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INTRODUCTIONS OF SPECIES TRANSPORTED IN SHIPS' BALLAST WATERS: THE RISK TO CANADA'S MARINE RESOURCES

by

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ABSTRACT

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On April 24, 1991, a workshop entitled "The Risk to Canada's Marine Resources of Species Carried in Ships' Ballast Waters" was held at the Bedford Institute of Oceanography (BIO) in Dartmouth, N.S. The workshop focused on the problem of harmful marine organisms transported in ships' ballast waters and subsequently introduced into new ecosystems. The danger posed by such introductions has already been witnessed in the Laurentian Great Lakes, in Australia, and in other parts of the world. With the dramatic changes in global shipping technology and traffic patterns in recent decades, the risk of introductions from this vector has increased proportionately.

The problem also threatens the coastal waters of Atlantic Canada, because this is where major commercial fisheries and many aquaculture sites are located. The danger is both ecological and economic in nature, because shipping and aquaculture are fundamentally incompatible industries. The solution does not lie in simple extension of the measures initially introduced to protect the Laurentian Great Lakes, because the types of ships entering Canada's coastal regions, and the conditions mediating the ballast waters they carry, are significantly different from those in freshwater regimes.

The consensus reached by the expert group attending the workshop was that the transport of harmful organisms in ships' ballast waters is a problem of global dimensions that poses a significant threat to the marine ecosystems of Canada. The threat was perceived as immediate and pressing. The appropriate response embodies two phases. First, there is a need to define the scale and nature of the current imports of organisms to Canadian marine waters. Secondly, control measures must be identified and implemented, and they must be international in scope, given the nature of the shipping industry. The problem is complex, and the cost of action may initially seem appreciable; but there is potentially a far greater cost to doing nothing at all. A unique feature of the problem is that control measures must be proactive, rather than simply reactive, because the situation is almost always irreversible once a species or disease agent has been introduced; and the incurred costs then become inescapable. A complete list of the recommendations forthcoming from this workshop is contained in Part II of this report.

RÉSUMÉ

Smith, T.E., and S.R. Kerr. 1992. Introductions of species transported in ships' ballast waters: The risk to Canada's marine resources. Can. Tech. Rep. Fish. Aquat. Sci. 1867: v + 16 p.

Le 24 avril 1991, l'Institut océanographique de Bedford a été l'hôte d'un atelier portant sur la menace que posent les organismes transportés dans les eaux de ballast des navires pour nos ressources marines. On y a débattu du problème de l'introduction d'organismes nuisibles provenant des eaux de ballast dans de nouveaux écosystèmes, phénomène dont on a déjà pu observer les effets dans les Grands Lacs, en Australie, et dans d'autres régions du monde. Les changements radicaux qu'ont connu la navigation et le transport maritimes à l'échelle mondiale au cours de dernières décennies ont encore accru cette menace.

Le problème touche aussi les eaux côtières du Canada atlantique, qui sont le site des principales pêches commerciales et exploitations aquicoles Le danger est à la fois écologique et économique, le transport maritime et l'aquiculture étant des industries fondamentalement incompatibles. Or, la solution ne réside pas dans un simple élargissement des mesures initialement adoptées pour protéger les Grands Lacs, car les navires qui pénètrent dans les eaux côtières du Canada et les conditions propres à leurs eaux de ballast sont de genres bien différents des ceux que l'on rencontre en eaux douce.

Les experts présents à l'atelier se sont entendus sur le fait que le transport d'organismes nuisibles dans les eaux de ballast des navires est un problème de dimensions globales, qui menace gravement les écosystèmes marins du Canada. Ils on perçu cette menace comme imminente et pressante. La solution à envisager comporte deux étapes. En premier lieu, il convient de définir l'ampleur et la nature des importations actuelles d'organismes dans les eaux maritimes canadiennes. En second lieu, il faut concevoir et mettre en oeuvre des mesures restrictives, cela à l'échelle internationale étant donné la nature de l'industrie du transport maritime. Le problème est complexe et sa solution paraîtra peut-être coûteuse initialement, mais l'inaction pourrait s'avérer encore plus onéreuse. On devra s'y attaquer d'une façon proactive, et non se contenter de réagir. En effet, une fois qu'un organisme ou un agent pathogène s'est introduit dans le milieu, la situation est presque toujours irréversible et les coûts qui y sont associés sont alors inévitables. Une liste complète des recommandations formulées à l'atelier est présentée dans la deuxième partie du rapport.

OVERVIEW

Since the advent of iron construction in the 1880s, sea-going vessels have taken on and discharged water as ballast to ensure stability and the safety and comfort of the ride. The ballast waters,[1] and the sediments sometimes picked up with them, often contain aquatic organisms, which survive the journey and are discharged when the waters are released. The lockers in which anchor chains are housed while the vessels are in transit also provide conditions amenable to the survival of marine organisms, which are then introduced to new waters when the anchor and its chain are deployed. In these and similar ways (e.g., external fouling), aquatic organisms can be transported rapidly from one part of the world to another. Once introduced into the new environment, some organisms will flourish, and their populations may alter the species composition of the receiving ecosystem and thereby create significant problems. A recent example is the European zebra mussel (*Dreissena polymorpha*), which is believed to have been introduced into the Great Lakes via ballast water discharged in 1988 (Hebert et al. 1989). Within 1 yr the mussel population had grown enormously, and the organisms were covering and blocking water intake pipes and many other types of underwater structures. The species is expected to expand its distribution extensively throughout the freshwaters of eastern North America. Current estimates suggest that measures to deal with the zebra mussel will cost between $400 million and $500 million each year (Schormann et al. 1990).

Pathogens imported with ballast waters, or via the organisms contained therein, can also introduce diseases against which native species have no defense. As yet we are not aware of any such occurrences in Atlantic Canada. However, this is no guarantee that such invasions are not impending or already in progress, as awareness of disease agents typically occurs only after the agent is established.

There is little doubt that the potential for marine organisms and disease agents to be introduced through the discharge of ballast waters and sediments is an important environmental issue. Ballasting poses particular potential for harm to our coastal areas, where much commercial fishing takes place and where many aquaculture sites are located. Thus it poses an economic threat as well as a threat to human health.

The international traffic in ballast water should also be seen in a broader ecological context. Among the more significant aspects of contemporary environmental change are coastal eutrophication, acid precipitation, anthropogenic contaminants, and depletion of the ozone layer, all of which are known to be increasing at a rate and on a global scale that is unprecedented in human history. It remains to be proven that global warming by the greenhouse effect, largely due to anthropogenic sources, is also modifying the environment on a global scale. Assuming a context of widespread environmental modification, ballast transport can be seen as a fast, efficient vector for rapidly testing novel varieties of organisms for their abilities to colonize the newly transformed environments. Clearly, not all such introductions would be welcome from a human perspective. In

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[1]Ballast water should not be confused with bilge water. Bilge water is composed of water and oil leakages from the machinery spaces and other parts of the ship; these accumulate in the lowest part of the ship, called the bilge. Bilge waters could contain viable micro-organisms but are not considered to pose a serious risk for species introductions.

particular, humans are likely to perceive the introduction of toxic algae to newly eutrophied coastal waters as offering particular potential for harm. In appraising this risk it is well to remember that aquaculture operations are themselves a form of coastal eutrophication and thus offer the potential for close linkage between the transport of inimical species and their exposure to humans.

WHY THE CONCERN NOW?

Although it may seem that all possible introductions of unwelcome species must have already occurred, dramatic changes in global shipping technology and traffic patterns over the past 30 yr have increased the risk of such introductions (Kerr 1990). Ships are faster and follow tighter schedules, thereby increasing the probability that unwelcome species will survive the journeys. Vessels are larger and therefore capable of carrying larger volumes of ballast water. They enter Canadian waters in ballast more frequently; and new routings increasingly feature journeys originating in exotic regions and, as coastal eutrophication continues to develop globally, ships ballasting in areas with waters of an increasingly unsavoury nature.

The creation of new ports can also affect the rate of invasions. At the time of writing, three deep-water harbours were being considered for development in Nova Scotia alone: Kelly Rock Quarry, near Kelly Mountain; Point Tupper Properties at the Strait of Canso; and Digby Neck. Once in use, these areas will be exposed to large quantities of ballast waters and to the risks posed by the organisms and disease agents the waters will inevitably carry.

Testament to the immediacy of the potential threat are numerous recent introductions - some harmful - in ports on the west coast of the United States, in Australian marine ports, and in other regions around the world (Carlton 1985; 1989; Jones 1991). It is not at all unlikely that similarly unwelcome introductions could have recently occurred on the east and west coasts of Canada. What is likely is that they have simply not been detected, as few qualified observers are in a position to notice such changes unless the effects become severe.

Yet the problem cannot be solved just by extending the measures applied to the Great Lakes, for the situation in Canada's coastal regions is significantly different. Ships entering Atlantic ports are larger and can carry larger volumes of ballast water. More vessels, such as large bulk carriers picking up quarry materials in the Maritimes, arrive in ballast. The shipping patterns of the vessels also vary from those of vessels capable of using the St. Lawrence Seaway, resulting in other sources of organisms and different conditions mediating their survival while in transit.

While much remains to be learned about the transport and introduction of species by ballast waters, two conclusions seem clear. First, the threat to Canada's coastal regions is immediate and pressing. Secondly, while efforts to control the problem will be breaking new ground in this country, Canada's actions can be informed by the experience of other countries, such as Australia (Jones 1991) and the United States.

PART I: SUMMARY OF THE APRIL 24, 1991, WORKSHOP

Because of concern that the issues discussed in the preceding section of this report could have serious ramifications for Canadian marine ecosystems, the

Marine Ecology and Ecosystems Subcommittee of the Canadian Atlantic Fisheries Scientific Advisory Committee requested that a 1-d workshop be held to consider the issue of the introduction of inimical species via ballast waters. It was initially hoped that all Canadian marine waters could be considered, but travel constraints prevented attendance by experts on the Pacific and Arctic ecosystems. Accordingly, the focus in what follows is on the implications for Atlantic Canada. Although the implications for other regions of Canada are generically similar, there are important regional differences that deserve further scrutiny in their own right. Therefore, the following summary of the workshop proceedings should be interpreted as being specific to the concerns of Atlantic Canada and as no more than a loose and incomplete guide to concerns requiring attention in other regions of the country.

The purpose of this section is to summarize the principal issues that were identified as important considerations during the workshop; a subsequent section sets out the recommendations for further action that were identified in the course of discussion. Citations lacking a date and publication reference in the bibliography refer to material presented during the course of the proceedings; this material should be regarded as "personal communication" until it finds its way into the formal scientific literature. Where possible, preference has been to cite published sources, even where the material was initially provided during the workshop proceedings.

CONDITIONS MEDIATING TRANSPORT AND INVASION

Typically, vessels take on ballast at or near the point of departure and release it at or in the approaches to the receiving port. However, the ballast water may be supplemented or partially released during the journey. In cases where waters from a number of sources are mixed within the ship, the result can be any combination of salt water, brackish water, and freshwater distributed throughout the various ballast tanks the vessel may possess. These variations in salinity will affect the survival of the organisms in the ballast tanks and their ability to reproduce while in transit, as will other factors, such as the temperatures they are exposed to, the availability of oxygen, and the availability of nutrients and other food sources. Any or all of these factors can change with the introduction of new waters taken on during the journey, as those waters will themselves have characteristics that increase or decrease the viability of organisms. For example, they may contain varying amounts of nutrients or pollutants.

Organisms and disease agents may also reside in the sediments that collect at the bottom of the ballast tanks. These sediments will be of two types: those taken on from the environment when ballast water is loaded (such as silt and sand), and those created within the ballast tanks by the organisms in the water (for example, fecal matter, exuviae, and corpses). Both types of sediments can be found in dedicated ballast tanks and in cargo holds used temporarily for ballast.

After each trip, temporary ballast tanks (cargo holds) are cleaned thoroughly in preparation for the cargo and the sediments are usually dumped overboard - a practice that should be eliminated. However, because dedicated ballast tanks are cleaned less frequently, the materials in them are often from several different sources. These undisturbed sediments provide a prime refuge for a variety of organisms, particularly those whose resting stages (periods during which they are essentially dormant) dramatically increase their ability to remain viable.

The age of the ballast waters and their sediments will vary greatly depending on how long the ship is in transit and how often the waters are replaced. Different types of vessels will carry different amounts of ballast waters. For example, a wood chipper travelling from Japan to British Columbia can typically carry up to 20 million litres, while a collier sailing from Asia to British Columbia might have as much as 100 million litres on board. With volumes as large as these, it can take several days to pump the water on board while the ship is steaming. All of these features, including the configuration of ballast tanks and cargo holds within the ship, will vary with the type of vessel, its cargo, and the practices of the particular crew.

The result is that it is very difficult to generalize about the way marine organisms are transported in ships' ballast. This constrains our understanding of the sequence of events in the dispersal and introduction of exotic organisms via ships' ballast waters and limits our current knowledge to that of ballast on its arrival in the receiving port.

Even once an organism has been introduced into the receiving port, there is a variety of factors that will contribute to or inhibit the organism's viability - for example, the extent to which the new environment is polluted, and the salinity and temperature of its waters. Unless the biological, physical, and chemical conditions are "right," successful colonization will not occur.

THE INTRODUCTION OF DISEASE-CAUSING AGENTS

Ballast waters introduced into a new environment can carry pathogens, or organisms which themselves carry pathogens, that may cause diseases against which native species have no immunity. The carrier organisms that may be associated with these processes will not necessarily themselves be susceptible to the causal agents, but neither will the native organisms in the receiving waters necessarily be resistant; disastrous instances of such introductions (by various vectors) have been reported (Stewart 1991).

Critical to the "successful" invasion of a pathogen are its invasiveness, its vulnerability to factors in the new environment, and its ability to reproduce. But perhaps more important are the ways it interacts with the host species and the environment. As with the introduction of any new species, a successful pathogen invasion will not occur unless all factors are "right."

As yet there are no documented accounts of diseases being introduced to Atlantic Canada through ballast waters. However, awareness of disease agents almost always occurs only after the agent is conspicuously established; and the causes can seldom be accurately defined after the fact.

The following are some examples of introduced diseases and disease agents described at the workshop (Stewart 1991):

- In the mid-1800s a disease affecting the European crayfish was noticed in Italy. While its origins cannot be proven, the theory is that a fungus was transferred to the species by crayfish introduced from America. Although the American crayfish is not susceptible to the fungus, the European species is, and it has since been virtually eliminated from most of Europe. In this case, what was a normal flora for one species turned out to be deadly for another.

- The effects of an introduced species can also be relatively indirect, yet still devastating. For example, the dinoflagellate *Gyrodinium* cf. *aureoleum* is thought to have been recently transported from Europe, where it perhaps was an introduced species, and first became apparent in North America during blooms along the eastern coast of the United States. Large numbers of blue mussels and lady crabs died, fish catches dropped (perhaps because the fish were avoiding the blooms), and people exposed to the bloom waters reported adverse reactions. Although the effects of the dinoflagellate were indirect, it clearly had both an ecological and an economic impact.

- As a further example, salmonids in North America are regularly vaccinated against furunculosis, a highly virulent and fatal disease. Although it is now endemic here, its origin is disputed. One school of thought contends that it originated in brown trout in Germany and was possibly transported to this continent via Great Britain where it was first observed. Others suggest that it originated with rainbow trout or Pacific salmon, and was a relatively new introduction to European waters. Whatever route the pathogen actually took, the point is that analysis in such cases is a matter of reconstruction, not prediction, as awareness of the disease typically occurs only after the agent is established.

RECENT BLOOMS OF TOXIC ALGAE IN ATLANTIC CANADA

In an attempt to monitor blooms of toxic algae in the Atlantic region, the Bedford Institute of Oceanography is conducting a phytoplankton sampling program, described during the proceedings of the workshop (S.R. Durvasula). In part, the purpose is to identify specific blooms and avoid the associated health risks. These include the risks posed to humans through the consumption of fishery products that have themselves consumed the phytoplankton, as well as risks posed to the organisms themselves, especially those captive in aquaculture sites. Another purpose is to identify the associated variables that must be present in order for blooms to occur, thereby enhancing our ability to predict such occurrences.

To date, phytoplankton sampling in Atlantic Canada has shown that the frequency of toxic algal blooms that occur in and around Nova Scotia during the summer has trebled over the past 15 yr (J.S.S. Lakshminarayana). Some recent examples are:

- the 1987 bloom of *Nitzschia pungens* f. *multiseries* in Cardigan Bay, P.E.I., which caused amnesic shellfish poisoning (also known as domoic acid poisoning), with several cases resulting in human death;

- a bloom in 1990 of *Dinophysis norvegica*, which resulted in the first recorded case of diarrhetic shellfish poisoning in North America (S.R. Durvasula); and

- potential problems arising from the import of toxic algae carried by ships visiting the Magdalen Islands (B. Morin). This possibility is now under active investigation, and the results should be known in the near future.

Apart from these examples of local interest in Atlantic Canada, numerous transfers of algal species have been documented on a global scale. Two instances of non-toxic introductions are *Biddulphia sinensis*, transported in the early 20th century from Asiatic waters to northwestern European seas, and *Leptodinium viridis*, thought to have been carried in ships' ballast to Helgoland waters, where it now blooms episodically. Of greater import in the present context are a number of species of two genera of toxic dinoflagellates that have greatly extended their ranges in recent years. *Gyrodinium aureolum*, known to have been confined until 1966 to the Norwegian coast, now occurs throughout northern Europe, causing haemolytic and ichthyotoxic fish kills. Its congener, *G. catenatum*, which is an agent for paralytic shellfish poisoning and was once thought to be from southern California, is now apparently cosmopolitan, having reportedly been found in Portugal, Spain, Japan, and Tasmania (S.R. Durvasula). Three species of the potentially toxic *Alexandrium* genus, *tamarensis*, *catanella*, and *minutum*, are known to have been recently introduced into Australian waters by ships ballasted in Japan (Hallegraeff et al. 1990; Hallegraeff and Bolch 1991). These are some of the best-documented cases where ballast transport by shipping activity is the probable vector. However, there are numerous other instances where the evidence for ballast-water introductions, always circumstantial at best, is less unequivocal but nevertheless likely. In these instances, the ancient Scottish verdict "not proven" is not a reassuring basis on which to predicate the continued health of our coastal waters.

To better understand the risks that dinoflagellates and other potentially toxic algal species pose to Canada's human and marine populations, research must be focused on where the organisms are coming from (for example, are they being introduced via ballast waters?), what conditions are required for their introduction to be successful, and which species are potentially toxic. There are associated sampling problems. For example, getting adequate samples can be difficult, as the blooms may last only 4 to 5 d, depending on circumstances, whereas the typically affordable routine sampling frequency is once per week at best (S.R. Durvasula).

POTENTIAL SOLUTIONS

The problem of controlling the transport of exotic organisms, including disease agents, via ships' ballast can be attacked at various stages: before departure, during departure, during ballasting, after ballasting but before the ship has departed, during the journey, or on arrival. A variety of methods has been proposed, but many appear impractical.

Current procedures for ships entering Canadian waters en route to St. Lawrence Seaway ports request voluntary compliance with a program to control the locations at which ballast waters are discharged. The program was not made mandatory because of the potential for conflict with the imperative that the safety of ships and crews be the most important consideration. Assuming that regulations which violate those considerations would not be respected anyway, a voluntary program seemed to be the best option. Moreover, it should be clearly understood that the guidelines described below are the only ballasting provisions that apply to ships entering Canadian waters, and that these provisions apply exclusively to vessel traffic destined for the St. Lawrence Seaway. At the present time, there are no comparable guidelines in place to regulate the ballasting conduct of any ships entering any Canadian waters other than the St. Lawrence Seaway.

The guidelines are as follows:

- Vessels are requested to perform open-ocean exchange (OOE) outside the continental shelf in waters over 2,000 m deep or, failing that possibility (i.e., for reasons of safety, or for shipping routes that transit the United States coast and never cross such depths), in the Laurentian Channel (the Gulf of St. Lawrence back-up zone) in the area between 61° and 63° W and in water deeper than 300 m. Designation of this zone is based on preliminary evidence of its safety and efficacy, but definitive assessment of this measure remains to be performed; this should be considered a matter of considerable priority. It must be clearly stressed that the availability of this zone, or some comparable alternative, is critical to the guidelines now in place for the protection of the Great Lakes; because the issue may well fall "between the stools" of non-overlapping jurisdiction of the relevant authorities, we particularly flag this as a consideration that must be dealt with as a matter of national importance.

- No ballast water is to be on board on arrival at the Seaway entrance, except for unpumpable ballast water, permanent ballast water, or ballast water not intended for discharge. Note that the last category seems of questionable authenticity.

- As of 1991, no water can be discharged above Québec City. The purpose is to avoid vessels taking on each other's ballast waters - and organisms along with them before entering the Seaway.

Clearly, OOE is the proximate method of choice. It is the cheapest immediate option, and the findings of the most recent St. Lawrence Seaway project indicate that it may be partially effective (Locke et al. 1991). In addition, it is seen as being safe for many types of vessels, sea-state permitting. It is not a complete solution, however, and should be viewed instead as the most immediate and practical partial solution that could quickly be put in effect. Its efficacy appears even less general in coastal waters, because 40,000 t (deadweight) or less is generally perceived as the approximate safe upper limit for OOE. Ballast exchange may put the structural integrity of a ship at risk in many vessels longer than is typical of that tonnage. "Top-loading," involving a partial draw-down of ballast, followed by the flushing action of ballast replacement, is the best that can be safely achieved in many larger ships (Jones 1991). While the ships entering the St. Lawrence Seaway must, of course, be smaller, vessels greatly in excess of 40,000 t frequently visit ports on the Atlantic and Pacific coasts of Canada.

EFFECTIVENESS OF OPEN-OCEAN EXCHANGE (OOE)

A recent study at the entrance to the St. Lawrence Seaway sought to determine the extent to which Canada's guidelines were actually complied with, and whether OOE is effective at eliminating freshwater organisms that would otherwise gain access to the Great Lakes (Locke et al. 1991). The results showed that OOE is at least partially effective in providing protection for the Great Lakes.

Although this is encouraging in itself, the study also indicated that most of the sampled ships took on ballast waters in salt water ports and exchanged them in salt water off Atlantic Canada's coast. While this group poses little threat to freshwater regions of Canada, it appears to pose considerable risk to our coastal regions and is therefore of concern. A significant portion of Seaway traffic - 30 vessels in 1990, representing 15% of all traffic entering the Seaway that was known to be carrying ballast water, had taken on or exchanged ballast in the Gulf of St. Lawrence back-up zone. Of these, 15 reported carrying ballast water previously obtained from the following sources: 4 from American ports, 2 from the Atlantic Ocean, 2 from the North Sea, 3 from the Mediterranean Sea, 2 from freshwater European ports, and 2 from Asian ports. Without direct samples to indicate what these vessels were carrying and what viable biota they discharged in Gulf waters, it is difficult to speculate on the associated risks. But it is obvious that some of this traffic discharged ballast obtained in what could be characterized as "high-risk" locales. Whether any organisms actually survived the event or possessed potentially harmful attributes remains unknown.

In the course of the study, Locke et al. (1991) encountered several obstacles in their attempts to obtain representative samples of the ballast waters and their contents, both because of the design of the vessels and because of practical limitations imposed by the shipping industry. If monitoring is to be effective, weaknesses in sampling procedures need to be addressed. Inconsistencies in the records kept by crew members were also noted, but many of these deficiencies are currently being addressed by the

Canadian Coast Guard. Presumably, inconsistencies in reporting are a transitory problem that can be corrected as the program develops.

CONCLUSION

The consensus of the expert group attending the workshop was that the transport of harmful organisms in ships' ballast waters is a serious global problem, posing a significant threat to the integrity of Canadian aquatic ecosystems. Of particular concern has been the Australian experience of the introduction of toxic algae to aquaculture systems. Atlantic Canada appears equally at risk, as does the Canadian Pacific coast, with the additional complication, unlike Australia, that Canada enjoys continental shelves that are contiguous with a number of political jurisdictions. Control measures that are practical and effective must be identified and implemented, and they must be international in scope. In addition, the measures must be proactive in nature, rather than simply reactive, as the situation is essentially irreversible once a species or disease agent has been introduced.

PART II: RECOMMENDATIONS

The ideal solution to the problems addressed at the workshop would be to have nothing but non-toxic ballast, free of hazardous biological agents, discharged in Canadian waters. See Stewart (1991) for a possible approach to that ideal. But in light of the apparent impracticality of that approach, the following recommendations of the expert group attending the workshop merit consideration. These centre on the question of establishing what is now entering the country and posing risks (Recommendations 1 to 5 below) and, given that some measure of risk is discerned, what practical measures can be taken, both immediately and in the medium term, to minimize the potential harm (Recommendations 6 to 10 below). Although the focus here is on Atlantic Canadian waters, because that was the focus of the workshop, it should be stressed that the considerations raised here apply with equal force to ports on the Pacific coast, although the details may differ somewhat, and that similar considerations may apply to the Canadian Arctic. These latter questions remain to be pursued and should not be neglected.

In effect, a difficult judgement is required. If we accept, on the one hand, that marine traffic is a necessity which cannot be greatly modified without intolerable hardship to society, then the best we can hope to do is reduce the rate of harmful species introductions to some arbitrary level that society may deem acceptable. On the other hand, if the basic premise is to establish some form of global, sustainable system of trade, then more imaginative solutions must be sought. The former premise seeks to reduce the probability of inimical introductions, not to eliminate them; the latter approach holds that the probability must be reduced to zero. These are fundamentally different goals.

The primary recommendations forthcoming from the workshop are the following:

1. The imperative task is to determine what potentially harmful exotic organisms are currently entering Atlantic Canada's coastal waters, or can be expected to do so at some time in the near future. This much requires programs to sample ballast waters, associated sediments, and the chain lockers of ships now entering the region's waters. Although various taxonomic groupings of organisms have demonstrable capacity to elicit harmful effects, particular effort in Atlantic Canada should be directed

toward identifying algal species carried in ballast waters and sediments (including those in resting stages), and toward determining their potential for causing toxic blooms in coastal waters, or contaminating coastal waters with resistant stages that persist in the sediments. The danger that toxic algae might threaten the continued development of a burgeoning aquaculture industry was perceived by workshop participants as the most immediate potential consequence of uncontrolled imports of organisms carried in bulk by ships. These questions cannot be answered by extrapolation from the ballasting characteristics of ships that utilise the Seaway, for there are many differences between Seaway ship traffic and that entering Atlantic Canadian ports.

2. A second imperative is to evaluate the existing Gulf of St. Lawrence ballast exchange zone in order to determine if its waters are in fact inhospitable to colonization by the organisms being exchanged there. The supposition of ultimate lethality to the exchanged organisms, grounded on theoretical understanding of the system, provided the basis for its demarcation. That supposition remains to be verified. Note that in the course of the most recent St. Lawrence Seaway investigations, a database of picoplankton samples was compiled, zooplankton species were identified and enumerated, and ships utilising the exchange zone were identified, together with their sources of ballast. Analysis of this database could potentially identify organisms capable of surviving, or not, in the Gulf of St. Lawrence exchange zone. The continued designation of this zone as a recommended locale for ballast exchange when safe conduct, or lack of opportunity, precludes OOE implies an obligation to ensure its safety and efficacy from the ecological standpoint.

3. Examine the existing database acquired by the Canadian Coast Guard, with particular attention to the ballasting sources of shipping traffic inbound to Canadian waters. This inexpensive form of survey would provide valuable information on the sources and volumes of ballast water and sediments imported to Canadian waters by foreign shipping, and would also provide, in considerable measure, advance information on the hazardous imports of most immediate consequence. The primary utilities of such data would be: a) to assist in identifying areas of the globe that are thought to pose the greatest risk for hazardous imports of biota to Atlantic Canada, and b) to provide a general profile of the types of shipping that utilise Atlantic Canadian waters, together with their associated ballasting characteristics. Similar considerations, as noted above, apply to Pacific and Arctic jurisdictions within Canadian waters, but such studies should be tailored to the specific nature of traffic entering those areas. Research of this kind is inexpensive and has provided information of substantial value to the Australian authorities that pioneered its use.

4. Compile a list of taxonomic groups and disease agents most likely to present a risk if they are introduced into Canadian waters via ships' ballast. In particular, the focus should be on potentially toxic phytoplankton species, as some expertise in this area is already available in Nova Scotia and because these are the species that have caused the most prevalent problems in other parts of the world to date. Habitats particularly susceptible to invasions should also be identified. Note that this approach proved useful in Australia.

5. Investigate the role of chain lockers, which provide a haven for species that attach themselves to the chain and anchor while they are deployed. The chains, and the lockers where they are stored in transit, could then act as vectors for the import of unwanted foreign organisms. In Australia, studies have shown that anchor chains and chain lockers are

indeed a problem in this respect. No comparable studies have been made to date in Canada.

6. Improve access to ballast waters for the purpose of sampling. Current ship design does not lend itself to adequate sampling of ballasted organisms, making it often difficult and sometimes dangerous to determine what organisms are being imported. This need should be drawn to the attention of the international shipping community, presumably through Canadian representation to the International Maritime Organization of the United Nations. Unlike the short-term solution of OOE, this is a medium-term approach. Note that although this consideration is presumably predicated on the lifetime of vessels now in operation, as retrofit is not a likely option, this does not mean that it is rational to defer early action.

7. Determine safe, practical, and economical methods for decontaminating or otherwise ensuring the safety of ballast water imports, recognising that such measures are unlikely to be accepted and implemented by the shipping industry unless they are equitably applied and generally acceptable to what is already an economically troubled industry. Numerous suggestions have been made, ranging from the wildly impractical through to the possible. Hard facts are lacking, although the International Maritime Organization and the Canadian Coast Guard have recently taken steps to address the issue, as have Australian authorities. Canadian agencies such as the Department of Fisheries and Oceans also need to be involved in the matter, in order to ensure that essential expertise within associated government departments is not overlooked. Again, this is a medium-term solution to a serious problem; because it is not a short-term response to a crisis is not an excuse for inaction.

8. Integrate research-and-control efforts with those of the United States - if for no other reason than to keep the Canadian industry competitive. Note that current American legislation (the Glenn Bill) explicitly requires coordination with Canada in the course of executing a detailed schedule of targets. To do this will require that the affected Canadian authorities make a concerted effort to integrate their activities in a manner not ordinarily required.

9. Determine whether the ballast water exchange zone should be extended beyond the 200 mile-limit (the EEZ), as has been done by Australia and is being contemplated by the United States. If we follow the United States in adopting this measure, what supplementary regulations concerning the Americas must also be adopted? For example, ships that originate from ports on the east coast of the United States, or from the Caribbean or South America, may never leave coastal waters before entering Canadian jurisdiction. In this context, it is relevant to note that a toxigenic strain of cholera recently reported in fish and shellfish in Mobile Bay, Alabama, has been traced to the ballast water of foreign ships (Anonymous 1991). This discovery has intensified the pressure on United States' authorities to protect the country's territorial limits, either by the adoption of voluntary guidelines, as recommended by the United States Coast Guard, or by regulation, as has been advocated by other sectors. Because the action of United States' authorities has immediate implications for shipping transitting our waters, Canada should place itself in an informed position so that it can respond effectively to American initiatives.

10. Increase awareness among the public through the publication of materials intended for audiences of informed laypeople. Increase the exchange of relevant information among scientists working with different groups of organisms, with different habitats, and in different regions.

All of the foregoing measures, or some affordable mix of these as resources warrant, are strongly recommended for action. The problem will not wait, nor will it go away.

CONCLUSION

Clearly, there is ample justification for considering that the current traffic in potentially harmful species, carried in ships' ballast water and associated sediments, poses a serious risk to Canadian ecosystems. The prudent path is to develop a preventive program, profiting where possible on the experiences of other jurisdictions (e.g., Australia) in order to devise institutional, scientific, and monitoring roles adequate to meet the perceived risks. Such a program should also be introduced before the situation shifts to one of responding to problems, rather than preventing them. Preventive measures, if wisely devised and skilfully implemented, are potentially far less expensive than remedial action taken after an unwanted species has been introduced.

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APPENDIX 1: WORKSHOP PARTICIPANTS

The Risk to Canada's Marine Resources of Species Introductions
Carried in Ships' Ballast Water

April 24, 1991
Main Auditorium
Bedford Institute of Oceanography (BIO)
Dartmouth, Nova Scotia

Alexander, R. - Department of Fisheries and Oceans
Bugden, G. - Department of Fisheries and Oceans
Carlton, J.T. - Williams College
Cutting, R.E. - Department of Fisheries and Oceans
deFreitas, T. - National Research Council
Durvasula, S.R. - Department of Fisheries and Oceans
Fleck, T. - Ship Safety Branch, Canadian Coast Guard
Gordon, D.C. - Department of Fisheries and Oceans
Kerr, S.R. - Department of Fisheries and Oceans
Lakshminarayana, J.S.S. - Faculté de Science, Université de Moncton
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Smith, P.C. - Department of Fisheries and Oceans
Smith, T.E. - TES Technical Services
Sprules, W.G. - University of Toronto
Stewart, J.E. - Department of Fisheries and Oceans
Sweeney, R. - Department of Fisheries and Oceans
Worms, J. - Department of Fisheries and Oceans

APPENDIX 2: WORKSHOP PROGRAM

The Risk to Canada's Marine Resources of Species Introductions
Carried in Ships' Ballast Water

April 24, 1991
Main Auditorium
Bedford Institute of Oceanography (BIO)
Dartmouth, Nova Scotia

0900-0910 h: Introduction (S.R. Kerr, BIO)

0910-1000 h: Ballast-water transport of marine organisms: A global overview of the existing potential for harm (J. Carlton, Williams College, Mystic Seaport, Mystic, Conn.)

1000-1010 h: Coffee break

1010-1100 h: Ballast-water transport of inimical organisms: Current research results from the St. Lawrence Seaway investigations (W.G. Sprules and A. Locke, University of Toronto, Toronto, Ont.)

1100-1120 h: The potential for global traffic in pathogens via ships' ballast (J.E. Stewart, BIO)

1120-1140 h: Recent observations of toxic dinoflagellate blooms in Atlantic Canadian waters (S.R. Durvasula, BIO)

1140-1200 h: Risks of exotic species introductions in the Gulf of St. Lawrence, and transport of toxic algae in the Magdalen Islands (B. Morin, IML, P.Q.)

1200-1220 h: Shipping is an essential economic activity: What is the prudent course of action? (S.R. Kerr, BIO)

1220-1330 h: Lunch break

1330-1430 h: Discussion: Open forum for attendees to express concerns, for a maximum of 3 min each. If additional time is required by any participant, please arrange this beforehand with the organizer, S.R. Kerr. Hand-outs in the form of hard copy would be a welcome supplement for this part of the exercise - these would help to ensure that cogent points are not overlooked in the final report from the workshop. The time allocated for this part of the exercise can be somewhat flexible, depending on the wishes of participants.

1430-1700 h: Formulation of recommendations for action: What must/can be done to eliminate the risks of ballast water imports to Canadian marine waters? In particular, the end result sought from this open discussion period will be a concrete set of recommendations, to be set in report form as quickly as possible, outlining how Canada should respond to identifiable needs to protect its marine resources.

Topics for Consideration in the Afternoon Session:

The morning session is primarily focused on information, to ensure that all participants are informed on the problems and issues that require urgent attention. The primary focus of the afternoon session is on actions that may be required in order to resolve potential problems in Canadian coastal waters. The topics listed below are set out in order to focus discussion, not to stifle it; other points of view are welcome.

1. How does the ballast-water vector affect the ability of habitat/ environmental managers to meet their responsibilities, relative to the imperatives of the shipping industry?

2. What do we need to know about the problem, with particular respect to marine ecosystems, that is not known now?

3. How can Canadian response to the issue in marine regions best be coordinated with scientific and regulatory initiatives now being undertaken elsewhere - e.g., in the Laurentian Great Lakes in particular, and in the United States and other jurisdictions in general?

4. In concrete terms, what useful investigations can be proposed to meet the needs identified above, with particular emphasis on Canadian marine waters?

5. Specifically, consider the following "straw man" for discussion purposes.

   a) The most pressing priority is to consider the "safety" or otherwise of the "back-up" ballast water exchange zone currently designated in the Gulf of St. Lawrence for shipping which is destined to enter the Seaway and which cannot safely exchange ballast water on the high seas. Question: Does current practice merely transfer a Great Lakes problem to the Gulf, or does it represent a prudent improvement on an earlier lack of measures?

   b) The next priority is to evaluate the risk to Canadian aquaculture enterprises of unwanted species introductions carried in ballast water, and of potential toxic dinoflagellates in particular.

   c) A further priority is the question of ecological harm potentially caused to natural aquatic systems by the introduction of exotic organisms.

   d) For the sake of argument, it may be considered that the prudent course of action is to request (or require?) that all foreign shipping entering Canadian waters exchange ballast on the high seas prior to entry. Comparable guidelines exist at the moment for shipping entering the St. Lawrence Seaway and Australian waters, and may soon be implemented for United States marine waters. Do we have the evidence necessary to support such a request (or regulation)? If not, what evidence might be considered adequate?