to be done to perfect various options, or that there are other interesting but unproven technologies to consider, should not be allowed to obscure the fact that technologically and economically feasible means to deal with ballast do in fact exist at the present time. Both retrofitting for top-down flow-through exchange and shoreside treatment present reasonable means to significantly reduce the threat of new invasions in the immediate future. They may not be the ideal or ultimate technologies, and further work on other options should certainly continue. But that is not a valid excuse for the lack of current action. Moreover, it is illogical to put off changes in new vessel construction in hope of having some wonderfully cheap alternative come on line in the future, because any future reductions in the cost of other options are highly unlikely to overcome the increase in the cost of retrofitting old vessels.

§ 4. Aquaculture: Teach them to grow a fish

The term “aquaculture” is sometimes used to mean any form of cultivation of aquatics, which includes growing of fish for bait or aquaria as well as for food, or even stocking of

natural waterways. I am using it here in the more limited and common sense of production of aquatic organisms under controlled conditions (more or less) for use as food. That point is important, particularly to aquaculturists who resent being painted with a broad brush, when considering the history of exotic invasions in the Great Lakes. A general survey of all documented introductions between 1810 and 1991 conducted by some of the leading researchers in the Great Lakes, often cited in the literature, ascribed 29% of total introductions to "unintentional releases," including aquaculture. But their actual coding of 33 species of aquatic fauna – including fish, mollusks, crustaceans, oligochaetes, other invertebrates, and bacterial and protozoan pathogens – included none that were actually classified as releases from "aquaculture" *per se*.[181] In fact, a case can be made that "aquaculture" – in the limited sense distinct from older practices of cultivating new species of fish in natural lakes and rivers, which were associated with the introduction of the alewife, common carp, furunculosis, and *Glugea hertwigi* – has never been clearly associated with a significant introduction to the Great Lakes.[182] (One exception may be whirling disease, caused by *Myxobolus cerebralis*, a protozoan whose mechanism of release is unclear, although it was first documented in an Ohio aquaculture facility.[183]) Thus, proponents of the aquaculture industry may argue that there is no scientific basis for even considering that industry to be a vector of concern.[184]

That is an argument, but one which is not persuasive, if for no other reason than the fact that aquaculture is a relatively new and expanding industry in the United States and Canada. Fishery managers tend to look back at artificial stocking in natural lakes and rivers as the precursor to modern aquaculture, and then lump them together in the classification of "unintentional releases" or "intentional introductions," because those were the closest historical precursors. More to the point, there are perfectly logical reasons to be wary of accidents occurring as a result of the expansion of aquaculture in the future regardless of the lack of clear historical or empirical proof of danger. With the possible exception of certain closed recirculating aquaculture facilities, one must assume that any organism widely cultivated will have opportunities to escape. Exotic species used for aquaculture are likely to be exactly the sort of species successful at invasion if released by reason of their adaptability to the climate and strong breeding characteristics. As one scientist puts it, there are "ecological perils implicit in the characteristics of those species that make those species ideal for aquaculture."[185] The really big and bad ones such as the sea lamprey and the zebra mussel come along only infrequently, and each has its own unique history. One might have learned, from the devastation of the sea lamprey, that the key is to watch out for what swims up the canals. But that historical lesson was not good preparation for the invasions of the

[181] Edward L. Mills, Joseph H. Leach, James T. Carlton, and Carol L. Secor, "Exotic Species in the Great Lakes: A History of Biotic Crises and Anthropogenic Introductions," *Journal of Great Lakes Research* (1993), vol. 19, no. 1, pp. 1-54, 7-8, Table 3.

[182] See also the list of the thirteen most significant introductions in Mills, *et al*., *ibid.*, pp. 1-54, 43.

[183] Mills, *et al*., *ibid*, pp. 1-54, 20.

[184] This was the sense of comments from one or more industry experts at the American Fisheries Society Symposia, "Private Agriculture Safeguards for Great Lakes Biological Integrity" (Dearborn, MI, August 29, 1996).

[185] Dr. George Spangler, comments at the American Fisheries Society Symposia, "Private Agriculture Safeguards for Great Lakes Biological Integrity," Dearborn, Michigan, August 29, 1996.

European ruffe and the zebra mussel in ballast water. Attempts to attack these problems "scientifically" with careful statistical analysis are of limited value as a guide to evaluating future threats.[186]

In fact, up until now the great preponderance of aquaculture in the United States has used native catfish and trout species, with almost half of total production (49%) being catfish, which has been concentrated in the southern states. But the industry is now beginning to make more use of exotics such as African tilapias and Asian carps.[187] An exotic blue tilapia which escaped from aquaculture in Florida has established itself in the Everglades, where it is causing serious damage to native fish and vegetation.[188] Considering that there have been few exotic fish used in aquaculture in the Great Lakes in the past, just as there have been few alligators cultivated here, it therefore is not particularly significant to observe that we have suffered few invasions from exotic fish or alligators from aquaculture in the past.

The best expert opinion on the nature of the threat comes from the US National Science and Technology Council Joint Subcommittee on Aquaculture (JSA), which is a strong proponent of aquaculture development. The JSA has identified the following "challenges" in their national plan for aquaculture in the United States:

> As US aquaculture continues to expand, it must be sustainable and environmentally compatible. We need substantially better knowledge about possible interactions between aquaculture and natural environments to minimize the potential for habitat degradation, disease transmission, genetic dilution of wild stocks through interbreeding with cultivated strains, introduction of non-indigenous species into natural waters, and discharges of wastes, toxins, and excess nutrients.[189]

[186] That sort of statistical study is of very real value, but only within limits. Scientists are trained to quantify. Few biologists want to appear at a conference without their bar and whisker graphs. But the quantifications, trends, and linear correlations they seek to draw out of those data sets are often vague or misleading (as they themselves often warn their audiences) because of the inability to control for historical change in the ecosystem, including the historic and non-repetitive perturbations of human activities as well as the chaotic and nonlinear changes in ecosystem interactions. Ecology, which might be thought of as the current history of paleontology, is very much what the paleontologist Stephen Jay Gould has called a "historical science," in which "verification by repetition," the stereotypical talisman of the scientific method, is inapplicable "because we are trying to account for uniqueness of detail that cannot, both by laws of probability and time's arrow of irreversibility, occur together again." Stephen Jay Gould, *Wonderful Life: The Burgess Shale and the Nature of History* (New York: W.W. Norton, 1989), p. 278. This point is far from being merely academic or philosophical. It plays a critical part in the politics of ecology. Whether the subject is aquaculture or global warming, there will always be an argument, based on a false image of science, that we need to wait for more "science" to prove the connection in quantitative terms.

[187] Rebecca Goldberg and Tracy Triplett, *Murky Waters: Environmental Effects of Aquaculture in the US* (New York: Environmental Defense Fund, October 1997), p. 22, Figure 1.3, p. 50.

[188] Goldberg and Triplett, *supra*, pp. 11, 52.

[189] National Science and Technology Council Joint Subcommittee on Aquaculture (JSA), *Draft National Aquaculture Development Plan of 1996* (Washington DC: JSA, 1996), § 4.4.5, p. 9. (This is still the most current version of this policy statement by JSA as of July 15, 1999.)

Also, it is important to note that the possible injury to biodiversity can come from more than just the introduction of a new species of fish. It includes (1) pathogens, to which agricultural fish are highly susceptible because of their high concentrations and the stresses of their artificial environment, and (2) dilution of the genetic diversity of native species by specialized aquaculture strains of the same species.

§ 4.1. Profile of the aquaculture industry

Aquaculture in the United States and Canada is very much on the beginning or "take off" segment of the S-curve so familiar to both ecologists and economists. That does not mean that it can safely be predicted to climb to the top of the curve. It just means that current growth is relatively rapid, beginning from very low levels, and that it has definite potential. Promotional literature for the development of aquaculture often points out that fish farming was first practiced as long ago as 2,000 BCE in China.[190] Nevertheless, aquaculture is still more of a potential than a major economic activity at the end of the Twentieth Century.

It did not begin in the United States, and then only in a rather limited form, until the last part of the Nineteenth Century. Up until the early 1960s, it was fairly restricted in the types of fish cultivated, and "Many of these early attempts at fish husbandry failed…."[191] Aquaculture in the United States includes catfish, salmonids (predominantly trout), mussels, oysters, shrimp, and even alligators. The oldest, largest, and most economically viable sector of aquaculture is the farming of catfish in the southern states. (Catfish accounts for 49% of total production[192] and 84% of the increase in US production from 1983 to 1993.[193]) Even this is small scale, although it has been growing. Catfish farming has gone from approximately 400 acres in 1960 to 161,000 acres in 1991, with 59% percent of that in the State of Mississippi.[194]

Generally, aquaculture in the United States has been described as "the fastest growing agricultural sector, with production increases of 265 percent reported between 1980 and 1993."[195] However, "Despite this rapid growth, domestic aquaculture still provides less than 10 percent of the nation's total seafood supplies. Over 40 percent of the fish and shellfish consumed in the US is imported…."[196] (And that, it must be remembered, is a limited part of the US diet. Although seafood has been increasing in popularity, the average per capita consumption of seafood in the United States was still only 15.5 pounds in 1990.[197]) The

[190] LaDon Swann, *A Basic Overview of Aquaculture*, Illinois-Indiana Sea Grant Program Technical Bulletin Series #102 (West Lafayette, IN: Purdue University, August 1992), p. 2.

[191] LaDon Swann, *supra*.

[192] Goldberg and Triplett, *supra*, p. 22.

[193] JSA, *supra*, § 2, p 3.

[194] LaDon Swann, *supra*., p. 3.

[195] Michigan State University, *Water Impacts*, vol. 16, No. 3 (Lansing, MI: Michigan State University Institute of Water Research, March 1995), p. 3.

[196] *Water Impacts*, *supra.*

[197] LaDon Swann, *supra*, p. 3.

most recent figures available from the JSA show that aquaculture production for food in the United States in 1997 weighed in at 774 million pounds and was valued at $717 million.[198] (Not a staggering amount in a national economy with a GNP of over 7 trillion in 1995. But it does represent a simple annual average growth of 17% in weight and 19% in value during the last ten years of 1987-1997.)

In the "North Central Region" of the United States, a US Department of Agriculture (USDA) region which includes all of the Great Lakes states except Pennsylvania and New York, the two predominant species are catfish and trout. The largest percentage of catfish producers in the North Central region are in Missouri, Kansas, Illinois, Ohio, and Nebraska (in that order) and the largest percentage of producers of trout are in Wisconsin, Michigan, and Minnesota (in that order).[199] Wisconsin production has a "current" estimated value (probably based on mid-1990s figures) of $8.8 million a year.[200] Pennsylvania, the leading state in the USDA's "Northeast Region," produced trout worth $16 million in 1995, but it is unclear how much of this was in the Great Lakes watershed.[201] Aquaculture in the Province of Ontario has been almost entirely production of rainbow trout, by reason of provincial policy, although the Ontario Ministry of Natural Resources significantly widened the number of species allowed for production in 1995.[202] The great majority of the Ontario aquaculture facilities are in the "southern peninsula" between Lake Huron and the eastern lakes, squarely within the Great Lakes watershed. Ontario production came between 7.0 and 7.5 million pounds and C$12.5 to C$14.0 in 1995.[203]

§ 4.2. Aquaculture technology

As a matter of basic physics and biology, aquaculture has an obvious potential for producing high-quality protein far more efficiently than terrestrial agriculture.[204] But small-scale producers frequently meet with unpleasant surprises in the form of large capital investments required for the facilities,[205] the difficulty of maintaining consistent water quality (including problems with levels of heat, air, nutrients, and toxins, the problem of handling waste water), and the problems of preventing spread of diseases in highly

[198] Joint Subcommittee on Aquaculture, "US Private Aquaculture Production for 1985-1997," at ag.ansc.edu (Washington, DC: JSA, February 18, 1999).

[199] Leroy J. Hushak, *North Central Regional Aquaculture Industry Situation and Outlook Report*, vol. 1 (Ames, IA: Iowa State University North Central Region Aquaculture Center, August 1993), p. 16.

[200] Wisconsin Sea Grant Advisory Services web sit on "Aquaculture" at www.seagrant.wisc.edu (October 27, 1998).

[201] M.J. Spatz, J.L. Anderson, and S. Jancart, *Northeast Region Aquaculture Industry Situation and Outlook Report*, Rhode Island Agriculture Experiment Station publication no. 3352 (Kingston, RI: Rhode Island Agriculture Experiment Station, 1996).

[202] Richard D. Moccia and David J. Bevan, *Aquastats 95*, ACE order no. 96-001 (Guelph, ON: University of Guelph, August 1996), available at www.aps.uoguelph.ca.

[203] Moccia and Bevan, *ibid*.

[204] LaDon Swann, *A Basic Overview of Aquaculture*, Illinois-Indiana Sea Grant Program technical bulletin series #102 (West Lafaette, IN: Purdue University, August 1992), p. 3.

[205] Personal interview of Dr. Don Garling, an aquaculture specialist and member of the Michigan Aquaculture Advisory Committee, at Michigan State University in Lansing, MI; and Swann, *supra*.

concentrated and stressed populations. Aquaculture facilities are quite varied in design and degree of sophistication. They may consist of isolated ponds, cages connected to public waters, artificial raceways (almost exclusively for trout), and closed recirculating systems. Ponds, which may resemble the layout of terrestrial agricultural fields, require a lot of land. Cages (highly disfavored by US Great Lakes conservation agencies) result in discharge of wastes to public waters and present a high probability of escapes. Raceways require specialized construction and a good source of fresh water, unless they are combined with a water recirculating system. Closed recirculating systems, which may resemble huge, factory-like aquaria, require expensive pumping, feeding, cleaning, and water control equipment. But they can be highly productive and environmentally clean. One closed recirculating facility in Pennsylvania produces 500,000 pounds of hybrid striped bass, tilapia, steelhead, and yellow perch in huge tanks while recirculating 98% of its water.[206] From the point of view of preventing both escapes of exotics and discharge of harmful wastewater, these systems are much preferred over the others, especially the cages.[207]

§ 4.3. The supply and transportation of organisms

The fish or their eggs may come from anywhere. This includes (1) natural stocks in the same watershed (which almost always require a permit from the conservation authorities), (2) cross-trading between different aquaculture farms (which may require little in the way of permits and documentation), or, (3) more commonly, one of a relatively small number of large farms (which will usually require some sort of permit or health certification from agriculture or conservation authorities). Most of the trout producers in the eastern United States buy eggs from large farms in the western United States.[208] Sources for stock used in the Great Lakes region varies. For example, Michigan brook and brown trout eggs are produced almost entirely within Michigan,[209] but most of the rainbow trout producers in Michigan buy eggs from a single large supplier in the State of Washington, which sends them by air freight, along with a certification that they are free from disease. [210]

Aquaculture diseases. Disease is a major concern for the aquaculture industry. Many of the same pathogens which have minimal effects in the natural environment become a serious problem for aquaculture fish because of their high densities, poor water quality,

[206] Rebecca Goldberg and Tracy Triplett, *Murky Waters: Environmental Effects of Aquaculture in the US* (New York: Environmental Defense Fund, October 1997), p. 15.

[207] Goldberg and Triplett, *ibid*.

[208] Swann, *ibid*, p. 8.

[209] Joyce R. Newman and Niles R. Kevern, *Production of Michigan Aquacultural Products*, Michigan Agricultural Experiment Station research report RR 526-1 (East Lansing, MI: Michigan State University Agricultural Experiment Station, April 1994), p. 7.

[210] Charles J. Chopak and Joyce R. Newman, *Aquaculture: Status and Potential of Michigan Agriculture – Phase II*, Michigan State University Agricultural Experiment Station special report no. 50 (East Lansing, MI: Michigan State University Agricultural Experiment Station, September 1992), p. 7; and Newman and Kevern, *supra*.

inadequate nutrition, and poor sanitation.[211] In addition, the transportation of fish for use in aquaculture, even if not exotic species, has the potential to transport exotic pathogens which can have a serious impact on native strains of the same species with less resistance to those pathogens.[212]

The Joint Subcommittee on Aquaculture (JSA) has observed that "the US government's ability to prevent and control aquatic animal diseases is presently inadequate. The government's effectiveness is impaired by a fragmented, uncertain, and incomplete Federal regulatory framework, often characterized by disagreements among agencies with roles and responsibilities in aquatic animal health."[213] Also, the lack of a "competent authority" for aquaculture disease control at the federal level in the United States (meaning, technically, one agency with clear authority over the issue) has been of concern to authorities in the European Union, who do not generally consider US regulation of the industry to be up to par.[214] The US Animal and Plant Health Inspection Service (APHIS) in the US Department of Agriculture (USDA) is developing regional laboratories for better certification of US agriculture products for export.

On the import side, the Michigan Department of Agriculture (MDA) and Michigan State University (MSU) are working to develop cheaper and faster laboratory techniques for the identification of diseases in fish imported for aquaculture,[215] and the Great Lakes Fishery Commission (GLFC) has published a model program for controlling pathogens in salmonid imports.[216] The GLFC guidance is provided to aquaculturists, but not actually required to be used, under the Michigan Aquaculture Development Act.[217] MDA has active programs, in coordination with the Michigan DNR, for monitoring specific diseases such as the whirling disease, which is common among salmonids.[218] (Whirling disease is caused by *Myxobolus*

[211] APHIS, *Overview of Aquaculture in the United States* (Fort Collins, CO: USDA APHIS Centers for Epidemiology & Animal Health, October 1995), p. 16; and LaDon Swann, *Diagnostic Services in Illinois and Indiana*, Sea Grant #IL-IN-SG-FS-91-10 (West Lafaette, IN: Purdue University, undated), p. 1.

[212] Rebecca Goldberg and Tracy Triplett, *Murky Waters: Environmental Effects of Aquaculture in the US* (New York: Environmental Defense Fund, October 1997), p. 52. See also James E. Stewart, "Introductions as a Factor in Disease of Fish and Aquatic Invertebrates," *Canadian Journal of Fisheries and Aquatic Sciences* (1991), vol. 48 (Supplement 1), pp. 110-117.

[213] JSA, *Draft National Aquaculture Development Plan of 1996* (Washington DC: National Science and Technology Council Joint Subcommittee on Aquaculture, 1996), § 4.4.6, p. 9. (This is still the most current version of this policy statement by JSA as of July 15, 1999.)

[214] Terry L. Medley, *APHIS Aquaculture Industry Report* (Riverdale, MD: Animal and Planet Health Inspection Service Legislative and Public Affairs, July 1996), p. 1; and *Draft National Aquaculture Development Plan of 1996*, *supra*, § 4.4.6, p. 10.

[215] Presentations at the Michigan Department of Agriculture Aquaculture Advisory Committee, Lansing, MI, November 10, 1998.

[216] *Great Lakes Fish Disease Control Policy and Model Program*, Great Lakes Fishery Commission Special Publication 93-1 (Ann Arbor, MI: Great Lakes Fishery Commission, January 1993).

[217] Michigan Compiled Laws, MCL § 286.877(c).

[218] Denise Yockey, *State Agriculture Director Announces Monitoring Strategy for Whirling Disease in Fish*, MDA news release (Lansing, MI: MDA Marketing and Communications Division, August 25, 1998); MDA, *Reportable Animal Disease List*, MDA public advisory, apparently annual (Lansing MI: MDA Animal Industry Division, August 1998).

cerebralis, a protozoan originally exotic to the Great Lakes, whose mechanism of release is unclear, although it was first documented in an Ohio aquaculture facility.[219])

The diagnosis of diseases depends on specific protocols, developed by biologists and veterinarians in response to specific outbreaks. Nor do there even seem to be any established field or laboratory protocols for the detection of a wide number of pathogens known to be present in non-salmonid species of fish around the world,[220] but not yet known to be a problem in the Great Lakes. Disease diagnosis, for fish as well as humans, requires a fair amount of expertise and experience.[221] It also requires an opportunity to observe the population providing the eggs under controlled conditions. The fact that the industry is structured in such a way that most imported eggs are supplied by a small number of large and easily identified farms offers government regulators an excellent target of opportunity for quality control of the supply. But that requires some effective exercise of authority at federal and international levels.

§ 4.4. Genetic modification

Genetic modifications bear on the exotic problem in two ways. Genetic modification can be used as a method for preventing invasions. Grass carp and other salmonids which have been modified at the point of fertilization to have an extra set of chromosomes, making them "triploids" instead of normal "diploids," are thereby made sterile. This has been particularly desirable in the case of grass carp because they are useful in the control of exotic and other nuisance aquatic weeds. It may also have collateral benefits for aquaculture in that triploid fish will not fully mature, and thus maintain more desirable flesh.[222] But this technique is far from foolproof. It requires careful testing of stocks (using blood tests) to insure that no normal diploids are present. Contrary to early expectations, a diploid male may be able to impregnate the eggs of a triploid female. Also, experiments with oysters indicate that some sterilized organisms can revert back to a fertile state.[223]

Genetic modifications, through either simple selection and inbreeding or more sophisticated techniques for modifying genes or transplanting them from one organism to another ("transgenic" organisms) amount to human creation of exotics. Some species, such as salmon, may be deliberately selected for characteristics which make them more suitable for aquaculture, such as lower aggression, but which have the potential to be harmful if

[219] Edward L. Mills, Joseph H. Leach, James T. Carlton, and Carol L. Secor, "Exotic Species in the Great Lakes: A History of Biotic Crises and Anthropogenic Introductions," *Journal of Great Lakes Research* (1993), vol. 19, no. 1, pp. 1-54, 20.

[220] See the list of pathogens around the world in APHIS, *Overview of Aquaculture in the United States* (Fort Collins, CO: APHIS Centers for Epidemiology & Animal Health, October 1995), pp. 14-15, table 7.

[221] See Joyce R. Newman and Niles R. Kevern, *Production of Michigan Aquacultural Products*, Michigan Agricultural Experiment Station research report RR 526-1 (East Lansing, MI: Michigan State University Agricultural Experiment Station, April 1994), p. 10.

[222] From the Victorian Fisheries Institute web site at www.fishnet.au (accessed February 18, 1999).

[223] Rebecca Goldberg and Tracy Triplett, *Murky Waters: Environmental Effects of Aquaculture in the US* (New York: Environmental Defense Fund, October 1997), p. 14.

spread to the native stock.[224] More generally, the simple fact that the inbred stocks have less genetic diversity can cause ultimate loss of genes in the native population.[225] Such inbred strains have not been considered a major threat to biodiversity by many biologists, based on good experience with terrestrial organisms. But some researchers point out that "terrestrial breeding programs may not be an appropriate model upon which to base regulations for the aquatic sector, partly because so much of aquatic biodiversity is found in wild populations,"[226] and others warn that the escape of exotic cultured stocks could cause "devastation."[227] The potential for contamination of native stocks by genetically modified fish is considered a matter of concern by the United Nations Food and Agriculture Organization (FAO).[228]

A vice president of the World Bank has said that "The next great leap in producing food will come from 'domesticated' and genetically improved varieties of fish and other seafood."[229] The only US policy statement on the issue seems to be the general note of concern in the "challenges" quoted above in the JSA plan for aquaculture.[230] The Canadian Government is actively promoting a "biotechnology strategy" which includes creation of transgenic fish and other aquatic organisms.[231] That program is led by the Department of Industry (Industry Canada). The Department of Fisheries and Oceans (DFO) is supportive of the Industry Canada plan, but somewhat more cautious about the use of transgenics. DFO notes that "transgenics, such as carp that have the rainbow trout growth hormone gene, are considered by some as new organisms for which there is little existing information relevant to their behavior, interaction, or performance in the wild; nor is there any appropriate theoretical basis for prediction."[232]

[224] Goldberg and Triplett, *ibid.*, pp. 53-55.

[225] Kjetil Hindar, Nils Ryman, and Fred Utter, "Genetic Effects of Aquaculture on Natural Fish Populations," *Aquaculture*, vol. 98 (1991), pp. 259-261. See also R.W. Doyle, N.L. Shackel, Z. Basiao, S. Uraiwan, T. Matricia, and A.J. Tolbot, "Selective Diversification of Aquaculture Stocks: A Proposal for Economically Sustainable Genetic Conservation," *Canadian Journal of Fisheries and Aquatic Sciences* (1991), vol. 48 (Supplement 1), pp. 148-154; Aquatic Nuisance Species Task Force, *ibid.*, p. 10. On the mixed state of affairs in 1991, see also Paul J. Wingate, "US State's View and Regulations on Fish Introductions," *Canadian Journal of Fisheries and Aquatic Sciences* (1991), vol. 48 (Supplement 1), pp. 167-170.

[226] Devin M. Bartley and Eric M. Hallerman, "A Global Perspective on the Utilization of Genetically Modified Organisms in Aquaculture and Fisheries," *Aquaculture*, vol. 137 (1995), pp. 1-7, 4.

[227] James W. Fetzner, Robert J. Sheehan, and Lisa W. Seeb, "Genetic Implications of Broodstock Selection for Crayfish Aquaculture in the Midwestern United States," *Aquaculture*, vol. 154 (1997), pp. 39-55, 50.

[228] See FAO, *Code of Conduct for Responsible Fisheries* (Rome: UN FAO, 1995), § 9.3.1.

[229] Ismail Serageldin, quoted in DFO, *Aquatic Biotechnology*, Department of Fisheries and Ocean discussion document attached to the Canadian Biotechnology Strategy (Ottawa: Industry Canada, Bio-Industry Branch, August 6, 1998), § 3.

[230] JSA, *Draft National Aquaculture Development Plan of 1996* (Washington DC: National Science and Technology Council Joint Subcommittee on Aquaculture, 1996), § 4.4.5, p. 9. (This is still the most current version of this policy statement by JSA as of July 15, 1999.)

[231] DFO, *Aquatic Biotechnology*, Department of Fisheries and Ocean discussion document attached to the Canadian Biotechnology Strategy (Ottawa: Industry Canada, Bio-Industry Branch, August 6, 1998), § 3.

[232] DFO, *ibid*, § 5a.

§ 5. Baitfish: The little fish that got away

Baitfish dealers are an even more diffuse and varied group than aquaculturists, although the two categories overlap, and the regulatory challenge is even greater in this area. A few general surveys of baitfish activities in the general region have been conducted.[233] Researchers from Michigan and Minnesota Sea Grant are currently conducting an in-depth field study of baitfish, with the cooperation of some industry interests, in order to (1) better evaluate the nature of the exotics threat, and (2) identify specific points where government or industry interdiction of exotic transfers might be effective.[234] Their final report is not yet available. But we do already know that a substantial amount of live bait is moved around the Great Lakes states and the Province of Ontario, across watersheds, and that it is subject to very little control.

Annual sales of both wild and cultured baitfish in the US and Canada are worth something in the area of one billion dollars per year.[235] "Although the exact size of the industry is not known, nearly all states east of the Rocky Mountains, as well as Arizona and California west of the continental divide, have some bait farming. Species of fish and shellfish produced include: golden shiners, fathead minnows, goldfish, carpsuckers, bluntnose minnows, tilapia, suckers, and crayfish."[236] Most harvesters and dealers are small-scale independent operators,[237] but they are quite capable of transporting live fish for long distances with relatively simple technology such as oxygen tanks, aerators, and live wells.[238] Bait may be collected out of either public waters, with permits from the local conservation agencies, or from private ponds specially maintained for that purpose. What bait is used, where it comes from, and where it goes, may vary during the season, especially in the Great Lakes region.

---

[233] *E.g.*, some of the more recent are Thomas J. LoVullo and Jay R. Stauffer, Jr., "The Retail Bait Industry in Pennsylvania," Matthew K. Litvak and Nicholas E. Mandrak, "Ecology of Freshwater Use in Canada and the United States," *Fisheries*, vol. 18, no. 12 (December 1993), pp. 6-13; and Herbert R. Ludwig, Jr., and Jay A. Leitch, "Interbasin Transfer of Aquatic Biota via Anglers' Bait Buckets," *Fisheries*, vol. 21, no. 7 (1996), pp. 14-18.

[234] Brief from Dr. Douglas Jensen, Minnesota Sea Grant, and Dr. Ron Kinnunen, Michigan Sea Grant, to the Great Lakes Commission Panel on Aquatic Nuisance Species, Ann Arbor, Michigan, January 28, 1999. Their study seeks to apply the "HACCP" system, developed in food safety control, to the management of exotics in bait handling and aquaculture. "HACCP" stands for "hazardous analysis of critical control points," *i.e.*, strategic analysis of targets of opportunity for effective control of a system, by either the government or the industry. Their study is near the end of the first of two years of scheduled work.

[235] Matthew K. Litvak and Nicholas E. Mandrak, "Ecology of Freshwater Use in Canada and the United States," *Fisheries*, vol. 18, no. 12 (December 1993), pp. 6-13, 6. One billion dollars is a very round figure, based on 1991 estimates that were rather rough at that time, and is offered here just to establish an order of magnitude.

[236] LaDon Swann, *A Basic Overview of Aquaculture*, Illinois-Indiana Sea Grant Program technical bulletin series #102 (West Lafayette, IN: Purdue University, August 1992), p. 6.

[237] Litvak and Mandrak, *supra*, pp. 6-13, 12, also citing L.A. Neilson, "The Bait-Fish Industry in Ohio and West Virginia, with Special Reference to the Ohio Sport Fishery," *North American Journal of Fisheries Management*, vol. 2 (1982), pp. 232-238.

[238] Litvak and Mandrak, *ibid*.

Those dealers making an ongoing business out of it do have a natural interest in avoiding the collection of non-target organisms and parasites. It is common to use nets or screens of specific mesh size to filter out unwanted fish, and some of the dealers make a practice of transporting their own clean water to the harvest site in order to avoid picking up veligers and microorganisms.[239] It is not clear how common these preventative measures are, or what their true level of effectiveness is.

Historically, out of an estimated 168 native species that have become established outside their range within the US, it is believed that about 58 (35%) were introduced as bait or forage fish.[240] In addition, as in the case of aquaculture, baitfish can be a source for diseases.[241] Researchers conducting actual sampling of bait have found that "a substantial number of species were used outside their native distributions," including many that are illegal to import, and that many fishers routinely dump their unused live bait in the non-native waters.[242] Other researchers studying the transfer of bait from the Mississippi River Basin to the Hudson Bay Basin came up with the following calculations, which can be applied with even greater force to transfer of bait into the Great Lakes:

> Specifically, we estimate the probability of a single angler on a single angling day in the Hudson Bay releasing live bait from the Mississippi River basin to be 1.2/100. But when the cumulative number of trials – 19 million angler days per year – was considered, the estimated probability of bait bucket transfer occurring one, 100, or even 10,000 times in 1 year approaches 1.0. In light of these findings, we conclude that drastic policy measures would have to be undertaken to reduce anglers' potential for contributing to the dispersal of aquatic species.[243]

All of the Great Lakes states and the Province of Ontario have statutes authorizing their conservation agencies to prohibit such introductions. But the enforcement problems can be overwhelming. The following comment from one state administrator in the Great Lakes provides, as he puts it, a good "reality check" on the problem of regulating baitfish. It also indicates the manner in which transportation of baitfish for use in local aquaculture as well as angling complicates the nature of the problem:

> Virtually all of the baitfish used both for angling bait and for feeding predator fish in culture in Illinois are produced out of state. I can't begin to estimate how many hundred million fish…. We have neither the personnel nor the resources to institute a *meaningful*

[239] Brief from Dr. Douglas Jensen, Minnesota Sea Grant, and Dr. Ron Kinnunen, Michigan Sea Grant, to the Great Lakes Commission Panel on Aquatic Nuisance Species, Ann Arbor, Michigan, January 28, 1999.

[240] Litvak and Nicholas E. Mandrak, "Ecology of Freshwater Use in Canada and the United States," *Fisheries*, vol. 18, no. 12 (December 1993), pp. 6-13, 7, citing W.R. Coutenay, Jr., and J.N. Taylor, presentation to the Symposium on Stock Enhancement in the Management of Freshwater Fish (Rome: European Inland Fisheries Advisory Commission, 1984).

[241] James E. Stewart, "Introductions as a Factor in Disease of Fish and Aquatic Invertebrates," *Canadian Journal of Fisheries and Aquatic Sciences* (1991), vol. 48 (Supplement 1), pp. 110-117.

[242] Litvak and Nicholas E. Mandrak, "Ecology of Freshwater Use in Canada and the United States," *Fisheries*, vol. 18, no. 12 (December 1993), pp. 6-13, 9, 10, Table 2.

[243] Herbert R. Ludwig, Jr., and Jay A. Leitch, "Interbasin Transfer of Aquatic Biota via Anglers' Bait Buckets," *Fisheries*, vol. 21, no. 7 (1996), pp. 14-18, 14 (abstract).

> inspection program for ANS contained in these shipments and have the fish arrive at their destination *alive*. We have one fish hatchery in our system which receives 50,000,000 fathead minnows annually just to feed musky fingerling and bass broodstock. This is not to mention the hundreds of small mom and pop bait shops which receive small shipments weekly. We can and do request that producers spot-check their shipments for unwanted species. We do not have a practical, enforceable way of requiring it.[244]

Further insight may be provided by the Sea Grant study mentioned above. But it seems obvious from the basic structure of the industry that any effective controls would have to be put in place at the source (at the location of major harvesting waters) rather than in the stream of transportation (during which time for inspections, as well as opportunities, are rather limited) or at the receiving point (at hundreds of small shops). This, in turn, requires a high level of coordination between the conservation authorities of the receiving jurisdiction and the conservation or agriculture authorities of the sending jurisdiction.

§ 6. Aquaria and ornamental ponds: Exotics for sale

About 10% of homes in the United States have aquaria, and purchases of live "ornamental fish" for aquaria and ponds amount to more than $600 million a year in the US.[245] A single large aquarium supply house may market 3,000 distinct breed lines. Tampa, Florida, is the major port of import for the United States, doing about $7 million per year.[246] The greatest proportion of these is "tropical fish," both freshwater and saltwater. The majority of these are imported from countries such as Thailand, Indonesia, Singapore, Hong Kong, and the Philippines.[247] Many other tropical fish are cultivated in Florida and other southern states for both domestic and foreign sales.

The term "tropical fish" is sometimes used as a synonym for aquarium fish. Although it is much smaller, there is also a significant trade in "coldwater" fish (all freshwater), some of which are deliberately used for stocking ornamental ponds in temperate climates. For example, aquarium supply houses advertise the Japanese Colored Koi (*Cyprinus carpio*), a coldwater freshwater fish recommended for use in either large aquaria or ponds, which is most active in temperatures of 10º–23º C (50º–74º F), but will also survive in ponds frozen over on the surface.[248] More generally, fish are highly varied creatures. Some species

[244] Mike Conlin, Chief, Division of Fisheries, Illinois DNR, letter (February 9, 1999). Emphasis in original.

[245] Aquatic Nuisance Species Task Force, *Findings, Conclusions, and Recommendations of the Intentional Introductions Policy Review*, report to Congress under Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 § 1207 (16 USC § 472) (Washington, DC: US Fish and Wildlife Service, March 1994), p. 6, based on data from the Pet Industry Joint Advisory Council in 1994.

[246] Aquatic Nuisance Species Task Force, *supra*, p. 6.

[247] Agriculture Plant and Health Inspection Service (APHIS), *Overview of Aquaculture in the United States* (Fort Collins, CO: USDA APHIS Centers for Epidemiology & Animal Health, October 1995), p. 16; and LaDon Swann, *Diagnostic Services in Illinois and Indiana*, Sea Grant #IL-IN-SG-FS-91-10 (West Lafayette, IN: Purdue University, undated), p. 11.

[248] See the "Coldwater Species Profiles" at Aquaria Central web site, www.aquariacentral.com/fishinfo/cold.

double as both "tropical" and "coldwater," although it might be few if any of these which would survive in a frozen-over pond. The goldfish, now common throughout North America, was an ornamental fish release from China. Other aquarium releases into the Great Lakes include the bluespotted sunfish, snails, crustacea, and a number of particularly noxious aquatic weeds.[249] With the continuing increase in the popularity of exotic fish for aquaria and ponds, there is no reason not to expect such invasions to continue.

§ 7. Legal regimes for controlling ballast water: Acting locally and thinking globally

Ballast water is becoming a global issue. Although there has been considerable discussion about the need to institute technological changes allowing vessels to deal with their ballast water in a more effective and safe manner, the exclusive approach, to date, has been on the sort of exchange regime used in the Great Lakes (described in § 3.6 above). The critical limitation on exchange is the fact that it cannot always be done, absent some changes to piping systems, without endangering the safety of the vessel. All of the exchange regimes, whether voluntary or mandatory to some extent, provide some sort of exception when a master decides that it is not safe to exchange. Under the terms of most regimes, including the national regulations to eventually be instituted in the United States under NISA 96,[250] that is then the end of the issue. Little else in the way of remedial action is required in any of the regimes around the world except in the Great Lakes.

As policymakers in both the United States and Canada consider what the substance of their future national regimes will be, under NISA 96 and the Canada Shipping Act, there is a need to address all of the defects in the current Great Lakes regime. Those include the questionable relevance of the current delineation of the open ocean area for exchange as the area outside the arbitrary EEZ 200-mile line, the reliance on salinity as a regulatory standard, the low level of the nominal exchange required, the overall ineffectiveness of exchange with current ballast tanks and piping systems, the problem of the unpumpable slop and sediment on the bottom of the NOBOB tanks, and the problem of safety due to the same limitations of current design. No problem is more pressing than safety. This is the thing which completely undermines the prospects of further progress on ballast water in the immediate future.

Also, there is a fundamental legal and political issue to be resolved about the relationship between local, national, and international regimes. This is closely connected to the safety issue, but is broader than that. Should laws on ballast water by subordinate jurisdictions (US states, Canadian provinces, or local ports and municipalities) be preempted by national regimes for the regulation of shipping? Should those national regimes, in turn,

[249] Edward L. Mills, Joseph H. Leach, James T. Carlton, and Carol L. Secor, "Exotic Species in the Great Lakes: A History of Biotic Crises and Anthropogenic Introductions," *Journal of Great Lakes Research* (1993), vol. 19, no. 1, pp. 1-54.

[250] National Invasive Species Act of 1996, Public Law 104-332 (26 October 1996), codified at 16 USC §§ 4701 *et seq.*

be limited by the terms of any international regime to be developed? Preemption is an issue likely to be raised in the United States under NISA 96 as some US states, particularly California, consider concurrent regulation of ballast water which would impose stricter local standards. Although the issue is quite complex, and likely to be litigated, a close analysis of NISA 96 indicates that it would not preempt such local controls as long as the state avoids specifying design or equipment standards considered the special purview of the US Coast Guard under other long-standing marine safety statutes.[251] However, under some versions of the international convention on ballast water currently being negotiated at the International Maritime Organization (IMO), any requirement for the vessel owner or master to take remedial action to correct the situation when exchange proves to be unsafe would be specifically precluded by the terms of the convention. (See § 7.5. below.)

No one argues that a master should conduct an unsafe exchange. The question is what the master or the owners of the vessel should do about that – whether the master should be required to use an alternate exchange site where that vessel can exchange safely, the owners should be required to make modifications to the vessel allowing it to do so, or the owners should be required to otherwise treat or properly dispose of the water. In the absence of some such requirement, vessel owners will be encouraged to simply maintain vessels which might not be able to conduct safe exchanges in order to take advantage of this free pass – a situation which could lead to the extended use of older unsafe ships, and thus diminish maritime safety, as well as undermine progress on ballast water.

More generally, there is a fundamental question as to whether or not the local and regional environmental communities who have taken the lead in forcing national and global attention to the issue should surrender their ownership of it to the national bureaucracies in Washington, DC and Ottawa or the diplomatic committees in London – all venues which are strongly dominated by the shipping industry. If they do so, it is clear that a lowest common denominator of minimum and ineffective standards – accompanied by many years of delay in instituting such standards – will become the norm for everyone in the world. Unless the Great Lakes community thinks globally about the politics of this issue, we may discover that we have no more ability to act locally in the future.

[251] I provide this analysis, in great detail likely to be of interest primarily to other lawyers, but written with explanations intended to make it understandable to a lay person, in Eric Reeves, *Analysis of Laws & Policies Concerning Exotic Invasions of the Great Lakes*, a report commissioned by MDEQ OGL (Lansing, MI: MDEQ OGL, March 15, 1999), § 220. The most important court cases, which lay out the relevant preemption doctrine in the context of prior conflicts over state regulation of oil tankers on the West Coast, are *Ray v. Atlantic Richfield Co*., 435 US 151 (1978) and *Chevron USA, Inc. v. Hammond*, 726 F2d 483 (9th Circuit 1984). *Ray* is a US Supreme Court case which held that the State of Washington could impose special local operational requirements on tankers entering Puget Sound, such as a requirement for tankers without double hulls to have tug escorts, but could not specify design, construction, and equipment standards for vessels, because these are preempted by comprehensive federal marine safety statutes. Note that the state could impose an "either-or" requirement – either have a double hull or have a tug escort when you show up here – even though it could not have required all tankers to have double hulls. *Chevron* is a US Court of Appeals case, applying the rules in *Chevron*, which held that the State of Alaska could require oily ballast not maintained in segregated tanks to be treated ashore even if the water met US federal standards for discharge. In addition, there is a specific provision in NISA 96, at 16 USC § 4725, which should be read to disavow Congressional intent to preempt state controls on ballast water.

§ 7.1. Ten years of activity on ballast water: A quick review of the bidding

The Great Lakes and the world. It was Canada and the United States, acting in response to the invasions of the unique freshwater system of the Great Lakes by the ruffe and the zebra mussel, and Australia, acting in response to invasions of its unique saltwater ecosystem by toxic dinoflagellate algae and other organisms, which made ballast water an issue for the world. In 1993, the United States promulgated the first mandatory legal regime requiring regular ballast water exchange for vessels entering the Great Lakes. (See the detailed description of the Great Lakes regime in § 3.6 above.) In 1998, Canada enacted the statutory authority to institute a nationwide mandatory regime, although it has not yet promulgated regulations. While keeping in mind the important role that Australia has played, particularly in demanding international attention to the issue, one can in fact say that it all began here in the Great Lakes. The following chronology sums up the history of the last ten years:

AUG 1988 In response to the detection of the ruffe and the zebra mussel in the Great Lakes, the Great Lakes Fishery Commission and the International Joint Commission request that the Governments of the United States and Canada require the exchange of ballast water on ships entering the Great Lakes.[252]

MAY 1989 The Canadian Coast Guard issues Voluntary Guidelines for the Control of Ballast Water Discharges from Ships, recommending use of exchange.[253]

FEB 1990 In response to outbreaks of toxic dinoflagellates, the Australian Quarantine and Inspection Service (AQIS) issues Voluntary Guidelines for Ballast Water and Sediment Discharge from Overseas Vessels Entering Australian Waters.[254]

SEP 1990 The International Joint Commission and the Great Lakes Fishery Commission issue a joint report recommending that the Governments of the United States and Canada require the exchange of ballast water on ships entering the Great Lakes, coordinate their programs, promote international standards, and develop a long-term research strategy, including study of redesign and retrofitting of vessels to maximize safe and effective ballast exchange.[255]

---

[252] International Joint Commission and Great Lakes Fishery Commission, *Exotic Species and the Shipping Industry: The Great Lakes-St. Lawrence Ecosystem at Risk* (Ann Arbor, MI: Great Lakes Fishery Commission, September 1990), pp. 11-14.

[253] Daniel Gauthier and Deborah A. Steel, *A Synopsis of the Situation Regarding the Introduction of Nonindigenous Species by Ship-Transported Ballast Water in Canada and Selected Countries*, Fisheries and Aquatic Sciences report 2380 (Mont-Joli, Québec: Fisheries and Oceans Canada, 1996), § 3.2, p. 7.

[254] Gauthier and Steel, *ibid.*, § 5.2.1., p. 24.

[255] International Joint Commission and Great Lakes Fishery Commission, *Exotic Species and the Shipping Industry: The Great Lakes-St. Lawrence Ecosystem at Risk* (Ann Arbor, MI: Great Lakes Fishery Commission, September 1990), recommendations on p. 9.

NOV 1990 The United States enacts the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA 90),[256] which applies only to the Great Lakes and connected waters, mandating the US Coast Guard to issue voluntary guidelines six months after the act and mandatory regulations two years after the act.[257]

JUL 1991 The Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) issues draft International Guidelines for Preventing the Introduction of Unwanted Aquatic Organisms and Pathogens from Ships' Ballast Water and Sediment Discharges, recommending ballast exchange.[258]

DEC 1991 The Canadian Great Lakes Laboratory for Fisheries and Aquatic Sciences issues a report on the effectiveness of ballast exchange in the Great Lakes under the 1989 Canadian guidelines.[259]

APR 1993 The US Coast Guard issues mandatory regulations under NANPCA 90, requiring exchange or alternative measures on all vessels entering the Great Lakes in ballast (applicable to vessels headed to both US and Canadian ports in the Great Lakes).[260]

JUL 1993 At the urging of Australia, with support from New Zealand, Canada, and the United States, the Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) forms a Ballast Water Working Group (BWWG).[261]

NOV 1993 The International Maritime Organization (IMO) General Assembly adopts Guidelines for Preventing the Introduction of Unwanted Aquatic Organisms and Pathogens from Ships' Ballast Water and Sediment Discharges, recommending ballast exchange.[262]

MAY 1994 The Australian Quarantine and Inspection Service (AQIS) develops a draft Australian Ballast Water Strategy for a comprehensive program of research on control measures.[263]

OCT 1996 The United States enacts the National Invasive Species Act of 1996 (NISA 96),[264] mandating the US Coast Guard to issue national voluntary guidelines one year after the act and national mandatory regulations three years after issuance of the guidelines, if the voluntary guidelines are found to be ineffective.[265]

---

[256] US Public Law 101-646 (November 29, 1990), codified at 16 USC §§ 4701 *et seq.*

[257] 16 USC § 4711(b).

[258] International Maritime Organization Marine Environment Protection Committee Resolution 50(31), 31st Session (London: IMO, July 1991).

[259] A. Locke, D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen, *Effectiveness of Mid-Ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water*, Fisheries and Aquatic Sciences Report 1822 (Burlington, ON: Great Lakes Laboratory, 1991).

[260] 58 *Federal Register* 18334 (April 8, 1993), adding 33 CFR Part 151, Subpart C, §§ 151.1500 *et seq*.

[261] Daniel Gauthier and Deborah A. Steel, *A Synopsis of the Situation Regarding the Introduction of Nonindigenous Species by Ship-Transported Ballast Water in Canada and Selected Countries*, Fisheries and Aquatic Sciences report 2380 (Mont-Joli, Québec: Fisheries and Oceans Canada, 1996), § 5.0, pp. 14-15.

[262] Resolution A.774(18), 18th Assembly (London: IMO, November 4, 1993).

[263] Gauthier and Steel, *supra*, § 5.2.1., p. 25.

[264] US Public Law 104-332 (October 26, 1996), amending Public Law 101-646 (November 29, 1990), 16 USC §§ 4701 *et seq*.

[265] 16 USC § 4711(c), (e), and (f).

OCT 1997 The Canadian Department of Fisheries and Oceans (DFO), the Canadian Department of Transport (Transport Canada), and the US Coast Guard adopt a Binational Ballast Water Research Strategy to support critical changes in the Great Lakes regime.[266]

APR 1998 The US Coast Guard proposes national voluntary guidelines under NISA 96, along with revisions to the existing Great Lakes mandatory regulations raising the regulatory standard for measuring the adequacy of ballast exchange.[267] Because of strong opposition by the shipping industry, those proposed improvements to the Great Lakes regulations are rejected in the interim rule issued in May 1999.[268]

OCT 1998 Canada enacts an amendment to the Shipping Act authorizing the government to issue mandatory regulations for the management of ballast water throughout Canada.[269]

MAY 1999 The US Coast Guard issues an interim rule promulgating national ballast water exchange guidelines, with mandatory reporting requirements. Proposed improvements to the Great Lakes regulations are rejected.[270]

Activity in other jurisdictions. A number of other countries, and some state and local authorities in the United States and Canada, have taken limited action. These include promulgation of voluntary guidelines, imposition of voluntary or mandatory reporting requirements, use of emergency authority to react to specific outbreaks of identifiable organisms, and some, tentative steps towards the development of a mandatory exchange regime along the lines of the Great Lakes regime.

Australian agencies have authority to act against specific identifiable outbreaks of toxic dinoflagellates (a health threat to the shellfish industry) and other identifiable organisms under various health and pest control laws, but there is a lack of clear responsibility for administration of a ballast water program among federal and state officials.[271] New Zealand promulgated Voluntary Controls on the Discharge of Overseas Ballast Water within New Zealand in March 1992.[272] The New Zealand Ministry of Agriculture has authority to take action against an identifiable infestation under the Biosecurity Act of 1993, but use of that authority has been largely limited to requesting reports of compliance with the voluntary

[266] Canadian DFO, Transport Canada, and US Coast Guard, *1996-1997 Binational Report on Protection of Great Lakes Water Quality*, report to the International Joint Commission under Annex VI, § 2 of the GLWQA 1978/1987 (Cleveland, OH: US Coast Guard, October 14, 1997), §§ 240-242.2, pp. 17-21. A slightly amended version of the binational ballast water research strategy was also endorsed by the Great Lakes Commission Panel on Aquatic Nuisance Species in February 1998.

[267] 63 *Federal Register* 17782 (April 10, 1998).

[268] 64 *Federal Register* 26672 (May 17, 1999).

[269] Canadian Shipping Act, Revised Statutes of Canada, RS-9, § 657.1, as added October 31, 1998.

[270] 64 *Federal Register* 26672 (May 17, 1999).

[271] Daniel Gauthier and Deborah A. Steel, *A Synopsis of the Situation Regarding the Introduction of Nonindigenous Species by Ship-Transported Ballast Water in Canada and Selected Countries*, Fisheries and Aquatic Sciences report 2380 (Mont-Joli, Québec: Fisheries and Oceans Canada, 1996), § 5.2.1, pp. 25-26.

[272] Gauthier and Steel, *ibid.*, § 5.3.1, p. 31.

guidelines[273] and emergency action against Tasmanian ballast carrying larvae of the North Pacific seastar (*Asteria amurensis*).[274]

Other regulatory action has been taken in Israel, Chile, Japan, Tasmania, the Red Sea Ports, the Ukraine, Humbolt Bay, CA, and the Port of Vancouver, BC.[275] Guidelines or advisories, sometimes backed up by limited emergency authorities, have been promulgated in the United Kingdom, Germany, and Sweden.[276] The regulation is typically tentative. For example, the Harbor Master of the Port of Vancouver, British Columbia, has issued a "standing order" under local authority, mandating ballast water exchange.[277] However, despite the fact that compliance has only been about 80%, the port has yet to test its authority to enforce the standing order.[278]

Three states of the United States on the Pacific Ocean have taken some legislative action, but only of the most tentative nature. One of those states, California, is considering potentially significant legislation.

The Alaska legislature passed a 1992 resolution requesting that the US Coast Guard prohibit all discharge of ballast from foreign coasts in Alaskan waters.[279] The US Coast Guard has no general authority over discharge of ballast in Alaska until eventual implementation of mandatory regulations under NISA 96, which is still more than three years away at best. But there is a presidential memorandum[280] imposing limited exchange requirements on tankers engaged in the export of Alaskan oil under separate statutory authority to allow such exports with "such terms and limitations…as are necessary or appropriate to ensure that such exports are consistent with the national interest."[281]

Hawaii and California have each enacted temporary measures for information-gathering and coordination. Hawaii enacted a temporary law directing state agencies to form a state "alien aquatic organism task force," in cooperation with federal agencies, in order to develop a "comprehensive plan" on preventing introductions.[282] That statutory direction already expired, by its own terms, on June 30, 1998.[283] Similarly, California enacted a state Aquatic

[273] Gauthier and Steel, *ibid*, § 5.3.1, pp. 31-32.

[274] Andrew N. Cohen, *Ships' Ballast Water and the Introduction of Exotic Organisms into the San Francisco Estuary: Current Status of the Problem and Options for Management* (Richmond, CA: San Francisco Estuary Institute, October 1998), Appendix C, pp. 64-65, citing B. Hayden, "A New Zealand Perspective on Ballast Water," in J.T. Carlton, ed., *Ballast Water: Ecological and Fisheries Implications* (Copenhagen: International Council for the Exploration of the Sea, in press).

[275] Cohen, *ibid*, Appendix C, pp. 65-67.

[276] Gauthier and Steel, *supra*, § 5.4. pp. 34-36.

[277] *Vancouver Port Corporation, Ballast Water Exchange Program* (Vancouver, BC: May 1997).

[278] Personal communication from the Vancouver Harbor Master. The port views the compliance problems as a matter of lack of knowledge of the requirements. Also, there is concern about the safety of exchange.

[279] Cohen, *supra*, Appendix C, p. 66, citing Alaska Legislative Resolve No. 85 (June 8, 1992).

[280] Presidential Memorandum (April 28, 1996), at 61 *Federal Register* 19507 (May 31, 1996).

[281] US Public Law 104-58 (November 28, 1995), § 201, amending 30 USC § 185(s).

[282] Hawaii Act 237, Relating to Harmful Aquatic Life (June 17, 1997), Laws 1997, Chapter 237, § 1.

[283] Hawaii Act 237, Relating to Harmful Aquatic Life (June 17, 1997), Laws 1997, Chapter 237, § 2(d).

Nuisance Prevention and Control Act (ANSPCA) in 1992,[284] which declares that the California Department of Fish and Game "shall adopt the International Maritime Organization's 'Guidelines for Preventing the Introduction of Unwanted Aquatic Organisms and Pathogens from Ships' Ballast Water and Sediment Discharges' as adopted on July 4, 1991, as the policy of this state…."[285] It is not clear what legal significance it has for a state to adopt voluntary international guidelines as "policy." The California act does not give the Department of Fish and Game any enforcement authority other than authority to demand that vessel operators return ballast water report forms distributed in cooperation with the US Coast Guard.[286] It appears that the department may not have even attempted to implement this.[287] By its own terms, the California ANSPCA expires on January 1, 2000.[288] Neither of these state enactments was calculated to test the limits of state authority over ballast water in commercial shipping.

§ 7.2. California AB 703

AB 703, a bill passed by the California Assembly and currently under active consideration in the California Senate, would be the first enactment of a substantive mandatory regime by a state in the United States.[289] It would give California water quality boards authority to institute an exchange regime similar to that used in the Great Lakes, but with some significant improvements. Instead of the salinity standard, the regulatory standard would be a 95% exchange by volume. Vessels would be granted safety exemptions when exchange is not safe. But, after several years of studies and reports, the boards would have the authority to require more. In the current version, as amended on April 6, 1999, by the California Senate:

> On and after January 1, 2003, the statewide general waste discharge requirements prescribed pursuant to this section shall require management of ballast water discharges that reflects the greatest degree of reduction in the discharge of exotic ballast water organisms that the board determines, based on the best available information, to be feasible through the application of the best available technologies that are economically achievable. On and after January 1, 2003, the requirements shall include a prohibition on the discharge of exotic ballast water organisms if the board determines, based upon the best available information, that the requirement is technologically available and economically achievable.[290]

[284] California Statutes 1992, Chapter 840, amending California Fish and Game Code §§ 6430-6439.

[285] California Fish and Game Code § 6432.

[286] California Fish and Game Code §§ 6433-6435.

[287] Andrew N. Cohen, *Ships's Ballast Water and the Introduction of Exotic Organisms into the San Francisco Estuary: Current Status of the Problem and Options for Management* (Richmond, CA: San Francisco Estuary Institute, October 1998), Appendix C, p. 66.

[288] California Fish and Game Code § 6439.

[289] California Assembly Bill, AB 703, to make amendments to the California Water Code, introduced by Assembly Member Lempert on February 24, 1999. It passed the Assembly and was under active consideration by the Senate Committee on Environmental Quality as of July 6, 1999.

[290] AB 703 § 2, making amendments to California Water Code at § 13275(i) (bill amended July 6, 1999).

If a state becomes involved in prescribing specific technologies for shipboard use, that would likely run afoul of United States rules on federal preemption, which prohibit a state from interfering with commercial vessel design, construction, and equipment standards traditionally prescribed by the US Coast Guard under vessel safety statutes.[291] However, that does not prohibit a state from requiring a vessel to follow special operational requirements when in its local waters, including a requirement to have ballast water treated ashore if it does not meet state standards.[292]

§ 7.3. US NISA 96

The National Invasive Species Act of 1996 (NISA 96)[293] mandates a nationwide regime which is generally modeled after the regime in the Great Lakes under the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA 90),[294] but with some variations which significantly weaken it. The legislation was passed in the closing days of the 104th Congress in October of 1996 by unanimous consent motions in both houses, with very little debate or discussion, after last-minute amendments were negotiated off the record to satisfy the objections of the shipping industry.[295] Although there was a large number of cosponsors for the legislation and unanimity in the votes, this broad agreement was obtained because (1) the legislation, as originally drafted, was designed to move the nation only slowly and tentatively towards a nationwide regulatory regime, and (2) the last-minute amendments obtained by the shipping industry, particularly a sweeping safety exemption, effectively eviscerated the ability of the US Coast Guard to develop a meaningful regime. Both of those issues are discussed below.

---

[291] See *Ray v. Atlantic Richfield Co.*, 435 US 151 (1978).

[292] See *Ray*, *ibid*., and *Chevron USA, Inc. v. Hammond*, 726 F2d 483 (9th Circuit 1984).

[293] National Invasive Species Act of 1996, US Public Law 104-332 (October 26, 1996), making amendments to the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, US Public Law 101-646 (November 29, 1990), codified at 16 USC §§ 4701 *et seq*.

[294] Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, US Public Law 101-646 (November 29, 1990), codified at 16 USC §§ 4701 *et seq*. "NANPCA 90" is used here to refer to the statute before the 1996 amendments in NISA 96.

[295] The final bill was HR 4283, substituting for similar bills introduced as HR 3217 (Congressman LaTourette of Ohio, Republican) and S 1660 (Senator Glenn of Ohio, Democrat), both of which had numerous co-sponsors from both parties, with amendments by the managers on the floor of the House (therefore never discussed in either hearings or committee reports) before final passage. The first version voted on, as HR 3217, which had already been amended to meet objections in the Senate, was passed in the House of Representatives by unanimous consent at 142 *Congressional Record* H10918-H10927 on September 24, 1996. The Senate objections, mainly objections from the shipping industry, were not satisfied. Without consideration in the Senate, it was brought back to the floor of the House as HR 4283, with further amendment, and passed by unanimous consent at 142 *Congressional Record* H12147-12152 on September 28, 1996. In that version it was brought to the Senate and passed by unanimous consent at 142 *Congressional Record* S12398-12401on October 3, 1996. It was signed by the President on October 26, 1996. Comments from the American Maritime Congress on the proposed nationwide guidelines relate the effects of industry lobbying to have the special safety exemption inserted at the last minute. Gloria Cataneo Tosi, American Maritime Congress, US Coast Guard NPRM Docket USCG-98-3423, Comment #57 (August 7, 1998), p. 5 of document, p. 3 of AMC enclosure.

Comparing NISA 96 with other US pollution laws. The history of environmental law is a story of legislation by disaster. Moreover, the political and legal responses to those disasters are usually incremental and incomplete. The wreck of the *Torrey Cannon* in Great Britain prompted the Congress of the United States to enact the Water and Environmental Quality Improvement Act of 1970.[296] Continued deterioration of water quality under that legislation, characterized by Congress and the Supreme Court as "inadequate in every vital respect,"[297] led to a total overhaul of our theory and practice of water pollution control in the Federal Water Pollution Control Act Amendments of 1972[298] (and to the first Great Lakes Water Quality Agreement of 1972[299]). The discovery of toxic waste dumps at Niagara Falls, New York, at Montague, Michigan, and at other locations around the United States led to the enactment of the US Superfund Act (CERCLA) in 1980.[300] And, finally, the *Exxon Valdez* oil spill led to significant changes in ship design and navigation requirements enacted in the Oil Pollution Act of 1990 (OPA 90).[301] Between the *Torrey Cannon* and the *Exxon Valdez*, while we were still struggling with the relatively simple technical matter of what should be

[296] US Public Law 91-224 (April 3, 1970), with legislative history in House Public Works Committee, House Report No. 91-127, HR 4148 (March 25, 1969), at 1970 USCCAAN 2691, 2692. Although the original Federal Water Pollution Control Act was actually enacted in 1948 (62 Statutes 1155, June 30, 1948), and often amended after that, the 1970 amendments were significant, albeit inadequate, in adding "new sections on liability for cleaning up oil discharges, discharge of hazardous substances, discharge of sewage from vessels [and] demonstration projects for cleaning up pollution in the Great Lakes…." Senate Public Works Committee, Senate Report No. 92-414, S 2770 [Public Law 92-500] (October 28, 1971), at 1972 USCCAAN 3668, 3670, which reviews the history of federal water pollution legislation from 1948 to 1972 at pp. 3669-3670. One of the most important provisions was the enactment of the principle of strict liability for the costs of oil spills, within low limits, whereas the previous legislation on oil spills applied only to spills which were grossly negligent or willful. House Public Works Committee (1969), *ibid.*, at 1970 USCCAAN 2692.

[297] *EPA v. California*, 426 US 200, 203 (1976), quoting Senate Public Works Committee, Senate Report No. 92-414, S 2770 [Public Law 92-500] (October 28, 1971), at 1972 USCCAAN 3674.

[298] US Public Law 92-500 (October 18, 1972), codified at 33 USC §§ 1251 *et seq.*, and now known commonly as the Clean Water Act, since amendments in US Public Law 95-217 (December 27, 1977), as well as the Federal Water Pollution Control Act. "Water pollution law today [in the US] begins with…the Federal Water Pollution Control Act Amendments of 1972…." William H. Rodgers, Jr., *Environmental Law* (St. Paul, MN: West, 1994), § 4.1, p. 247. "For point sources, costs of achieving but the first levels of technological controls were enormous: $10 billion for municipalities, $36 billion for industry…." *Ibid*. Although this was a system for permitting pollution, it was consciously designed to squeeze down the amount of pollution permitted over the years (with the unrealistic goal of near-virtual elimination by 1985). One of the most important features of the permitting system was that it was designed to be "technology-forcing." *Ibid*., § 1.4, p. 53. The other critical element of the regime was expansion of the principle of strict liability for the cost of all spills first established in 1970. (This also became the central element in the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), 42 USC §§ 9601 *et seq*., enacted in 1980.)

[299] See Theodora E. Colborn, Alex Davidson, Sharon N. Green, R.A. (Tony) Hodge, C. Ian Jackson, and Richard A. Liroff, *Great Lakes: Great Legacy?* (Washington, DC: Conservation Foundation, 1990), p. 3.

[300] The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), US Public Law 96-510 (December 11, 1980), codified at 42 USC §§ 9601 *et seq*. The waste sites are discussed in House Interstate and Foreign Commerce Committee, House Report No. 96-1016, HR 7020 (May 16, 1980), pp. 18-19.

[301] US Public Law 101-380 (August 18, 1990), which made amendments to the Clean Water Act (Federal Water Pollution Control Act), 33 USC §§ 1251 *et seq*., and other places. See the description of "operational and technological controls" imposed on the shipping industry by OPA 90 in William H. Rodgers, Jr., *Environmental Law* (St. Paul, MN: West, 1994), § 4.9E, pp. 387 *et seq*.

required for moving big steel tubs of oil safely around on the water without running into rocks, the world suffered spills in excess of a million gallons, each, from the *Argo Merchant*, the *Burmah Agate*, the *Georgia*, the *Olympic Glory*, the *Arkas*, the *Alvenus*, and the *Puerto Rican*.[302] (The double-hull requirement for new oil tankers, required by OPA 90, is adding about 10% to 20% to new construction costs.[303]) Although the invasion of the zebra mussel via ballast water is likely to have much more severe long-term effects on the ecology of North America than the *Exxon Valdez* oil spill,[304] it has obviously had nothing like the same impact on the public consciousness. In terms of politics, the zebra mussel is more like the *Torrey Cannon*. It therefore should not be a surprise that the first piece of legislation designed to address the problem on a national level, NISA 96, is just as "inadequate"[305] as was the Water and Environmental Quality Improvement Act of 1970. NISA 96 and other tentative measures on exotics being adopted around the world only make sense if understood as the first attempts to frame a rational and effective regime.

A mandate for delay. NANPCA 90 directed the US Coast Guard to put out voluntary guidelines six months after enactment, to be followed by mandatory regulations two years after enactment on November 29, 1990.[306] The Coast Guard was able to almost meet that direction with regulations issued on April 8, 1993.[307] NISA 96 directed the US Coast Guard to put out national voluntary guidelines within one year after enactment on October 26, 1996,[308] and to follow that up with national mandatory regulations,[309] *if* the guidelines are found to be inadequate after a review to be conducted not less than three years after issuance of the guidelines,[310] and *after* a report to that effect to Congress.[311] NISA 96 also directs the US Aquatic Nuisance Species Task Force (ANS Task Force) to develop criteria for the Coast Guard to use in determining the effectiveness of the voluntary guidelines.[312]

---

[302] Rodgers, *supra*, § 4.9, Table 4-13, p. 376, using information from *Golob's Oil Pollution Bulletin*.

[303] Everett C. Hunt and Boris S. Butman, *Marine Engineering and Economics Cost Analysis* (Centreville, MD: Cornell Maritime Press, 1995), p. 1-6.

[304] See § 2.3 above, and Glenn Zorpette, "Mussel Mayhem Continued: Apparent Benefits of the Zebra Mussel Plague are Anything But," *Scientific American*, vol. 275, no. 2 (August 1996), pp. 22-23. There are, of course, still lingering effects from the spill in Prince William Sound, including lack of full recovery of some native aquatic populations in 1999. But the basic fact is that those effects are limited in space and time. The zebra mussel is creating comparable injury to native habitats as it continues to spread across the North American Continent, and it only become worse with time.

[305] Environmental groups commenting on the proposed national guidelines under NISA generally agree that "in light of the significant problems posed by non-native species, the proposed regulations are inadequate for managing the threat of these species for several reasons." Warner Chabot and Michael Lozeau, Center for Marine Conservation, US Coast Guard NPRM Docket USCG-98-3423, Comment #27 (June 8, 1998), p. 1.

[306] 16 USC § 4711(a)-(b).

[307] 58 *Federal Register* 18334 (April 8, 1993), adding 33 CFR Part 151, Subpart C, §§ 151.1500 *et seq*.

[308] 16 USC § 4711(c)(1). All of the Congressional directions in the act are to "the Secretary of the department in which the Coast Guard is operating," a customary technicality which is understood to mean that the Coast Guard is the agency responsible for implementing them (just as the Canadian Parliament's authorization for regulations to be issued by the "Governor in council" is taken to mean the cabinet and responsible ministries).

[309] 16 USC § 4711(f)(1).

[310] 16 USC § 4711(f)(1) and (e)(1).

[311] 16 USC § 4711(f)(1) and (2)(A).

[312] 16 USC § 4711(e)(3).

All of these requirements may seem like minor points of administrative process. However, especially given the controversy which has already arisen over the proposed national guidelines, they are in fact prescriptions for significant delay before any national mandatory regulations go into effect. This was very much part of the original compromise built into the legislation. The primary sponsor of the legislation in the House of Representatives was Congressman Steve LaTourette.[313] He explained the overall design of the legislation on the floor of the House:

> This balanced, moderate approach has broad bipartisan support. There are now 40 cosponsors for this legislation. There are some interests who want an enforceable regulatory program immediately while there are others who only want voluntary guidelines with no possibility of mandatory regulations. The bill chose to take the middle path, the compromise approach of requiring mandatory regulations only if they are necessary.[314]

The US Coast Guard has been directed to navigate a political course somewhere between the rock of industry opposition to any requirements for changes in ship design and the whirlpool of vacuous guidelines which will invite new invasions of exotics. This is not a course which the Coast Guard (or any other federal agency) can be expected to sail with any confidence or speed. It was not until April 10, 1998, six months after guidelines were to go into effect, that the Coast Guard put out proposed guidelines,[315] and not until May 17, 1999, more than another year, that the guidelines were issued in an "interim rule."[316] We may expect that there will be a considerable amount of additional delay, as well as political difficulty, in conducting the evaluation of the program, obtaining the statutorily required guidance from the ANS Task Force, framing a politically defensible report to Congress, overseeing the necessary research projects, and developing actual nationwide regulations. It is worse than that, in fact, because meaningful regulations cannot be written without returning to Congress for new statutory authority. As I explain below, the special safety exemption obtained by industry at the last minute from the Senate has made any such regulations unenforceable.

A shell game over "safety." The provisions on the Great Lakes regime and the US nationwide regime in NISA 96 (each regime is separately laid out in the current version of the statute) are just enough alike to be misleading. Both say, basically, (1) exchange your water, (2) if you can do so safely, or (3) develop some sort of alternative means for managing the problem. But there are subtle differences in the way those propositions are stated for the two regimes, an important difference between the two safety exemptions, and

[313] Republican from the 19th District of Ohio, a diverse district on Lake Erie near Cleveland, Ohio, and an area sensitive to the impacts of exotics on the Western Basin of Lake Eire.

[314] 142 *Congressional Record* H10925 (September 24, 1996).

[315] 63 *Federal Register* 17782 (April 10, 1998).

[316] Interim rule with request for comments at 64 *Federal Register* 26672 (May 17, 1999). On June 16, 1998, in response to several requests from the shipping industry (along with strong objections to the guidelines) the Coast Guard had extended the comment period on the proposed guidelines until August 8, 1998. 63 *Federal Register* 32780 (June 16, 1998).

a critical difference between how the safety exemption relates to the development of alternative management. This calls for a detailed parsing of the language of the statute. In the following, except where otherwise noted, the subsections discussed are subsections of 16 USC § 4711 in NISA 96 as currently enacted and codified.

To begin with, although there is an analogous transition from guidelines to regulations in each regime, the structure is different. The provisions on the Great Lakes regime laid out in subsections (a) and (b) of § 4711 mandate guidelines in brief and general terms, and then provide detailed requirements for what should be contained in the subsequent regulations. The provisions on the national regime in subsections (c) and (f) of § 4711 provide separate detailed requirements for what should be contained in the national guidelines, and then mandate regulations in brief and general terms, along with a provision at (f)(3) which allows for general revision of the regulations in accordance with any "international agreement." This opens up the valuable possibility that future nationwide regulations could be much more flexible and creative than either the Great Lakes regulations or the nationwide guidelines. But that possibility is still limited by the special safety exemption.

To emphasize again, there is no question but that there must be a safety exemption in some form. No one argues that breaking ships in half is an acceptable way to prevent exotic invasions. The questions are (1) who decides that the use of the exemption is valid, and (2) what happens then, after it is determined that a certain vessel cannot safely exchange? The views of the shipping industry on this issue are clearly articulated in formal comments submitted to the Coast Guard on the proposed national guidelines, which presumably reflect many of the points raised during lobbying done off the record with the Senate. They argue (1) that it ought to be the unquestionable decision of the master of the vessel, and (2) after that, once it becomes obvious that particular vessels or fleets cannot conduct safe exchanges, the industry has absolutely no further obligation to do anything. That comes through quite clearly in the comments on the proposed national guidelines. A comment by the International Chamber of Shipping begins as follows with the inarguable proposition that safety must come first:

> …there should be much greater emphasis on the need for the absolute acceptance of the master's decision on whether to commence the process, suspend operations when in progress, or abandon the process, if he feels that safety is or may be jeopardized, that machinery is in doubt, or crew fatigue demands it.[317]

Accordingly, the International Chamber of Shipping urges the adoption of a clause in the regulation which specifies that the master "retains absolute discretion"[318] to forgo any exchange, subject to no requirement of evidence of reasonableness or review by the Coast Guard. Even more, the Chamber argues that any requirement to exchange in an alternate site will be dangerous:

[317] Alex Bilney, International Chamber of Shipping, US Coast Guard NPRM Docket USCG-98-3423, Comment #54 (August 6, 1998), p. 2.

[318] Bilney, *supra*, p. 2.

> In the very early stages of discussion at IMO [the International Maritime Organization]…. It was recognized that if a master knew that there was a requirement for alternative procedures and subsequent delay by diversion into a designated area or the need to discharge ballast elsewhere than the loading berth, this may create the commercial pressures that will lead to him taking a chance in mid-ocean when conditions are marginal. The tighter a bad weather schedule is, the more likely such a risk will be run.[319]

The vessel must not ever be delayed, for fear that the master will break it in half in order to avoid that delay. Why? Who sets the parameters for how close to the edge the master operates in order to avoid the cost of delay? In this manner, an otherwise legitimate concern for safety is used to negate any responsibility for the environment, using the lives of the crew as hostage.

The American Maritime Congress also urges recognition of the "absolute discretion" of the master, although in slightly more reasonable terms leaving some possible opening for a "good faith" test,[320] and then adds a critical point about the overall evolution of the regime:

> And additionally, any record of compliance or non-compliance must take into account the design of the vessel. For certain vessels, it is inherently unsafe to accomplish ballast water exchange when underway on the high seas – as it may also be for any vessel under certain sea and weather conditions. Neither the master of these vessels nor the owner/operators should be penalized or given a "black mark" for non-compliance for safety reasons, or, in essence, for failing to be able to put a square peg in a round hole.[321]

No vessel, nor its owner, is to be singled out for notice on account of the fact that it is incapable of running a clean operation. Although not explicitly stated, the obvious concern is that the Coast Guard or the Congress will then begin to require the necessary design changes for making the fleets able to run clean.

Throughout the many comments from these and other industry groups, the theme of "safety first" is strongly and consistently articulated. That is a theme which resonates deeply with the ethic of the Coast Guard. What is not usually so clearly articulated is that, in fact, "safety" is a euphemism for "commercial convenience." It is as if the owners of the oil tankers announced that they should not be expected to clean up their spills because, after all, it is highly dangerous for untrained merchant seamen to go mucking about in an oil slick without specialized equipment and training in occupational health safeguards. That is certainly true. But the Clean Water Act and OPA 90 require them to develop or contract for

[319] Bilney, *supra*, p. 3.

[320] Gloria Cataneo Tosi, American Maritime Congress, US Coast Guard NPRM Docket USCG-98-3423, Comment #57 (August 7, 1998), pp. 4-5 of document, pp. 2-3 of AMC enclosure. Similarly, the Chamber of Shipping of America argues that the master's decision "if made in good faith, should be absolute and not subject to challenge by the port state authorities," but goes on to say, "The Chamber, however, recognizes the need for some objective criteria which provides guidance to the US Coast Guard and the regulated community as to what constitutes a 'good faith' decision…." Kathy J. Metcalf, Chamber of Shipping of America, US Coast Guard NPRM Docket USCG-98-3423, Comment #60 (August 6, 1998), p. 3.

[321] Gloria Cataneo Tosi, *supra*, p. 7 of document, p. 5 of AMC enclosure.

competent and safe response capability. The industry is not allowed to say that they cannot be bothered to do the job safely. Why should they be able to say that when the threat to the environment is from ballast water? The marine industry is no doubt just as acutely aware of this obvious analogue as anyone in the environmental community, and it is for that reason that they also object to the characterization of biological spills in ballast water as "pollution."[322]

Unfortunately, the maritime industry succeeded in obtaining a poorly considered exemption for "safety" which enacted a significant portion of their demands. This occurred during the last minute action at the end of the 104th Congress as NISA 96 came up for a second try in the House, rewritten to satisfy the Senate.[323] In order to clearly understand what happened during this complex political maneuvering, it is best to take it from the beginning and work through the chronology.

What we began with was the Great Lakes regime under NANPCA 90, which contained its own provisions designed to insure safety. Subsection (b) of § 4711, originally enacted under NANPCA 90, directed the Coast Guard to insure that the regulations "(F) protect the safety of– (i) each vessel; and (ii) the crew and passengers…and (G) take into consideration operating conditions…." But that provision did not trump another provision in the same subsection, § 4711(b)(2), which authorized the Coast Guard to require an exchange in "other waters," inside the usual 200-mile limit of the exclusive economic zone, when safety permitted, or to require some environmentally sound method of alternate treatment to be used. Following that statutory guidance, the Coast Guard promulgated a provision in the Great Lakes regulations giving the master appropriate alternatives:

> The master of any vessel subject to this subpart [the Great Lakes regulations in 33 CFR Part 151, Subpart C] who, due to weather, equipment failure, or other extraordinary conditions, is unable to effect a ballast water exchange before entering the EEZ [200-mile zone], must employ another method of ballast water management…or request from the COTP [the Coast Guard Captain of the Port in Buffalo] permission to exchange the vessel's ballast water within an area agreed to by the COTP at the time of the request and must discharge the vessel's ballast water within that designated area.[324]

The designated area was left open to negotiation, but as a matter of administrative

---

[322] The International Chamber of Shipping argues that "the emotive word 'pollution' should not be used." Bilney, *supra*, p. 4. The comment from the German Federation of Shipowners starts by arguing about the philosophical concept. "In the sense of the term 'pollution' the matter is not really pollution. Spread of aquatic nuisance species is a naturally occurring phenomenon. Marine creatures are free to move around the globe anyway, and nature will always create checks and balances in the medium and long term." German Federation of Shipowners (*Verband Deutscher Reeder*), US Coast Guard NPRM Docket USCG-98-3423, Comment #33 (June 12, 1998), p. 3. The German Federation of Shipowners goes on, however, to say that an exchange of "90% can surely be accepted as a practical target." *Ibid*.

[323] In the House at 142 *Congressional Record* H10918-H10927, re HR 3217 (September 24, 1996) and 142 *Congressional Record* H12147-12152, re HR 4283 (September 28, 1996). In the Senate at 142 *Congressional Record* S12398-12401, re HR 4283 (October 3, 1996).

[324] 33 CFR § 151.1514.

practice it has been understood that a request to use the Gulf of St. Lawrence west of the 63º west line of longitude would be approved. The Coast Guard has also been attempting to obtain advice from the scientific community on other appropriate sites which might be available in more sheltered waters along the Northeast Coast of the United States.[325] In many cases, the vessel operators and the Coast Guard agreed upon an alternate treatment method, on a case by case basis, as an alternative to use of the alternate exchange site. That was not because the vessels in those cases could not have safely exchanged in the Gulf of St. Lawrence or in the open Atlantic. It was simply because they were already well up into the St. Lawrence Seaway when problems with their original exchange were detected in boardings and they had no wish to turn around.

In other words, as it became clear in the actual implementation of the regime by the Coast Guard in the Great Lakes, the Coast Guard would never force a master to conduct an exchange which the master felt was unsafe, but that did not give the vessel a free pass to dump the dirty water in the Great Lakes. They were instructed to inform the operational command at the Buffalo Marine Safety Office and some alternative was agreed to. It was an agreement under compulsion, to be sure, because the Coast Guard would not allow a vessel to discharge ballast and take on cargo otherwise. But it was very much a matter of polite negotiation over what options were reasonable, in which industry always had the option of appealing up the chain of command to Washington, DC. The alternative was either an exchange in the more sheltered waters of the Gulf of St. Lawrence, or a specially authorized alternative treatment on a case-by-case basis, before the vessel was cleared to enter and discharge.[326]

[325] Such advice was just provided in a report to the ANS Task Force, Alfred M. Beeton, James T. Carlton, Bridget A. Holohan, Glen H. Wheless, Arnoldo Valle-Levinson, Lisa A. Drake, Gregory Ruiz, Linda McCann, William Walton, Annette Frese, Paul Fofonoff, Scott Godwin, Jason Toft, Lisa Hartman, and Elizabeth von Holle, *Ballast Exchange Study: Consideration of Back-Up Exchange Zones and Environmental Effects of Ballast Exchange and Ballast Release*, report to National Sea Grant, NOAA, and EPA (Ann Arbor, MI: Cooperative Institute for Limnology and Ecosystems Research, November 1998). The report indicates, for example, that exchange may be appropriate as close as 100 kilometers (54 nautical miles) off the approach to Boston. Ibid, p. v., par. 16

[326] I personally participated in the resolution of most of those cases as the program staff officer in the Ninth Coast Guard District in Cleveland, in consultation with the operational commander in Buffalo. I report the results of some of these "problem vessel" cases in M. Eric Reeves, "Techniques for the Protection of the Great Lakes from Infection by Exotic Organisms in Ballast Water," in Frank M. D'Itri, *Zebra Mussels and Aquatic Nuisance Species* (Chelsea, MI: Ann Arbor Press, 1997), pp. 283-299, 288-289, Table 1, notes a-e. One vessel, early on before my tenure, was allowed to salt up the tanks to meet the 30 ppt regulatory standard. We quickly declared that to be an insufficient treatment option for any future case. Two other vessels chlorinated their tanks, subject to approval of the local authorities, in Canada, where they discharged the residual water. (Follow-up testing confirmed a good kill.) One vessel, a chemical carrier, had the unusual capacity to shift the water to a heated cargo tank and cook it. (They got it above 60° C (140° F), in accordance with scientific advice.) One vessel which had chosen its own alternate exchange site without prior approval was allowed to proceed after biological testing confirmed the effectiveness of that exchange. And one vessel which had lied about conducting an exchange was forbidden to discharge, subject to a threat of criminal prosecution brought personally home to the master by a joint boarding of Canadian and US marine safety officers in Canadian territory, backed up by a US attorney in New York ready and willing to indict if the vessel failed the outgoing inspection. It passed. But the Canadians also levied a criminal fine for the false report on their exchange during entry into the Gulf of St. Lawrence. These cases illustrate both the seriousness of the

That authority remains in place for the Great Lakes. But the safety exemption now applicable to any nationwide regulations is very different. How different, unfortunately, is made clear by the comparison between the two provisions appearing in NISA 96 when it was passed twice by the House of Representatives. When it came up the first time on September 24, 1996, it contained the following provision, at subsection (k) of § 4711, set forth as a special statutory safety exemption rather than as a consideration for the Coast Guard in framing the regulations:

> **(k) Safety exemption**
>
> **(1) Master discretion**
>
> The master of a vessel is not required to conduct a ballast water exchange if the master decides that the exchange would threaten the safety or stability of the vessel, its crew, or its passengers because of adverse weather, vessel architectural design, equipment failure, or any other extraordinary conditions.
>
> **(2) Other requirements**
>
> A vessel that does not exchange ballast water on the high seas under paragraph (1) shall not be restricted from discharging ballast water in any harbor unless the Secretary [the Coast Guard] issues requirements applicable to such vessel under subsections (b)(2)(B)(ii), (b)(2)(B)(iii), (c)(2)(D)(ii), or (c)(2)(iii).[327]

The subsections cross-referenced are the provisions mandating the Great Lakes regulations and the national guidelines which authorize the Coast Guard to require use of alternate exchange sites or alternate management methods. Thus, this provision would have authorized the same procedure already used in the Great Lakes for the nationwide regime. In case there was any doubt about that intent, Congressman Sherwood Boehlert from New York commented on the floor that "This language codifies the existing exemption found in the Great Lakes regulations…. We note that the bill authorizes the Secretary [the Coast Guard] to identify other methods of managing ballast water or other locations for ballast water exchange. If safe and available, a vessel may be required, by regulation, following notice and opportunity for comment, to conduct such other ballast water management practices as are identified by the Secretary [Coast Guard]…."[328]

This, however, was not the sort of safety exemption that industry wanted. The Senate declined to act on the legislation until the House of Representatives brought it back to the floor on September 28, 1998, with what is now the version of the special safety exemption in NISA 96. Paragraph (k)(1) was not changed. The insidious change appeared as

Coast Guard's effort to enforce the regime and the creativity with which individual cases were worked out in negotiations with the industry. We may, however, have succeeded too well in convincing the industry they were going to dislike an expansion of the Great Lakes regime to the United States as a whole.

[327] 142 *Congressional Record* H10920 (September 24, 1996).

[328] 142 *Congressional Record* H10923-H10924 (September 24, 1996).

subparagraph (k)(2)(A):

> **(k) Safety exemption**
>
> **(1) Master discretion**
>
> The master of a vessel is not required to conduct a ballast water exchange if the master decides that the exchange would threaten the safety or stability of the vessel, its crew, or its passengers because of adverse weather, vessel architectural design, equipment failure, or any other extraordinary conditions.
>
> **(2) Other requirements**
>
> **(A) In general**
>
> Except as provided in subparagraph (B), a vessel that does not exchange ballast water on the high seas under paragraph (1) shall not be restricted from discharging ballast water in any harbor.
>
> **(B) Great Lakes**
>
> Subparagraph (A) shall not apply in a case in which a vessel is subject to the regulations issued by the Secretary under subsection (b) of this section [authorizing the regulations for the Great Lakes].[329]

Subparagraph (A) gives the vessel a free pass to dump the dirty water under any national regulations. Subparagraph (B), fortunately, preserves the terms of the existing exemption and alternative procedures for the Great Lakes. The clear intent of subparagraph (A), unfortunately, is highlighted by the contrast with both the previous version rejected by the Senate and the contrast with the provision in subparagraph (B).

Although the members of the House interested in this legislation spoke in oblique terms about the "limited amendments requested by the other body,"[330] some of them did realize that a lot had been given away to industry. Congressman LaTourette noted that "Many concerns were raised about the potential impact of the Senate amendments."[331] Congressman James Oberstar[332] noted that "this bill contains certain exemptions which concern me. I intend to further examine these provisions and their impacts…."[333] That offers hope that there may in fact be time to fix this fatal defect between now and three years hence when the Coast Guard begins to propose national regulations. But it would be a strategic mistake of the highest order to wait until after those regulations are promulgated,

[329] 142 *Congressional Record* H12149 (September 28, 1996), and as codified at 16 USC § 4711(k).
[330] Congressman Oberstar, 142 *Congressional Record* H12146 (September 28, 1996).
[331] 142 *Congressional Record* H12146 (September 28, 1996).
[332] Democrat from 8th District of Minnesota, and ranking minority member on the House Transportation and Infrastructure Committee, which oversees the Coast Guard. The 8th District includes Duluth, which is the largest port on the Great Lakes.
[333] 142 *Congressional Record* H12146 (September 28, 1996).

more than three years from now, and then litigate the effect of this exemption. That battle, won by industry in the Congress, cannot be reversed by the Coast Guard or the courts. It must be fought again in the Congress.

Aside from a general interest in preserving the biodiversity of the nation and the planet, what difference does this defect in the national regime make to resource managers and environmental groups working to protect the Great Lakes? A great deal. Even though there may be legal authority to force retrofitting design changes on the vessels entering the Great Lakes through the Seaway, it will remain a political impossibility to do so as long as any such action discriminates against the Seaway trade. The costs, small as they may be, must be equal among all the ships sailing to different ports of the United States – unless, perhaps, there is a way to specially compensate the Seaway trade for the extra expense. (See § 10 below.)

An 85% solution. Because of the defects in the salinity standard discussed above (§ 3.6), the Coast Guard had proposed to replace that, in both the Great Lakes regulations and the nationwide guidelines, with a performance standard. Instead of being a regulatory standard, salinity would simply be evidence, among other things, that an adequate exchange has taken place. And in place of a nominal exchange of 85% under the old 30 ppt salinity standard, the Coast Guard had proposed that it should be set, for the present time, at 90% of volume. The Coast Guard would have called this a "reasonably complete exchange," given the current limitations in vessel designs, while emphasizing that a 100% removal or treatment of the water was the ultimate goal.[334]

Judging from the equally vehement comments from both sides – from the industry groups protesting that 90% is unreasonable, and from the environmental groups protesting that anything less than at least 95% is inadequate – it appears that the Coast Guard had struck just the sort of middle-ground compromise typical and appropriate for a government agency trying to balance environmental protection against economic cost.[335] In fact, given the fallacies of the salinity standard, the simple fact that the Coast Guard was considering moving to a performance standard – and provoking a national debate about how much is enough – was probably much more important than whether the current standard is nominally set at 85%, 90%, or 95%. Unfortunately, however, the Coast Guard completely retreated from any modification of the current salinity standard in the interim rule put out on May 17, 1999.[336]

[334] 63 *Federal Register* 17782 (April 10, 1998), NPRM to amend 33 CFR Part 151. See preamble discussion at 63 *Federal Register* 17785, definition at page 17789 (proposed 33 CFR 151.1504), and substantive requirement, with evidentiary presumptions, at page 17789 (proposed 33 CFR 151.1508(a)(1)). By inventing this term of art, the Coast Guard was incurring the risk of creating an analogue to the infamous "best practicable control technology currently available (BPT)" and "best available technology economically achievable (BAT)" under the Clean Water Act. I plead guilty to being the one who came up with it.

[335] Again, I plead guilty to the offense.

[336] Interim rule with request for comments at 64 *Federal Register* 26672 (May 17, 1999).

§ 7.4. Canada Shipping Act

On October 31, 1998, Canadian Parliament enacted an amendment to the Shipping Act, roughly the equivalent of the US Clean Water Act with regard to pollution from shipping sources, providing in full that "The Governor in Council may make regulations respecting the control and management of ballast water."[337] That one sentence is the entire enactment on ballast water. That is the Canadian equivalent to the 53 pages of NISA 96 printed in bill form and the 19 sections of law making up NANPCA 90 and NISA 96 as currently codified in the US Code.[338] Such regulations have not yet been developed.

The exact language of that one sentence is of great importance. It was originally drafted to authorize regulations requiring the "exchange" of ballast water. That would have made it much more like NISA 96, which relies on exchange as the only available tool for control of ballast water. But careful study of the defects in NANPCA 90, and the loss of the *Flare* off the coast of Canada after apparently conducting a ballast exchange, prompted the Canadian government to request broader authority for "control and management" of ballast water.[339] This general grant of authority, not restricted by the many qualifications and restrictions in the US legislation, will allow the Canadian Department of Transport (acting for the "Governor in Council") to eventually develop a much more rational and effective ballast water control program. But that may well be many years away, as they will no doubt have to deal with the same strong opposition which shipping interests have had to the proposed US Coast Guard nationwide regulations under NISA 96.

§ 7.5. MARPOL

The issue of exotics in ballast water is now on the international agenda in the form of discussions and voluntary guidelines recommending ballast exchange developed by the International Maritime Organization (IMO) in London.[340] IMO promulgated non-binding Guidelines for the Control and Management of Ships' Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens in 1997.[341] These, very much like the US regulations and the Canadian voluntary guidelines, recommend the use of exchange when possible but caution against the risk of losing stability or incurring hull stress. A

[337] Canadian Shipping Act, Revised Statutes of Canada, RS-9, § 657.1, as added October 31, 1998.

[338] 16 USC §§ 4701 *et seq*.

[339] Information on the history of the Canadian amendment, and the loss of the *Flare*, via personal communications from the Canadian Departments of Fisheries and Oceans (DFO) and Transport (Transport Canada).

[340] The International Maritime Organization (IMO) is a "specialized agency" of the United Nations, originally established as the "Inter-Governmental Maritime Consultation Organization" in 1948, a forum for consultation on matters of safety and prevention of pollution in shipping, and the forum in which most of the major international conventions on maritime safety and environmental protection are negotiated.

[341] Resolution A.774(18) of the IMO 20th General Assembly (London: IMO, November 4, 1993). These were developed by a committee of IMO, the Marine Environment Protection Committee (MEPC), and a Ballast Water Working Group (BWWG) within that committee. The three nations with the primary interest in the subject, the United States, Canada, and Australia, have had the most active representation in the BWWG.

revision to these guidelines in 1997[342] added more specific guidance on safety considerations limiting the use of exchange,[343] and recognized the use of the flow-through method of exchange as a means to avoid the stability and stress problems.[344] At this time the IMO ballast water guidelines are just guidelines, not part of any legal convention. Australia had been strongly advocating that the guidelines be made into a binding international convention as an "annex" to the International Convention for the Prevention of Pollution from Ships (MARPOL),[345] which would then come into effect as international law after being adopted by a sufficient number of the maritime nations.[346] Most other nations have no noticeable enthusiasm for a ballast water convention.[347] Even Canada and the United States, despite their own domestic legislation on the subject, have some reservations about adoption of an international convention because of the issue of the safety of exchange on current vessels.[348]

As mentioned above, there is reason to be concerned that the prospective international convention under MARPOL could preclude more effective requirements at the national and local level. The central working draft of the international convention currently under consideration at the IMO Marine Environment Protection Committee (MEPC) would provide

[342] Resolution A.686(2), IMO 20th General Assembly (London: IMO, November 27, 1997).

[343] Resolution A.686(2), *supra*, Appendix 2.

[344] Resolution A.686(2), *supra*, Appendix 2, § 1.3.2. The "flow-through method" is some means of changing the water while maintaining a constant (or near constant) load of water in the tank, thus avoiding any of the problems with stability and hull stress created by the pump-down and pump-up method of exchange. However, absent the retrofitting of new pipe ends, the only way that most existing vessels can accomplish a flow-through exchange is by pumping the water upward and out through the hatches or vent pipes on the deck. This is not as efficient, and may also create safety problems through either over-pressurization of the tanks or free water on the decks. A much more effective, and completely safe, flow-through exchange could be accomplished by simply adding one new pipe end to the top of each tank and flushing the water out the bottom via the existing pipes.

[345] The International Convention for the Prevention of Pollution from Ships, done at London, November 2, 1973, amended by the Protocol of 1978. (These are ratified treaties, with Senate treaty numbers, 92-2 and 96-1, but they have not yet been entered in the Department of State's official listing in Treaties and International Agreements (TIAS). They are unofficially reported in full, with annotations, at The Maharaj Nagendra Singh, *International Maritime Law Conventions* (London: Stevens & Sons, 1983), vol. 3, pp. 2272 *et seq*. and 2414 *et seq*.) and also available (by mail order purchase) from IMO in London at www.imo.org. They are collectively called "MARPOL 73/78" or just "MARPOL," (although this is not actually an acronym for the name of the convention), with various "annexes" on specific types of pollution: Annex I on oil, Annex II on noxious liquid substances in bulk, Annex III on harmful substances in packages, containers, or tanks, Annex IV on sewage, and Annex V on garbage. Each of these amount to an independent convention. For example, the annex on garbage, an "optional annex" which has been adopted by the United States, but not by Canada, is "MARPOL Annex V." The United States has adopted all annexes, but Annex IV on sewage has not yet gained the required adoption to come into force. Most of the major maritime nations, including the United States and Canada, are signatories to MARPOL and most of its annexes.

[346] Any new annex on ballast water would be an "optional annex." The rules of the basic MARPOL convention provide that an optional annex comes into force when not less than 15 states having a combined merchant fleet making up 50% of the world's tonnage assent to it, but individual nations can opt out. MARPOL 73, articles 14-15.

[347] Personal discussion with Mr. Thomas Morris, Transport Canada, Ottawa, the Canadian representative to the Ballast Water Working Group.

[348] Personal discussions with US Coast Guard and Transport Canada officials.

that "Parties [which means the national states, such as Canada and the United States, joining in the convention] shall not apply any requirement on a ship relating to ballast water management options where the ship's ballast water management plan indicated that it is unsafe or the master otherwise reasonably determines that undertaking such an operation would jeopardize the safety or stability of the ship, its crew, or passengers."[349] Comments from the US representatives to MEPC note some concern with this provision. "As new management techniques are developed, ships should integrate the ability to conduct such methods and therefore a ship should not be exempt from complying simply because its plan states that it is unsafe."[350] But one should not take too much comfort from this mild objection put on the record by the United States, because the US counter-draft does not clearly correct this critical provision in the MEPC draft.[351]

§ 8. Great Lakes legal regimes for control of aquaculture, bait, and aquaria: Holes in the dike

The Great Lakes make up one aquatic ecosystem, and cannot be protected from invasion by any exotic which any state or province along its shores allows into the basin. That would seem to make it obvious that there is a need for binational and regional coordination of policies for the regulation of aquaculture, baitfish, and aquaria.[352] There are, however, no legal mechanisms for insuring such coordination.

[349] MEPC, "Harmful Aquatic Organisms in Ballast Water," Report of the Working Group on Ballast Water convened during MEPC 42, MEPC 43/4 (January 5, 1999), Annex 1, "Proposed Amendments and Comments on the Draft Regulations for the Control and Management of Ship's Ballast Water and Sediments to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens (in the form of an Annex to MARPOL 73/78)," Regulation 4.5.

[350] MEPC, "Harmful Aquatic Organisms in Ballast Water," Comments on the Report of the Working Group on Ballast Water convened during MEPC 42 (MEPC 43/4), MEPC 43/4/4, submitted by the United States (April 1, 1999), Annex 2, "International Convention/Annex for the Management of Ship's Ballast Water and Sediments to Prevent or Minimize the Transfer of Harmful Aquatic Organisms and Pathogens," p. 5, insertion 2(bis) note.

[351] *Ibid*., 2(bis)-(2)(ter), 4(bis)(1). The US counter-proposal is highly ambiguous. It says that the ship which cannot safely exchange shall "only discharge the minimum amount of ballast water essential for the ship's operation to the extent permitted and in accordance with the requirements of the Party in whose waters the discharge takes place," which might be read to allow a nation to impose other technological options, but that interpretation is not consistent with other US language saying that "A port State(s) may…*allow* a ballast management techniques as an alternative to another technique provided for in this Convention…." (Emphasis added.) The US language is certainly superior to the MEPC draft, in that it takes out the outright prohibition against stricter national standards. But it does so in a way which creates real potential for litigation over the issue, particularly if a subordinate jurisdiction (US state or Canadian province) attempts stricter regulation.

[352] "Rigorous review of all exotic introductions and consultations with all concerned jurisdictions and user groups should precede any planned introduction." Jon G. Stanley, Robert A. Peoples, Jr., and James A. McCann, "US Federal Policies, Legislation, and Responsibilities Related to Importation of Exotic Fishes and Other Aquatic Organisms," *Canadian Journal of Fisheries and Aquatic Sciences* (1991), vol. 58 (Supplement 1), pp. 162-166, 165.

§ 8.1. State and provincial laws in the Great Lakes

The Federal Aquatic Nuisance Species Task Force conducted a superficial survey of US state laws controlling exotic species throughout the United States in 1991.[353] While indicating that many states were beginning to strengthen their authority to control exotics at that time, the responses from the states presented a general picture of weakness and incoherence in regulatory policy. The definition of what types of organisms were covered varied widely and, although all states had some authority to prohibit or permit some categories of aquatic organisms, "Many states cited no particular criteria by which permit applications are judged."[354]

A survey of federal, state, and provincial laws in the Great Lakes region which I recently conducted on behalf of the State of Michigan indicated that only some improvements have been made to that general picture in the ten years since.[355] All of the states in the region have some provision restricting the introduction of exotic fish, more or less, usually subject to rather wide discretion on the part of the state conservation agency.[356] But the statutes are rather uneven in their focus and coverage. All of the eight US states and Ontario have what is theoretically a "green list," in the sense that statutes or regulations require positive permits or listing before fish are introduced, but which may or may not actually be promulgated in statute or regulation. Coverage is uneven. Michigan's separate green lists, for example, apply only to aquaculture[357] or game fish.[358] The Michigan regulations promulgated under the general conservation statute for other fish, which may be limited by the terms of that statute, have only a "red list" of prohibited species.[359] Most jurisdictions, while requiring positive permitting before any introductions, have few statutory or regulatory standards for fully evaluating such introductions. The prohibitions are typically limited, vague, and qualified. There are few statutory standards for

[353] Aquatic Nuisance Species Task Force, *Findings, Conclusions, and Recommendations of the Intentional Introductions Policy Review*, report to Congress under the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 § 1207 [16 USC § 4727] (Washington, DC: ANS Task Force, US FWS & NOAA, March 1994). The 1991 study was impressionistic rather than systematic in nature, because it was based on responses to questions and those responses were noticeably uneven in evident interest and detail.

[354] Aquatic Nuisance Species Task Force, *ibid.*, p. 10. On the mixed state of affairs in 1991, see also Paul J. Wingate, "US State's View and Regulations on Fish Introductions," *Canadian Journal of Fisheries and Aquatic Sciences* (1991), vol. 48 (Supplement 1), pp. 167-170.

[355] Eric Reeves, *Analysis of Laws & Policies Concerning Exotic Invasions of the Great Lakes* (Lansing, MI: MDEQ Office of the Great Lakes, March 15, 1999). The study was commissioned by the Office of the Great Lakes, Michigan Department of Environmental Quality, in accordance with mandates in the Michigan *Nonindigenous Aquatic Nuisance Species State Management Plan* (Lansing, MI: MDEQ Office of the Great Lakes, January 1996). The study was based on a systematic review of conservation and environmental statutes and regulations (but not internal enforcement policies) in the eight US Great Lakes states, the Province of Ontario, and the two federal governments, which are reviewed in detail, with full citations, in the report.

[356] The term "conservation agency" is used here as a generic stand-in for a department or ministry of natural resources, a conservation department, or a fish and wildlife service, division, or commission.

[357] Michigan Compiled Laws, MCL § 286.875(1).

[358] Michigan Compiled Laws, MCL § 324.45906.

[359] Michigan Administrative Code, MAC R 299.1051, R 299.1052 (1979), issued under the authority of Michigan Compiled Laws, MCL § 324.45906 (replacing MCL § 308.115 *et seq*.).

implementation of the statutes by the relevant agencies, *e.g.*, presumptions for or against introduction, provisions for scientific review or interagency and public consultation, or environmental impact studies. There are few provisions for record-keeping and inspection to insure compliance. The Minnesota Chapter 84D on Harmful Exotic Species[360] is the one great exception to this overall picture. I review it in further detail below.

More generally, there is little in the way of legislative strategies – or mandates for agencies to develop strategies – for dealing with different vectors. Nowhere is there any legislation establishing the principle that "the polluter pays," through either liability or tax schemes. (Many of the fees, for licenses to import exotics, and penalties for violations of rules against importation or introduction, are miniscule in terms of both the required regulatory programs and the potential harm of introductions.) Some significant vectors of concern, such as baitfish and aquaria, have not really been addressed. And there are few provisions for interstate and binational coordination of programs in order to establish consistent policies and legally effective rules for the Great Lakes ecosystem as a whole.

A general survey of Canadian provincial wildlife acts recently conducted for the Canadian Wildlife Service came to similar conclusions. That report observed that "considerable variation occurs in the approach used to permit/deny species entry, the words used to mean native or non-native, definition of exotic, the range of prohibited species listed, and the degree of control exercised over the issue of alien species management; thus the approach across Canada at the provincial level is very inconsistent."[361]

Responsibility for protection of the ecosystem against invasion of exotics in the United States is typically assigned to a conservation agency, generally responsible for fisheries and other natural resources, such as a department or ministry of natural resources. That is usually not the same agency with primary responsibility for prevention of water pollution, such as a department of environmental protection, and is sometimes not the same agency responsible for support of aquaculture, usually a department of agriculture. The conservation agency responsible for the fisheries is typically the agency with responsibility for policing watercraft as well. But none of these agencies, or any other agencies at the state and provincial level, have undertaken regulation of commercial shipping. That has generally been deferred to the federal government.[362]

Again, it is much the same pattern on the northern side of the Great Lakes. Provincial responsibility for response to water pollution is generally the responsibility of the Ontario

[360] Minnesota Statutes, MS §§ 84D.01 *et seq*.

[361] Cathy Keddy, *Canada's Capability for Managing Alien Organisms: Implications for Conserving Native Biodiversity*, report prepared for the North American Wetlands Conservation Council (Canada) and the Canadian Wildlife Service (Ottawa: Canadian Wildlife Service Biodiversity Branch, November 1997), p. 7.

[362] In the US, primarily the US Coast Guard, implementing Titles 33 and 46 of the US Code, as well as the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, as amended by the National Invasive Species Act of 1996, US Code at 16 USC §§ 4701 *et seq.*, hereinafter referred to as National Invasive Species Act or NISA. That does not mean that federal authority is exclusive.

Ministry of the Environment,[363] fisheries are the responsibility of the Ontario Ministry of Natural Resources,[364] which does have authority over licensing of aquaculture[365] (as do some US state conservation agencies), and commercial shipping is generally the responsibility of the federal Department of Transport.[366]

Although there is a good foundation for regional coordination of policy in the form of existing organizations such as the Great Lakes Commission[367] and the Great Lakes Fishery Commission,[368] there is no recognition of the need to establish legally effective regional policies in state and provincial statutes on exotics. None of the statutes giving the conservation departments authority to control exotics provide that disapproval of a species by other jurisdictions in the region or a regional body is a basis for prohibition or regulation. None of the various statutory regimes even contemplate the idea of a regional green list.

To be clear, all of the Great Lakes states and the Province of Ontario have statutory provisions of one type or another providing some agency of the state with authority to control the introduction of fish or some larger set of aquatic organisms. No state or provincial executive branch (nor the executives in either of the two federal governments) are completely powerless to act. In general, however, that authority is incoherent, in the sense that legislative enactments in most states are unfocused. They do not reflect a clear legislative policy or a strong mandate for action.

These observations are not meant to disparage the good work of conservation officials throughout the region. To the contrary, I have been consistently impressed by the degree to which dedicated officials in all eleven jurisdictions have done their utmost to fill the breach with intelligent regulatory schemes, local agency policies, management plans, voluntary industry guidelines, and public education programs. They also work well together at the regional level in such forums as the Great Lakes Commission on Aquatic Nuisance Species, which is a model for regional coordination now being imitated by state officials around the country.

But it would be a fallacy of composition to assume that a collection of intelligent and well-focused individuals must necessarily amount to an intelligent and well-focused policy

[363] Ontario Environmental Protection Act, Revised Statutes of Ontario, RSO Chapter E.19.

[364] Fish and Wildlife Conservation Act, Statutes of Ontario 1997, Chapter 41. The Ministry shares responsibility for fisheries with the Federal Department of Fisheries and Oceans under the Canada Fisheries Act, Revised Statutes of Canada, RS Chapter F-14.

[365] Fish and Wildlife Conservation Act of 1997, Statutes of Ontario 1997, Chapter 41, § 47.(1), and Game and Fish Act Regulations with Respect to Fish, Ontario Regulation 267/95.

[366] Canada Shipping Act, Revised Statutes of Canada, RS Chapter S-9.

[367] Great Lakes Basin Compact, authorized with exceptions by US Public Law 90-419 (July 24, 1968), adopted by the Great Lakes states at Illinois Compiled Statutes, 45 ILCS §§ 145/0/01 *et seq*., Indiana Code, IC §§ 14-25-13-1 *et seq*., Michigan Compiled Laws, MCL §§ 324.32101 *et seq*., Minnesota Statutes, MS §§ 1.21 *et seq*., New York Environmental Conservation Law, ECL §§ 21-0901 *et seq*., Ohio Revised Code, ORC §§ 6161.01 *et seq*., Pennsylvania Statutes, 32 PS §§ 817.1 *et seq*., and Wisconsin Statutes, WS §§ 14.78 *et seq*.

[368] Convention on Great Lakes Fisheries between the United States of America and Canada, signed at Washington September 10, 1955, US DOS Treaties and International Agreements Series, TIAS 3326.

regime at the collective level of their government jurisdictions or the region. And it would do those individuals no favor to ignore the fact that they are plugging holes in dikes. They are running out of fingers. They are forced to frequently devote scarce resources to chasing after species already established in the ecosystem, fighting a rearguard action with few resources and only tentative political support from their legislatures. There is, in fact, only one jurisdiction in the region, Minnesota, which has legislated a comprehensive scheme specifically focused on exotics, which gives their enforcement agency a strong mandate for action. The rest of the agencies, including the several agencies of the two federal governments, are working with a patchwork of various authorities and with much less than a clear mandate for strong preventative action.

Minnesota. As noted above, Minnesota has a comprehensive regulatory scheme which is far more comprehensive than any other state statute on the subject in the region. The statute, Chapter 84D on Harmful Exotic Species, has wide coverage over all animals and plants, classifies exotics into specific categories and, theoretically, controls all introductions.[369] It provides an array of authorities, and expresses a strong mandate for positive action on the part of the Minnesota Department of Natural Resources. Just as important, the statute is implemented by detailed regulations in which the DNR fleshes out specific procedures for examining new species and the purposes for which they are to be used. This includes, for example, a requirement that those wishing to handle a prohibited species for special purposes provide "a written contingency plan for eradication or recapture in the event of an unauthorized introduction of the prohibited exotic species."[370] The statute also mandates the establishment of a comprehensive administrative program, including strategic planning, educational programs, and regional coordination.

An important feature of the Minnesota statute, notably absent from all other state and provincial statutes in the region, is a definite process for bringing new species to the attention of the conservation agency for classification and regulation. A person "may not introduce" an "unlisted species" without first notifying the Department of Natural Resources (DNR) and submitting it for classification as "prohibited," "regulated," or "unregulated."[371] The DNR has promulgated detailed regulations on the information which the applicant must provide, including such requirements as "scientific-based information about the ability of the unlisted exotic species to naturalize, displace native species, and harm natural resources or their use in similar climates and latitudes."[372] In general, the Minnesota listing criteria are environmentally protective. The criteria strengthen the power of the DNR because they put the exclusive emphasis on protection of the state ecosystem. The potential economic value of the proposed introduction is *not* a statutory criterion, although it will no doubt have weight regardless. The most important flaw is the lack of reference to any regional standards. In order to protect the Great Lakes as a whole, any individual state agency responsible for classifying species needs to be able to use a regional prohibition as an

[369] Minnesota Statutes Chapter 84D, MS §§ 84D.01 *et seq*.
[370] Minnesota Rules, MR Part 6216.0265, subdivision 5A(6).
[371] Minnesota Statutes, MS § 84D.06, subdivision 1.
[372] Minnesota Rules, MR Part 6216.0290 *et seq*. and Minnesota Rules, MR Part 6216.0290, subpart 1A(9).

absolute trump. It may not be fair, however, to expect the Minnesota legislature to have made provision for a regional process which has yet to be created.

§ 8.2. US and Canadian federal laws

United States. The primary US federal conservation statute applicable to exotics is the Lacey Act, originally enacted in 1909, and administered by the US Fish and Wildlife Service (USFWS) in the US Department of the Interior. This act and its administration by the USFWS follows the general pattern, evident in many states, of very general statutory authority, without clear standards or strong mandates, accompanied by tentative implementation by the responsible agency.

Its terms are broad in scope. Part of the act, a section in the US Criminal Code, provides that "importation into the United States…of the zebra mussel…*and such other species* of wild mammals, wild birds, fish (including mollusks and crustacea), amphibians, reptiles, brown tree snakes, or the offspring or eggs of any of the foregoing *which the Secretary of the Interior may prescribe by regulation to be injurious to* human beings, to the interests of agriculture, horticulture, forestry, or to the wildlife or the *wildlife resources* of the United States, is hereby prohibited."[373] Under this provision, the Department of the Interior has authority to prohibit a wide variety of aquatic organisms from being imported into the United States, although the terms of this statute do not extend to plants or microbes. (A long list of other provisions in the US Code gives the Animal and Plant Health Inspection Service (APHIS) in the US Department of Agriculture authority to control the importation of various plants, insects, parasites, and animal pathogens.[374]) Does this part of the Lacey Act authorize the USFWS to prohibit the importation of any exotic not otherwise authorized – thereby creating a regulatory "clean list" or "green list" of approved species? Given the documented damages done by exotics and the substantial nature of the threat of future invasions, it would seem that there is a reasonable basis for categorizing all new imports as presumed "injurious" until otherwise proven.

Other parts of the Lacey Act contained in Title 16 of the US Code on Conservation make it illegal "to import, export, transport, sell, receive, acquire, or purchase in interstate or foreign commerce…any fish or wildlife taken, possessed, transported or sold in violation of any law or regulation of any State or in violation of any foreign law, or…any plant…."[375] This "piggyback provision," putting the weight of the US federal government behind the conservation statutes of the states, has been viewed by the Department of Interior and the Fish and Wildlife Service as the primary mandate of the Lacey Act.

[373] US Code, 18 USC § 42(a)(1) (emphasis added).

[374] Federal Plant Pest Act, 7 USC §§150aa-150jj, Plant Quarantine Act, 7 USC §§ 151-164a, 167, Federal Seed Act, 7 USC § 1581, Federal Noxious Weed Act, 7 USC §§ 2801-2814, provisions on grasshopper control at 7 USC § 148f, on quarantine of imported animals at 21 USC §§ 102-105, on contagious diseases at 21 USC §§ 111-114a-1, and many other specific provisions on specific pests and animal diseases in the US Code.

[375] 16 USC § 3372(a)(2).

Although there seems to be statutory authority to set nationwide regulatory standards for importation of exotic fish and wildlife under the provision in Title 18, DOI and USFWS have shied away from any such program by long-standing policy.[376] In the words of one USFWS official, "the federal government's responsibilities are to support state or foreign regulations when such regulations are violated. Regulations that control the introduction of fish into the open waters of the United States are each state's responsibility."[377] It is not clear how this is reconciled with the President's executive orders on exotics, issued in 1997 and 1999, which directed federal agencies to take action to restrict introduction within the limits of their authority.[378] The Secretary of the Interior recently commented on the obvious need for a national "green list," but asserted that the DOI maintained only a "red list" of species already proven to be harmful because that was the only thing authorized by the federal statutes.[379]

Canada. The primary conservation statute is the (Canadian) Fisheries Act.[380] The act is enforced at the federal level by both Environment Canada and the Department of Fisheries and Oceans (DFO), now including the Canadian Coast Guard (which does not, however, have general law enforcement authority), and also by the provincial ministries of natural resources. The Fisheries Act says very little about exotic species in so many terms, but gives the government broad authority to issue regulations "respecting the conservation and protection of fish" and the "transporting, possession and disposal of fish."[381] More specific provisions in the Ontario Fishery Regulations,[382] issued under the Fisheries Act, provide authority for controls on exotics at the provincial level.

As in the US, there is sharing of authority between the federal and provincial governments. Theoretically, the federal government has exclusive power to "regulate" fisheries,[383] but the provinces have a "proprietary" interest in the protection of the fisheries as a natural resource, and the federal government has deputized the provincial ministries to carry out much of the Fisheries Act, particularly with regard to the freshwater fisheries of the Great Lakes. (As a matter of practical policy, it is analogous to the deference of the US Fish and Wildlife Service to the US states.) The Canada-Ontario Agreement of 1994[384] provides for sharing of responsibilities for exotics within the context of Lakewide

[376] A very limited set of regulations controlling certain fish and other aquatic organisms, particularly salmonids, promulgated under 18 USC § 41, are in the Code of Federal Regulations at 40 CFR § 16.13.

[377] James P. Clugston, Director of USFWS National Fishery Research Laboratory, "Strategies for Reducing Risk from Introductions of Aquatic Organisms: The Federal Perspective," *Fisheries*, vol. 11, no. 2 (March-April 1986) pp. 26-29, at 28-29.

[378] OE 11988, Exotic Organisms (May 24, 1977), superceded by EO 13112, Invasive Species (February 3, 1999), 64 *Federal Register* 6183 (February 8, 1999).

[379] Bruce Babbitt, Secretary of the Interior, interview on National Public Radio, "Talk of the Nation Science Friday" (February 2, 1999), Hour 2.

[380] Revised Statutes of Canada, RS Chapter F-14.

[381] Revised Statutes of Canada, RS Chapter F-14 § 43(b)-(c).

[382] Ontario Regulation 89-93.

[383] *Attorney General of Canada v. Attorney General of Ontario*, AC 700 (1898).

[384] The Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem, 1994. (Effective from April 1, 1994 to March 31, 2000.)

Management Plans under the Great Lakes Water Quality Agreement of 1978/1987. Both governments have committed to develop and implement "joint federal and provincial plans to control the introduction of undesirable species and mitigate the negative impacts of non-indigenous nuisance species, such as zebra mussels and ruffe. The federal government will continue the control program on sea lamprey."[385]

§ 9. Binational regional coordination in the Great Lakes

The two primary forums for regional coordination on exotics are the Great Lakes Fishery Commission and the Great Lakes Commission Panel on Aquatic Nuisance Species (ANS Panel). The Fishery Commission, a binational body established by the Convention on Great Lakes Fisheries,[386] is mandated to "formulate a research program…to determine the need for measures to make possible the maximum sustained productivity of any stock of fish…to determine what measures are best adapted for such purpose"[387] and "to recommend appropriate measures to the Contracting Parties,"[388] which are the federal governments of the United States and Canada. This is exactly what the Fishery Commission did when it recommended action to control exotics in ballast water to the two governments in 1988,[389] and thereby prompted the development of the voluntary Canadian ballast guidelines, adopted in 1989, and the enactment of the first legislation on the subject in the form of the US Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990.[390]

That act, in turn, contained a US Congressional mandate for the Great Lakes Commission to establish a regional Panel on Aquatic Nuisance Species (as well as a mandate for the US federal government to create a national Task Force).[391] The original interstate compact creating the Great Lakes Commission provided for full participation by the Provinces of Ontario and Quebec as though they were "states,"[392] but this provision and others implying authority to enter into binational arrangements or discussions were excepted from the Congressional approval in definite terms. In the later action mandating the creation of the ANS Panel, Congress partially relaxed its earlier expression of disfavor towards any form of binational coordination, saying that the panel is encouraged "to invite representatives from the Federal, provincial or territorial governments of Canada to

[385] Canada-Ontario Agreement, *supra*, § 4.3.

[386] Convention on Great Lakes Fisheries between the United States of America and Canada, signed at Washington, September 10, 1954, Treaties and International Agreements Series, TIAS 3326 (September 10, 1954).

[387] Convention, *ibid.*, article IV, subsection (a).

[388] Convention, *ibid.*, article IV, subsection (b).

[389] International Joint Commission and Great Lakes Fishery Commission, *Exotic Species and the Shipping Industry: The Great Lakes-St. Lawrence Ecosystem at Risk* (Ann Arbor, MI: Great Lakes Fishery Commission, September 1990), pp. 11-14.

[390] US Public Law 101-646 (November 29, 1990), codified at 16 USC § 4701 *et seq.*, now commonly referred to as the National Invasive Species Act (NISA).

[391] 16 USC § 4723.

[392] Great Lakes Basin Compact, article II, paragraph B. The original compact is printed in full, along with the Congressional approval with exceptions, in US Public Law 90-419 (July 24, 1968).

participate as observers."[393] The statutory mandate for the ANS Panel is, among other things, to "(A) identify priorities for the Great Lakes region….(B) make recommendations to the [national] Task Force….[and] (C) coordinate, where possible, aquatic nuisance species program activities in the Great Lakes…."[394] Also, the national Task Force is instructed to "request that the Great Lakes Fishery Commission provide information to the [ANS Panel] on technical and policy matters related to the international fishery resources of the Great Lakes."[395]

Finally, the Great Lake Water Quality Agreement of 1978/1987 (GLWQA 78/87)[396] charged the binational International Joint Commission (IJC) to conduct studies of the Great Lakes ecosystem and provide "advice and recommendations to the Parties [the two federal governments] and to the State and Provincial Governments."[397] The IJC was already established, before the GLWQA 78/87, as a binational commission to mediate rights in the use of Great Lakes water under the Boundary Waters Treaty of 1909.[398] The GLWQA 78/87, gave the IJC important new responsibilities for monitoring the quality of that water. The agreement has been primarily focused on chemical contaminants, although exotic species and ballast water are mentioned in Annex 6, Review of Pollution from Shipping Sources, in the current agreement. There is at the present time a debate inside the Great Lakes environmental community about whether or not the focus of the agreement should be expanded from the traditional concentration on chemicals to consider habitats and exotics as well. According to the agreement, its general purpose is "to restore and maintain the chemical, physical, and *biological* integrity of the waters of the Great Lakes Basin Ecosystem."[399]

§ 10. Political economics: The use and misuse of economics, and the political realities of environmental regulation

Just as in physics every action is associated with a reaction, in economics every benefit is associated with a cost. I might take that analogy one step further to say that in politics every public policy promoted by some interest is opposed by another interest. This is not because people are evil (whether or not they are) but simply because they are rational. The basic organizing principle of evolution, economics, and politics, is selection through the process of competition. The special interest which does not look out for its interest may be

[393] National Invasive Species Act, 16 USC § 4723(a)(3). It might be argued that this is not permission to speak with "observers," but the infinitive "to participate" is quite encouraging.

[394] National Invasive Species Act, 16 USC § 4723(a)(1).

[395] National Invasive Species Act, 16 USC § 4723(a)(2).

[396] Great Lakes Water Quality Agreement of 1978, as amended by the Protocol of 1978 (signed at Ottawa by the US Secretary of State and the Canadian Minister of Foreign Affairs, November 22, 1978). The GLWQA 78/87 is not a ratified treaty, but is formally recognized by US statutes and the Canada-Ontario Agreement.

[397] Great Lakes Water Quality Agreement of 1978/1987, article III, § 1(c).

[398] Treaty between the United States and Great Britain relating to Boundary Waters, and Questions Arising between the United States and Canada, signed at Washington, DC January 11, 1909, 36 Stat. 2448, TS 548, 12 Bevans 319.

[399] Great Lakes Water Quality Agreement of 1978/1987, article II (emphasis added).

replaced by another who does. The business person who does not work to delay and subvert the process of government regulation may go out of business. The responsible industry leader who absorbs too much in the way of marginal costs doing the right thing may be outbid by the sleazebag competitor who does not care. This does not mean that all special interests are hypocritical in their protestations of promoting the public interest or that all industry representatives are lying when they say that they want to work with government regulators in a cooperative manner. But it does mean that, in order to be effective, we must give them an incentive.

As soon as we begin to talk about policies for the prevention of exotic invasions – or as soon as we begin to get specific about effective controls on such things as ballast water or aquaculture – the industry becomes wary of "excessive environmental regulation" and the "economic costs." As soon as we begin to talk about "costs and benefits," the environmentalists become wary of a sellout. How can you put a price on preservation of the environment, particularly when we are faced with permanent loss of biodiversity?[400] How can you put a dollar sign, Canadian or US, on our vision of the Great Lakes? The answer is that you can – that we all do every day, whether or not we like to think about it – and that you had better learn how to put a price on it if you want others to value it. But the environmentalist suspicion of cost/benefit analysis is in fact justified, for exactly the same reason that the industry suspicion of environmental regulation is justified – because the analysis is often sloppy. It is often sloppy in not fully accounting for the real costs of environmental degradation and loss of natural resources. It is often sloppy in not accounting for the realities of the market and the costs of marginal returns. And, what is the very worst of both worlds, it is often sloppy in not anticipating unintended consequences which give us low levels of environmental protection at high costs. I will try to avoid those errors here.

There are two basic problems in economics, relevant to all areas of environmental regulation, which bear on the problem of exotics. The first is the problem of accounting for the intangible values and public externalities which are not normally reflected in market transactions – which thereby justify governmental intervention to correct that market failure. The second is the problem of accounting for the action of markets on the margin and the unintended consequences of regulation – which amount to governmental failure.

My focus, in this section, is almost entirely on ballast water. That is because, as a matter of fact, it is not clear that there are any substantial costs to be concerned about in making the obvious and necessary reforms in the regulation of commercial uses of aquatics in aquaculture, baitfish, and aquaria. That may be debatable. But the industries concerned have yet to make a case that better federal, state, and regional coordination of existing regulatory programs, or development of better quality controls at critical points in the business processes, would harm those industries in any way. That sort of thing might well

[400] For a discussion of the many objections to cost/benefit analysis by environmentalists, especially as it applies to biodiversity, and some answers to those objections, see Alan Randall, "The Value of Biodiversity," *Ambio* (April 1991), vol. 20, no. 2, pp. 64-68. He quotes, among other things, the suspicion of the "slick terrain" of economic analysis, and the view that "Assigning value to that which we cannot understand except in the most superficial ways is the ultimate in presumptuous folly." *Ibid.*, p. 65.

benefit those businesses to some extent. (That does not mean that it might not hurt some individual businesses, having difficulty coming up to standard. But, as a matter of public policy, that is not our concern. If regulation of the industry helps separate out the competent from the incompetent, that is good for both the environment and the economy.) Outright prohibition of commercial use of some species of exotic fish does in fact cause significant opportunity cost to those businesses. But here it seems so obvious that the benefit to the public of keeping out detrimental exotics so clearly outweighs the benefit to business of being able to make use of them that there is really very little to analyze and no strong argument against an outright prohibition. The more relevant issues to be debated, regarding regulation of commercial uses, are the more familiar legal process questions about how to coordinate government policies and create regulatory programs which are efficient, for both the public and industry – how, in other words, to keep down the "transaction costs" of regulation.

§ 10.1. The value of steel and fish: Putting down your money and making your choices

A fundamental principle of both democracy and economics, as both are more or less accepted in the liberal democracies of the United States and Canada, is that everyone's desires for good things in life are worthy of respect.[401] From the agnostic view of neoclassical economic theory (which seeks thereby to be objective and scientific, although there are some interesting philosophical problems with this claim) the goal is the greatest good for the greatest number, however those numbers might define what is good for themselves.[402] The prevailing schools of modern economic theory[403] also maintain that, in

[401] Some Canadians may immediately object that the sacred principle of the "pursuit of happiness" at the individual level, enshrined in the Declaration of Independence of the United Colonies, was never so enthusiastically accepted in the more "communitarian" colonies to the north which decided to stay out of that war. Although that is true, it is not really on point. It is not so much a question of respect for individual freedom as it is a question of respect for a whole constellation of values which go under the classic term of "liberalism" (including values considered both "liberal" and "conservative" in modern US and Canadian politics) and which are strongly shared in the US, Canada, and the other western democracies. Although Americans lean more strongly toward support of individual rights against the state in general, Canadians actually lean more strongly toward support for freedom of expression and respect for divergent communities. See the discussion and data in a basic textbook on Canadian politics, Stephen Brooks, *Canadian Democracy* (Don Mills, ON: Oxford University Press, 2nd ed., 1996), pp. 43-61. Although modern economic theory is biased toward market solutions as a matter of instrumental efficiency (and is thus often used as a tool for "conservative" arguments against government intervention for public welfare) the fundamental philosophical premise of modern utilitarian economics, often called "welfare economics," is also highly "communitarian" in calling for the greatest good for the greatest number and, as is developed in the text here, can also be used as argument for government intervention in appropriate circumstances. The general point, fundamental to classic liberalism, and shared by the US and Canadian democracies (at least in our better days) is respect for the values of others.

[402] These are known technically as the goal of "optimality" and the principle of "consumer sovereignty." "Optimality," or "Paerto optimality," is a condition in which no one's condition can be improved without a greater injury to the condition of others, and is basically a modern restatement of Jeremy Bentham's "Utilitarianism," for which the phrase "greatest good for the greatest number" comes. Although it is a generally accepted goal, there are some technical and ethical problems with it. The technical problems include the possibility of multiple, even infinite states of Paerto optimality, not all of which are optimal in a larger

general, a free market is the most efficient way to achieve that goal. But the bias in favor of a free market, although very strong, is instrumental rather than ideological. Modern economics clearly recognizes the existence of "public goods," "externalities," and "market failures" which justify intervention for the greatest good. Although it makes it inconvenient to do the math, there is nothing in economic theory which justifies ignoring a value or a cost just because it is difficult to put a price tag on it.

Moreover, in its bias toward the free market, economic theory is just as critical of pleas for government interventions in favor of "economic development." When we talk about the need to do something serious about ballast water in Seaway shipping, advocates for Seaway shipping warn of the "economic" consequences to the industry of the United States and Canada. But the same parties, in arguing for continued government subsidy of the Seaway, use an "economic" argument that ignores the importance of free markets. "One thing that bothers me…" says the Administrator of the US St. Lawrence Seaway Corporation, "is that everyone talks about the cost of the Seaway. This is significant, but we should focus more on the economic benefit, which is enormous. When you talk about the two nations investing from $70 million to $80 million in the Seaway System, you also have to look at the gigantic economic benefit, the number of jobs, the personal income, the economic activity which directly and secondarily results from Seaway commerce. Not enough people look at that side of the equation."[404] This is good political rhetoric, very commonly used, but it is the sort of bad economic theory that bothers any serious economist. The economist looks further, to what is really the other side of the equation. The other side of the equation is the "opportunity cost,"[405] the resulting economic benefits which could be enjoyed by the public

sense. The ethical problems include the lack of anything – at least explicitly – about equity. Nevertheless, it provides at least a starting point for the analysis of social goals. "Consumer sovereignty" is simply the basic principle of liberal democracy, that everyone has a right to decide what is best for themselves. Again, there are technical and ethical problems. The technical problems include information costs and the value of education in changing desires. The ethical problems include the lack – at least explicitly – of protections for fundamental rights. Again, however, it provides a starting point.

[403] The prevailing school of economics, when not just making a hegemonic claim to be "economics" without any further explanation, as if none were required, is known variously as "classical liberalism," "neoclassical economics," or, oddly enough, "welfare economics." It is also sometimes called "free-market economics," which does accurately express the technical bias towards free markets, but incorrectly implies that preference for a free market is a first principle of analysis. The first principle is, in fact, social welfare. Critics of this prevailing paradigm accuse it of being insensitive (or something worse) about social problems of war, poverty, and the environment. Leaving problems of war and poverty aside, I would point out that most of the literature and work in the subfield of "environmental economics," which is being drawn upon here, is in fact neoclassical welfare economics. A good, short, very readable primer available in paperback is Ian Hodge, *Environmental Economics: Individual Incentives and Public Choices* (New York: St. Martin's Press, 1995). Other basic texts are Per-Olov Johansson, *An Introduction to Modern Welfare Economics* (Cambridge: Cambridge Uni. Press, 1992), and Daniel Bromley, *Environment and Economy: Property Rights and Public Policy* (Oxford: Basil Blackwell, 1991).

[404] David Sanders, Administrator, St. Lawrence Seaway Corporation, quoted in "An Insider's Perspective," *Seaway Review* (January–March 1997), vol. 25, no. 3, pp. 19-21, 19.

[405] This part of the discussion is Econ 101 textbook stuff, and I apologize for boring some readers with the basics. As one writer points out, the economics insight about opportunity costs and the inefficiency of such government spending "seems so obvious that one can wonder why it is worth discussing," but, as that same writer documents, the obvious point is all-too-often forgotten in political debate. Steven E. Rhoads, *The*

if the government money spent on the subsidizes were allocated by markets instead. Any expenditure of money, whether for dog food, computers, or the steel shipped through the Seaway, has ripple effects through the economy, creating economic benefits, jobs, and personal income. The question is where the money is best spent for maximum effect. This is a question of efficiency. And, unless definite public goods or externalities not reflected in market prices are identified, the market is the far more efficient means for obtaining the maximum increase in these secondary economic benefits, jobs, and personal income. If the government expenditure on the Seaway lowers the cost of incoming steel, as it certainly does, then there certainly is a benefit to industries who depend on heavy use of steel. But that artificially lowers the competitive value of the all the alternative goods in the economy. It lowers the relative value of domestic iron ore and the domestic shipping which carries that ore inside the lakes. It lowers the relative benefits to those who produce substitute materials, such as wood and plastics. It lowers the economic benefits otherwise available to those who manufacture products which make less use of steel, such as computers (which have had massively beneficial ripple effects throughout the economy) and, yes, even dog food. If buying a second car is not artificially cheap, you might decide to spend more time on long walks with your dog instead of long drives in that second car or you might decide to buy a bicycle instead – either of which would benefit your health and lower medical costs. This may sound silly, or not. It depends on your personal choices. But the whole point of the free market is that it enables you to make your personal choices, silly or not, in incalculable small ways which add up to economic growth and prosperity for all. I cannot predict what actual decisions millions of people will make in response to higher steel prices. Nor can an economist. But neither of us has to. That is the beauty of leaving it up to the free market.

This does not mean that there might not be an argument in favor of subsidization of the Seaway, but simply that it is not logically based on the benefits of normal economic activity that are most effectively generated by the free market. As I will discuss below, there is an argument that the Seaway provides a special "public good" not encompassed by this sort of normal market activity.

What, then, does justify governmental interference in the market? The market fails to efficiently allocate goods and services when some activity generates a significant "externality." Externalities can be either good or bad. When they are good, they may also be special kinds of indivisible externalities called "public goods." When they are bad, they are sometimes called "social costs" or "negative externalities." In the field of environmental economics, a negative externality is "pollution." Externalities, good or bad, can be technically defined as "effects on third parties that are not transmitted through the price system."[406] Another way it is often stated is that the market price does not reflect the "true cost" of the economic activity. The ship that spills oil without having to pay for the clean up and the damages to natural resources is getting a "free ride" at the expense of the public

Economist's View of the World: Government, Markets, & Public Policy (New York: Cambridge Uni. Press, 1985), pp. 11-24 (quote on p. 11).

[406] Rhoads, *ibid*., p. 67. The concept of externalities, and its application to legal rules, is also extensively treated in Henry G. Manne, ed., *The Economics of Legal Relationships: Readings in the Theory of Property Rights* (St. Paul, MN: West, 1975), pp. 351 *et seq*.

because those very real costs are not reflected in the market price of oil. The fishers who drive a species to extinction through over-fishing have created a "tragedy of the commons" because they have taken the common resource without paying for the full cost of it.

Putting a price tag on the environment. The difficulty of putting a price on environmental quality is not, in principle, any reason to ignore its value. It is sometime said that "an economist is someone who knows the price of everything but the value of nothing." Those who work in the subfield of environmental economics might wish that were so, because the problem is actually just the opposite. Economists know very well that intangibles such as our desire for "ecosystem health" or "natural balance" have some real value. The problem is that it is difficult to put a price tag on these things, and therefore they do get left out of the equations too often. The following categorization of potential environmental values – all of which are applicable to the problem of exotic invasions – provides an analytical framework for making sure that nothing gets left out of the accounting.[407] The distinction between the two main categories, "use value" and "non-use value," reflect in a rough way the distinction between the concept of the environment as an "economic resource," or a concept of environmental protection as an issue of "sustainable development," on one hand, and the broader concept, on the other, of the environment and natural balance as something of profound human or spiritual importance. Without going too far into that philosophical debate (which I will touch on again below), my point here is to emphasize that both concepts (which in fact overlap) are relevant to the cost/benefit analysis:

(a) "Use value." This is the value of things in the environment as resources. It includes (1) "direct use value," which may be either (i) "priced" or (ii) "unpriced," and (2) "ecological function value." In the case of exotic invasions, the use value to be protected includes the native fisheries and other uses of the natural system which are impaired by invasions. The fisheries have direct priced value when fish are sold, and also unpriced value consisting of the use of the fish for recreation (which indirectly generates priced value in terms of tourism dollars). The integrity of the native system also has use values which are both priced and unpriced. A direct priced value is the amount of money that will not have to be spent on control measures, such as the sea lamprey control program or the cleaning of zebra mussels out of water pipes, if the native system is not impacted by invasions. An unpriced direct value of the same nature is the value to consumers lost when the zebra mussel causes taste and odor problems in water supplies, blooms of submerged aquatic vegetation, or added bioaccumulation of toxics which harm human health. One must also subtract from the lost value whatever value is gained from clearer water, which is certainly attractive, or possible assistance to increased production of mayflies, which benefit fishing.

These are the familiar sorts of things that we try to put a price on when talking about the damage done by past invasions (discussed in § 2.3 above). They include such things as $3 billion a year in cost to the US Great Lakes and Mississippi Basin from the zebra mussel,

[407] Adapted from Ian Hodge, *Environmental Economics: Individual Incentives and Public Choices* (New York: St. Martin's Press, 1995), p. 7, figure 1.2.

significant damage (maybe in the range of $1 billion per year?) to a Great Lakes fishery worth maybe $3 billion dollars per year (but compensated for, in part, by artificial stocking of other exotic fish) by the lamprey. However great these costs may be, it must be remembered, they are "sunk" costs. That damage has already been done,[408] and has to some extent been compensated for by control measures. But it does have relevance to the cost/benefit of future prevention measures if one assumes that future invasions, of creatures unknown and unpredictable, with equally unknown and unpredictable ecosystem effects, are likely to occur in the absence of effective preventative measures.

(b) "Non-use value." This includes (1) "option value," (2) "bequest value," and (3) "existence value." Non-use value, particularly bequest and existence value, are where the cold-blooded economists and political scientists take account of the intangibles. This includes, among many prosaic things, the more deeply-felt "spiritual" or "philosophical" values, including even the non-anthropocentric view, sometimes called "deep ecology," that the natural world has a moral claim to existence separate from its utilitarian value to humanity. In fact, the anthropocentric and non-anthropocentric points of view fade into each other in a rather fuzzy manner[409] and, as a matter of general public policy or social

[408] There is an instinctive and perfectly understandable desire to say that "someone should pay" for the terrible damage already done to the Great Lakes. But righteous anger does not make for good public policy. We will in fact only make ourselves pay if we increase the cost of commerce in the Great Lakes in a futile attempt to prevent environmental damage already done. There is absolutely no doubt that, if we knew back then what we know now, that the US and Canada never should have spent large amounts of public money to construct the St. Lawrence Seaway and Welland Canal system. Just in terms of dollars spent and tolls collected, the system has never paid for itself. What we have also lost due to past invasions such as the sea lamprey and the zebra mussel, and other public money and environmental value due to the interior support for Seaway shipping, in the form of such things as dredging, is enormous. See the history of damage to the Great Lakes reviewed in William Ashworth, *The Late Great Lakes: An Environmental History* (Detroit, MI: Wayne State University, 1987). But all of that is water and ships under the bridge. The Great Lakes region has long since built up an industrial infrastructure which is dependent on international trade through the Seaway. It may well be, as argued in this paper, that the Seaway trade needs to be taxed to pay for the cost of preventing future damage, thus putting a price on the value of what is still here to be preserved. But any attempt to collect for past damage is futile. One should take solace from the fact that there are better arguments, even if they seem rather cold, for preventative measures.

[409] As a practical matter, at least, the two philosophical viewpoints mix in public views of the environment. "At this point, the homocentric [anthropocentric] and ecocentric [non-anthropocentric] ethics seem to be combined in many people's minds, rather than competing." Gerald T. Gardner and Paul C. Stern, *Environmental Problems and Human Behavior* (Boston and Toronto: Simon and Schuster, 1996), pp. 65, citing P.C. Stern, T. Dietz, G. Guagnano, and L. Kalof, "Values, Beliefs, and Emergent Social Objects: The Social-Psychological Construction of Support for the Environmental Movement," paper presented to the Annual Meeting of the American Sociological Association, Los Angeles, August 1994.

I would also argue, as a philosophical matter, that the idea of there being a fundamental ontological distinction between the human species and the rest of the environment as a ground for moral principles is logically inconsistent with the very ecological viewpoint of life on the planet as an interconnected whole. In other words, to be an environmentalist is to recognize some basic kinship with other species, particularly those which show evidence of self-consciousness to some degree. Conversely, to be an environmentalist is also to recognize the complexity of the results of evolution, the uniqueness of the human species (on this planet, at least), and the dramatic transformations which have occurred on the planet, with or without human intervention. Strange as it may seem, an argument is made against the non-anthropocentric view by one of the most ardent environmentalists, and a particularly strong advocate for the preservation of biodiversity, the

science, we do not really need to sort it all out here. It is sufficient to note that people have a whole variety of complex and difficult-to-define feelings about the value of natural things, that those feeling have a real effect on their quality of life, including their mental and physical health, and that those commonly held feelings are entitled to respect in a democratic polity premised on promotion of the general welfare. The social scientists – and also the policy advocates, charged with making convincing arguments to political leaders accountable to the people – are not really concerned with the ultimate philosophical foundations of these feelings, however interesting they may be. We are concerned with documenting the reality and objective consequences of those feelings.

The first subcategory here, "option value," is really the unpredictable value of use in the future. It is what is being identified when environmentalists argue for preservation of the rain forests because the multitude of planet and animal species contained therein, many not yet identified, may have important future use for pharmaceuticals. Maybe, or maybe not. Some skeptical economists argue that advances in bioengineering are making such future value less significant and that, anyway, if the rain forests really had that sort of future value, pharmaceutical companies would be buying up large tracts for private preservation. And what, if any, is the option value of maintaining some semblance of a "natural ecosystem" in the Great Lakes? No one is predicting that the next invasion of the Great Lakes by an unknown exotic is going to wipe out some native creature in the Great Lakes which holds the secret to the cure for cancer. No. But future invasions of the Great Lakes by a wide variety of organisms with unpredictable ecosystem interactions could well result in significant decreases in water quality (both biologically and chemically) and loss of recreational value. Imagine a Great Lakes with chronic taste and odor problems, floating

paleontologist Stephen Jay Gould. He argues that, from the point of the view of the planet (metaphorically speaking) and the long reaches of geological time, our human pretensions to be either caretakers or destroyers of Gaia are irrelevant. He suggests, instead, that we should view our efforts to preserve the environment in this epoch of human existence as "a pact with our planet." He goes on to say that "She holds all the cards, and has immense power over us – so such a compact, which we desperately need but she does not at her own time scale, would be a blessing for us and an indulgence for her. We had better sign the papers while she is still willing to make a deal. If we treat her nicely, she will keep us going for a while. If we scratch her, she will bleed, kick us out, bandage up, and go about her business at her own scale." Stephen Jay Gould, *Eight Little Piggies: Reflections in Natural History* (New York: W.W. Norton, 1993), pp. 50-51.

There are, of course, other philosophical bases for an environmental ethic which should at least be taken note of, many of which are difficult to discuss here because they are based on revelation rather than rational argument. (That does not necessarily mean more "spiritual." I believe that Stephen Jay Gould's formulation is every bit as spiritual as Chief Seatlh's reported speech to President Franklin Pierce, "How can you buy the land?", or Vice President Al Gore's formulation of environmentalism as an obligation of Christian "stewardship," despite the fact that Gould bases his entirely on science.) The ethical basis for environmentalism in religion, which would seem to apply with particular force to the obligation to preserve the variety of creation (whatever one thinks is the ultimate source of that creation) is reviewed, with respect to Native American, Hindu, and Christian traditions, among others, in both Gerald T.Gardner and Paul C. Stern, *Environmental Problems and Human Behavior* (Boston and Toronto: Simon and Schuster, 1996), pp. 33-52; and Al Gore, *Earth in the Balance: Ecology and the Human Spirit* (Boston: 1992), pp. 238-265. However, without taking anything away from Vice President Gore's eloquent and refreshing appeal to Christian ethics in support of environmentalism in the United States, the review in Gardner and Stern shows that religious traditions tend to lack practical effect as motivators for environmental protection even when they would seem to be explicitly environmental traditions.

clouds of organic material with bioaccumulated contaminants, periodic catastrophic blooms of submerged vegetation or toxic algae, widespread fish diseases or dieoffs, or chronic outbreaks of human pathogens or parasites. All speculative. But who predicted the devastation done by the sea lamprey or the carpeting of the bottom of the Western Basin of Lake Erie by zebra mussels? Given the transformations already observed (and the potential increase in vulnerability due to global warming) this is not fanciful. All those possibilities have a great deal of relevance to the option value of ecosystem integrity in the Great Lakes. We may not want to sell Great Lakes water to the rest of the world – or, at least, we want to be very careful about how we get into that line of commerce – but this reservoir of unfrozen fresh water, the largest in the world and 18% of total supply,[410] certainly has considerable economic option value in a world running short of fresh water.

More generally, economic expansion, the movement to decentralized post-industrial methods of production, and the aging of the populations in advanced economies, along with environmental deterioration of many areas around the world, are all likely to make the future recreational value of the Great Lakes increase enormously.[411] These are options not to be lightly discarded. I should make clear that I am using "recreation" in a broad sense which includes much more than just the opportunity to fish, swim, or make a nuisance out of oneself on a "personal watercraft." What we are really talking about here is the importance of preserving a connection to the natural environment – a connection which would be poorly satisfied by the transformation of the Great Lakes into little more than artificial fish-stocking ponds or swimming and boating pools, paved over on the bottom by zebra mussels and sterilized by organochlorides, even if the water were very nice and clear. There is a growing body of scientific evidence documenting something environmentalists have always felt was intuitively obvious – which is that human beings need exposure to natural ecosystems in order to preserve mental and physical health. This is called the "biophilia hypothesis." It is relevant to both present use value and option value, but it may be particularly relevant to option value because we might not know how much we miss biodiversity until we lose it. Gerald Gardner of the University of Michigan and Paul Stern of the National Research Council sum up the literature as follows:

[410] US EPA and Environment Canada, *The Great Lakes: An Environmental Atlas and Resource Book* (Chicago: US EPA Great Lakes National Program Office, 3rd ed., 1995), p. 3.

[411] The Great Lakes region has gone through distinct, although overlapping, phases of economic development, from fur-trading, to logging, to farming and fishing, to industrialization, and to recreational use. Industry in the region is certainly not dying, and has in fact undergone a significant revitalization in the 1990s, due in part to healthy competition from foreign industry and globalization of markets. This is still the "industrial heartland" of both the US and Canada, and not all that rusty a "rustbelt" at that. See The Federal Reserve Bank of Chicago, "The Midwest Economy in an Interdependent World Market," *Chicago Fed Letter*, No. 116 (Chicago: Federal Reserve Bank of Chicago, April 1997). But the nature of "industry" itself is undergoing significant transformation towards decentralization and less-intensive resource use (which is the fundamental economic response to "limits to growth") while disposable income in the advanced economies is increasing. Although predictions in economics are just as dangerous as predictions in ecology, all of this makes it a fairly good bet that the relative value of recreational resources (especially compared to the value of the same natural resources for extraction and heavy industrial use) will continue to increase, and probably at better than linear growth.

> Biologists Rene Dubos (1968), Hugh Iltis, Orie Loucks, and Peter Andrews (1970) have argued that humans have an innate need to be near plants, animals, and other natural stimuli. These scholars claim that if humans are deprived of these stimuli, human emotional health may be impaired. Natural stimuli, more specifically, include the shapes of foliage and vegetation, the sounds and motions of animals and bodies of water, annual seasonal changes, and so on….
>
> Recently, Edward Wilson (1984) and others (Kellert and Wilson, 1993) have extended Dubos/Iltis et al.'s idea into what Wilson calls the "biophilia hypothesis." This hypothesis holds that humans have a genetic, evolution-based need for "deep and intimate association with the natural environment, particularly its living biota [plants and animals]" (Kellert and Wilson, 1993, p. 21) for maintenance of physical and emotional health and for personal fulfillment. Dubos, Iltis et al., Wilson, and others argue that more and more people will be living in environments lacking natural stimuli in coming years. As global population grows, more people will live in urban areas (Ross, 1994), which are filled with concrete, glass, and steel structures, but generally lacking in natural stimuli. Expanding human settlements will also continue to consume farmlands, woods, and wilderness areas. And more people are likely to be exposed to deteriorated environmental conditions such as air pollution. As a result, these scholars predict, growing numbers of people will suffer impaired emotional and physical health. Indeed, illness and other pathology now found in urban areas versus rural areas may be caused in part by the absence of natural stimuli in urban areas today.[412]

Gardner and Stern, after a careful review of experimental data in addition to this literature, find that "When held up to the strictest standards of empirical proof for a genetic predisposition, the evidence for the biophilia hypothesis does not appear at this point compelling…. However…we are impressed by the number and variety of research results that are consistent with the biophilia hypothesis."[413] The source of biophilia, as a matter of evolutionary theory, remains unproven by the available evidence. But there seems to be strong indication that humans are biophilic – which therefore provides the justification for considering it a significant element in the cost/benefit analysis.

The second subcategory, "bequest value," is closely related to option value. This is a matter of how much we value the "biological heritage" we pass to future generations, as distinct from the future use we can somehow capitalize on during our lifetimes. Both evolutionary theory[414] and the traditional laws of inheritance[415] suggest that human beings

[412] Gerald T.Gardner and Paul C. Stern, *Environmental Problems and Human Behavior* (Boston and Toronto: Simon and Schuster, 1996), pp. 183-184. Bracketed insertions are from the original. The references cited in the quote are to Rene Dubos, *So Human an Animal* (New York: Scribner, 1968); Hugh Iltis, Orie Loucks, and Peter Andrews, "Criteria for an Optimum Human Environment," Bulletin of the Atomic Scientists (1970), vol. 25, pp. 2-6; Edward Wilson, *Biophilia: The Human Bond with Other Species* (Cambridge, MA: Harvard Uni. Press, 1984); S. Kellert and E. Wilson, eds., *The Biophilia Hypothesis* (Washington, DC: Island Press, 1993), p. 21; and S. Ross, "World's Population Moving into Cities," Ann Arbor News (Ann Arbor, MI: September 20, 1994), p. A-6.

[413] Gardner and Stern, *ibid*., p. 192.

[414] In fact, recent re-evaluations of both psychology and politics in light of evolutionary theory suggest that transmission of wealth and power ("resources," in a broad sense) to succeeding generations is the penultimate human value, second only to procreation itself. (We are speaking here of what in fact people do

put a high value on being able to pass on wealth to their descendents. But this does not necessarily generalize into a desire to save natural resources for all. Both of these two subcategories, option value and bequest value, are subject to private "discounting." I value more what I can extract from resources right now, rather than preserving it for future options or bequests to the benefit of all humanity, because I get to enjoy it now, and also pass along what I gain to my immediate family. (There may be a total loss in resource value. But there is a gain to me and my descendants, which is what I and my genes mostly care about.) Another aspect of this problem is that there is often a significant conflict between the "private discount rate," a high rate putting preference on immediate gain, and the "social discount rate," a lower rate reflecting a greater desire on the part of society as a whole to preserve resources for the future.[416] When analyzing what is good public policy, we are entitled to use a lower, social discount rate – which means putting a higher value on options and bequests.

Also, it is interesting to note that the future amount of option and bequest value may be raised by change in marginal value. The concept of "marginal value" points out that the

value, aside from whether or not, as a philosophical matter, they should value.) On the general theory of human evolution applied to psychology and politics see Robert Wright, *Moral Animal, Why We Are the Way We Are: The New Science of Evolutionary Psychology* (New York: Random House, 1995), and Roger D. Masters, *The Nature of Politics* (New Haven, CN: Yale Uni. Press, 1989). Comparative analysis of long-range human economic development suggests that human societies have differed in their emphasis on two basic survival strategies, whose terms are taken directly from evolutionary biology, where the same differences were first noted in non-human species. The first strategy is an "r-strategy" of maximum reproduction, followed by the majority of human societies over time and space. The second is a "K-strategy" of accumulation of resources (in part through limitation of fertility) followed by very early European tribes, and which eventually led, through various twists and turns of feudalism, to the "European miracle" of capitalism, the industrial revolution, and to everything that we now know as "economic progress." In other words, bequest value is at the core of all other economic values. See E.L. Jones, *The European Miracle: Environments, Economics, and Geopolitics in the History of Europe and Asia* (Cambridge: Cambridge Uni. Press, 1981).

[415] See the descriptions of various forms of inheritance in Roman, German, and English Common Law in Oliver Wendell Holmes, *The Common Law* (Boston: Little, Brown, 1881), pp. 340 *et seq*., and of other ancient systems in Thomas E. Atkinson, *Handbook of the Law of Wills* (St. Paul, MN: West, 1937), pp. 5 *et seq*. Atkinson comments that inheritance is provided for in "every civilized nation," *ibid*. Aside from the general protection of a right to inherit property, common to most societies in some form, the early English Common law which served as the basis for both the US and Canadian legal systems put strong emphasis on protecting inheritance through primogeniture (the limiting of the whole real estate to the first-born son, practiced in medieval England and Germany) and the entailing of land (selling or devising land subject to a right of inheritance by another, which is still current in Anglo Saxon law) to protect the value of the inheritance. Those who have succession rights can also sometimes bring actions against their predecessors for waste of the land. The rule of primogeniture (a cruel rule which was discarded in the modern Common Law) happens to be in perfect accord with the logic of evolutionary theory. See Robert Wright, *Moral Animal, Why We Are the Way We Are: The New Science of Evolutionary Psychology* (New York: Random House, 1995), pp. 172 et seq. (That does not mean that it was a good thing. But it makes the point that the desire to pass down an intact legacy is a fundamental human desire.)

[416] Ian Hodge, *Environmental Economics: Individual Incentives and Public Choices* (New York: St. Martin's Press, 1995), p. 40. This explains in part why there are many public rules for preservation of resources, such as protections for wetlands and endangered species, which require private landowners to do more to preserve what is on their land than what they are willing to do themselves. Hodge does not go into an analysis of all the reasons for the differential between the public and private discount rates, and that is an area of theory which would take up too much space here.

current value of something depends on how much of it one already has relative to the current supply. (This is the basic insight behind the statement that "It's all a matter of supply and demand." Another way of putting it, which gets right to the point, is that "All the action is on the margins.") One of the classic examples used to explain the concept is the comparison of water and diamonds. Water is intrinsically more valuable than diamonds. You need it to live. You can survive without diamonds. But Marilyn Monroe did not sing that "water is a girl's best friend" because diamonds are relatively scarce compared to water. Most of us have enough water to live, and could do with a few more diamonds. If we are dying of thirst on the desert, that is different, and we value the water more. With apologies for belaboring that concept (because it may be the single most important concept in all of economics) I would submit that the marginal decrease in the relative supply of biodiversity in the future of the planet, which is almost a certainty at this point, will increase the future value of that commodity to humans beings finding themselves increasingly starved for natural stimuli. One only needs to think of the tremendous amount of money which inhabitants of affluent societies are willing to spend on entertainment, recreational vehicles, and all manner of personal health products in order to see the potential market for providing unique biodiverse enclaves as they become more scarce.[417]

The last subcategory of non-use value, "existence value," is the most difficult to measure – and therefore is the one most often left out of cost/benefit analyses – but may be the most important value of all. "Existence value" is the value of knowing that something exists, even if one does not ever make (or even intend to make) use of it. I may put a real value on the continued existence of whales, spotted owls, and elephants, even if I have no intention of ever traveling to the particular areas of the oceans, the woods, or the savannas to actually see them. There is nothing frivolous or silly about this aspect of environmentalism. Consider the same principle in an entirely different realm of life. What civilized person would not feel a sense of loss if all the original works of the Italian Renaissance artists were destroyed, even if he or she were never planning to travel to Italy? In fact, the Allies took extra measures under direct orders from General Eisenhower, which did cost lives, to avoid the destruction of similar treasures during the Second World War.[418] Or, to be less dramatic, consider the simple pleasure which many people take in reading gossip about celebrities they never expect to ever meet, even though similar stories which are honestly fictional in novels and short stories have far better plots and character descriptions. They like to know (or think) that the people they are reading about are real. And it sells in the supermarkets just as well as fish.

Putting an actual price on environmental existence value is not always so easy. One measure might be the contributions which people make to environmental organizations. But

[417] There is considerable theoretical and empirical basis for believing that societies increase their value of environmental quality as they become more affluent. Thus, putting economic expansion over environmental protection is self-contradictory and non-economic. As we enjoy the benefit of expansion, we shift towards having more regret for the loss of the environment we have trashed along the way.

[418] Eisenhower's orders, and an account of Allied losses in an attempt to follow those orders at Monte Cassino, are related in Robert Leckie, *Delivered from Evil: The Saga of World War II* (New York: Harper and Row, 1987), pp. 635-637.

that in fact seriously understates the real value. Most of us are "free riders" on the work of environmental organizations. To begin with, most of us do not give to every cause which we support, often because our contribution is relatively small (unless we are rich enough to make noticeable bequests, which is an entirely different matter), because we hope (rationally) that some others will, and because we resent all those other free riders out there. (This is a basic problem in "game strategy" called the "Prisoner's Dilemma."[419] The dilemma is that cooperation to achieve a common good would benefit all parties, but only if they all cooperate, and each individual has a strong incentive to defect from cooperation, especially if someone else might. This is in structure exactly the same as the "tragedy of the commons" in resource management. All fishers would benefit by preservation of the stock. But each individual fisher will benefit more by taking as much fish as possible – especially if others are doing so. Thus, they are all prisoners a self-defeating competition.) In addition to that basic problem, environmental organizations are especially disadvantaged because the most important good they produce is information, which is a largely indivisible "public good." In balancing my relative contributions to a charity for the homeless versus an environmental organization, I tend to short-change my favorite environmental organizations in comparison to how deeply I feel about the cause because the organizations I like the best are already doing a fairly good job of bringing issues onto the public agenda. (The homeless shelter, by contrast, is not providing an indivisible public good. Every contribution means another bed or meal.) Once the issue is on the agenda, I and all other environmentalists can also do much by paying attention to how we vote, in order to encourage government to adopt parts of the agenda we support. This is the sad paradox which makes it hard for environmental organization to do well during periods when they have done an excellent job of publicizing their issues and there is widespread public support for their cause.[420] The way

[419] The Prisoner's Dilemma, and some of the ways it is overcome, is laid out in detail in Roger D. Masters, *The Nature of Politics* (New Haven, CT: Yale Uni. Press, 1989), pp. 153 *et seq*. The broader "game theory," used by both economists and political scientists to explain the strategic choices of "rational actors," including Prisoner's Dilemma, the Chicken Game, the Assurance Game, a description of the tragedy of the commons, supergame structures, and a description of the "public goods" concept, is laid out with precise mathematics, but very concisely, in Michael Taylor, *The Possibility of Cooperation* (Cambridge: Cambridge Uni. Press, 1987). This is a very valuable primer on why people do not do what they should do for their own good, and on how the problem can be overcome, which is relevant to the politics of all environmental issues.

[420] Consistently, since the beginning of this decade (if not before) a majority of people polled in the United States have said that environmental protection is a priority issue, and that they support more rather than less environmental protection. This wide-spread support for environmental policies has made it what political scientists call a "valance" issue, meaning that it is assumed to be a mom-and-apple-pie, something which most people accept uncritically as a good thing. As one observer notes, "candidates are apt to lose more than they gain by emphasizing the economy over the environment." Riley E. Dunlap, "Public Opinion and Environmental Policy," in James P. Lester, ed., *Environmental Politics & Policy: Theories and Evidence* (Durham, NC: Duke Uni. Press, 2nd ed., 1995), pp. 63-114, 107. See, also, Gerald T.Gardner and Paul C. Stern, *Environmental Problems and Human Behavior* (Boston and Toronto: Simon and Schuster, 1996), pp. 60-63. Similar support is evident in Canada. The Minister of the Environment reported in 1996 that "60 per cent of Canadians feel their health has already been affected by toxics in the air and water" and "a stunning 96 per cent told pollsters that they believe it is important to have national environmental standards…." Sergio Marchi, Minister of the Environment, "Speech to the inSight and Globe & Mail Conference" (Toronto, April 26, 1996).

Nevertheless, despite widespread public support, and Democratic and Liberal administrations which are at least superficially supportive of environmental protection, "many groups are currently experiencing a membership decline." Helen M. Ingram, David H. Colnic, and Dean E. Mann, "Interest Groups and

that we escape the free-rider problem, usually, is through government programs which make everyone (or at least a good number of others) contribute something. Therefore, the same persons who neglect to contribute to an environmental cause may well support taxing themselves for the same purpose. Government is, in this case, the more efficient means for capturing the value otherwise lost by the lack of a pricing mechanism in the market. That is why we have government environmental programs. (This is not an argument against supporting environmental organizations. Please, by all means, do so.)

So what does it all add up to? The different categories of value overlap in real life, and there are a number of practical problems limiting the ability of economists to measure non-use values. (Field experiments have been done in order to determine actual "willingness to pay" for public goods such as environmental quality, and they do result in some substantial price tags, but work in this field is fairly rudimentary.[421]) Nevertheless, there are some general indicators of reasonable parameters. For example, old polling data from 1970 in the US, which is the year in which the US enacted the largest piece of air pollution control legislation,[422] indicates that 54% of the heads of households were "willing to pay $15 a year more in taxes to finance [an] air pollution control program."[423] A much more detailed survey taken after the *Exxon Valdez* spill in Prince William Sound, in 1989, asked heads of households in the US, outside of Alaska, very specific questions about what they would be willing to pay in an initial one-time tax to prevent or mitigate another spill in that area. More specific questions, backed up by technical information tend to produce much more thoughtful and realistic answers. It was clear from the way the questions were put in this survey that the amounts asked for would only go to prevent or mitigate spills of that type in that area in the future, not to prevent all forms of pollution or prevent it in all areas of the

---

Environmental Policy," in Lester, *ibid*., pp. 115-145, 141. These observers ascribe the problem to being without "a clear enemy," such as was previously provided by Republican administrations in the US. *Ibid*. But a more basic problem may be that environmental groups are victims of their success. Given the free-rider problem and the public good they produce in the form of information, one might wonder why anyone at all gives to environmental organizations. Ingram, Colnic, and Mann frankly observe that "the ideological and policy appeal of environmental interest groups defies the rational actor thesis" which underlies strategic game theory and much of modern economics and political science. *Ibid*., p. 116. In other words, environmentalism happens because it is like a religion. Another way of putting it is that the ideological aspect of the cause makes giving generate what the economists call the "warm glow" effect, which is itself its own reward.

[421] See Ian Hodge, *Environmental Economics: Individual Incentives and Public Choices* (New York: St. Martin's Press, 1995), pp. 58 *et seq*. Economists also attempt to measure the converse value, which is "willingness to accept compensation," and which usually results in a higher price for the same level of environmental quality. In other words, people tend to put a higher price on what they perceive as pollution or damage to public resources, already theirs by right, than on gaining access to new resources which they do not perceive as already theirs by right. This may reflect what some see as an irrational failure to consistently price the value of all goods. Or, it might simply be perfectly logical application of the principle of marginal rates of return. What you already own as a property right, or what is already legally promised to the public as a public trust, is a social measure of the base investment in the resource, and additional benefits on the margin are therefore of less value.

[422] The Clean Air Act Amendments of 1990, US Public Law 101-549 (November 15, 1990), making amendments to the US Code at 42 USC §§ 7401 *et seq*.

[423] Riley E. Dunlap, "Public Opinion and Environmental Policy," in James P. Lester, ed., *Environmental Politics & Policy: Theories and Evidence* (Durham, NC: Duke Uni. Press, 2nd ed., 1995), pp. 63-114, 72, table 4.1.

US. Also, it is important to note that the survey excluded Alaskan residents, and thus focused on non-use existence value for the general population rather than more personal interest in Prince William Sound. With respect to this one-time tax proposal, 67% were willing to pay $10, 52% were willing to pay $30, 51% were willing to pay $60, and 34% were willing to pay $120.[424]

According to 1990 and 1991 census data, there are approximately 12.6 million US and Canadian heads of households in the Great Lakes basin.[425] (This does not include all the inhabitants of the eight states and the two provinces, nor any of the people outside those jurisdictions who regularly use the basin for recreation.) It would probably be reasonable to assume that half of those heads of households care about preserving the existence of the natural biodiversity in the basin. Some would care much more if it were put in more pointed terms, such as saving their local beach from catastrophic blooms and dieoffs or their favorite game fish from extinction. A conservative estimate might be that 6.3 million heads of households would be willing to vote to use $10 per year and $60 in a one-time payment the first year, out of their general tax dollars, to prevent new exotic invasions of the Great Lakes. That would produce a value of $63 million per year on preventative programs in the Great Lakes, and a one-time value, to initiate needed technological changes, of $378 million in the first year.

This is by no means a full accounting. This is mostly non-use and non-use existence value. It is quite clear that fishers, users of water in industrial facilities, and residents impacted by taste and odor problems in their drinking water, among many others, would be willing to pay a great deal more to prevent such problems. A full accounting of all costs would probably bring us into the range of $1–2 billion per year. Unfortunately, those other costs do not translate into political support for government action in any amount reflecting the true cost because of the problem of marginal rates of return. Those who have already been harmed by the major invasions of the past – although they know who they are, and are in some cases extremely angry about the cost – have already been impacted. Programs to prevent new invasions will benefit someone else, not yet identified, but may well not provide the same level of benefit to those already impacted. (This is, in political terms, the problem of the "special interests" not reflecting the "general interest.") That is why the great preponderance of the control and research efforts have gone into dealing with past invasions, to the justifiable benefit of those identifiable interests severely impacted by the past invasions, rather than to programs to prevent new invasions, despite the obvious logic in favor of putting the weight of effort into prevention. Again, what is rational for individuals or discrete groups is not rational for the society at large. This is one reason why,

[424] Ian Hodge, *Environmental Economics: Individual Incentives and Public Choices* (New York: St. Martin's Press, 1995), p. 78, table 5.3.

[425] The 1990 (US) and 1991 (Canadian) population for the Great Lakes basin, based on slightly different watershed boundaries, are given as totaling 33,191,365 in US EPA and Environment Canada, *The Great Lakes: An Environmental Atlas and Resource Book* (Chicago: US EPA Great Lakes National Program Office, 3rd Ed. 1995), p. 4, Great Lakes Factsheet No. 1. The US ratio of (population)/(heads of household) was 2.62 in 1989. Mark S. Hoffman, ed., *The World Almanac and Book of Facts 1991* (New York: World Almanac, 1990), p. 551. Assuming that approximately the same ratio applies in Canada, 33,191,365 ÷ 2.62 = 12,668,460.

as a matter of practical politics, it is important to identify the more general non-use value, even though it is much less in absolute amount.

The most expensive preventative measure, but also the most valuable, is an effective option for dealing with ballast water. It could cost as much as $1.2 million per ship to retrofit existing vessels with a control technology or (in combination, or alternatively) as much as $2 per metric tonne ($2,000/1,000 MT, in the terms of the estimates given in § 3.7 above) to exchange or treat the water effectively. (These are all high estimates.) Let us look at these figures as a sanity check. There are about 25 core vessels in the third party Seaway fleet who regularly trade into the Great Lakes, among a larger variety of 200 to 300 vessels showing up each year. Although the figures are much less certain than we would like, we can safely assume that the amount of foreign ballast water being carried into the Seaway each year is something less than 1 million metric tonnes per year. (The best available estimate given in § 3.2 above was 720,000 MT/YR.) Therefore, $63 million per year in non-use value of prevention would more than cover yearly treatment of the water at $2 million per year and leave a great deal of value left over to cover enforcement, research, and preventative programs addressing all the vectors of concern, as well as a comfortable cushion if the estimate of the quantity of water is too low. The initial start up non-use value of $315 million above the yearly allocation ($378 – $63 million) would cover retrofitting 260 vessels. That is more than ten times the core number, and more than the number of vessels actually showing up in a typical year. The optimum number of vessels to retrofit would in fact be much less. This makes it pretty obvious that the benefits exceed the costs. But that does not answer the question of how to structure an effective regulatory program for internalizing the costs and creating the needed change (and does not mean that the public should have to actually bear the cost of preventing the biological pollution).

Perception of risk. Before discussing regulatory strategies, I should mention something about the perception of risk. The really bad ones, such as the sea lamprey and the zebra mussel, come along much less frequently than the more ordinary nuisances. That does not in any way mean that we are safe from the next big one for a while. Unfortunately, however, that is sometimes how the public perceives the nature of the probability of rare events. On the other hand, there is a general psychological tendency to underestimate the probability of fairly frequent events and overestimate the probability of highly infrequent events. There may be some rather complex perceptual and emotional factors behind this, or it may be simply a cognitive tendency – simple mental sloppiness – to average out estimates on unknowns. (Or perhaps it compensates for the first tendency to some extent?) At the same time (which may seem inconsistent with that averaging tendency, and is also contrary to the whole logic of insurance) there is generally a much greater willingness to pay the cost of insuring against relatively infrequent but low cost risks than to pay for insuring against relatively frequent but highly costly risks (even when, mathematically, the benefit works out to be exactly the same). In other words, people are relatively more motivated to take action to prevent risk of events which are more common, even if less disastrous.[426]

[426] The literature on all these psychological factors is reviewed in Gerald T.Gardner and Paul C. Stern, *Environmental Problems and Human Behavior* (Boston and Toronto: Simon and Schuster, 1996), chapter 9.

This has some interesting but confusing implications for public discussion and educational efforts on the issue of exotics. It might imply that the public is too quick to assume that another invasion as bad as the zebra mussel will not happen again for a while – because it just did – or too quick to assume that such dramatic invasions are frequent. However they perceive that, they are more likely to feel motivated to take action (vote and spend their money) to prevent the almost constant but relatively less harmful flow of less notorious creatures than they are to take the same action to prevent another really bad one in the future. To be honest, scientists need to be quite clear that they cannot predict when another really bad one will come in. But they can appropriately stress the virtual certainty that we will continue to suffer the less severe impacts of many less noticeable creatures, at an almost steady rate, unless better preventative measures are taken. Also, this may warn those of us steeped in the issue, who tend to be more concerned about the unpredictable ecosystem effects and the ultimate loss to the biodiversity of the planet, that the general public might actually be much more concerned about the fact that exotics are simply a "nuisance."

§ 10.2. All the action is on the margins: Some familiar economic fallacies

Before getting into the serious nitty-gritty of how to make a regulatory program work, we should clear the deck of a few common economic fallacies which tend to obscure intelligent discussion of these issues:

Compensating a failing industry. The fact that the public would be willing to pay something to have the pollution prevented – and that there is in fact a real value which the market is not currently internalizing in the price system – does not mean that the public should pay the affected industry a subsidy or "compensation" to cover their costs of correcting the problem. These compensations are frequently requested, and most often granted, when an industry is already on the ropes and pollution controls have the possibility of putting individual firms out of business. But the fact that a particular industry is producing a product for which there is already a low demand in the market (or is highly inefficient in producing that product) is an absurd reason to give it a bonus for also being a polluter. We normally proceed, as a matter of both legal philosophy and economic logic, on the basis of the proposition that "the polluter pays." There is room for some accommodation here. A public subsidy to correct an externality is not in principle a violation of economic principles, and it should be considered if there is a form of subsidy which will in practice result in an efficient allocation of resources. In fact, a fundamental principle of economics known as the "Coase Theorem" holds that it makes absolutely no difference in the total welfare produced for society whether a polluter is penalized or paid off for not polluting if one ignores the "transaction costs" involved in making and allocating the payments.[427] The

[427] Ronald H. Coase, "The Problem of Social Cost," *Journal of Law and Economics* (October 1960), vol. 3, pp. 1-44, reprinted in Henry G. Manne, ed., *The Economics of Legal Relationships: Readings in the Theory of Property Rights* (St. Paul, MN: West, 1975), pp. 127-167.

problem, however, is that in real life transaction costs are significant. Those include information costs, the costs of policing parties to insure honesty, political costs, and the costs of capture of benefits by the interests being subsidized.[428] On the other hand, the transaction costs of regulatory programs and administration of penalties – many of them the same types of cost – can also be substantial. Underlying all this, there are significant issues about how to adjust marginal rates of cost and benefit in an efficient manner. Failure to account for those significant issues can result in regulatory programs which are not only inefficient but also counter-productive.

Passing the costs along. A common objection to government regulation (whether through prohibitions or taxation) is that "the costs will just be passed along to the consumer." In economic theory the appropriate response to this objection is a disdainful look combined with that Generation X response, "And your point is…?" Passing the costs along to the consumer is precisely the point of the market. That is how we achieve overall economic efficiency. If the market price of oil reflects the true cost of the collateral damage to the environment, more people will conserve energy or use alternative energy resources. If the fishers have to pay high license fees to protect the common fishery, the higher price of fish will reduce consumption (or increase the use of aquaculture fish) and save the species from extinction. Raising the price of the harmful activity – preferably no more and no less than the true cost – is the best possible result of government intervention in the market.

The lowest common denominator. Frequently, as we have been doing in the case of ballast water, the government gets into the questionable business of trying to specify an "engineering standard" based on some standard of "technological feasibility" or "economic reasonableness." Aside from the very big question of whether or not the government should be in this business at all (which I discuss further below) a common fallacy is the notion that what is feasible and reasonable has to be so for everyone in the business, doing business just as they have always done so before. In other words, the feasibility or reasonableness standard becomes a standard based on the lowest common denominator set by the most inefficient or highly polluting segments of the industry. This ignores the basic nature of life

[428] For example, US federal subsidies to local municipalities for the improvement of their waste water treatment system have been extremely expensive and ineffective, in part because of the political capture of the projects as pork barrels. Steven E. Rhoads, *The Economist's View of the World: Government, Markets, & Public Policy* (New York: Cambridge Uni. Press, 1985), p. 44. More generally, the experience with even relatively well designed subsidy programs in a variety of areas has demonstrated that the resulting costs from political capture of the programs are overwhelming. As Rhoads sums it up, "The competition for special compensation is not just a zero-sum game. It is a negative-sum game. Even the fellow who wins as many as he loses, loses on balance because of the unproductive time he, his lawyers, and lobbyists have spent playing the game and because government so often deals with the equity concerns by stopping efficient moves and creating inefficient programs (e.g. shoring up failing industries) rather than by simply compensating losers from the larger pie that greater efficiency has made possible. Moreover, in the real world the weakest and poorest are often the last rather than the first to get special compensation. And, as some of the most thoughtful economists know, the costs of pulling and hauling go far beyond economics since the political fabric is stained when government makes more and more 'explicit decisions about the fate of particular groups and communities.' When compensation is needed, economists generally favor providing it to individuals, not to regions or industries." Rhoads, *ibid*., 99-100, quoting Charles Schultze, *The Public Use of Private Interest* (Washington, DC: Brookings Institution, 1977), p. 75.

in business. The free market separates out competitors and promotes efficiencies by distinguishing, at the marginal rate of return, between those who can make a profit at that rate and those who cannot – and also by forcing some of those who cannot to alter their business practices so that they will. This fallacy has reared its ugly head in our attempt to deal with ballast water in the form of an assumption that any treatment method found to be reasonable for the industry must be economical for the maximum loads of ballast currently carried into the Great Lakes.[429] Once there is some cost attached to the quantity (or organic content) of water carried, most vessel owners will find ways to reduce that through better planning of cargo commitments and ballasting operations. The average will come down. There are of course costs associated with the adjustments which have to be made. But it is the essence of business, the wonder of the free market, that smart business people will find the cheapest alternatives or combinations of measures. Some will not succeed in doing so. Some vessels which would have carried cargoes out of the Great Lakes will forego those cargoes because bringing in the necessary ballast on the inbound trip has become too expensive for them. But they will open up that business for competitors who have found a way to manage their ballast more efficiently. Our public policy should be to encourage that competition to a higher level, rather than protecting all businesses against failure at a low level of efficiency.

§ 10.3. The policy options: Command, Litigation, Markets, unintended consequences, and real solutions

When an externality is identified – and there are many of them, once one begins to look – there are four basic public policy options: Those are (1) to use some sort of non-regulatory or quasi-regulatory approach (education and voluntary programs), (2) to regulate through prohibitions and permits, often including specification of engineering standards (a command system), (3) to regulate through the creation of private rights and liability which can be either negotiated or litigated in court (private property rights), or (4) to regulate through some sort of incentive system (either the negative incentive of taxation, the positive incentive of subsidies, or some combination thereof) designed to stimulate market solutions. There are also mixed approaches, such as regulatory prohibitions accompanied by private rights, or the creation of a market in pollution permits (which combines aspects of both a command and a market system). In the area of environmental law, we have generally used a regulatory command system. According to a considerable body of scholarship on the subject, that approach has generally been a costly failure. In the case of the regulation of ballast water under the current US law, our current combination of voluntary programs and a regulatory command system is not yet very costly, in terms of the burden on the marine industry, but it is most certainly a failure in terms of effective and timely action.

[429] See, e.g., Aquatic Sciences, *Examination of Aquatic Nuisance Species Introductions to the Great Lakes through Commercial Shipping Ballast Water and Assessment of Control Options, Phase II Final Report*, ASI Project E9225/E9285 (St. Catherines, ON: Aquatic Sciences, August 1996), p. 41, where it is proposed that all options involving treatment of ballast water must be evaluated relative to the maximum capacities of the vessels.

Non-regulatory and quasi-regulatory approaches. First, as the economists take pains to point out, it may literally "not be worth the bother" of trying to do much about it. Most externalities are minor, and the process of trying to readjust the market to make the price perfectly reflect all these minor costs generates other costs and inefficiencies which overwhelm the benefit to be achieved by the exercise. I may be justifiably infuriated by people who litter, but the costs of policing the streets to prevent littering or of prosecuting a private lawsuit to redress my sense of injury is a lot more than the cost of simply paying for municipal street cleaning services. That said, there may still be some value in less costly non-regulatory or quasi-regulatory approaches. A nominal prohibition of littering, to express social disapproval, may have value even if it is too expensive to enforce. Similarly, public education efforts may be cost-effective – although that is probably debatable in the case of littering.

There are likely to be vectors for transport of exotics across ecological zones that are impossible to seal off with any reasonable effort. Millions of recreational boats and bait buckets being carried across the landscape from river to pond cannot be inspected and sterilized without a massive level of governmental expenditure and intrusion.[430] The best that government managers can do about that is establish some common-sense rules, make them as consistent and understandable to the public as possible, enforce them where practical, or where most important to address specific hot spots, and spread the word with educational programs and voluntary efforts by concerned user groups. (But the high ratio between cost and benefit we face when trying to prevent the spread of exotics already established somewhere in the Great Lakes is all the more reason to put our effort into preventing invasion of the basin in the first place.) Public education, supported by some formal sanctions which are difficult to actually enforce, is basically the approach taken by a number of the US states, especially Minnesota and Michigan, to help slow down the spread of exotics around the region.[431] It is certainly less expensive (and less intrusive, which is a type of cost) than an inspection program. Whether or not it actually pays off is another question. Minnesota Sea Grant has done some public opinion polling to document that people are at least paying attention to the message – and have been using the information from the polling to more effectively allocate their exotic educational budget. For example,

[430] There may be an exception, although that has yet to be demonstrated. The "100th Meridian Initiative," much like the voluntary ballast exchange program for controlling the ruffe in Lake Superior, relies on the fortunate existence of a natural ecological barrier as a line of defense. The idea is to stop the spread of the zebra mussel to the western half of North America by getting all the jurisdictions astride the 100th meridian – Texas, Oklahoma, Kansas, Nebraska, South Dakota, North Dakota, and Manitoba – to cooperate with aggressive educational and voluntary programs to intercept zebra mussels carried on trailered boats. See US Fish and Wildlife Service, *The 100th Meridian Initiative: A Strategic Approach to Prevent the Westward Spread of Zebra Mussels and Other Aquatic Nuisance Species*, report to the Western Regional Panel on Aquatic Species (Manhattan, KS: USFWS Region 6, 1998), available on line at http://www.wrp-ans.org/. But there has been less than full participation by all the jurisdictions, and the political difficulty is that we are asking those who have the least to gain to do the most about the problem.

[431] See the educational materials put out by a number of the US Great Lakes states at the Great Lakes Information Network (GLIN) web site, "Exotic Species in the Great Lakes Region," http://www.great-lakes.net/envt/exotic/exotic.html.

they have found that signs posted immediately at the ramps where people pull their boats out of the water seem to have the most impact on behavior.[432]

Similarly, US and Canadian federal authorities have worked with marine industry to encourage voluntary controls on exotics in ballast water. One of these efforts, the program for the control of the European ruffe in Lake Superior through voluntary exchange of ballast water in the depths of the lake, was in fact initiated and developed by the two major domestic shipping associations, the Canadian Shipowners Association (CSA) and the Lake Carriers' Association (LCA). The public received the benefit of this program for virtually nothing – for little more than the time that it took to go to a few meetings and get the names of the US and Canadian Coast Guards added to the bottom on the voluntary guideline as official blessing of the program. The two industry associations gained some well-deserved public recognition, the warm glow[433] which comes from the sincere desire to be doing the right thing, and the benefit of being left free to design and police the program themselves. That is economic efficiency. Unfortunately, such warm-and-fuzzy "win-win" voluntary efforts have real limits. No matter how much industry leaders might sincerely want to do the right thing (a very real factor, in my opinion, for the representatives of CSA and LSA whom I have dealt with) they cannot voluntarily assume too many costs without endangering their competitive position. Where they have a significant monopoly over the relevant market (which is true, in some sense, of the two domestic lake carrier associations[434]) they have some latitude to indulge themselves in warm glows or write off the costs to good public relations. But even monopolies must compete against potential suppliers of substitute goods. If the lakers incur too much expense trying to help out with the exotics already in the Great Lakes, they thereby endanger their competitive position against the Seaway shipping (ironically the very source of the exotics) which is selling foreign steel to replace domestic ore.

Where there is more direct head-to-head competition, the problem is even more severe. When the Vancouver Harbour Master asked the shipping industry using his port to participate in a voluntary program for the exchange of ballast water, the representatives of the industry readily agreed to participate, but asked him to issue a standing order making it a

[432] Jeff Gunderson, *Three-State Exotic Species Boater Survey: What do boaters know and do they care?* (Duluth, MN: University of Minnesota, 1998), at www.d.umn.edu/seagr/areas/exotic/bt_survey.html.

[433] Economists, who are not quite so humorless as many think, actually refer to this in the literature as the "warm glow effect." Whatever the biological or psychological basis for it, many people do take pleasure in doing good things.

[434] Before both LCA and CSA express outrage at this statement, a little explanation. The economic monopoly is both legal and economic, in fact, even if not in any way in violation of the anti-trust laws of the two nations. The legal monopoly consists mainly of the protection of the cabotage laws, restricting trade between domestic ports to the ships of each nation. The economic monopoly is a "natural monopoly" due to the structural economic efficiencies of both vertical integration and inter-firm cooperation which characterizes the domestic shipping industry in the Great Lakes. There is nothing evil in this. In fact, it is probably the type of monopoly which benefits the public. And, like all monopolies, it is incomplete. The competition created by substitute sources, whether the Seaway shipping, barges on the Mississippi, or the trains, keeps Great Lakes shipping fairly competitive and efficient.

mandatory program in order to establish a level playing field for all the ships which might incur delays or other costs due to conducting exchanges.[435]

Also, we need to recognize that voluntary programs, while reducing compliance and enforcement costs, may in fact obtain less compliance than programs with legal enforcement. The voluntary guidelines for exchange of ballast on vessels entering the Great Lakes put out by Canada in 1989 do seem to have achieved a respectable level of compliance. According to survey reports (which is an important limitation on the reliability of the measure) the level of compliance with the voluntary guidelines was 89%.[436] But compliance became virtually 100% according to enforcement measures (more objective, even if far from perfect) after the US instituted mandatory regulations in 1993.[437] Enforcement of the mandatory regulations also led to additional measures, such as a requirement for exchanges on vessels stopping at intermediate coastal ports, which had not been observed under the voluntary program. The cost to the US taxpayer for that US Coast Guard enforcement program in the Great Lakes, in order to achieve that additional 10% (or more) of compliance with the same exchange regime, was about $300,000 per year during that period.[438] Although that fails to account for the significant level of Canadian governmental support for the US Coast Guard enforcement program, which should be assumed to be at least equal in cost, it seems to have been a relatively good investment in raising the level of compliance.[439]

Regulation through prohibitions, permits, and prescriptions. This is what most social control consists of, going back to the Ten Commandments and the Twelve Tables of Rome, and it is a reasonable approach for the obvious things. The laws against murder and theft are fairly understandable and, although we might get into complexities about the degree of culpability in various situations, the prohibitions are accepted as nearly absolute without argument. Although there is a thing known as "justifiable homicide" in the Common Law of the US and Canada, we do not need to establish regulatory agencies to permit a certain amount of homicide. (The issues of abortion and euthanasia show where that analysis may break down on the edges, but the main point remains valid.) On the whole, we can quite

[435] Communication from Captain Chris J. Badger, Harbour Master, Vancouver Port Corporation, Vancouver, BC. The standing order is entitled the *Vancouver Port Corporation, Ballast Water Exchange Program* (Vancouver, BC: May 1997).

[436] A. Locke, D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen, *Effectiveness of Mid-Ocean Exchange in Controlling Freshwater and Coastal Zooplankton in Ballast Water*, Fisheries and Aquatic Sciences Report 1822 (Burlington, ON: Great Lakes Laboratory, 1991), p. 8.

[437] The number of "problem vessels," relative to the number of vessels entering with ballast, declined from 7.4% to 1% over the five years from 1993 to 1997, and those "problem vessels" found to initially be not in compliance were required to take remedial measures, such as treatment of the water, to correct the problem. M. Eric Reeves, "Techniques for the Protection of the Great Lakes from Infection by Exotic Organisms in Ballast Water," in Frank M. D'Itri, *Zebra Mussels and Aquatic Nuisance Species* (Chelsea, MI: Ann Arbor Press, 1997), pp. 283-99, 288-9, table 1 and notes.

[438] Based on figures which I compiled (and officially reported to US Coast Guard Headquarters) while in charge of administration of the program on the staff of the US Coast Guard Ninth District in Cleveland, OH.

[439] To be clear, the level of protection is still far from satisfactory, for all the reasons given in § 3.6 above. All that is being discussed here is the relative level of compliance in comparing the voluntary and mandatory programs which were substantially the same in substance.

efficiently state a general prohibition in absolute terms and let the courts deal with the very few special cases which test the limits of the rules.

Things become a great deal more complicated, however, when we try to take that traditional approach to the complex issues created by pollution. The essential problem with pollution is that, as much as we might not want to admit it, we want to have a certain level of pollution. The US Federal Water Pollution Control Act Amendments of 1972[440] promised to clean up all US navigable waters by 1985.[441] Theoretically, that should have not been necessary, because all pollution of US navigable water was already prohibited by the Refuse Act of 1899.[442] Instead, what we have had, under both of the major pieces of water and air pollution legislation enacted around the same time in the early 1970s,[443] is three decades of prohibitions, exceptions, studies, attempts to prescribe engineering standards, more studies and exceptions, and the establishment of a massive and expensive system for permitting pollution. Serious study of the history of these two fundamental pieces of pollution legislation in the United States raises serious questions about whether or not they have made any substantial contribution to the promotion of water and air quality, and certainly indicates that they have been more expensive and less effective than anyone, industrialist or environmentalist, would want.[444]

This is not a criticism of the basic goals of the legislation, nor a condemnation of the US Environmental Protection Agency, which is the lead agency for the enforcement of most US environmental statutes. One observer notes that "no organization could possibly cope with the continuing flow of legislation and the detailed regulatory responses required of EPA."[445] Aside from the sheer massiveness of the task (which is not really a problem facing the US Coast Guard in carrying out its responsibilities to regulate ballast water under NISA 96), EPA has faced some basic problems built into the structure of the legislation (which is very

[440] US Public Law 92-500 (October 18, 1972), codified at 33 USC §§ 1251 *et seq.*, and now known commonly as the Clean Water Act, since amendments in US Public Law 95-217 (December 27, 1977), as well as the Federal Water Pollution Control Act.

[441] US Public Law 92-500 (October 18, 1972), § 2, codified at 33 USC §§ 1251(a)(1).

[442] Section 13 of the Rivers and Harbors Appropriations Act of 1899, 30 Statute 1151, chapter 425, § 13 (March 3, 1899) codified at 33 USC § 407, commonly known as the Refuse Act of 1899. This interesting provision, still part of US law, is notable for the way it states the prohibition of any discharge in absolute terms (although it excepts municipal sewage, and provides for permits for some other discharges under the authority of the US Army Corps of Engineers, which oversees harbor works), and for the fact that the only provision for enforcement is by criminal prosecution (under § 16 of the same act, at 33 USC § 411, which provides for criminal fines and imprisonment). It was, of course, quite ineffective.

[443] The US Federal Water Pollution Control Act Amendments of 1972 became part of what is now most commonly known as the Clean Water Act, and the associated air legislation was the Clean Air Amendments of 1970, Public Law 91-604 (December 31, 1970), which are part of a larger scheme called the Clean Air Act, codified at 42 USC §§ 7401 *et seq.* For a detailed review of the history of these associated statutes, the regulatory philosophy underlying both the air and water legislation, and the political conflicts manifest in both, see William H. Rodgers, Jr., *Environmental Law* (St. Paul, MN: West, 1994), chapters 3 and 4.

[444] Some of the literature is reviewed in Steven E. Rhoads, *The Economist's View of the World: Government, Markets, & Public Policy* (New York: Cambridge Uni. Press, 1985), pp. 40 *et seq.* See, also, the legal history provided in Rodgers, *ibid.*

[445] Rhoads, *ibid.*, quoting Robert Crandall, "Environmental Protection Agency," *Regulations* (November-December 1980), p. 20.

much the same problem facing the US Coast Guard under NISA 96). The first problem facing the regulatory agency is the difficulty of deciding what is reasonable to prohibit and permit. This puts the agency into a long process of negotiation with the regulated industry. The industry has the advantage in available information. The industry has no incentive to make the process easy for the agency (despite diplomatic protestations of wanting to work with the agency in a cooperative and non-adversarial manner), and has no incentive to advance the state of the technology. As one representative of the auto industry put it in discussions about achievable technology for emission standards, "We're all worried that if we sound hopeful, what will the damned standards be tomorrow?"[446]

That expression of a very understandable reservation about the process from the point of view of the industry could well have been a quote from a representative of the shipping industry working with the government agencies on ballast water. At one of many meetings I attended on the Great Lakes Ballast Water Demonstration Project, a cooperative government-industry project to experiment with filtering and some other technologies,[447] one of the other government representatives asked an industry representative whether or not this project would demonstrate the economic feasibility of filtering as a shipboard technology. The question was answered by the consulting engineer, who very honestly and directly replied that "This project cannot prove that filtering will be economically feasible, but it might prove that it will not be."[448] It was simply not designed for that purpose. Industry representatives, bringing considerable expertise in naval architecture, marine engineering, shipboard operations, and maritime commerce, have closely worked with the US Coast Guard, the Marine Board, the Federal ANS Task Force, the Great Lakes Panel on Aquatic Nuisance Species, the Canadian maritime agencies, and the maritime agencies of other nations at the International Maritime Organization, from the very beginning of the process, ever since ballast water became an issue in 1988. Their attitude has been completely cooperative and responsible. And, as one might expect, they have completely dominated discussion of the technical issues. How could they not? And what is the result after a decade of study? The result is no clear analysis of the costs of the competing technologies,[449] much less any agreement on one or more which are "economically

[446] Rhoads, *ibid*., quoting a Chrysler vice president in Bernard Asbell, *The Senate Nobody Knows* (Baltimore: Johns Hopkins Uni. Press, 1978), pp. 318-26.

[447] See Allegra Cangelosi, "The Algonorth Experiment," *Seaway Review* (January-March 1997), pp. 29-33.

[448] I did not write down the words at the time, but that is very close to the exact language, and certainly accurate as a paraphrase. I will decline to identify the specific meeting or the participants. My point here is to make a general observation about the nature of the process, not to embarrass individuals.

[449] The only systematic attempts to compare the economic feasibility of leading technological options have been the 1992 Pollutech study funded by the Canadian Coast Guard and, to a somewhat lesser extent, a 1993 study by the Australian Quarantine and Inspection Service (AQIS). See Pollutech Environmental Limited, *A Review and Evaluation of Ballast Water Management and Treatment Options to Reduce the Potential for the Introduction of Non-Native Species to the Great Lakes, Technical Appendix B, Ballast Water Treatment*, report prepared for the Canadian Coast Guard (Sarnia, ON: March 31, 1992); Australian Quarantine and Inspection Service, *Ballast Water Treatment for the Removal of Marine Organisms*, Ballast Water Research Series Report No. 1 (Canberra, Australia: Australia Government Publishing Service, 1993). Both of these reports have been received rather critically by industry representatives (often making valid points about

feasible." A leading example of this failure to deal with the central issue was the much-anticipated, long-overdue report of the Marine Board of the US National Research Council, which was specifically mandated to identify feasible options by NISA 90, and which shut down consideration of alternatives not being actively considered by the Marine Board during the years of its preparation. The report, finally published in an expensive and hard-cover glossy form in 1996 (not quite in time to be available before the drafting of NISA 96) contained a great deal of interesting and useful analysis in qualitative terms. But it completely neglected to provide anything in the way of quantitative cost comparisons and, although it suggested further work on several leading options, failed to provide the estimates documenting that any of them would be economically feasible.[450] This has left the US Coast Guard in the position of having no better option than to once again go back to the industry experts and ask them, again, what they would like to do. At a recent workshop on ballast water technology, a representative from the US Coast Guard Research and Development Center, newly assigned to be in charge of the problem, indicated that he would be looking

---

the assumptions going into the estimates) but the industry groups have never provided their own comparative cost analyses in a similar form.

Several excellent reports on individual technologies have been recently provided by an overlapping group of researchers centered around the University of Michigan. See, (1) re biocides, Larissa M. Lubomudrov, Russell A. Moll, and Michael G. Parsons, *An Evaluation of the Feasibility and Efficacy of Biocide Application in Controlling the Release of Nonindigenous Aquatic Species from Ballast Water* (Ann Arbor, MI: University of Michigan, November 1997); (2) re filtering, Michael G. Parsons, Russell Moll, Thomas P. Mackey, and Rendall B. Farley, *Great Lakes Ballast Demonstration Project -- Phase I* (Ann Arbor, MI: Cooperative Institute for Limnology and Ecosystem Research, University of Michigan, 1997); and, (3) re flow-through exchange retrofitting, Michael G. Parsons, "Flow-Through Ballast Water Exchange," a background paper for the Society of Naval Architects and Marine Engineers (SNAME) Ad-Hoc Panel on Ballast Water Exchange, SNAME Annual Meeting, San Diego, 1998.

The 1997 study by Lubomudrov, *et al*., is an especially good example of a serious cost analysis, done on several sliding scales which reflect critical parameters such as concentration of the biocide (how much do you need to kill?) and numbers of metric tonnes (how much do you need to treat?) which are all-too-frequently left out, or poorly specified, in scoping studies. It serves, also, as proof that serious cost analysis is quite doable, and with relatively quick and cheap studies not requiring field work or experimentation. The upshot of these separate studies is to indicate that (1) a possibly acceptable biocide, glutaraldehyde, may cost $600 to $6,000 per 1,000 tonnes, depending on concentration and whether or not there is pre-filtering, which is not included in these figures, (2) retrofitting filters on existing Seaway vessels will cost something more than $1 million, based on a handysize bulker of 29,210 DWT, and (3) retrofitting for flow-through exchange may range from $200,000 to $1,000,000 in capital costs "for existing large vessels" (referring, among other types of ships, to a very large Capesize bulker of 190,000 DWT and a Suezmax-range tanker of 120,000 DWT). There are a number of debatable assumptions which go into those last figures for flow-through retrofitting and, as one can see from the summary here, it is not really compared to the filtering estimate because entirely different sizes of vessels are being discussed. The lack of truly systematic comparisons continues to plague work on this subject.

[450] Marine Board, National Research Council, *Stemming the Tide: Controlling Introductions of Nonindigenous Species by Ships' Ballast Water* (Washington, DC: National Academy Press, 1996). The omission of systematic and quantitative cost comparisons is particularly noticeable in light of the comparisons provided in the 1992 Canadian report, which seemed to have been heavily drawn upon by the Marine Board for other purposes. Pollutech Environmental Limited, *A Review and Evaluation of Ballast Water Management and Treatment Options to Reduce the Potential for the Introduction of Non-Native Species to the Great Lakes, Technical Appendix B, Ballast Water Treatment*, report prepared for the Canadian Coast Guard (Sarnia, ON: March 31, 1992). (As noted above, the shipping industry has not received the Canadian report with much favor.) In this story, the Marine Board is the dog that did not bark.

anew at all options, that he could not proceed except in a close partnership with industry, and that we should look forward to a 15 to 20 year research effort to identify feasible options.[451] During all this time, one must always keep in mind, new ships which will be in service for 20 to 30 years, which could be fitted with technology for far cheaper than what it will cost to retrofit old vessels, are being built without any requirements whatsoever.

In fact, after ten years of special committees, workshops, scoping studies, and continued efforts to work out "cooperative solutions" with industry, the only answer which has been produced is, in essence, "it needs more work." There is always some other interesting technological gismo to be looked at. Always "another snake oil salesman," as one of the industry representatives himself often put it. But no option is ever deemed acceptable. And, in the meantime, the industry representatives have succeeded in securing significant protections against being forced to adopt any meaningful measures in the future through special protections written into NISA 96 and the draft annex to MARPOL on ballast water. (See §§ 7.3, 7.5 above.) No one should be surprised. Any US Coast Guard officer coming out of the inner councils of MEPC in London expressing dismay that the convention is becoming a means of insulating industry from serious regulation would playing the part of the Vichy French policeman in *Casablanca* coming out the gaming room in the back, saying that "I'm shocked, shocked to discover that gambling is taking place in this establishment!"[452] That is the way the game is played by big people. Government-industry collaboration, what has lately been called "partnering," may sound like a nice idea. But the industry interests are not the authentic "partners" of the government agencies. Partnership means an identity of interest, in both law and politics, and a government partnership with industry in that sense is a violation of the fiduciary responsibility to the general public. This sort of collaboration is fundamentally undemocratic because it favors the powerful and well-organized interests over the more diffuse and local environmental interests.[453] Those local environmental groups are also "special interests." No one really speaks for the "general interest" – but that is what the government agencies are supposed to attempt to do. That is why we have government agencies rather than business syndicates to run our public affairs.

When we finally get around to legislating engineering standards at some time far in the future, it is almost a sure bet that they will be subject to the "grandfathering" which is very typical in both environmental regulation and international maritime regulation. Unless it is done with great care, such a provision can led to some of the worst unintended consequences of engineering regulations. A grandfather rule provides that an auto, facility, or vessel already built with current technology is exempt from making the technological

[451] Presentation by Dr. Robert R. Hiltabrand, US Coast Guard Research and Development Center, presentation to the "Ballast Water Workshop," April 28, 1999, at the 9th International Zebra Mussel & Aquatic Nuisance Species Conference, Duluth, Minnesota, April 26-30, 1999.

[452] Harsh words, perhaps. But this basic strategy, of using the MARPOL convention to protect the industry from national and local regulation, was blatantly advocated to me, while I was on active duty, by a retired US Coast Guard admiral working as a marine industry consultant. He did not understand that he was talking to someone who would prefer to work for the environmental community rather than the industry after he retired.

[453] On general problems in such cooperative approaches to environmental regulation, by someone who favors the cooperative approach within limits, see Edward P. Weber, *Pluralism by the Rules: Conflict and Cooperation in Environmental Regulation* (Washington, DC: Georgetown Uni. Press, 1998).

improvements, or is given some other dispensation in terms of the extent or timing of those improvements. This has the effect of making old autos, facilities, and vessels which might otherwise have been removed from service in the natural course of things, and which are often the worst polluters, relatively more valuable – which means that they are kept in service longer. This has had an especially ill effect on auto emission standards in the United States, because older autos are dramatically worse polluters. It has a similar effect in the shipping industry, where the older vessels are more likely to spill oil, and, even worse, are more likely to have casualties which kill people.

Strangely enough, engineering standards are counterproductive on the other side of the equation as well. A firm engineering standard is set by the government, usually reflecting some rough average of cost/benefit which ignores wide variances in cost/benefit among various segments of the industry, including not only variances in age but also variances in overall technological design, economy of scale, operating market, and (not an inconsequential factor) sophistication of management. Those on the low end of the scale (high cost and low benefit) will beg for grandfathering provisions and other special exemptions, and engage in the classic delaying tactics which can negate enforcement efforts for years.[454] Those on the high end of the scale will met the standards, collect their public relations kudos for being responsible companies, and do little more, even though they could do much more to reduce their pollution.

It may seem intuitively impossible that we could be stuck with these unintended consequences on both ends of the curve, but that is in fact part of the mystery of marginal rates of return, in contrast to average rates of return. An illustration, based on a plausible scenario for the regulation of ballast water, may clarify this. Suppose that the US Coast Guard eventually settles on filtering as an engineering solution many years from now. (It still seems to be the preferred technology, for reasons which are not entirely clear.) Let us suppose that the standard is 50 microns, because that is the lowest level which seems to be economically feasible for most vessels, and it gets a lot of the big things we want to get. (That includes adult aquatic animals, fish eggs and veligers, most of the mussel veligers – or at least messes them up quite a bit as they plop through – and big pieces of plants and seeds. It misses a number of smaller organisms, such as some of the invertebrate eggs in the range of 20 to 100 microns, microscopic pieces of weeds, algae cysts in the range of 5 to 25 microns, some of the fungi in the range of 1 to 100 microns, some of the protozoa in the range of 1 to 80 microns, and bacteria and viruses which are less than 1 micron.) Many of the newer and larger ships, taking advantage of new construction and economies of scale, can actually do quite a bit better. It may well be that they could filter down to 25 microns or adopt other measures, such a filtering system combined with an ultraviolet system. This is a fair assumption, based on the *a priori* assumption that the level of 50 microns is only settled upon as the engineering regulatory standard (after many years and marginal but important improvements in the technology) because it can be done at a reasonably tolerable cost for

[454] The problems of the regulatory process should be so familiar to both industrialists and environmentalists reading this that it needs no elaboration. If not, please see Steven E. Rhoads, *The Economist's View of the World: Government, Markets, & Public Policy* (New York: Cambridge Uni. Press, 1985), pp. 41 *et seq*., which details the failure of compliance with programs administered by EPA.

the *average* vessel. Some vessels will fall below and above that average. (Given the realities of the political process, probably more will fall on the side of doing less than they can, because they will be silent, while those who are being asked to do more than they can will protest loudly.) Those who fall above will have no incentive to do any better. Some of those below may pay an exorbitant cost, and may even be driven out of business. But many other ships, particularly those older handysize bulkers in the Seaway trade which are worth only $1 to $10 million each on their useful life and would cost a $1 million apiece to be retrofitted, will be grandfathered. They will still be required to conduct exchanges, but only at the old nominal exchange level of 85% (making certain assumptions about salinity, which we know to be false). Old NOBOBs will remain exempt, under the assumption that making them give up sufficient cargo for a partial exchange ("swish and spit") would put them out of business. Under the new national regulations (per the current rule in NISA 96) there will be a blanket exemption, now viewed as part of the grandfathering which is only reasonable, for old vessels which cannot safely exchange.

The result is that there are four groups of vessels: (1) Group One is exempt, and is not required to make any other adjustments, such as installing some other technology, cheaper although less effective, or forgoing some cargo loss, in the case of the NOBOBs, in order to conduct exchanges. This is a great loss to the environment because of the heavily contaminated water which will continue to come in. It is a loss to the economy because it is a reward for inefficiency. And it may well also be loss to safety, because these include rust buckets which would have otherwise gone sooner to scrap. (2) Group Two is not exempt, but is having great difficulty meeting the requirement, and, given the competitive pressures, either goes out of business or goes into another trade. This is a loss to the economy. It is a benefit to the environment, in that these vessels no longer bring in any water. But it is a benefit bought at a great cost. (3) Group Three includes vessels clustered around the "average" for which the regulatory engineering standard was designed. If the standard was well designed (a questionable assumption about something engineered by government bureaucrats) they will be providing a good benefit to the environment for a reasonable economic cost. (4) Group Four includes the vessels that really could do much better (filter at 25 microns, or use an add-on) but who have no incentive to do so. This is a loss for the environment.

I have not afflicted the reader with the graphs of intersecting curves, shaded areas, and formulas which you see in an economics textbook, because I want to be honest about the fact that I do not have sufficient information to predict the shape of the curves or the quantitative values to put into the formulas. It depends, in essence, on how large each of the four groups of vessels are and how high the cost benefit curves rise for each of the vessels in groups two through four. But here is the point. Only Group Three represents an efficient cost/benefit balance. All other groups represent a loss to the environment or to the economy. There might be an overall benefit to the environment if Group Two, alone, is extremely large. But that will be bought at great cost to the economy, and is therefor not likely to be tolerated. The better bet is that Groups One and Four will be rather large, and will therefore result in a significant loss to the environment. The most tragic aspect of this situation may be that the industry mangers and engineers in Group Four, those in the best-

run, most sophisticated, and generally most responsible fleets of the world – those from whom we might otherwise expect the invention of creative cost-effective solutions – have no incentive to cooperate in inventing those solutions. That is a tremendous opportunity loss for everyone.

This analysis does not, of course, depend on whether the US Coast Guard selects filtering or some other technology. It applies equally to levels of required exchange or levels of treatment with ultraviolet light, biocides, or heat. In sum, therefore, the traditional regulatory approach being used by the US Coast Guard (under mandate from the US Congress) is a prescription for delay, ineffectiveness, high cost to industry, and discouragement of creative solutions. It is better than nothing. But we can do better.

All that said, regulation in the traditional form of prohibitions and permits might be perfectly appropriate for some of the other vectors, particularly the commercial use of exotics in aquaculture, baitfish transportation, and aquarium fish sales. The reason is that, in many cases, there may be no technological or economic limitations on the practicality of a policy of zero discharge. Just as we are not interested in permitting a certain acceptable level of murder or theft, we are not interested in permitting a certain level of discharge of detrimental species – or to recognize the use of detrimental species as a legitimate economic activity. The rub, however, comes in when we try to define which species (or genetic strains) are in fact detrimental – and who has the burden of proof on that issue. Here, there are significant transaction costs to consider, mainly in the form of "uncertainty cost," which is the cost of generating good scientific information on the risks. In other words, it may be perfectly feasible to have a policy of "zero discharge" of bad organisms, but it is not so feasible to have a policy of "zero risk" in defining which organisms are bad. Other things being equal, there is good legal and economic logic to a decision rule which says that the proponent of the use has the burden of proof to show a reasonably low level of risk. Also, it is important that the process for making the determination include input from others, in the environmental community, who have a significant interest in providing contrary information. The worst inefficiency of current federal, state, and provincial regimes for control of these vectors in the Great Lakes is probably less in the fact that they rely on traditional command regulation and more in the fact that they do not address this critical problem of obtaining relevant information through clear approval criteria and provisions for regional coordination. It is costly to industry, as well as to the environment, because the existing processes are chaotic and there is little justification for one jurisdiction continuing to prohibit the commercial use of an exotic organism which another jurisdiction is allowing to be used in the basin.

Regulation through private rights and liabilities. This approach is worth mentioning, although it does not appear to have much application to the primary problem of ballast water. It might have more application to the vectors involving commercial use of exotics and other fish – aquaculture, bait, and aquaria – although I would propose to venture only speculative comments on the feasibility of that here. As has been recently illustrated in the case of highly publicized litigation in the United States via class action suits brought against tobacco and guns, private litigation can be a supplement or augmentation of regulation by

government agencies. More generally and prosaically, the whole complex mixture of private rights and liabilities which we inherit from our traditional Common Law constitutes, in essence, a system of regulation of certain externalities by private action.[455] When a private party sues and wins massive damages for injuries suffered because a badly designed automobile gas tank caught fire, that does indeed raise the cost of making automobiles (which is not necessarily a bad thing, please remember) and, more significantly, calls attention to the need to put a few more resources into designing better gas tanks on the next model. The problem with this system of regulation, particularly in the more litigious United States, is that the "transaction costs" in the form of attorney fees, years of delay in resolution of issues, and process failures can be very high.

Nevertheless, private litigation has often been an extremely valuable tool for environmental organizations to bring attention to an issue and put pressure on errant industries or slow-moving regulatory agencies. This is the sense of a petition recently submitted to US EPA protesting the blanket exemption of ballast water from regulation under the US Clean Water Act National Pollution Discharge Elimination Permitting System.[456] More directly, is there room for effective private litigation against businesses which negligently release nuisance species?

In the case of ballast water, the problem of assigning causation to a discrete group of shipping interests would probably make certification of a class action and proof of the case rather difficult. In the case of an identifiable release from an aquaculture facility or bait dealer (which could possibly be linked back to a specific facility by genetic analysis) there are better prospects for successful litigation under basic Common Law theories of negligence or "nuisance," a rather arcane and confused area of tort law, but one which has been used in the past to redress environmental damages. One of the requirements in most jurisdictions is that the party seeking to sue for a "public nuisance" demonstrates some special damage, above that suffered by the general public. In the case of exotics affecting the quality of local fishing, local fishing groups might well be able to satisfy that requirement as a class.[457] In the case of a release of a cold water fish used in an aquarium or

[455] This is a focus of a relatively new area of cross-disciplinary study known as "economics and law," which explores the methods by which legal rules of property, tort (civil wrongs), and contract serve as a regulatory system for economic allocation of resources. See the collection of seminal writings in Henry G. Manne, ed., *The Economics of Legal Relationships: Readings in the Theory of Property Rights* (St. Paul, MN: West, 1975), or a newer review of issues in Robert L. Rabin, *Perspectives in Tort Law* (New York: Little, Brown and Co., 1994).

[456] Craig N. Johnson, Attorney for Pacific Environmental Advocacy Center, letter to Carol Browner, Administrator, US EPA, "Petition for repeal of 40 CFR § 122.3(a)" (January 13, 1999). The groups joining in the petition are Northwest Environmental Advocates, San Francisco Bay Keeper, Center for Marine Conservation, Chippewa-Ottawa Treaty Fishery Management Authority, People for Puget Sound, Great Lakes United, Dogwood Alliance, Great Lakes Sport Fishing Council, Pacific Coast Federation of Fisherman's Associations, Coastal Waters Project, Friends of San Juan, Association of California Water Agencies, Quoddy Spill Prevention Group, and Delta Keeper.

[457] For the history and general principles of nuisance law, see W. Page Keeton, ed., *Prosser and Keeton on the Law of Torts* (St. Paul, MN: West, 1984), chapter 15, especially § 90. For a short review of modern cases using nuisance law to redress environmental damage, see William H. Rodgers, Jr., *Environmental Law* (St. Paul, MN: West, 1994), chapter 2.

an ornamental pond, there is an "intervening action" by the person who bought the fish and released it which may well shield the aquarium supply house from liability under nuisance or general negligence law. This does not, of course, protect the person who actually dumped out the aquarium into the lake. But then there is a problem in proving that the species later found to be established in that lake came from that particular aquarium owner, as well as the practical difficulty of collecting any significant damages from the individual defendant.

In this sort of case, which is structurally similar to the tobacco company and gun dealer cases, one might sue under the theory of products liability. This requires showing that a product was produced or put into commerce in a "negligent" manner, or that the product itself was "unreasonably unsafe" or "defective."[458] Either formulation is basically the legal equivalent of a cost/benefit test. Should aquaculture and bait dealers be prepared to be held liable for accidental releases – and perhaps be compelled to buy insurance against that event, which would then internalize the risk into the cost of the product? Should the aquarium dealers selling cold-water fish to the Great Lakes region (which are readily identifiable from their sales catalogues) be responsible for turning loose dangerous products? These are all untried but potentially interesting questions.

Regulation through market incentives. Incentives can be either negative, in the form of graduated penalties or taxes, or positive, in the form of subsidies or rebates. They are more complex to design up front, and also highly controversial, which is why they are so seldom used. But they do have the potential to generate real payoffs in terms of environmental protection. Incentive schemes are often opposed by environmentalists because they seem to legitimize pollution by making it a "cost of doing business" or "selling the right to destroy the environment." This objection, however, ignores the reality of the problem of cost and benefits, and the significant failures of regulation by prohibition and permitting. Environmentalists who instinctively reject incentive schemes as an immoral sellout should ask themselves why the industrialists also dislike incentive schemes. In fact, for the business that is high up on the benefit/cost line in the area where the government-mandated technology is less burdensome than it should be, or for the business that is getting an exemption or successfully resisting enforcement, there is no attraction in moving to a negative incentive scheme. They are already doing less then they would have to do if they actually paid for the right to pollute and, as one observer puts it, "The business world knows that some environmentalists prefer a pure law to pure air."[459]

During my tenure as an active-duty US Coast Guard officer responsible for administering the Great Lakes ballast water regime, I was often amazed by the uncritical acceptance of a regime whose flaws I publicized. We have known for a long time that the level of exchange is manifestly inadequate, that the salinity standard we use to enforce it is fallacious, and that the NOBOB exception drives a gaping hole in the regulatory regime. Nevertheless, many people seem to be strangely reassured (judging from many uncritical

[458] See Keeton, *ibid*., chapter 17.

[459] Steven E. Rhoads, *The Economist's View of the World: Government, Markets, & Public Policy* (New York: Cambridge Uni. Press, 1985), p. 53.

press accounts) that we have a regulatory requirement in place. If we have a prohibition in place, no matter how flawed, that seems to be inherently reassuring. To be clear, it is far better than nothing. But any idea that we are anywhere near a 100%, 99%, or 90% level of protection is silly. As I sometimes put it to environmental groups who *did* express anger at the inadequacy of the regime, the only way to get a 100% level of protection against ballast water is to shut down the Seaway. That is not going to happen. (And talk about wanting it to happen, by some groups, only destroys their relationship with their natural allies in the governments of the Great Lakes region, without whom we cannot hope to make progress.) The practical question to consider, therefore, is how we can move the level up from the nominal level of 85% (effectively much less) to 90%, and then to 95% or 98%, including the NOBOBs, and as soon as possible. Time is a critical factor in the calculus here. A 90% solution put in place two years from now will do a lot more to protect the Great Lakes than a 95% solution that takes another ten years to put in place. If I have to accept the charge of being ritually impure in order to accomplish that goal, that is something this environmentalist, for one, is quite willing to live with.

The distinct advantages of an incentive system are as follows: (1) It would allow us to begin to institute practical measures immediately, by imposing low-level pressure to affect basic management decisions, such as the decision to load full cargo on a NOBOB or engage in cross-ballasting of a NOBOB inside the Great Lakes, which are completely unaffected by the current regulatory regime. (2) It would reverse current incentives for the shipping industry regarding the development of technological options and making them cost-effective. Currently, their rational motivation is to overstate the prospective costs, and to carefully avoid identifying any creative measures which might prompt the governments of the Unites States and Canada to institute mandatory changes. The longer we study the problem, the better for them. If they were paying a tax based on the quantity and contamination of the ballast discharged, they would have a positive incentive to develop new technology as soon as possible. The better the technology they come up with, the stronger would be their argument that no future increase in the level of taxation is necessary. And we would be happy to agree with them. (3) Individual firms whose ships and management skill allow them to achieve a higher level of effectiveness than their competitors, the Group Four above, would be motivated to do so. They would pay less tax and gain a justly-deserved competitive advantage. They would gain a larger share of the trade, to the great advantage of the environment. Conversely, the Group One and Two firms, who cannot clean up their water efficiently, would go out of business or lose their shares of the market.

Another way to look at points (2) and (3) above is that an incentive system is a system of incentives for the *regulators* as well as for the *regulated*. The better that the regulated industry does in making efficient and effective changes, the less the incentive for the regulating agency to crank up the level of taxation. The agency and the industry are not "partners" – always a problematic formulation of their relationship. But this would allow them to be parties to a political contract, from which both would benefit.

Although ballast water is the most obvious subject for application of an incentive approach, there might also be a useful application for some aspects of other vectors. For example, state and provincial agencies might consider putting a tax on the proportion of non-target species found in samples of baitfish shipments (even when not prohibited exotics). Not all buckets need to be inspected, as long as the sampling is random and unpredictable. But it would provide a powerful incentive for the industry to refine their processes for selection of baitfish.

Although an incentive system is clearly in accord with economic logic, the Seaway might argue that a tax on ballast water (or expensive prohibitions) would be bad for the environment because it would have the unintended consequence of diverting more of the internal trade from ships to trains, with resulting increases in air pollution. That argument is not necessarily convincing, given the high level of public subsidization of the Seaway trade as it is. But it can also be argued that all forms of transportation are highly subsidized in both the US and Canada, and this is no place to rewrite the general ground rules.[460] One might say the same thing about the argument that we should try to change basic standards for controlling air emissions by what amounts to a special subsidy of the shipping industry. However, the argument here, on behalf of industry, is that the significantly lower amount of air pollution per tonne of cargo carried by shipping constitute a positive externality which is not currently captured by the market (or government subsidy policies), and which should therefore by factored into any government environmental policy regarding shipping. There is something to that. There remain some highly complex questions about the synergistic interaction of taxes, subsidies, and regulatory costs in various competing segments of industry which are beyond the analysis I can present here.[461] As a matter of basic public

[460] See, for example, the complaints about government favoritism towards railroads hauling grain from the interior to the seacoast in competition with Canadian shipping through the Seaway, and the comparison in resulting air emissions, in Canadian Shipowners Association and the Chamber of Maritime Commerce, "A Competitive Vision for the Great Lakes - St. Lawrence Waterway: An Initiative of Canada's Marine Industry" (Ottawa: CSA, October 1997), on line at http://www.shipowners.ca/Vision Paper.html.

[461] This is where the mathematics becomes serious, and one must resort to professional economists, who may themselves not be able to answer the questions on the available data. Much like ecosystem effects of disturbances, changes in tax or regulatory policy can be buffered or amplified by prior states and distortions. For example, economists have pointed out that well-designed market incentive schemes for environmental protection can still result in excessive costs if the market being taxed is already subject to distortionary regulations or taxes. Lawrence H. Goulder, Ian W.H. Parry, Roberton C. Williams III, and Dallus Burtraw, "The Cost-Effectiveness of Alternative Instruments for Environmental Protection in a Second-Best Setting," *Journal of Public Economics* (1999), vol. 72, pp. 329-360. The argument here, on behalf of the Seaway, is that they are already wrongly disadvantaged by the lack of recognition of the externalized value of shipping in current public policies. Therefore a scheme of negative incentives, even if fair in principle, would be amplified in its negative effects on Seaway Shipping. (Command regulation would still be worse. Goulder, *et al*., *ibid*.) On the other hand, one might intuitively assume that, if the Seaway is in fact already over-subsidized by existing policy (a question of detailed econometrics, upon which I do not have sufficient information), then a negative incentive policy, properly designed, would only tend to compensate for the prior distortion. But such intuitions are not always reliable.

Aside from all this, there is the matter of an interesting but highly controversial thing called the "Porter Hypothesis," which proposes that environmental regulations can actually advance market growth by forcing industries to re-tool and become more efficient. This might have some application to sending aging handysize bulkers to scrap. One recent evaluation of this hypothesis suggests that such a "win-win" scenario is unlikely,

policy, moreover, one must ask if a plea for government subsidy in favor of marine transportation in this case is consistent with other public policies to promote the revitalization of the railroads, which can also be justified on environmental grounds. In other words, yes, the public might lose in increased air emissions from trains compared to ships, but nevertheless gain more by reduced emissions from trains compared to trucks and cars because of the overall support to railroad infrastructure. In political economics, just as in ecology, one much look at all the relevant changes in the system.

To punt on this question, I would suggest that incorporation of some compensating subsidy for the Seaway is well worth it if it is necessary to make the scheme politically acceptable. There is some room for negotiation here if we can come up with a political contract which benefits both the environment and the industry. A viable compromise, for example, might be a scheme in which the individual vessels were taxed according to the amounts and concentrations of dirty ballast being discharged, but 75% of the taxes collected were returned to the industry, in the form of rebates per volume or value of cargo carried. (The other 25% would go to support monitoring, enforcement, and perhaps government research on control options.) It would not be illogical to pay the same parties being taxed, because the ratio between tax paid and rebate received would vary with each individual ship or firm, depending on how effective they were in managing their ballast water. A well-run company could actually make money on its ballast water management, and there would be a definite incentive to build new, cleanly designed Seaway-sized vessels.

Nothing is quite so easy and effective as this might sound, and there are some problems in the monitoring of such a scheme. Careful attention would have to be paid, up front, to the development of meaningful laboratory protocols for evaluating the level of contamination in ballast water and the field protocols for sampling the discharges. Much of this work, however, has already been done in a number of studies conducted for the purpose of evaluating the current regime. Moreover, there are ways to improve existing sampling. There is no reason why ships cannot be required to install sample ports right on the discharge lines, much as they are required to have on marine sanitation discharge lines under Canada Shipping Act Regulations, and there are other monitoring techniques which might advance the reliability of the process.[462] Altogether, it should be no more difficult than it would be to monitor the performance of prescribed technologies. In this case, however, the focus would always be on the bottom line of the actual threat in the water.

– Ω –

but that it is not implausible for some favorable side-effects of environmental regulation to help lessen the costs somewhat. In other words, one might see a "win-not-lose-so-much" scenario. Anastasios Xepapadeas and Aart de Zeeuw, "Environmental Policy and Competitiveness: The Porter Hypothesis and the Composition of Capital," *Journal of Environmental Economics and Management* (1999), vol. 37, pp. 165-182.

[462] Monitoring options are discussed in Marine Board, National Research Council, *Stemming the Tide: Controlling Introductions of Nonindigenous Species by Ship's Ballast Water* (Washington, DC: National Academy Press, 1996), chapter 5.

Appendix: Terms and Acronyms

anadromous	Adj. Migrating up rivers from the sea to breed in fresh water.
ANS	Aquatic nuisance species.
ANS Panel	The Great Lakes regional federal, state, and tribal interagency committee, established under "NANPCA 90" to coordinate action on aquatic exotics, with the support of the Great Lakes Commission, a US interstate compact agency. Includes representatives of the eight US Great Lakes states, regional representatives of the same US federal agencies on the "ANS Task Force," Great Lakes tribes, Great Lakes environmental groups, and industry. Also includes observers from Canadian federal and provincial agencies (who are accorded a full role in actual deliberations). Web site at www.glc.org/ans/anspanel.html.
ANS Task Force	Also "ANSTF." The US federal interagency committee chaired by representatives of the US Fish and Wildlife Service and the National Oceanic and Atmospheric Administration, with representation by the US Coast Guard, US Army Corps of Engineers, US Environmental Protection Agency, and others. Web site at www.anstaskforce.gov.
APHIS	Agriculture Plant and Health Inspection Service, US Department of Agriculture. APHIS conducts inspections of ship cargoes for animal and plant pests, but does not inspect ballast water. Also has US federal responsibility for disease in aquaculture imports.
AQIS	Australian Quarantine and Inspection Service. Lead federal agency, for Australia, on ballast water control.
ballast water	Water used by a vessel to control immersion and trim in order to keep the vessel within efficient operating limits and preserve stability and hull integrity. Commonly confused with, but quite distinct from "bilge" water.
bilge water	Incidental waste water accumulating inside the vessel. Commonly confused with, but quite distinct from "ballast" water
benthos	Adj. "benthic." Bottom dwelling organisms. "Benthos" and "benthic" are commonly used in speaking of the bed of both saltwater and freshwater ecosystems.
BOB	"Ballast on board," or a vessel in that status. Includes a vessel full up "in ballast" or partially ballasted "with ballast."
bulk carrier	Also "bulker." A large merchant vessel, or freighter, which carries dry bulk cargoes such as grain, iron ore, and coal.
cabotage	Trade or navigation in coastal waters, usually used in reference to common legal rules restricting carriage of cargo between the ports of a nation to ships registered or "flagged" by that nation.

container ship	A large merchant vessel, or freighter, which carries standard size containers, which can be offloaded directly to trains and trucks.
CSA	Canadian Shipowners Association. Association of companies owning much of the major Canadian commercial vessels inside and outside of the Great Lakes.
cysts	Highly resistant and, encrusted, and dormant stages of algae and protozoans, commonly in the range of 5 to 25 microns in size.
DFO (Canada)	Canada Department of Fisheries and Oceans. Includes Canadian Coast Guard and DFO Science Branch, both of which have responsibilities for management of exotics in ballast water. The Great Lakes region is the responsibility of the DFO Central and Arctic Region, with a Great Lakes regional office in Sarnia, Ontario.
dinoflagellates	*Dinoflagellata*. Includes microscopic unicellular algae, some of which are highly toxic. These have been a special concern in ballast water infections of Australia.
DWT	Deadweight tonnes. The weight, given in English long tons (2,240 pounds) in the United States and in metric tonnes (1,000 kilograms) elsewhere, that a vessel will lift when loaded in salt water to its summer freeboard marks, sometimes called "summer deadweight tonnes" (SDWT) – a measure of the total capacity to carry crew, provisions, fuel, ballast, and cargo, not counting hull and machinery. Subtracting crew, provisions, fuel, and ballast from DWT gives "deadweight cargo carrying capacity" (DWCC), which is the actual capacity to carry cargo. Not the same as "tonnage" or "gross registered tonnage (GRT)."
EEZ	Exclusive economic zone, the area of the sea in which a coastal nation has the right, recognized under the United Nation Convention on the Law of the Sea and current customary international law, to control access to resources and enforce rules for the protection of those resources against pollution or damage. It extends up to 200 nautical miles from the "baseline," which is a smoothing out of the coastline according to a set of standard rules, and therefore is also known as the "200-mile zone."
extirpation	Local extinction.
externality	An effect on a third party, good or bad, which is not transmitted through the price system. In other words, a benefit or cost which is not accounted for in the market. In economic terms, pollution and destruction of common resources are negative externalities. Information, private economic development which creates wealth for others without compensation, and other "public goods" are positive externalities (although not all positive externalities are public goods).
flag state	The national authority which registers or "flags" a vessel. All vessels are required to register with some nation under international law. The flag state has general authority over the management and safety of the vessel, but may need the assistance of a "port state" to enforce that authority. Most of the leading maritime nations (including the US and Canada) require the vessels registering

	with them to be owned by their citizens and have extensive regulatory requirements (closely parallel between the two nations) to insure safety and environmental protection. Some other states, known as "flags of convenience," have much lower requirements, and are therefore cheaper to register with. See also "cabotage."
flow-through exchange	Exchanging ballast by a continuous process which maintains a constant load on in the tank. A bottom-up flow-through exchange can only be accomplished with a full tank. A top-down flow-through exchange can be accomplished with a tank at any level, including a "NOBOB" tank with slop and sediment. See "sequential exchange" and "partial exchange."
GLWQA (78/87)	The Great Lake Water Quality Agreement of 1978/1987. Formally, the Great Lakes Water Quality Agreement of 1978, as amended by the Protocol of 1987, signed at Ottawa by the US Secretary of State and the Canadian Minister of Foreign Affairs, November 22, 1978. The GLWQA 78/87 is not a ratified treaty, but is formally recognized by US statutes and the Canada-Ontario Agreement. It mandates the binational International Joint Commission (IJC) to conduct studies of the Great Lakes ecosystem and provide "advice and recommendations to the Parties [the two federal governments] and to the State and Provincial Governments" on protection of Great Lakes water quality." Article III, § 1(c).
GRT	Gross registered tonnage. A measure of volume, in units of 100 cubic feet or 2.83 cubic meters, of enclosed spaces in the vessel.
handysize ship	A bulk carrier ("bulker") or tank vessel in the range of 10,000 to 35,000 "DWT," usually small enough to fit through the St. Lawrence Seaway.
IMO	International Maritime Organization. IMO is a "specialized agency" of the United Nations, originally established as the "Inter-Governmental Maritime Consultation Organization" in 1948. It is a forum for consultation on matters of safety and prevention of pollution in shipping, and the forum in which most of the major international conventions on maritime safety and environmental protection are negotiated. See "MARPOL" and "MEPC."
Invasive Species Council	US federal committee to coordinate programs for all exotics (terrestrial, aquatic, and aerial) established by Executive Order (EO) 13112, Invasive Species (February 3, 1999), at 64 *Federal Register* 6183 (February 8, 1999).
JSA	Joint Subcommittee on Aquaculture, US National Science and Technology Council. A Federal interagency coordinating group to increase the overall effectiveness and productivity of Federal aquaculture research, transfer, and assistance programs to aquaculture. Chaired by the Department of Agriculture.
knot (kn)	A unit of speed, a nautical mile per hour. 1 knot = 1.151 statue miles per hour or 1.85 kilometers per hour. See "nautical mile." Almost all international shipping uses knots to measure speed, but US and Canadian lakers and inland barge traffic

	use miles per hour.
limnetic	Adj. Referring to the upper levels of a freshwater ecosystem. The freshwater counterpart to the "pelagic" areas and organisms of the sea.
LCA	Lake Carriers' Association. Association of companies owning most of the major US commercial vessels operating on the Great Lakes.
Marine Board	Committee on Ships' Ballast Operations, Marine Board, Commission on Engineering and Technical Systems, National Research Council, National Academy of Sciences.
MARPOL	The International Convention for the Prevention of Pollution from Ships, done at London, November 2, 1973, amended by the Protocol of 1978, called "MARPOL 73/78" or just "MARPOL," (although this is not actually an acronym for the name of the convention). The main convention has various "annexes" on specific types of pollution: Annex I on oil, Annex II on noxious liquid substances in bulk, Annex III on harmful substances in packages, containers, or tanks, Annex IV on sewage, and Annex V on garbage. "IMO," through the "MEPC" and its Ballast Water Working Group, has been developing an annex to MARPOL for international regulation of exotics in ballast water.
MEPC	Marine Environment Protection Committee, IMO. This is the committee of IMO concerned with "MARPOL," and it has a Ballast Water Working Group which has been developing an annex to MARPOL for international regulation of exotics in ballast water.
metric tonne (mt)	Also "metric ton." A mass of 1000 kilograms (2,205 pounds), also sometimes used informally as a volume of one cubic meter (m^3) because one metric tonne of water in volume is approximately equal to one metric tonne in mass. (A cubic meter of water (m^3) is 1.3 times a cubic yard.) A metric tonne of mass is equal to 1.102 English short or net tons (2,000 pounds) and 0.98 English long or gross tons (2,240 pounds). Approximately, 1 metric tonne of water (or m^3, to be more precise) = 264 US gallons.
micron (μ)	Length, one-millionth (10^{-6}) of a meter. Protozoan cysts may be as small as 5 microns. Active protozoans range from 30 to 300 microns. Zebra mussel larvae or veligers range from 70 to 290 microns.
mid-ocean	An inaccurate term often used for "open ocean."
millimeter (mm)	Length, one-thousandth (10^{-3}) of a meter.
mm	See "millimeter."
MSD	Marine sanitation device, a shipboard system for treating sewage before discharge (a holding tank, for discharge to shore, is technically referred to as an MSD under US law, even though it does not actually treat the sewage). Most systems work in two stages, a first-state settling and aeration tank using aerobic

bacteria to break down the sewage, followed by a second stage disaffection with either ultraviolet light (most common on Canadian and third-party vessels) or chlorine (most common on US lakers internal to the Great Lakes, which have also been installing a third dechlorinating stage in order to comply with Great Lakes standards on chlorine discharges).

mt/MT — See "metric tonne."

NANPCA 90 — Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, Public Law 101-646 (November 29, 1990), amended by the National Invasive Species Act of 1996 (NISA 96), Public Law 104-332 (26 October 1996), codified at 16 USC §§ 4701 *et seq*. NANPCA 90 established the first mandatory regime for controlling ballast water in the Great Lakes. Also provided for research programs and federal-state cooperative efforts on ballast water and other vectors, and established the federal "ANS Task Force" and the Great Lakes Commission "ANS Panel."

nautical mile (nm) — Standard distance used in both maritime and aeronautic navigation, equal to the average length of 1 minute of arc on a great circle of the Earth, and therefore also equal to 1 minute arc of longitude (measured by change in line of latitude). 1 nautical mile = 1.151 statute miles, 1.852 kilometers, or 6,076 feet.

NISA 96 — National Invasive Species Act of 1996, Public Law 104-332 (26 October 1996), codified at 16 USC §§ 4701 *et seq*. NISA 96 expands the provisions of the Great Lakes regime for controlling exotics in ballast water established under NANPCA 90 to the United States as a whole, with modifications. Technically, the statute is still NANPCA 90, as amended by NISA 96, but the extensive substantive amendments made by NISA 96, plus the greater ease of the later acronym, have led to "NISA" or "NISA 96" being the preferred common name for the statute.

lamprey — See "sea lamprey."

nekton — Adj. "nektonic." Free-swimming organisms.

NOBOB — "No ballast on board," or a vessel in that status. Most vessels categorized as having "no ballast on board" because they have pumped down to loss of suction are in fact carrying some amount of residual slop and sediment (about 160 metric tonnes, on average, for vessels entering the Great Lakes).

NIS — Nonindigenous species. Although not exactly the same term, commonly used interchangeably with "ANS" and "exotics."

North Central Region (NCR) — The US Department of Agriculture (USDA) region which includes all of the Great Lakes states except Pennsylvania and New York. The NCR has several centers for the study and promotion of aquaculture, including the North Central Region Aquaculture Center at Michigan State University.

NRT — Net registered tonnage. A measure of volume, in units of 100 cubic feet or 2.83

	cubic meters, of enclosed cargo-carrying spaces in the vessel, subject to special regulatory deductions. Supposedly the net after the subtraction of non-earning spaces from "gross registered tonnage (GRT)."
open ocean	Ocean areas away from the seacoast and over deep water, where the ecology is significantly different than in coastal or shallow areas because of low nutrients (oligotrophy), higher ultraviolet penetration, higher salinities, and different predators. Within the context of the Great Lake ballast water regime, refers to the ocean outside the regulatory limit of 200 miles off shore and 2000 meters of depth. But that limit is negotiable, depending on the currents and actual ecological conditions of the area in question.
partial exchange	Also called a "swish and spit." The idea, not yet put into practice, of putting a small amount of water into a largely empty tank on a "NOBOB" vessel and then pumping down to loss of suction again in order to wash out slop and sediment on the bottom of the tank. See "flow-through exchange" and "sequential exchange."
pelagic	Adj. Referring to the open waters of the sea and its organisms. The freshwater counterparts, properly speaking, are "limnetic" organisms. Pelagic organisms include both "plankton" and "nekton," and are distinguished from "benthic" organisms.
plankton	Adj. "planktonic." Mainly microscopic "pelagic" or "limnetic" aquatic life with little self-propulsion, drifting at various depths. Includes "zooplankton," small animals, "meroplankton," larval fish, "phytoplankton," small plants, and "macrophytes," small pieces or seeds of plants (such as algae).
port state	The national authority with jurisdiction over the waters through which a vessel sails. See "flag state."
preemption	The doctrine, in United States law, that extensive regulation of a subject by the US Congress prevents the US states from regulating the same subject. A related doctrine, often confused with "preemption" although technically distinct, is the doctrine that a US state may not impose an unreasonable burden on interstate and international commerce. Both of these doctrines come into issue when a US state engages in regulation of commercial shipping, which has long been an industry heavily regulated by federal law. However, the US federal courts are also deferential to the right of the US states to protect their natural resources. This conflict was dealt with in detail in the leading US Supreme Court case of *Ray v. Atlantic Richfield Co.*, 435 US 151 (1978).
Prisoner's Dilemma	A strategic game problem, representing a variety of problems in collective social action, which has the following structure: (1) If A and B both cooperate, they gain X. (2) If A defects from cooperation, while B cooperates, A gains a value Y which is greater than X. The same rule applies to B defecting while A cooperates. (3) But if A and B both defect (as they each have an incentive to do, under the prior rules) both gain a value Z, which is less than X. The paradigmatic example of the Prisoner's Dilemma structure in environmental problems is the

	"tragedy of the commons." The Prisoner's Dilemma can be overcome through a variety of means, including the establishment of a larger structure which rewards cooperation and punishes defections. That may be provided by a political authority, or by a continuing relationship between the players.
public good	Anything desirable which, once produced, tends to benefit a wide variety of people whether or not those other people compensate the person producing it, usually because it is structurally difficult to ration, price, or limit the good, sometimes because the good is indivisible. The most common (and valuable) public good is information. Once produced, it tends to benefit all, without further cost to the producer, and it is difficult (despite copyright protections) for the producer to recover the full value, in large part because it is indivisible. A public good is a positive "externality."
quagga mussel	*Dreissena bugensis*, a mussel which is closely related to the zebra mussel.
ppm (mg/L)	Parts per million.
ppt (o/oo)	Parts per thousand.
regime	A deliberately vague term for a system of social control which may include voluntary, mandatory, formal, informal, social, economic, political, or legal elements (as distinct from the more common meaning of a specific political administration).
ruffe	*Gymnocephalus cernuus*, a small and spiny bottom-feeding fish from Europe and Asia, called both "European ruffe" and "Eurasian ruffe."
Shipping Act	The Canadian federal statute for the general regulation of shipping, including pollution from ships. Revised Statutes of Canada, RS Chapter S-9. Parliament amended the Shipping Act in 1998 to provide that "The Governor in Council may make regulations respecting the control and management of ballast water." Shipping Act § 657.1, as added October 31, 1998.
sea lamprey	*Peromyzon marinus*, an anadromous parasitic fish.
Seaway Management Corporation	St. Lawrence Seaway Management Corporation. Canadian non-profit corporation, replacing the St. Lawrence Seaway Authority in 1998, which manages the Canadian portion of Seaway, including the Welland Canal (headquartered in Cornwall, Ontario).
sequential exchange	An exchange of ballast by pumping down a tank and refilling it (or, theoretically, filling up an empty tank and emptying it, but this is never done). See "flow-through exchange" and "partial exchange."
SLSDC	St. Lawrence Seaway Development Corporation. US public corporation which

	manages the US portion of the Seaway (headquartered at Massena, New York).
TEU	Twenty-foot equivalent unit. A standard container size, used as a measure of the carrying capacity of container ships.
tank ship	Also "tanker." A large commercial vessel which carries liquid cargoes such as crude oil, refined oil, or bulk liquid chemicals.
third party (foreign) vessel	Vessels entering the Great Lakes through the St. Lawrence Seaway which are neither US nor Canadian. They are subject to "port state" control under both US and Canadian law as they pass through internal territorial waters, and do not have the reciprocal right to nondiscriminatory regulation between US and Canadian vessels under the Boundary Waters Treaty.
tonnage	See "DWT" and "GRT."
tragedy of the commons	The loss of public resources, to everyone's detriment, because of a lack of an economic, social, or political structure assuring the cooperation of individuals. One of the common examples is a fishery not subject to any resource management by collective authority. All fishers will lose their livelihood if the stocks are exhausted. But each individual fisher has a strong incentive to take as much as he or she can before the exhaustion occurs (especially because he or she expects others to be doing exactly the same). This is a more specific version of a general strategic game among rational actors called "Prisoner's Dilemma." The behavior is not rational in collective terms. But it is at the individual level.
Transport Canada	Canadian Department of Transportation, the department responsible for general supervision and regulation of marine transportation. The Great Lakes region is the responsibility of the Ontario Region, headquartered in North York, Ontario.
UV	Ultraviolet light/radiation. Electromagnetic radiation in wavelengths between 4,000 angstroms (near visible) and 40 angstroms (near x-rays).
US Coast Guard (USCG)	The US agency responsible for general supervision and regulation of marine transportation. The Great Lakes region is the responsibility of the Ninth District of the US Coast Guard, headquartered in Cleveland, Ohio.
veliger	Larvae or young.
zebra mussel	*Dreissena polymorpha*, a European mussel (now a Great Lakes mussel) originally from the Black and Caspian Seas.