BALLAST WATER EXCHANGE:

EXPLORING THE FEASIBILITY OF ALTERNATE BALLAST WATER EXCHANGE ZONES IN THE NORTH ATLANTIC

Report from a Workshop held
October 27 & 28, 2003
Halifax, Nova Scotia

edited by
Judith Pederson, Massachusetts Institute of Technology

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Acronyms

ABWE	alternate ballast water exchange
ABWG	Atlantic Ballast Working Group
ABWEZ	alternate ballast water exchange zone
ANPRM	Advance Notice of Proposed Rulemaking
BIS	Block Island Sound region
BW	ballast water
BWE	ballast water exchange
CMAC	Canadian Marine Advisory Council
CSA	Canada Shipping Act
DOD	Department of Defense
DWT	deadweight tonne
EEZ	Exclusive Economic Zone
EKE	eddy kinetic energy
ETV	Environmental Technology Verification program
GIS	geographic information systems
IMO	International Maritime Organization
MARAD	U.S. Maritime Administration
MEPC	Marine Environmental Protection Committee
NANPCA	Nonindigenous Aquatic Nuisance Species Convention and Control Act (1990)
NAO	North Atlantic Oscillation
NAS	Nuisance Aquatic Species
NEANS	Northeast Aquatic Nuisance Species Panel
NISA	National Invasive Species Act (1996)
NOBOB	no ballast on board
NPDES	National Pollution Discharge Elimination Systems
ppt	parts per thousand
PSP	paralytic shellfish poisoning
SERC	Smithsonian Environmental Research Center
TAG	Technical Advisory Group
TBT	Tributyltin
USCG	U.S. Coast Guard
USEPA	U.S. Environmental Protection Agency

Foreword

Ballast water is a major vector for introducing marine and freshwater bioinvasions. Although the problem was eloquently identified by Charles Elton in his 1958 book, *The Ecology of Invasions by Plants and Animals*, it gained national and international importance with the introduction of the zebra mussel (*Dreissena polymorpha*) into the Great Lakes. Several actions were taken to reduce or prevent ballast water invasions. The International Maritime Organization (IMO) recommended that vessels have ballast water management plans, and, in 1993, provided guidance on ballast water management and a reporting form for monitoring ballast water exchange and treatment. The current Treaty, adopted by the IMO in July 2004, strengthens the voluntary guidelines (see Appendix I). The U.S. Congress passed the Nonindigenous Aquatic Nuisance Prevention and Control Act in 1990 and the National Invasive Species Act of 1996 that empowered the U.S. Coast Guard to enforce mandatory reporting and mandatory ballast water exchange for vessels entering the Great Lakes and Hudson River. Similarly, in 2001 the Canadian Ballast Water Guidelines were adopted to address this issue, following on earlier actions that were taken to prevent, reduce, or minimize introductions from ballast water.

Based on best available scientific knowledge at the time, voluntary guidelines in Canada were adjusted in 1999 to cover both the East and West coasts of North America to complement the mandatory and voluntary guidelines for the Great Lakes and Canada. The intent of the U.S. and Canadian laws and guidelines was to coordinate and complement monitoring and management activities to minimize introductions from ballast water released into waters shared by both countries. Policy makers in both countries recognized that it would be necessary to revisit these recommendations and develop better guidance based on scientific information. A critical component in reviewing the issues from a broader perspective was the inclusion of other stakeholders in the discussion. Stimulated by the success of the Great Lakes Region where the U.S. and Canada actively collaborate on managing ballast water, a comparable group was organized for the northeast Provinces of Canada. The Atlantic Ballast Working Group (ABWG) was formed in 1999 and has been actively involved in improving the quality of scientific data.

Based on the ABWG's recommendations, Transport Canada's Regional Director, William Scott, approved funding for research and development projects to address several questions raised by the ABWG. Two areas receiving support were (1) sampling ballast water from ships arriving at Canadian ports and (2) identifying the shipping routes and vessel traffic volumes in the North Atlantic Region. Transport Canada has a keen sense of urgency about these issues and need to address this regional problem. In 2001, the Northeast Aquatic Nuisance Species (NEANS) Panel was established as a regional committee (with Canadian members) of the U.S. Fish and Wildlife Service Aquatic Nuisance Species Task Force. A NEANS ballast water committee focuses on U.S. and Canadian maritime ballast water issues and is active in promoting reduction or prevention of ballast water introductions.

In September 2002, the first regional ballast water workshop for the North Atlantic was convened in Boston, Massachusetts, with policy makers, shipping industry representatives, state and federal agency representatives, scientists, and other stakeholders in attendance. Of the several recommendations for future action, the need to revisit the voluntary guidelines (recommended in 1999) was a high priority. This workshop, held in Halifax, Nova Scotia, in October 2003, evolved from regional concerns about the adequacy of current ballast water management approaches raised by working groups at the initial regional workshop. Although several issues were identified, this workshop focuses on the request to review and clarify the scientific basis for identifying alternate ballast water exchange zones.

The Steering Committee recognized early on that we would need the insights of all stakeholders and their collaboration to reach consensus on the difficult and challenging issues inherent in making difficult decisions and forwarding policy recommendations jointly to Transport Canada and the U.S. Coast Guard. The spirit of cooperation present at the workshop is evident in the consensus statement on potential alternate ballast water exchange zones. Both Canada and the U.S. are moving forward with ballast water regulations (the U.S. Coast Guard finalized rules in July 2004, see Appendix II; the current Canadian Guidelines and Annex 5 comprise Appendix III).

Although the workshop and its recommendations have no jurisdiction, we view the interest and efforts of the ABWG, NEANS, the maritime industry, environmental groups, and participation by Transport Canada and the U.S. Coast Guard as supporting the broader activities. The workshop has provided a venue for highlighting differences that are unique to this region. We are optimistic that the recommendations will be integrated into future policy decisions within the North Atlantic region.

Mike Balaban, Co-Chair
Judith Pederson, Co-Chair

September 16, 2004

EXECUTIVE SUMMARY

Introduction

Loading and discharging of ballast water is fundamental to safe shipping yet it poses largely unknown risks and has potentially hazardous consequences to coastal and marine ecosystems. Nonindigenous aquatic organism and pathogen invasions via ballast water discharge are recognized as a serious problem threatening global biological diversity, including renewable resources, and human health worldwide. Mid-ocean exchange of ballast water remains the most accessible and cost effective method to stem waterborne nonindigenous species introduction. Treatment of ballast water to eliminate or reduce risk of invasion is the preferred option and mid-ocean exchange is viewed as an interim and not very satisfactory solution. While a number of technologies are being tested onboard ships, these tests are still preliminary and on a limited scale. Where mid-ocean exchange is not possible due to weather and related safety issues, use of an Alternate Ballast Water Exchange Zone (ABWEZ) in more sheltered waters is sometimes available to shipmasters.

Although the legal structure is different in Canada and the U.S., both countries are striving to minimize or prevent ballast water introductions. Canada continues to revise guidelines (referred to as Annex V, Ballast Water Procedures for Vessels Proceeding to Ports on the East Coast of Canada, Draft 21) through a Canadian Marine Advisory Council (CMAC) with members from government, non-governmental organizations, industry, the scientific community and where possible, the U.S. Coast Guard (USCG). Transport Canada, Atlantic Region is responsible for the development of Annex V (Appendix III; see also comments by T. Morris, Appendix IV). The USCG has authority under the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 and the reauthorized National Invasive Species Act of 1996 to promulgate rules if voluntary guidelines are not being met. Because submission of required ballast water reporting forms is low, new rules are proposed to increase compliance and to require ballast water treatment of coastal traffic vessels. The final Rule, which became effective July 28, 2004, requires all vessels operating outside the U.S. Exclusive Economic Zone (EEZ) to exchange ballast water mid-ocean, retain ballast water on board, or use a USCG-approved alternative technology. Each vessel must have a ballast water management plan following the International Maritime Organization (IMO) guidelines and vessels operating within the EEZ must follow practices that minimize introductions (see summary by B. Patnaik, Appendix V).

Other efforts are also underway to improve compliance with existing regulations. Both Transport Canada and the USCG support identification of scientifically defensible and viable ABWEZ for the Atlantic Region. In Canada, the CMAC endorsed a research-oriented, precautionary approach. Transport Canada funded a research program carried out over 1999 to 2003 that focused on four main elements:

- Documenting shipping patterns and ship calls at Atlantic Canadian ports;
- Sampling and analyzing ballast water of ships from foreign destinations calling on ports throughout Atlantic Canada (Appendix VI);
- Studying dispersion and circulation patterns of east coast waters (Petrie et al. this volume); and
- Preparing geographic information system (GIS) maps of ballast water exchange data in Atlantic Canada (Kelly, this volume and Appendix VII).

In addition to these studies, other research in the Northeast Atlantic focuses on understanding the physical and biological oceanography of the area, developing models, identifying vectors of marine introductions, and assessing risks. Coastwise traffic moves goods primarily to the south and ballast water to the north, but coastwise traffic is exempt in the regulations. The Shipping Federation of Canada has adopted a Code of Best Management Practices for the

Great Lakes (Appendix VIII), but coastwise traffic is not included in the Code.

The focus of this workshop was on identifying alternate ballast water exchange zones that presented the least risk to coastal ecosystems, specifically for the coastwise traffic. The Steering Committee's intent was to integrate scientific information with issues and concerns of the shipping community, environmental groups, and other stakeholders in the process of exploring potential alternate regions for ballast water exchange. Based on vessel traffic within the North Atlantic, a region from Cape Hatteras to Atlantic Canada served to define the area of greatest concern. The workshop brought together scientists, maritime industry representatives, and policy makers as presenters of background for the participants. Working groups were formed to discuss each general topic and develop a statement reflecting their perspective on suitable alternate ballast water exchange zones. Each working group prepared statements (or highlights) that were presented to the participants for drafting a consensus statement. This joint consensus statement from the larger group discussion was reviewed by all, and revisions incorporated. It serves as a working document for consideration within the respective agencies and between the two countries. The technical presentations by speakers and a summary of a general discussion at the end of the first day follow the consensus statements and individual working group comments.

Background

The North Atlantic region consists of diverse habitats and covers three biogeographic areas, the Boreal, Acadian, and Virginian Biogeographic Provinces, and it is characterized by rocky coasts in the north and large wetlands and sandy areas in the south. Coastal traffic is characterized by ships transporting goods (e.g., petroleum products and gypsum) to southern ports and returning with ballast water, although there are exceptions. Some voyages are of short duration and may not have sufficient time for complete ballast water exchange. General characteristics of the Gulf of Maine and Mid-Atlantic Bight that cover the U.S. portion of the region were summarized by Beeton, et al. (1998) and provided background information for the participants. Ballast water exchange in the region was summarized in a white paper by Pederson and Fertig (2004; Appendix IX).

Physical Oceanography of the North Atlantic

The physical oceanography of the North Atlantic is complex in nearshore waters and in some regions the topography creates unique and unusual currents. The continental shelf tends to be broad in the Gulf of Maine and northern regions with deep channels of 250-300 meters and tidal ranges of 3 to 6 or more meters. The Gulf of Maine is a semi-enclosed body of water and this factor probably contributes to its high productivity. The waters that enter through the Northeast Channel may sweep into the Bay of Fundy before turning south and moving as a coastal current toward Massachusetts Bay, Georges Bank and the Great South Channel.

Townsend describes these flows and describes why currents move around Georges Bank in a clockwise flow. He stressed that in the Gulf of Maine, everything is connected to everything else. Townsend used the example of paralytic shellfish poisoning (PSP) to illustrate the complexity of the area's currents and how these influence coastal outbreaks of *Alexandrium* sp. Currents in the Gulf of Maine reflect variations in the cold Labrador currents, the position of the Gulf Stream and warm-core eddies, and fresh water flows from rivers, as well as the North Atlantic Oscillation. Data from satellite images and research cruises highlight the complexity and the challenges in predicting phytoplankton blooms, PSP events, and other phenomena in the Gulf of Maine. There are areas along the Nova Scotian coast where waters are continually mixed from depths of 70 m to the surface. One feature of the coastal current important to PSP events that has implications for ballast water discharge is the buoyant coastal current nearshore, which acts as a barrier to particles' reaching shore. It is possible for particles to reach shore by submergence (as might occur during vertical migration of plankton). These features are relevant to the focus of this workshop - namely identifying low risk areas suitable for alternate ballast water exchange.

Smith presented studies of his colleagues that focused on currents in the North Atlantic and examined specifically the risks associated with ballast water exchange at various locations offshore. The studies were motivated by a desire to examine offshore ABWEZ for Transport Canada. After summarizing what was known about currents in the North Atlantic in 2000, additional drifter studies were conducted supporting the observed southwestward movement of currents over the shelf and slope, punctuated by eddies. Smith's colleagues developed circulation models (verified by observations) that illustrated strong annual circulation patterns, but not horizontal dispersion. Other studies show a strong offshore kinetic energy gradient implying horizontal dispersion that would be important in evaluating risk of ballast water releases. Similarly they estimated vertical diffusivity and estimated that it would take 1-2 weeks to mix to a depth of 50 m. These data were used to assess risk assuming that a 10-20 day window of potential surface layer transport was of interest. The offshore region was divided into three or five sub-zones based on isobath and historic markers. They estimated both residence times and transit times to the coast and found that outside the 2500 m isobath the probability of passive particles reaching the shore was virtually zero, whereas it ranged from 4% to 8% in isobath depths of 200 m. Thus, they concluded that the safest area is outside the 2500 m isobath, with the caveat that transit times and dilution vary considerably in sub-zones closer to the coast.

O'Donnell highlighted the need to understand cross-shelf transport south of the Gulf of Maine as a very important issue for identification of ABWEZ. He used the example of salinity distribution in Long Island Sound (LIS) to illustrate how tides and flows are important in explaining salt concentrations in New York Harbor (NYH) and western Long Island Sound. In this case the saltier water flows from LIS to NYH via the East River and fresh water returns, resulting in western LIS being fresher than would be predicted. Thus, a ballast water regulation that only focused on the Hudson River would not be appropriate. Circulation along the Atlantic coast is measured by oxygen isotopes, fresh water flow from the Connecticut River, and by using radar to measure surface currents. O'Donnell also described tracking drifters by satellite as another way of measuring circulation. He summarized work that looked at all the data available on salinity and temperature across the shelf, and showed that for both temperature and salinity there is stratification that carries much of the shelf break waters during the summer, but it is less strong in the winter months. To review these data in the context of ballast water, more information on cross shelf transport is needed. For that, data from drifters are helpful. These data support the observation that cross shelf transport is higher in the summer than in the winter, i.e., the stratification makes the water more "slippery". Two approaches that are being used to estimate cross shelf transport including monitoring radioisotope distributions and releasing dyes and following dispersion. Both have been done in the LIS area. Measurements provide an estimate of spreading and suggest this occurs on the order of 10-20 km, which is small compared to the shelf width. O'Donnell noted, however, that there are few measurements for this area and fewer still in areas near estuaries where transport may occur at high rates. These data also do not account for the behavior of organisms that migrate vertically in the water column.

Ballast Water in the Northeast

Several papers focused on ballast water exchange in New England and Canada. They synthesize data collected from the mandatory reporting forms (both in the U.S. and Canada) and models to identify where materials discharged from vessels could reach the coast for different times of the year. In addition, geographic information system (GIS) maps were constructed from data that identified locations where ballast water exchange was initiated and ended for vessels entering through the EEZ. Analysis of shipping patterns in New England (including New York) suggests that about 25% undergo ballast exchange, with bulk carriers and tankers exchanging the most volume. Arriving vessels are represented nearly equally as being of domestic or foreign origin. Hines presented a paper co-authored with colleagues in which they estimated approximate exchange volumes from domestic carriers. Domestic discharges are likely to have higher concentrations of plankton that through repeated discharges may be more likely to survive. This work suggests that coastal traffic should be more carefully monitored and address these concerns.

De Lafontaine introduced his paper by reviewing the decision to use ballast water exchange as an interim treatment for minimizing and reducing introductions from ballast water. He noted the risks, to vessels, human safety, and the ecosystem associated with inefficiencies of ballast water exchange. He discussed this in the context of the history of the designation of the Laurentian Channel as an alternate ballast water exchange zone, designed initially for ships entering the Great Lakes. Much thought and scientific review was part of the decision making process. Nonetheless, concern for increased rates of introduction to the Channel areas continues for vessels with marine ballast that exchange or clean their tanks in this region. De Lafontaine briefly reviewed alternative ballast water treatment methods, and highlighted some of the newer approaches that may be economical, environmentally sound, and reduce or prevent introductions.

Simard presented the results of a study where she and her colleagues (Gilbert and Saucier) assessed the risk of using the Laurentian Channel as an alternate zone for ballast water exchange. They developed a 3-dimensional model that simulated conditions of 1986-1987, which has a resolution of 5 km and 73 vertical layers. Some of the data in the model include currents, temperature, salinity, turbulence, and ice thickness and concentration, as well as surface meteorological forcing variables. They ran model simulations for zooplankton and phytoplankton during periods of April to October (zooplankton) and April to November (phytoplankton). They also simulated flushing of surface particles in the Cabot Straits. The results indicated that several islands are at risk from phytoplankton inoculations, but a spring freshet will wash them downstream. Simulated zooplankton inoculations also indicate entrainment of organisms. Flushing simulations suggest surface particles could be quickly flushed from the alternate zone, but it is possible that these organisms could reach the coastal areas outside the Cabot straits. The recommendation is to not exchange high salinity ballast in the Laurentian Channel region as there is less risk of species surviving in the fresh waters of the Great Lakes. The study also notes that there is less risk during exchange in winter months and they recommended a precautionary approach in using this and other ABWEZ.

Geographic information systems (GIS) have provided insights not readily gained from data sheets. Kelly used geo-referenced reporting data (year 2002) from vessels conducting open water ballast exchange to map vessel movement tracks. Using GIS, he plotted the starting and ending points of ballast exchange based on reports submitted to Transport Canada. Using other ballast water management information, Kelly's models and GIS analysis allowed estimates of volumes exchanged and identified preferential routes used by traffic approaching the Canadian Exclusive Economic Zone. Zones of dispersion could be estimated to provide insights about regions that may have ballast water reaching nearshore coastal areas.

Shipping Industry Perspective on Ballast Water Management

Maritime trade contributes a value of hundreds of billions of dollars in Canada and the U.S., based on 2002 statistics. Of the 62 million tons in Canadian maritime shipments, over half was moved from the Canadian coast to the U.S. Atlantic coast. Shipping is essential to several industries and creates jobs throughout the region. Langevin reviewed the Shipping Federation's perspectives on ballast water management. She identified the concerns for coastal traders that are in partial ballast and will need to top off in 2-3 ports as they continue north. Others discharge remaining unexchanged ballast in East

Coast ports when they do not have a return cargo. The shipping community is looking for standards and treatment systems that are safe, efficient, non-hazardous, simple to operate, and inexpensive. Ballast water exchange requires extra hours, and depending on the distance can range from a few to over 40 hours. There are costs associated with the deviations, approximately $1300 /hour, which translates into $26,000 for a 20 hour deviation. Requiring a change in ballast exchange in one route is likely to result in cargo being transferred to another route. Langevin recommended that ABWEZ be within 50 nautical miles or less from shore, greater than 500 miles long, and apply to vessels originating south of the Chesapeake.

Metcalf highlighted similar shipping community concerns from the U.S. perspective. She noted the many factors that influence solutions to ballast water management and stressed the importance of a collaborative effort by all stakeholders. Metcalf stressed three areas of active involvement by her organization (Chamber of Shipping of America) - with international and regional groups developing standards, with briefings for legislators, and with the industry highlighting the seriousness of the problem through education. Metcalf focused on the costs of alternative treatment installation, ongoing operation and maintenance, and retrofitting. How these costs weigh against ballast water exchange will be an ongoing discussion. She suggests implementing incentive programs to encourage compliance with new approaches. One area where there is concurrence with the shipping industry and regulators is the need for a universal set of standards. State by state and country by country standards will only complicate efforts by vessels to comply.

Risk Assessment Systems

Risk assessment approaches vary considerably and have an impact on the outcome. Locke reviewed the science of risk assessment, provided an overview of the approaches that are used or in development, and used a case study to illustrate applications and outcomes. Risk assessment combines information, assumptions, uncertainties, and data into a process to assess environmental impacts. She identified the strengths and weaknesses of blanket or broad-based approaches with those using more detailed data, but requiring frequent analyses for specific occasions. Regulatory agencies are more likely to adopt a blanket approach, although in Australia they have a risk-based management approach that applies to all ships and requires details on ballast, species of concern, environmental conditions, frequency of occurrence and other risk-based factors. Locke compared two approaches used to evaluate risk associated with ballast discharge in the Laurentian Channel. The circulation study (see Gilbert et al., this document) used plankton and assumptions about the length of time particles would be retained in locations within the Channel areas and concluded that the Cabot Straits were acceptable low-risk areas for discharge. The traffic patterns approach used by RNT Consulting (see Appendix X) applied a probabilistic risk assessment procedure to a larger area that included the Cabot Straits. They concluded that the risk to the Laurentian Channel was low at ~0.5%, but there were no uncertainty analyses and no confidence limits included with their assessment. Locke identifies elements of good risk assessment that include being quantitative, uncertainty estimates, identification of invasion success, application of an iterative process to incorporate new information, and a need to keep it simple for stakeholders. Good risk assessment approaches highlight assumptions and identify areas of uncertainty as points of discussion.

General Discussion

The sessions ended with a general discussion of the presentations and how the information applied to identifying feasible ABWEZ. Patnaik moderated the dialog among the audience and speakers. There were several points highlighted.

1. It was suggested that organisms are released throughout the exchange process that Kelly mapped, and perhaps currents could be superimposed to give a better sense of seasonal and interannual effects on the exchange process.

2. It was noted that risk assessment requires much more information than currently is available. A lively discussion followed with various issues raised. Even with limited data, development of predictive models using physical oceanographic information has value. The counter argument was that almost none of the invasive species (e.g. green crab, zebra mussels) were predicted. Others suggested that we should narrow our focus to coastal traffic and assume that ships entering the EEZ have exchanged ballast and minimized that risk. If zero risk is the goal, then all organisms should be killed or ballast exchange prevented in nearshore areas.
3. The discussion moved on to address low and high risk outcomes and how these might lead to judgments that did not prevent invasions.
4. The discussion of hull fouling and the need for ballast altogether were also topics of discussion. The number of invasions associated with hull fouling is poorly documented, but remains a concern. The banning of tributyltin (TBT) may increase introductions from this vector. The IMO Treaty calls for Enhanced Survey Inspections. The IMO has recently increased the types of vessels that are required to undergo enhanced survey inspection as well as dry-docking approximately every five years. This may lessen hull fouling events.
5. Permanent ballast as dead weight of ships and the potential to design ballastless vessels were also raised as opportunities to minimize introductions from ballast water. This remains a topic for the future and was a stimulating end to the discussions of the day.

Working Groups and a Consensus Statement

The second day of the workshop, three working groups were formed to propose alternate ballast water exchange zones. The groups were divided by general interest areas - maritime industry, policy and regulatory, and scientific working groups. The industry group focused on minimizing economic costs and meeting regulatory requirements; the policy group identified the need for bilateral agreements using best knowledge available; and the scientists working group focused on minimizing risk of onshore invasions using currents, cross shelf transport and biology of organisms. A combined consensus statement was prepared based on the working group recommendations and discussions with the full assembly of participants. The areas of strong agreement and areas omitted from some statements or where there was differing viewpoints were identified and discussed in the closing session. The goal was to use the collective information of the participants and determine if there are areas where risks associated with ballast water discharge are acceptable to endorse an ABWEZ. The following statements highlight the consensus reached:

1. Based on available data (e.g., currents and cross shelf transport of particles), the slope break was identified as potential alternate ballast water exchange zones, especially for coastwise traffic, because currents were like to carry discharged particles away from shore.
2. Discharge within other regions have a higher risk for particles reaching shore than those discharged at the shelf break.
    a. Gulf of Maine vessels travel short distances, do not reach the slope break, and have short travel times. An area within the Gulf of Maine was identified as a potential location for discharge based on where currents are more likely to exit.
    b. Use of the Laurentian Channel as an alternate exchange zone is complicated by jurisdiction and its current designation as an ABWEZ for the Great Lakes. A review of its continued use and other options is recommended.
    c. Two areas identified as sensitive to invasions and recommended for no discharge are Georges Bank, and the Sable Island and Gully area that has been designated as a Marine Protected Area.
    d. There are restrictions in place around the Great South, Northeast, and Fundian Channels that are included in the recommendations.

These recommendations will be shared with Transport Canada, the US Coast Guard and the states and provinces bordering the region. Although new regulations at the state or province level are not anticipated, it is recommended that bilateral recommendations emerge as policies, to be implemented as international and national regulations are enacted.

CONSENSUS-BASED PROPOSED ALTERNATE BALLAST WATER EXCHANGE ZONES

This two-day workshop was designed to develop a consensus statement on the feasibility of alternate ballast water exchange zones in the North Atlantic. The area of focus was from Cape Hatteras through the northern ports of the Maritime Provinces. Coastal traffic is a significant component of vessel movement in this region with oil, gypsum and other goods frequently carried southward and vessels returning with ballast northward. Environmental concerns for the introduction and spread of marine invasive species is growing with the presence of an aggressive, invasive sea squirt, *Didemnum* cf. *lahillei*, on Georges Bank, the economic costs of a solitary sea squirt, *Styela clava*, to aquaculture in Prince Edward Island, and predatory whelk, *Rapana venosa*, in Chesapeake Bay. The goals of the workshop were to review the physical and biological oceanographic data, examine traffic patterns and ballast water management practices, gain insight into the maritime industry perspective, and review risk assessment and management approaches. Together this information was used to develop a statement on the feasibility of alternate ballast water exchange zones.

Major stakeholders were invited to attend including the marine industry, scientific community, policy makers, regulators, and nongovernment organizations. Three working groups, Maritime Industry, Policy, and Scientific, were formed to draft a statement on the feasibility of alternate ballast water exchange zones from each Working Group's perspective. Each Working Group's statement is presented after the General Workshop Consensus Statement.

The General Consensus Statement was drafted from comments and discussion of the full body of participants who were reconvened after the working group sessions. The discrepancies and omission that exist in the individual working group statements were discussed fully and consensus reached. Thus, the General Consensus Statement is presented first because it reflects the thoughtful comments in an acceptable language of all participants.

Since this consensus statement was prepared, two other major actions on ballast water exchange have been initiated by the International Maritime Organization (IMO) and the U.S. Coast Guard (USCG). The IMO finalized its Ballast Water Treaty in 2004 (which will take a year to ratify and several years to implement) that includes a depth guideline for ballast water discharge for vessels entering the EEZ of 200 meters (m) whereas previously it was 2000 m. The distance also has been modified and compliant exchange should be at least 200 nautical miles (NM) from shore (or as far from land as possible and at least 50 NM from shore). The 200 m depth is equivalent to the 100 fathoms proposed in the policy working group statement. (see Appendix I for specific language of Regulation B-4).

The second action taken was the July 2004 finalization of the USCG rule (Appendix II). This rule defines a compliant exchange as one which is no less than 200 NM from shore. There is no depth requirement because there is no consensus internationally (even though the IMO and Australia have adopted a 200 m depth) and hence the USCG believes that a distance of 200 NM is feasible and will allow more vessels to exchange ballast water.

Both the IMO and the USCG recognize that safety issues and security concerns may prevent vessels from exchanging in mid-ocean. There is a no delay clause in the IMO treaty (Article 13 of Regulation B-4). The USCG recommends that vessels may retain ballast on board, use an alternative, environmentally-sound treatment, or discharge minimal amounts of ballast within the 200 NM for safe operation.

Building on the information presented the first day of the workshop, our discussions explored the feasibility of alternate ballast water exchange zones (ABWEZ) for coastwise traffic. Our interest was in identifying environmentally protective solutions that are feasible and practicable for the maritime industry. For many vessels, coastal traffic will result in crossing an international boundary between the U.S. and Canada. Regulations are vague on ballast water management except to note that there should be no delay.

Our more stringent recommendations are at variance with the IMO and USCG regulations traversing along the coast. However, the IMO treaty (Article 2(3)) allows more stringent measures to be taken. The USCG did not address coastal traffic in the July 2004 regulations.

It may be that this workshop was ahead of its time using best available regional, scientific information combined with stakeholder perspectives in the identification of ABWEZ. The workshop recommendations do not have regulatory authority, but, as noted above, several examples of invasive species introductions elevate our concern for adequate options. The presence of *Didemnum* cf. *lahillei*, an aggressive, invasive sea squirt, on Georges Bank, one of the first to appear in deeper waters in this region adds a new dimension to the discussion—it is no longer a concern of nearshore waters, but deeper waters as well.

The Ballast Water Committee of NEANS and the CMAC are advocates for lowering risk associated with ballast water introductions. We are hopeful that an integrative approach will be taken into account and addressed appropriately at both the national and international levels.

Review of Criteria for Identification of ABWEZ

The overarching goal of this workshop was to use the best science available to identify potential alternate ballast water exchange zones that would minimize, reduce, and, if possible, prevent marine invaders from reaching coastal areas and integrate this with the perspectives of the maritime industry, environmental groups, and policy makers. The consensus statement should incorporate concerns about sources of highly invasive species, recognize the limitations and costs to the maritime industry, and be enforceable.

Workshop Consensus Statement: Integration of the Maritime Industry, Policy, and Scientific Working Groups by the Participants

A consensus was reached on proposed alternate ballast water exchange zones for the northeast region of North America based on criteria that offered the greatest level of protection to coastal areas. All participants contributed to the discussion–scientists, shipping industry representatives, agencies, and nongovernment organizations and had an opportunity to review and comment on the statement. This section of the report is the general consensus statement of the participants and integrates the three working group discussions into a single statement to be proposed as the working definition of interim alternate ballast water exchange zones (see later sections for details on the discussions and recommendations from each working group). The region from Cape Hatteras to offshore of the Nantucket Sound/Shoals; the Gulf of Maine; the Laurentian Channel; and the northern reaches of the Maritime Provinces was the focus of the oceanographic and industry discussions. Coastal traffic within this region is annotated in the Marine Industry Working Group statement. Alternate ballast water exchange zones were proposed based on physical (largely currents and dispersion of particles) and biological information and risk assessments presented in the workshop. In general, passive particles released along the continental margin (depths greater or within 100 fathoms or 200 m) have a greater probability of moving offshore than onshore. It was noted that larval and holoplankton organisms do not behave as passive particles and many have directed onshore movements. Thus, the estimated risks underestimate behavior of living organisms. It is also recognized that there are areas where constraints limit exchange, for example vessel traffic solely within the Gulf of Maine and Bay of Fundy are not near the shelf break. Thus, these areas have additional constraints and estimates of risk are much higher.

The general area of agreement is as follows:

1. Vessels originating from Cape Hatteras,

Chesapeake Bay, and Delaware Bay are advised to exchange ballast at or deeper than the 100 fathom or 200 m depth contour from Cape Hatteras to the Eastern most point of Georges Bank (approximately, latitude 35^{o} 30' N to 41^{o} 20' N; longitude 75^{o} W to 66^{o} W). It is also recommended that exchange not occur until vessels reach the 100 fathom region or beyond (Figure 1).

2. Based on the physical oceanographic currents, ballast water exchange along the northern flank of Georges Bank meets criteria of moving water away from the coast and thus could be considered as a reasonable ballast water exchange zone. However, the presence of an invasive sea squirt, *Didemnum* cf. *lahillei*, on the northern flank of Georges Bank argues against this recommendation and therefore this is an area to avoid.
3. Vessels traveling northward towards the Laurentian Channel and/or ports exchange ballast in waters deeper than 2000 m in the zone extending from 60^{o} W to 65^{o} W as currents are not likely to enter the Northeast Channel of the Gulf of Maine and because the Gully area near Sable Island is designated as a Marine Protected Area (MPA). (Figure 2, 3).
4. Vessels traveling from Boston and Portland to ports within the Bay of Fundy are advised to exchange within the area enclosed by the following corner positions: 42^{o} 50' N to 43^{o} 10' N on 70^{o} W and 43^{o} 50' N to 44^{o} 15' N on 67^{o} W. The currents in this region are most likely to transport passive material and organisms out of the Gulf of Maine and through the Great South and/or Northeast Channels. It is anticipated that ballast discharges will be diluted and minimally entrained in the coastal current along the Maine, New Hampshire and Massachusetts coasts. This zone also offers protection to the Bay of Fundy, based on prevailing currents (Figure 4).
5. The Laurentian Channel continues to be complicated by its designation as an alternate ballast water exchange zone for vessels entering the Great Lakes. Based on the current understanding of the region, exchange during the summer months puts the coastal regions at risk; there is less risk during the winter months. Based on available data, the area is not generally used as a ballast water exchange zone. The joint recommendation is to use the southwestern area of the Laurentian Channel from around 46^{o} N, 57^{o} 30' W to around 44^{o} N, 58^{o} 00' W on the Scotian shelf break. The inshore side of this zone would be delimited by the 100 fathom (or 200 m) isobath, while the offshore boundary would be the midline (or axis) of the Channel. In this area, the surface water generally moves offshore away from the coastal region of concern (Figure 2, see Figure 1 in Gilbert et al., this volume).
6. No recommendation was made regarding vessels traveling around to the Northern region of Newfoundland. The use of the southern slope water zone at depths greater than 2000 m is recommended for vessels traveling around the Northern region of Newfoundland.

It is proposed that alternate ballast water exchange areas, where there is consensus, be adopted as a working policy statement by both the U.S. and Canada for coastal vessel traffic until alternative treatment technologies are available. Areas that have greater uncertainty with regard to risk will require further discussion to resolve the complex set of constraints and issues, some of which are mutually exclusive. Because the "no action" alternative is considered potentially more deleterious than the proposed recommendations, we urge an adaptive management approach to adopting policy for the northeast region.

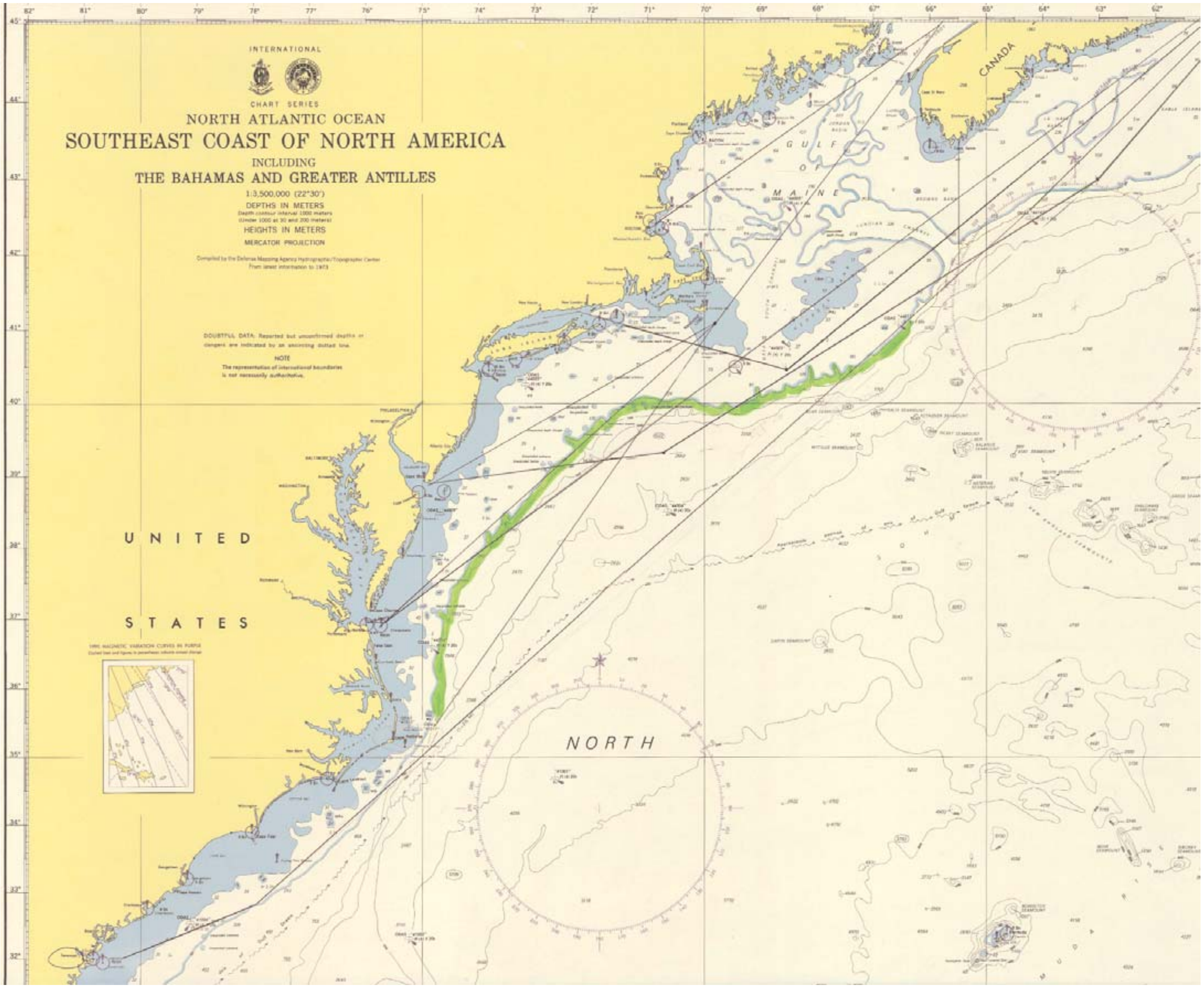

Figure 1. Proposed alternate ballast water exchange zone for coastwise traffic originating from Cape Hatteras, Chesapeake Bay, and Delaware Bay to ports north should initiate exchange when the 100 fathom or 200 m isobath is reached and follow it to a point to the east of Georges Bank (solid green line). Georges Bank is to be avoided as is the Northeast Channel.

Figure 2. Proposed alternate ballast water exchange zone for the area from Georges Bank to the Laurentian Channel was proposed by Transport Canada (see Figure 3). The solid green line indicates an area that may be used for coastwise traffic vessels entering the St. Lawrence Channel.

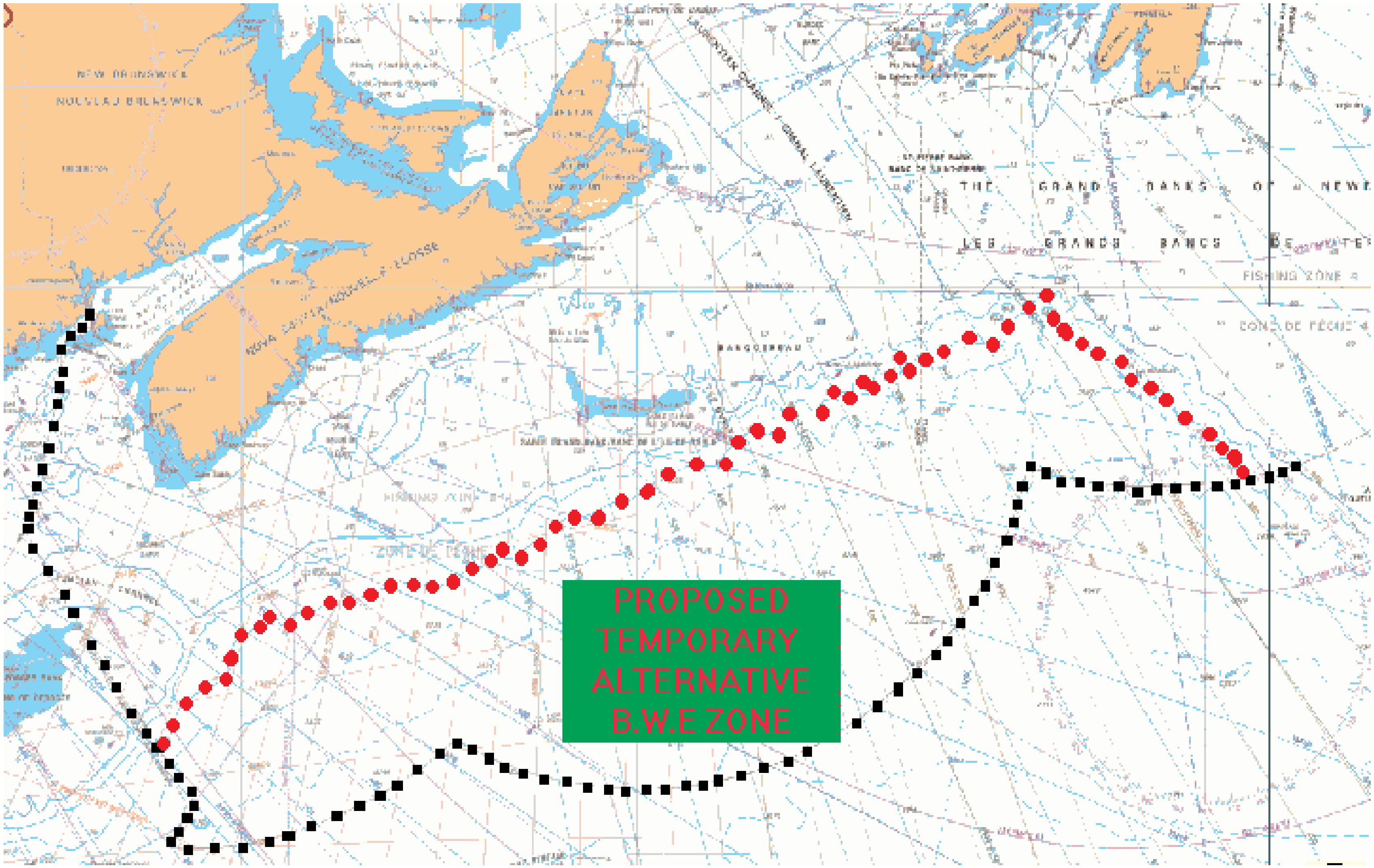

Figure 3. Proposed alternate ballast water exchange zone for the area from Georges Bank, the Northeast Channel and past Sable Island and the Gully. This map was provided by Transport Canada Marine Safety and recommends discharge in depths of 2000 m or greater.

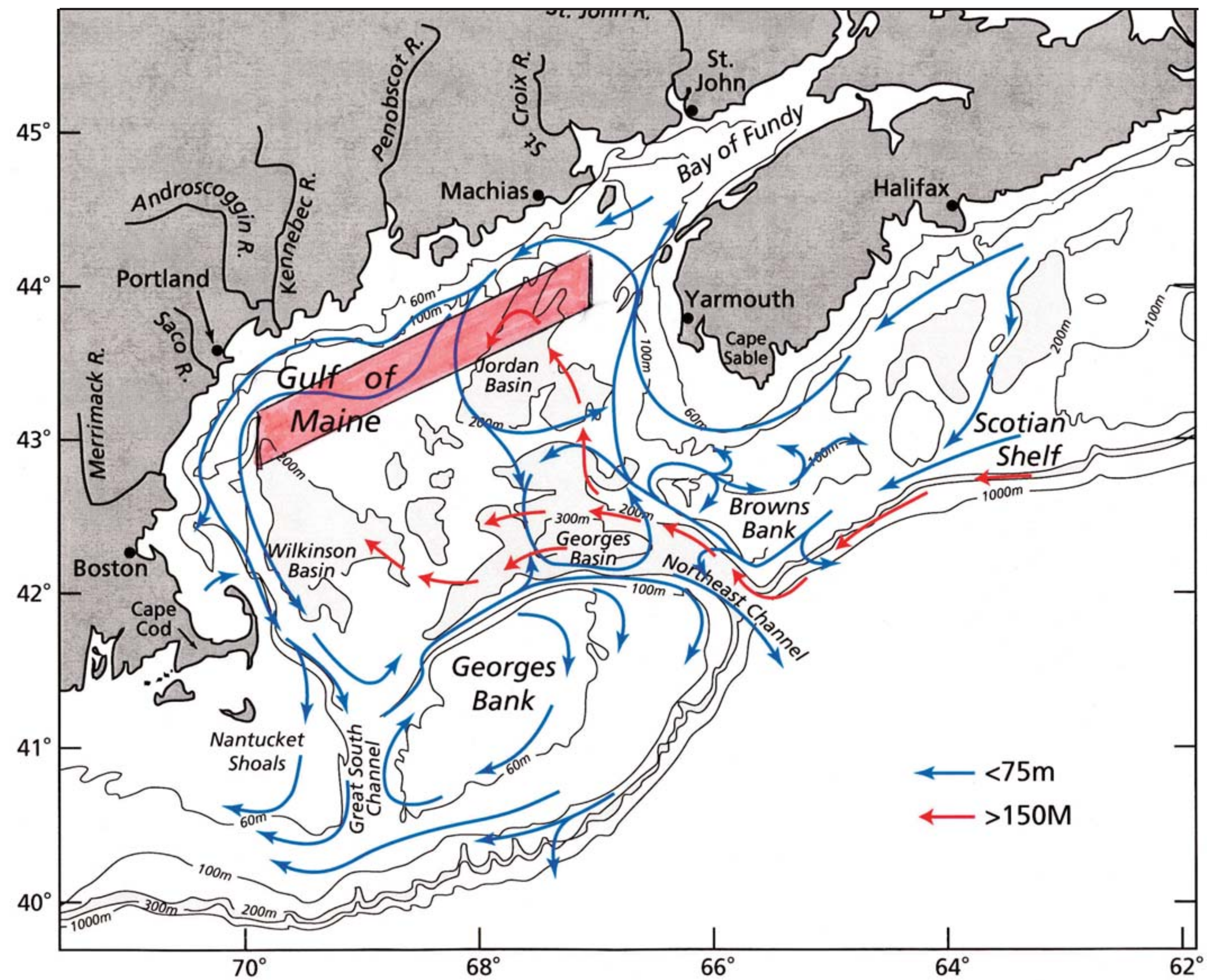

Figure 4. Proposed alternate ballast water exchange zone within the Gulf of Maine for traffic from Boston and Portland to ports in the Bay of Fundy. The region identified as an area where currents are more likely to carry particles out to sea rather than retain them in the Gulf or move them shoreward (see recommendations for criteria). Note that the blue arrows indicate within the top 75 m and the red arrows indicate currents at depths greater than 150 m.

Recommendations from the Maritime Industry Working Group

The following zones are recommended by the Maritime Industry Working Group.

1. Ships originating from south of Cape May, (Baltimore, Maryland and the Chesapeake Bay, Delaware River, and Philadelphia) en route to the St. Lawrence Seaway would exchange ballast water when 50 NM or more from shore. Two zones would be exempted – Georges Bank and Sable Island and Gully region.
2. Vessels en route from New York City and Boston, Massachusetts heading for Newfoundland have a normal route that will eventually take them offshore passing south about 40 NM of Sable Island including the Gully, which has been designated a Marine Protected Area. These vessels would exchange in depths greater than 1000 m (approximately 500 fathoms).
3. The Bay of Fundy area is more complex. The recommendation is to have a depth exemption in the Gulf of Maine and allow discharge of ballast of vessels originating in Boston and traveling to ports in the Bay of Fundy. These depths are approximately 50 fathoms (100 m) and a distance of approximately 40 NM offshore with exchanges occurring at a region before Grand Manan Island (before entering the traffic separation scheme).
4. The proposed recommendation for the Gulf of Saint Lawrence was to keep the Laurentian Channel exchange zone, primarily as a safety backup zone. This is an area where freshwater can be exchanged with saltwater, thus minimizing risk to the ecosystem. The main users of this area are the iron ore trade from the East Coast (North Shore of the St. Lawrence River), which is a winter trade. They may use this area in the winter. Thus, locally there is very little use, but a few ships might need it for a safety zone.
5. The area from Halifax through to the Laurentian Channel as a potential ballast water disposal area is still not defined and was not fully discussed during this workshop October 29, 2003.

These Maritime Industry recommendations were based on the Working Group comments and are presented as annotated discussion points. These comments reflect the maritime industry's perspective as well as scientists, policy makers, and other stakeholders. Coastal vessel traffic to the Little Narrows (Bras d'Or Lakes, Nova Scotia) region involves three vessels, all from U.S ports on the Eastern Seaboard, as follows:

- Two 20,000 ton ships calling at Boston, Massachusetts; Stony Point, New York; Norfolk, Virginia, Baltimore, Maryland; and Jacksonville, Florida
- One 40,000 ton ship calling at Jacksonville, Florida and Baltimore, Maryland.
- Charters require ballast water exchange (BWE) in accordance with International Maritime Organization (IMO) Guidelines, namely exchange in waters deeper than 2,000 m.
- Typical exchange times run between 24 to 36 h; hence this would require them to deviate 22 NM and reduce speed by 3-4 knots.
- In the winter, the 20,000 t ships cannot go so far offshore due to poor weather conditions. Ships coming from Boston, Massachusetts and New York would need a greater deviation to conduct BWE. This would apply to all ships going to Little Narrows and Hantsport in the summer and to ships going to Hantsport in the winter.
- Vessels going to Placentia Bay are primarily tanker traffic; the area is ice free year around.
- Canadian Maritime Agency Ltd. represents three product tankers per week following a route that at the time of the workshop was approximately 60 h from Boston or New York. BWE requires approximately 33 h.
- In order to conduct BWE in depths of 2,000 m would require a deviation of 40 NM adding 3-4 h to the voyage. This would bring the total time for the voyage to 64 h.
- Conducting BWE in waters outside the EEZ (200 NM limit); it would be necessary to extend the voyage an additional (approximately) 249 NM, adding 17 h to the voyage.

Whiffen Head receives approx 200 crude oil shuttle tankers per year coming from Portland, Maine; Bayway, New Jersey; Norfolk, Virginia; and Beaumont, North Carolina.

- Come By Chance receives smaller clean product tankers (40 – 60,000 DWT) from Portland, Maine; Boston, Massachusetts; and New York. This would total approximately 120 voyages per year.
- Simard provided input on vessels, especially tramp vessels (V/Ls) coming from Europe to the North American east coast and the Saint Lawrence River. Tramp V/Ls coming from South America to east coast North America, then up the St. Lawrence River and into the Great Lakes. The Great Lakes are the end point of voyages.
- Any vessels with ballast must exchange BW. However, most are not coming in ballast; perhaps as few as three in last few years. Exchange takes 6-8 h because it is partial ballast.
- When vessels have cargo, ballast is also used for trim. For example, in the winter time some vessels visit Baltimore, Maryland where they discharge some cargo and take on ballast for trim. These vessels do not move if they do not have cargo. Ballast from Baltimore and ballast used for trim that was loaded in Baltimore or coastal waters is considered as having to be exchanged if there was ballast or sediment in tanks. This business is highly competitive. These vessels do not go anywhere when there in nothing to pick-up - likened to a taxi.
- Vessels in Little Narrows now picking up coal in U.S. and thus reducing the amount of ballast and cutting the cost of voyage.
- Statia terminal trade originates as follows. Vessels that travel from Point Tupper, Nova Scotia to New York are smaller tankers of about 30,000 DWT.
- Iron ore trade is a replacement trade in the winter months to move ore to southeastern U.S. from Sept Isles and Port Cartier on St Lawrence River. In summer, ships are trading through the Great Lakes and St. Lawrence River to Europe in vessels of 60,000 DWT.
- Vessel owners are looking at alternate routes from New York and/or Cape May, New Jersey to Nova Scotia and Newfoundland.

Recommendations from the Scientists Working Group

The group recognized that ballast water exchange will never totally eliminate the risk of introductions. However, it is a better alternative than no ballast water management. In order to reduce the risk of nonindigenous species introductions to our waters, this group investigated options for ballast water exchange or release that would result in transport of released ballast away from the coast. Currently, the consequences of invasions are considered to cause the most impact to the highly productive inshore waters, where most anthropogenic activities and their effects are presently concentrated. Wild fisheries, aquaculture and tourism are among the economic activities that could be affected in this zone.

There are also many conservation issues. The highest risk of invasion was judged to occur when estuary/port waters are introduced to similar habitats, such as another estuary or port. Shelf waters were considered to constitute a somewhat lower risk of invasion to estuary/port habitats, with a further reduction in risk from offshore waters. The oceanography suggests that surface slope waters tend to disperse passive particles away from the continental shelf and coastal ecosystems, retaining them in the offshore (slope and oceanic) waters. Therefore, the mandate of this group was to identify specific areas that would minimize the risk of ballast water introductions to the inshore. At the same time, this group recognized that the selected areas needed to correspond as closely as possible to established shipping routes so as to minimize the costs to the industry. General criteria for ABWEZ:

1. Water movements in the ABWEZ should consistently transport away from shore and dilute the released ballast waters in both the horizontal and vertical directions.
2. Sensitive areas should be avoided. These constitute
   (a) areas where release is inadvisable for

reasons of the pristine or invasion susceptible nature of the environment, and

(b) areas where uptake is inadvisable because of high levels of established invasive and potentially harmful species.

3. It was assumed that inshore species would pose minimal risk if inoculated offshore, and that offshore species would pose minimal risk if inoculated inshore.
4. Risk in winter is less than that in summer. The winter risk is not zero due to the persistence of some species, although usually in lower concentration than in summer.
5. Sensitive ecosystems or aquaculture areas should be avoided.
6. Ships whose route takes them near to or outside the shelf break should exchange ballast water in the identified zones at or outside the shelf break.
7. Ships traveling north-south inside the region should also exchange ballast water.

This is to minimize the movement of species which are not currently observed throughout the entire region. Ideally, these ships should exchange outside the shelf break, but this is not always economically feasible. Alternative arrangements for these ships were discussed; these ABWEZ will reduce risk relative to carrying port water to similar ports, but risk will be higher than if these ships could complete an offshore exchange.

Specific Recommendations for ABWEZ

1. Area offshore of the shelf break, i.e., approximately 100 fathoms or the 200 m isobath extending from Cape Hatteras to east of New York City, thence following around the offshore edge of Georges Bank and terminating around 66º W south of the Northeast (Fundian) Channel. In terms of physical oceanography, this shelf break will tend to carry organisms along isobaths to the southwest and/or offshore.
2. An area along the northern edge of Georges Bank may be considered. A narrow zone between the 100 and 200 m isobaths will tend to carry particles out to the shelf edge, where it will be transported to the southwest. The Northeast Channel should be avoided. The political implications of an ABWEZ located adjacent to Georges Bank need to be investigated, and is not recommended given the presence of the sea squirt *Didemnum* cf. *lahillei* as a threat to the productive scallop and ground fish in the region.
3. Based on the work of Petrie and Soukhovtsev (2002), the area deeper than 2000 m off Nova Scotia, starting southeast of Cape Sable and continuing northeastward would be most suitable for BWE. This track should provide a wide berth to Sable Island and the Gully, and historical surface drift measurements suggests that the risk of passive particles in the surface water advecting onto the shelf is low (order 5%).
4. A zone southeast of Cabot Strait (in the vicinity of 45º 10' N and 59º W) was identified as an ABWEZ for safety discharges only. This zone is located offshore of the southwesterly Nova Scotia Current (which would carry particles in close proximity to the coastline of Nova Scotia) and on the continental shelf. Exchanges in this zone present another economically sound alternative for vessels bound for the Gulf of St. Lawrence. The scientific group advised that the presently accepted ABWEZ in the Laurentian Channel may pose an unacceptable risk of introductions to the Atlantic Coast.
5. Concern was expressed about the potential for identifying an acceptable ABWEZ in or on the approaches to the Bay of Fundy. This area does not meet the criteria discussed. The only suggestion was to conduct ballast water exchange offshore from the Maine coastal current prior to entry to the Bay of Fundy (the current is expected to provide a buffer, protecting the coastal regions). It was recommended that this ABWEZ, further defined in the General Consensus Section (see above) extend no further east than 67º W. This suggestion requires further scientific validation prior to use.
6. Winter traffic apparently may use a shore route in weather conditions when it is unsafe to follow the normal traffic routes. For these

vessels only, ballast water exchange may be conducted in the coastal zone. The risk of introductions is considered to be lower in winter because of lower cell concentrations and taxa in the ambient waters. Ships should remain offshore of the Maine coastal current within the buffer zone described in #5 above and in The General Consensus Statement (above). The details of this recommendation should be validated using surface drifters.

Recommendations of the Policy Working Group

The policy workgroup believes the optimal approach to managing coastwise ballast exchange should include the following:

1. Short term and long term goals;
2. Need public/stakeholders input;
3. Recognize U.S./Canadian regulations to address coastwise traffic; regulations should be consistent with each other and IMO;
4. Ensure compliance mechanisms are put in place;
5. Risk assessment should be conducted prior to establishing an ABWEZ;
6. Need to identify Alternate Ballast Water Exchange Zones within U.S and Canada and identify areas where BWE should not occur;
7. Best management practices could be established by the shipping industry;
8. Measures should be taken to ensure performance of BWE concerning reduction of the numbers of nonindigenous species;
9. Regulations should be simple and straightforward for the shipping industry/personnel.

The working group believes that the distance offshore where BWE should take place should not have any negative impacts to the coastal ecosystem. BWE should occur as far offshore as possible. Maps of physical oceanography, larval dispersion, and shipping routes and fishing grounds should be overlaid to determine ABWEZ. Foreign vessels entering U.S./Canadian waters that cannot conduct BWE 200 NM from shore due to safety exemptions should not be permitted to use the ABWEZ designated for domestic coastwise traffic between U.S and Canada. Closed or confined water systems are areas that BWE should not occur. Vessels should not uptake BW in infested areas. Areas of retention and/or dispersal of organisms should be identified in regulations as well as other documents easily made available to mariners (e.g. Notice to Mariners). In identifying ABWEZ, seasonality, temperature, salinity, and any other characteristics should be considered. Icy conditions may be a consideration as well. Proposed IMO regulations as well as U.S regulations recommend that ships should not deviate from their planned voyage to conduct BWE. Economic costs to the shipping industry should be balanced with the impacts of the environments and local communities. Risk needs to be defined. For example, is the risk of introduction of one species too high? Risk assessment should be conducted prior to establishing an ABWEZ. Enforcement should include reporting, inspections, and BW sampling to determine compliance. Short distance should be defined. History of invasions by exotic organisms seems to be more relevant than distance. Sampling includes biological analyses of species, as well as to determine BWE has been conducted (i.e. salinity test). The Policy Working Group believes bilateral national/regional agreements should occur. Consultations between governments in drafting consistent regulations should be pursued. Stakeholders must be included in the development of any regulation.

Literature Cited

Beeton A.M., J.T. Carlton, B.A. Holohan, G.H. Wheless, A. Valle-Levinson, L.A. Drake, G. Ruiz, L. McCann, W. Walton, A. Grese, P. Fofonoff, S. Godwin, J. Toft, L. Hartman, E. von Holle. 1998 (Draft). Ballast Exchange Study: Consideration of Back-up Exchange Zones and Environmental Effects of Ballast Exchange and Ballast Release. Draft Report to the National Sea Grant Program, National Oceanic and Atmospheric Administration, Washington DC and the U.S. Environmental Protection Agency, Washington, DC.

Petrie B. and V. Soukhovtsev 2002. Report on Oceanographic Studies related to Alternate Ballast Water Exchange Zones. Unpublished Report to Transport Canada.

Opening Remarks

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This workshop is intended to address issues relating to ballast water management with the interim, and imperfect, approach of ballast water exchange and imperfect coverage of the areas where ballast water is exchanged and unregulated, specifically coastal traffic. Three sets of international and regional guidelines and/or regulations are generally used in this area that are similar, but vary in details. This workshop is focused on building consensus on how to be consistent with these existing guidelines and regulations while proposing options for minimizing the gap in all regulations that does not address coastal traffic ballast exchange. There is a need to address the issues of coastal vessel reporting and to review what we know about the ecosystem to improve ballast water management in the region. This cannot happen without the insights and cooperation of the shipping industry and the regulators. I am very optimistic that we are going to come away from this meeting with a very powerful statement about what to do next and how to work towards a solution without proposing new regulations.

This presentation is a brief overview of global and regional ballast water issues, a review of regional species of concern and their impacts, highlights of current guidelines and regulations, and a quick comment on the status of alternative ballast water treatments. The presentations and tomorrow's working groups discussions are directed towards the feasibility of identifying alternative ballast water exchange zones within the Northwestern Atlantic.

Globally, 80% of world's goods are moved by shipping. Vessels require ballast for providing stability, maintaining trim, assisting maneuverability, compensating for weight during load transfers and loss, and reducing stress on hulls (NRC 1996). Since the 1880s, solid ballast such as shale, rocks, sand, and other heavy materials, was used to stabilize ships, but by the 1900s water replaced solid ballast. Ballast tanks vary in size (up to >200,000 m^3) and with pumping rates that range from 50 to 20,000 m^3/h (NRC 1996).

Because ballast water is taken up in harbors and estuaries and discharged in similar regions, the opportunity for organisms to survive is increased. Most marine organisms spend some part of their life history in the plankton, thus the pool of potential invaders includes nearly all marine species. Ballast water exchange is used to minimize introductions, but it is an not ideal solution. It adds to the cost of a voyage, carries a risk for vessel and human safety, and is not 100% effective in preventing release of organisms (Carlton 2001).

Despite these drawbacks, ballast water exchange is the interim method of choice for minimizing new introductions. Features of ship construction minimize the effectiveness of ballast water exchange. Internal structures maintain the integrity of the hull and ship, but also function to collect sediments and entrain organisms. For example, ballast water exchange may be 90% efficient, but the percentage of organisms that are exchanged may be only 60% of the total present in the tank (Rigby and Taylor 2000). In addition, sediment, often present in ballast water, accumulates on the bottom and structural elements of ballast tanks and serves as a habitat for benthic organisms. Grate openings of approximately one centimeter limit the maximum size of organisms that may be taken up during the filling of tanks. Although a concerted effort is underway to find alternative treatments, these efforts are several years away from being ready for commercialization.

Organism survivability is related to the physiology of the organisms and the length of time that they spend in the ballast tank, which could be 24 hours or several months. The longer the organisms are held within a tank the fewer survivors. In general, there are many less species discharged than taken up, and only a few of those that are discharged will survive, reproduce, and become established. Established populations may form small localized populations that may not disperse for years and then disperse rapidly. This lag time in dispersion of an invader adds to difficulties in predicting and identifying which species are of concern. Far less is known about disease-causing organisms, phytoplankton, and zooplankton than larger organisms (e.g. crabs, bivalves and sea squirts), but there are many more plankton species than larger organisms. The smaller organisms that survive may be an even greater threat to human and ecosystem health.

Introduced marine invertebrate and algal species identified in the Northeast U.S. are listed in Table 1, many of which may have arrived by ballast water. Two rapid assessment surveys of fouling communities on floating docks in harbors and marinas were conducted in August 2000 and 2003. Taxonomic experts identified native and non-native species, and identified those whose origins are unknown (i.e. cryptogenic species sensu Carlton 1996). Data from a survey in August 2000 in Massachusetts are shown in Figure 1.

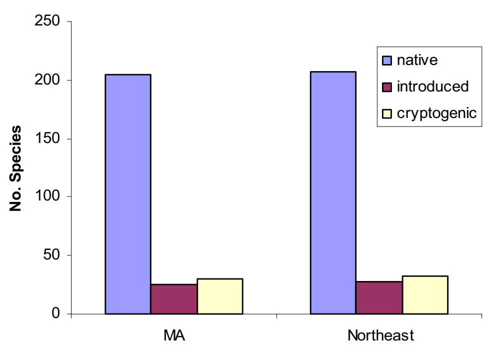

Figure 1. Number of native, introduced, and cryptogenic species found in fouling communities in Massachusetts (21 locations) and the Northeast (Portland, Maine through New York City; 20 locations).

Approximately 10% of the total species identified were introduced and approximately another 10% were cryptogenic, although the percent was often greater at a particular location. The total number of species in both surveys is 38 introduced and 35 cryptogenic species. Both the actual numbers of species and the percentage are less than you find in the Chesapeake Bay area and much less than you find in San Francisco (Ruiz 2000). Three new species were identified in 2000 and one identified in 2003; others have been identified by citizen scientists.

Several introduced species in the region illustrate how quickly organisms can disperse. *Hemigrapsus sanguineus* was first found near Cape May, New Jersey in 1986 and dispersed to northern Maine and as far south as North Carolina, whereas others continue to be found in only one location, e.g. *Sagartia elegans*.

Species also cause economic and ecological damage. Economically, the green crab, *Carcinus maenas*, has impacted is been a major predator in the intertidal area thus shaping this community in its role as one of the keystone species (Menge and Sutherland 1987). Recent studies show that it is competes with *Hemigrapsus sanguineus*, the Asian shore crab—a curious wrinkle on ecosystem dynamics. Another species that recently arrived in Canada is the green alga, *Codium fragile* ssp. *tomentosoides*. In Peggy's Cove, Nova Scotia, it has formed a near monoculture over the bottom in sub-tidal areas and displaced many native species and has altered the benthic community (Scheibling et al. 1999). Both species probably arrived by ballast water.

Another group of species that has created problems for the aquaculture industry are fouling organisms, e.g., tunicates, bryozoans and hydroids. The club tunicate, *Styela clava*, was present in Boston in the 1980s, but only recently arrived in Prince Edward Island. These species have settled on the mussel ropes where they outcompete the shellfish resulting in fewer and smaller mussels—creating economic losses for the mussel industry. Another tunicate, a compound sea squirt (known also as *Didemnum* cf. *lahillei*) is similar to recently described tunicates in New Zealand and California. It is noted for the large colonies, its rapid expansion, and aggressive growth in localities where it is found. [After the workshop, *Didemnum* cf. *lahillei* has been found growing on productive gravel scallop beds in the northwestern corner of Georges Bank.]

Table 1. Partial list of introduced species observed in surveys from Maine to New York City (see http://massbay.mit.edu). Data from participants in Rapid Assessment Surveys in New England from Maine through New York City.

Taxa /Genus species	**Common name**	**Native range**
Chlorophyceae		
Codium fragile ssp. *tomentosoides*	Green fleece alga	W Pacific
Rhodophyceae		
Bonnemaisonia hamifera	Red alga	Pacific or Europe
Grateloupia turuturu	Red alga	Pacific
Lomentaria clavellosa	Red alga	Unknown
Lomentaria orcadensis	Red alga	Unknown
Neosiphonia harveyi	Filamentous red alga	Pacific
Turbellaria		
Convoluta convoluta	Flatworm	Europe
Cnidaria		
Cordylophora caspia	Hydroid	Ponto-Caspian
Diadumene lineata	Orange-striped, green anemone	NW Pacific
Sagartia elegans	Purple anemone	NE Atlantic
Annelida:Polychaeta		
Janua pagenstecheri	Polychaete	Eastern Atlantic
Mollusca:Gastropoda		
Littorina littorea	Periwinkle snail	NE Atlantic
Mollusca: Bivalvia		
Ostrea edulis	European oyster	NE Atlantic
Arthropoda:Crustacea: Mysidacea		
Praunus flexuosus	Opossum shrimp	NE Atlantic
Arthropoda: Cirripedia		
Chthamalus fragilis	Little gray barnacle	Europe
Arthropoda: Isopoda		
Ianiropsis sp.	Isopod	Europe/Asia
Arthropoda: Amphipoda		
Caprella mutica	Skeleton shrimp	W Pacific
Microdeutopus gryllotalpa	Amphipod	Uncertain
Arthropoda: Decapoda		
Carcinus maenas	European green crab	NE Atlantic
Hemigrapsus sanguineus	Asian shore crab	NW Pacific
Kamptozoa		
Barentsia benedini	Nodding head kamptozoan	Europe
Bryozoa		
Alcynonidium sp.	Rubbery bryozoan	Unknown
Bugula neritina	Bushy red bryozoan	Uncertain
Membranipora membranacea	Lacy bryozoan	NE Atlantic
Urochordata:Tunicata		
Ascidiella aspersa	European sea squirt	NE Atlantic
Botrylloides violaceus	Orange and red sheath sea squirt	NW Pacific
Botryllus schlosseri	Golden star sea squirt	NE Atlantic or Pacific
Didemnum cf. *lahillei*	Compound sea squirt	Europe?
Diplosoma listerianum	Compound sea squirt	Europe?
Molgula manhattensis	Sea grape	Europe
Styela canopus	Club sea squirt	W Pacific
Styela clava	Stalked sea squirt	W Pacific

Given the concern about the impacts of introduced species and the potential for new species to arrive in ballast water; in 2002 a workshop was convened to review what is known about ballast water release in the region, the status of regulations and policies and what can be done to minimize or prevent new introductions. In New England, the amount of ballast water released is considerably less than in other parts of the country. The workshop presenters reviewed regulations, identified the shipping industry efforts, and highlighted how California and the West Coast are addressing ballast water issues. What emerged from the discussions of working groups was the need to identify alternate ballast water treatment rather than rely on ballast water exchange. However, because these alternative treatments are years away from being adopted, ballast water exchange at sea is the interim solution. Currently, vessels are required to exchange ballast water before entering the Great Lakes. All vessels are required to complete ballast water report forms that collect data on volumes exchanged, last port of call, any treatment, and other data to assist with monitoring ballast water management. For New England, only about 35% of the vessels are reporting on their ballast water management.

Globally and within Canada and the U.S., several major efforts are moving forward. Since 1988, the International Maritime Organization (IMO) of the United Nations has been working towards an international convention to require vessels to manage and treat ballast water, but until recently the guidelines were voluntary. [A meeting held on February 9-13, 2004 resulted in adoption of a Treaty to prevent and minimize introductions from ballast water and sediments. The Treaty will become official 12 months after ratification and affects 35% of the global shipping tonnage. Appendix I summarizes the convention and time table for implementation.] Although there is consensus that alternative treatments, such as physical, mechanical, chemical (biocides), and other methods are preferred options to ballast water exchange, only a few are being tested on vessels. This places greater need on identifying areas that are acceptable for ballast water exchange that minimize or prevent introductions.

Current regulations are primarily guidelines, except for the Great Lakes. The United States requires vessels entering the Exclusive Economic Zone (EEZ) to report on ballast water management, but treatment is optional. These reports are collected by the U.S. Coast Guard and data are managed by the Smithsonian Environmental Research Center. Currently, all coastal traffic is exempt from reporting and ballast water treatment.

Canada has voluntary guidelines that include reporting ballast management and exchange. The proposed Annex 5 mandates that all vessels entering the EEZ, including vessels entering from U.S. ports and traveling along the coast, submit reports on ballast water. Appendix IV summarizes Annex 5 with comments from a participant. The proposed annex recommends against discharging into the Laurentian Channel and proposes minimal ballast water discharge. The Laurentian Channel designation as a ballast water exchange site is highly controversial, but was based on best judgment at the time. Recent data suggest that for several months of the year, the area is vulnerable to discharges within the Channel introducing new species. Annex 5 also identifies sensitive areas for ballast water uptake: Chesapeake Bay, Georgetown, Lunenburg, Shelburne, and the Bay of Fundy shipping lane and some other areas.

Several studies have been commissioned by Transport Canada and their consultants to examine compliance with reporting, numbers and types of organisms in ballast water, and options for ballast water exchange. These studies, the U.S. Coast Guard reporting data, and data from other regions highlight the need to identify alternative ballast water exchange regions.

The purpose of this workshop was to develop a sound scientific understanding of the region—its physical oceanography, biology, regulations, traffic patterns, and vessel issues—and explore the feasibility of identifying alternate ballast water exchange areas.

The region was divided into three general areas: north of the Gulf of Maine; the Gulf of Maine, Bay of Fundy, and coastal Maine; and south of Cape Cod. Three presenters, Peter Smith, David Townsend, and James O'Donnell provide a synthesis of the physical oceanography within each of these regions. Current data suggest that the ballast discharge is greater in Canada than the U.S. and that coastal traffic is not required to report on ballast water management. The next presenters, Tuck Hines, Yves De Lafontaine, and Nathalie Simard review our understanding of the biology of the system and lessons from the Gulf of St. Lawrence on dispersal and retention. Anjuna Langevin and Kathy Metcalf present Canadian and U.S. shipping industries perspectives and highlight the shipping industries' activities and relevant regulations. The presentations conclude with Andrea Locke's discussion on risk assessment based on what we know. All participated in a panel discussion and identified topics for the working groups' deliberations.

The goal is to develop a strategy for reaching consensus on ways to reconcile the environmental and economic concerns to minimize and to reduce introductions from ballast water, specifically to review the feasibility of alternate ballast water exchange zones for coastal traffic. The long-term goal of preventing introductions and developing a regional ballast water management plan will include alternative technologies for treating ballast water, but that is beyond the scope of this workshop. The IMO, Canada and the U.S. are working towards adopting performance standards for treatment alternatives, providing opportunities for testing on board vessels, and developing a phase in period for older and newer vessels. The best estimates are that implementation will not occur until 2012 for the signers of the convention. There is an urgency to do better than a no alternative option while waiting for alternative technologies to be developed. This workshop focuses on scientific and technical information that may be used to identify alternative ballast water exchange zones, especially for coastal traffic vessels.

Literature Cited

Carlton, J.T. 1996. Biological invasions and cryptogenic species. Ecology 77:1653-1655.

Carlton, J.T. 2001. Introduced Species in U.S. Coastal Waters: Environmental Impacts and Management Priorities. Pew Oceans Commission, Arlington, Virginia.

Menge, B.A. and J.P Sutherland. 1987. Community regulation variation in disturbance competition and predation in relation to environmental stress and recruitment. American Naturalist 130: 730-737.

NRC (National Research Council). 1996. Stemming the Tide: Controlling Introdutions of Nonindigenous Species by Ships' Ballast Water. National Academies Press, Washington, DC.

Rigby, G.R. and A.H. Taylor. 2000 Progress in the management and treatment of ship's ballast water to minimize the risks of translocating harmful nonindigenous aquatic organisms. In *Marine Bioinvasions: Proceedings of the First National Conference*. J. Pederson, ed. MIT Sea Grant, Cambridge, MA, pp. 344-356.

Ruiz, G. 2000.Toward understanding patterns of marine invasions in time and space. In *Marine Bioinvasions: Proceedings of the First National Conference*, J. Pederson, ed. MIT Sea Grant, Cambridge, MA, pp. 37-39.

Sheibling R.E., W. Hennigartt and T. Balh. 1999. Destrutive grazing, epiphytism, and disease: the dynamics of sea-urchin kelp interations in Nova Scotia. Canadian Journal of Fisheries and Aquatic Science, 56:2300-2314.

Physical Oceanography

Aspects of the Oceanography of the Gulf of Maine Relevant to Ballast Water Issues

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INTRODUCTION

In this paper we discuss biological implications of descriptive physical oceanography. Following a general overview of the major features of the Gulf of Maine region, we explore how these physical characteristics affect certain processes important for transporting organisms and other materials. At the end are described some lesser known interesting and perhaps important peculiarities in the region.

The very broad continental shelf area typical of the Nova Scotia and Maine region, shown in a lighter shade than the deeper Atlantic Ocean in Figure 1, is typical of the Gulf of Maine. The Laurentian and Northeast Channels are deep (300 and 250 m, respectively), but shallow when compared to the North Atlantic Ocean. Given the unique characteristics and currents of the Gulf of Maine, we could conclude that it is a bad idea to exchange ballast water between the coast and the edge of the continental shelf, but that is not realistic.

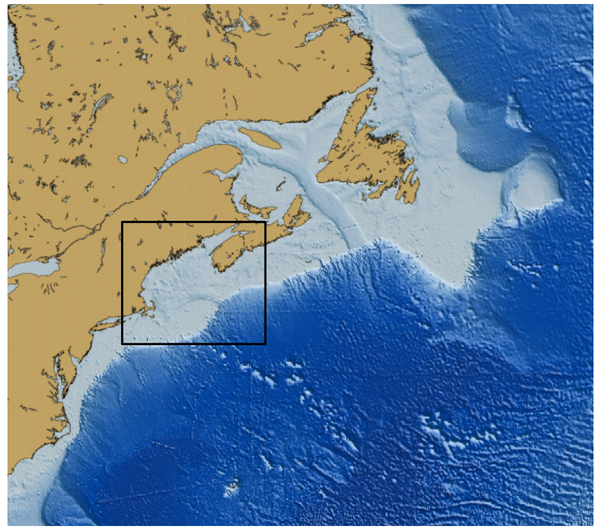

Figure 1. Map of the northwest Atlantic coast showing the broad continental shelf. Inset is the Gulf of Maine.

PHYSICAL CHARACTERISTICS OF THE GULF OF MAINE

Some of the major features of the Gulf of Maine contribute to its productivity. It is an isolated, semi-enclosed body of water that is blocked from the deep Atlantic Ocean by the Nantucket Shoals, Georges Bank, Stellwagen Bank, and the southwest Nova Scotian shelf region. Its only deep water access to the North Atlantic is through the Northeast Channel. North Atlantic water enters through the Northeast Channel and fills three major basins: Georges, Jordan, and Wilkinson Basins; and, with the physical characteristics of the Gulf, deep-water exchanges are limited.

Freshwater discharge into the Gulf of Maine comes from two primary sources: rivers and cold Scotian shelf water. Rivers account for about half of the freshwater in the Gulf of Maine. About half of the freshwater that flows into the Gulf of Maine is cold Scotian shelf surface water, which comes around southwest Nova Scotia. Figure 2 shows the general flow of water into the Gulf of Maine. Surface water enters from the north, where the winter frozen shelf water comes around the corner, along the coast, and eventually becomes the coastal current.

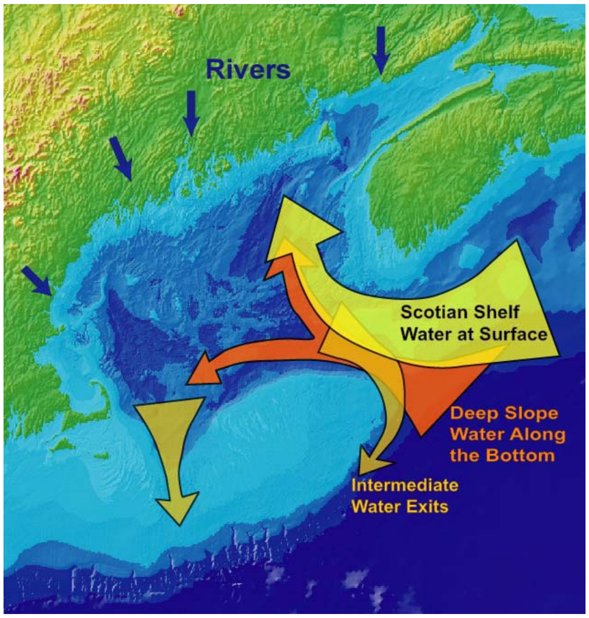

Figure 2. Map showing major freshwater inputs into the Gulf of Maine. Approximately half of the freshwater comes from the rivers; the remainder from the Scotian Shelf waters. Other arrows show deep slope water entry and flows and intermediate water exits. These water masses together with tidal mixing determine density distributions (base map from R. Signell, http://woodshole.er.usgs.gov/operations/modeling/index.html).

Tidal Waves

Tidal heights range from around three meters in the southern portion of the Gulf of Maine to six meters or more in some regions of the Bay of Fundy. In the North Atlantic Ocean tidal waves slosh around the perimeter of the North Atlantic basin (as it would if you were panning for gold), in a counterclockwise manner with an amphidromic point of no change in sea level in the center. A big tidal wave goes down the east coast of North America from north to south, passing by the opening of the Gulf of Maine, altering sea level inside and outside the Gulf with each pass (Figure 3). This tidal wave fills and then empties water from the Gulf. The trough line creates a vacuum and water empties out of the Gulf of Maine, as shown in Figure 3 by the stream and co-tidal lines. Then, with high tide in the Atlantic, the crest passes by the Gulf of Maine again, and sometime later water comes flooding back in.

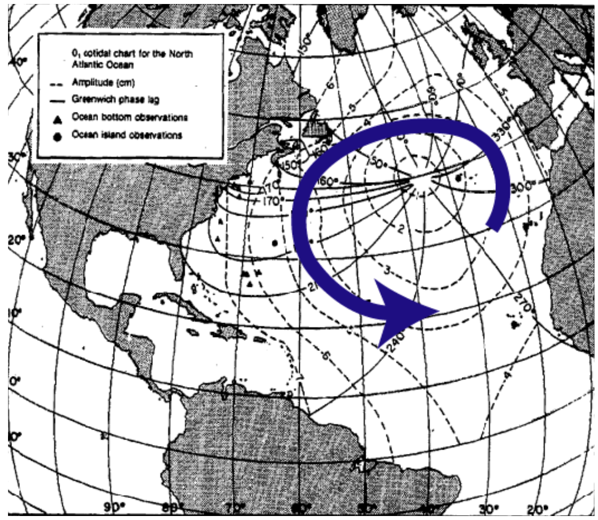

Figure 3. Tidal wave in the Atlantic Ocean that passes by the Gulf of Maine showing amphidromic point.

Not only does the water flow in, but the tidal wave is focused up into the Bay of Fundy, which is one of the reasons there are great tides up in the Bay. But, in general, the reason the tides in the Gulf of Maine are as big as they are is that the Gulf of Maine basin itself is in near resonance with the North Atlantic tidal waves, i.e. the amount of time it takes to fill the Gulf and empty the Gulf is on the same order of period of the North Atlantic tidal waves. The focusing leads to large tides in eastern Maine versus off the New Hampshire coast where they are quite small, which is observed as an east to west difference. The tides are greater in the spring period—compared to a neap tide.

Tidal Mixing in Coastal Currents

Tides are important for a couple of reasons. One of them is the rectification of rotary residual tidal currents. The northeast peak of Georges Bank illustrates this (Figure 4). The direction of the tidal currents at any hour into the tide are plotted and when the ends of these are conneted together they form a progressive vector diagram that shows these water currents moving in a nice ellipse. On the northern edge of Georges Bank this elliptical tidal current develops that encounters some friction with the bottom on the shallow bank, but when it moves off the bank into deeper water, the surface current no longer experiences as much friction and thus can move a little bit towards the northeast before it comes back onto the bank, and generates more friction once again. The result is a corkscrewing action that produces a jet-like current on the northern edge of the bank. But this happens not just on the steep northern edge of Georges Bank, but wherever there is an inclined bottom slope. This can also be seen in drifter tracks (shown on the satellite image, Figure 4). On the southern flank, which is more gently sloping, a drifter track reporting its position every 15 seconds is shown (Figure 4). It progresses in these beautiful ellipses, and it is moving to the Southwest. Along the coastline, tides will generate rectified currents, which contribute to the residual circulation. The tides mix the water from the bottom up and are influenced by the tidal current speed, how rough the bottom is, and the depth. There are some depths where, if shallow enough, the tide can mix the water all the way from the bottom to the surface. But, offshore in deeper water, where solar insulation is heating the water, the tide cannot reach the surface, and stratification develops.

There are places around the Gulf of Maine where vertical mixing is important, particularly around Nova Scotia and along the Eastern Maine coast. It can be observed along the edges of Georges Bank and Nantucket Shoals where cooler waters are tidally mixed. These areas are important in determining surface temperature of the waters; also, vertically mixing carries deep water nutrients up to the surface. And it can be quite dramatic. Off the southwest Nova Scotia coast is an example of a 72-meter water column that is fairly well mixed top to bottom. What was most interesting is if you take a plankton sample at the location where waters are mixed, there are sand grains at one-meter depth that are mixed all the way up to the surface and kept in suspension. That is vigorous mixing.

Water Density

The Northeast Channel provides access to the deep North Atlantic Ocean waters and allows for the influx of dense slope water along the bottom (Figure 2). Bigelow sampled from July to August and he plotted the depth of the 34 parts per thousand isohaline line. Slope water along the Continental Slope will spill into the Gulf of Maine, coming closest to the surface, turning to the right, (corresponding to Coreolis effect), fill-

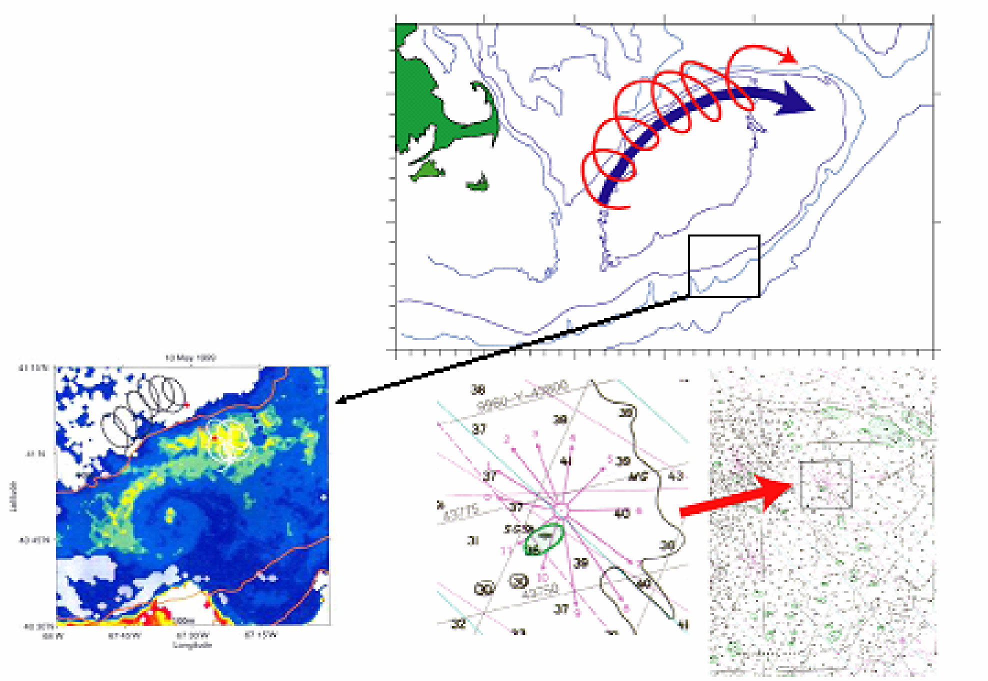

Figure 4. Rectification of rotary tidal currents on Georges Bank (drifter track from R. Limeburner, Woods Hole Oceanographic Institution, http://globec.whoi.edu). *Reprinted with permission.*

ing Jordan Basin, and then spreading down the Maine coast, and also spilling into Wilkinson Basin. All three of these basins then are filled to some extent with this warm and fairly salty, dense slope water sitting along the bottom. Density distribution of the waters in the Gulf can be explained with the tidal mixing along the coast, fresh water influxes, and this deep water coming in along the bottom.

If a transect was placed that goes from the Maine coast out across Georges Bank to the outer Continental Slope, a profile through the basin in the summertime would show three distinct water masses. At the surface, there is warm water from summer stratification, but trapped just beneath that is cold intermediate water, which is the remnant of the previous winter's convective mixing. Down at the bottom, the dense slope water that comes in to fill the basin is warmer and quite a bit saltier.

On Georges Bank adjacent to the Maine coast there is no dense slope water on the bottom; most of the slope water sits in a dome-like pattern in the centers of the basins. The average density of the waters from top to bottom is greatest in the middle of the basins. That means that sea level is actually depressed slightly directly atop these basins and slightly higher on either side, which sets up a baroclinic flow such that all this water wants to rush into the hole. But instead, because the earth is a rotating sphere, those waters are pulled to the right, so result is to produces a counterclockwise gyre-like circulation, in theory, around the Gulf of Maine basins; over Georges Bank it is just the opposite (Figure 5): there a clockwise flow is observed.

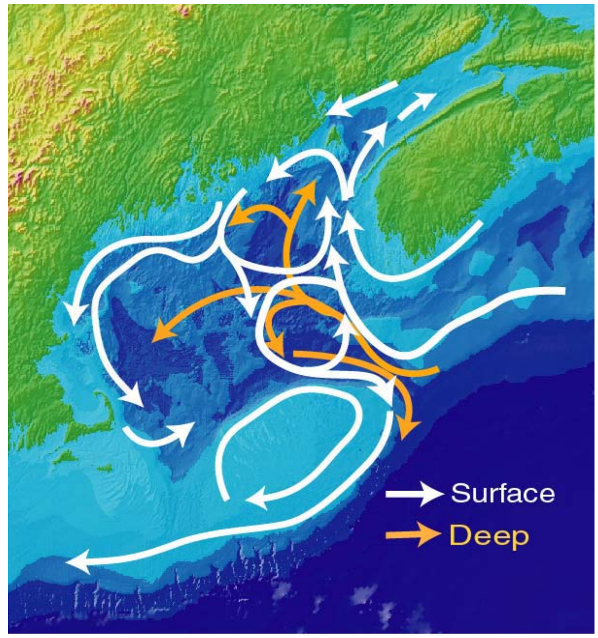

Figure 5. Circulation of currents in the Gulf of Maine (cyclonic) and Georges Bank (anticyclonic) at the surface and at depth (after N. Pettigrew, unpublished; base map from R. Signell, http://woodshole.er.usgs.gov/operations/modeling/index.html).

Even coastal waters from the Gulf of Maine can go back out onto Georges Bank. These patterns were confirmed by N. Pettigrew, (U. Maine, pers. comm.) with satellite tracked drifters. Some drifters go around Jordan Basin, others move down the coast to Massachusetts and eventually the find their way out on the Georges Bank and move around and then drift further down the coast (see O'Donnell's paper in this volume).

Residual Circulation

Figure 5 shows the residual circulation in the Gulf (and is rather messy with surface and subsurface flows), that fill Jordan and Wilkinson Basins with deep water entering through the Northeast Channel. There may be weaker cyclonic flows around the basins, but around Georges Bank there is a stronger flow. The point is that everything that enters the Gulf may go into the Bay of Fundy and go down the coast. Everything is connected, nothing is really isolated.

Maine Coastal Current

A closer look at the Maine coastal current reveals what is driving it and how it can be important. Scotian shelf water moving into the Gulf experiences intense tidal mixing and this is where some of the coldest waters in the Gulf of Maine are found because of this vertical mixing and upwelling. This cold tidally-mixed water forms a coastal current that encircles the Gulf. But along the Maine coast, this cold surface water current departs the coast and heads offshore as part of the main cyclonic circulation, but some of it does continue and meanders back in along the coast, so this is a very, very important feature. The branch point in the eastern Maine coastal current determines how much of this water goes offshore versus along the coast. Because of the vigorous tidal mixing and upwelling, very high nutrient levels in the upper part of the Gulf of Maine are observed in the summer months. It has been recorded at seven micromoles of nitrate in July, which is very high, and it enters the coastal current flow down the coast. The nutrient concentrations drop off some distance down the coast for several reasons. They are being taken up by phytoplankton and dispersed. There is progressive stratification and complex interactions occurring along the frontal region in and around this cold water. But this Scotian shelf water is the primary source of nutrient injections into the surface waters of the Gulf during the summertime. Our understanding of the dynamics of the system involves many U.S. and Canadian scientists, including Peter Smith and Jennifer Martin (see their papers in this volume).

Since 1998, the distributions and dynamics of *Alexandrium* sp., which is the paralytic shellfish poisoning (PSP) dinoflagellate in the Gulf of Maine, has been the focus of an integrated study (Figure 6). In 1998, data were collected during research cruises and satellite data were used from the same time to analyze the observations. Cells grew in the core and along the edges of the cold water, high nutrient currents in the northern Gulf of Maine. When the cells sit offshore, it is not much of a problem for the shellfish fisheries along the coast. What brings the PSP dinoflagellate into shore and how do the bivalves get exposed? Over the years, on average, there is a part of the Maine coast, usually between Mount Desert Island and Penobscot Bay, where shellfish are rarely affected by PSP. This void has always been a bit of an enigma. How can you get PSP on either side and seldom in the middle? That has become known as the sandwich phenomenon where you put the bread on either side of meat. It probably is related to the nature of the coastal current where there is exposure in the north to high *Alexandrium* sp. waters offshore that move towards the coast and eastern Maine. As that coastal current feature turns offshore, it results in an isolated patch of coastline that does not get exposed to these offshore sources of cells. This very phenomenon seems to have happened in August 2003.

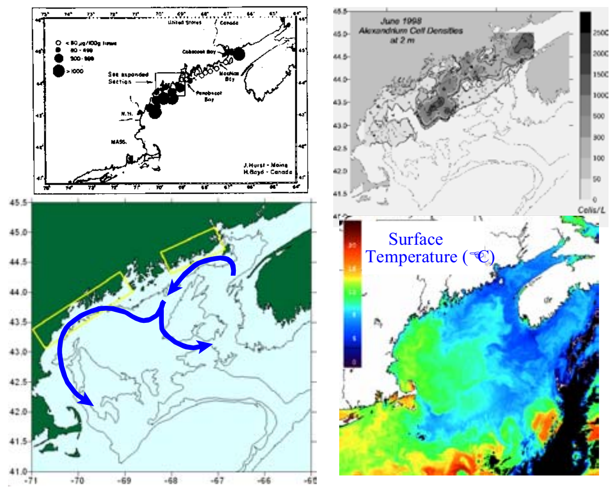

Figure 6. Diagram show distribution of Alexandrium concentrations throughout the Gulf of Maine, cell densities at 2 m and sea surface temperatures, and coastal currents illustrating the sandwich effect (after: Townsend et al., 2001; Hurst and Yentsch, 1981. *Figures reprinted with permission*).

It is the variable trajectories of this eastern Maine coastal current that is very important to understanding transport of materials along the coast, or what comes into the Gulf. What will happen to such coastal water materials? Will they be transported to offshore waters and reside out in the Gulf of Maine or will they move along the coast? A comparison of two satellite images taken on day 152 in 2001 and almost the same time in 1998 show that the 1998 trajectory branched off towards the middle of the Gulf of Maine and the 2001 currents continued along the coast before branching off (see Figure 5 for general surface flows illustrating this branching of coastal current). Thus, anything that those waters are carrying with them is going to be transported downstream.

This principle was the basis of dividing the coastline of Maine into three regions that might be influenced by offshore waters. One is the area in eastern Maine that is directly exposed to exchanges with the eastern Maine coastal current that abuts the coast very closely. Area 2 (between Penobscot Bay and Portland) is a highly indented coastline, whereas from Portland south is an almost straight coastline. In area 2, even if the outer coast is affected, waterborne contaminants may not reach the upper regions of the highly indented coastline. By correcting for linear distance of shoreline, offshore influences appear to be minimal in area 2 and more important on either side. Although the scale is small, the change in indentation can be seen in the maps. The geography changes markedly in western Maine and New Hampshire.

Circulation in the Gulf of Maine

A review of the circulation in the Gulf of Maine also provides insight into other influences (see Figures 2 and 5). Apart from the currents, where particles are flowing at the surface and what is driving them, major water masses also influence what happens - where they are coming from and where they are going. The deep water results in the penetration of the dense slope water that comes in and fills the basin, along with the cold Scotian shelf water coming in at the surface. In between the two, there is the cold intermediate water layer coming out of the Gulf of Maine (along with some surface water as well).

Farther to the north, the Labrador Current that enters the Gulf of Maine (Figure 7). Offshore is the Gulf Stream, but it is quite removed. The north wall of the Gulf Stream, though, will create warm core rings. Every once in a while these rings will impinge against the Northeast Channel, which will make the warm, salty slope water from Gulf Stream origin or North Atlantic central water, available to enter through the Northeast Channel, whereas at other times it will not. There is an interesting region referred to as the Slope Sea, which is the region where exchanges between the cold shelf waters of Labrador Current origin and the features that spin off and are affected by the Gulf Stream.

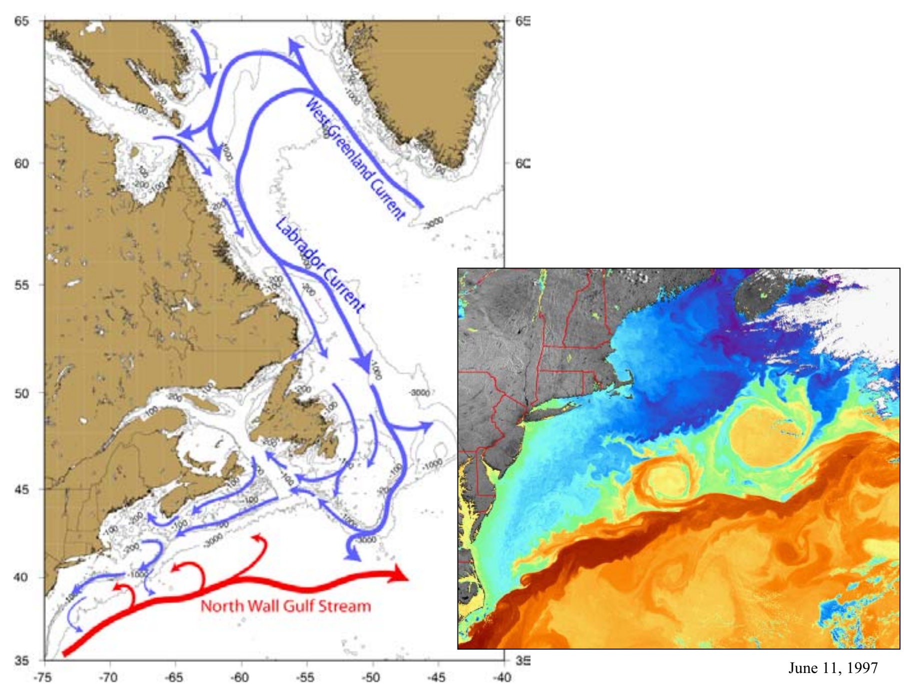

Figure 7. Large-scale circulation and offshore source waters. Arrows off the Gulf Stream indicate eddy formation of warm core rings (after Chapman and Beardsley, 1989, and Loder et al., 1998; satellite image from A.C. Thomas, University of Maine, http://wavy.umeoce.maine.edu)

Ballast Water Discharge

This discussion is relevant to ballast water exchange. When the cold, low salinity Scotian shelf current is altered, this is referred to as a "cross-over event." Normally, Scotian shelf water would correspond to the Coreolis effect and turn the corner from Nova Scotia and come into the Gulf of Maine. However, on a cruise in March and April of 1997, the shelf waters blew across to Georges Bank. This phenomenon was recorded because cod eggs were observed in our samples on Georges Bank that were clearly coming from the Brown's Bank and Scotian shelf area, and being brought down along the southern edge of Georges Bank. This means that the cold Scotian shelf waters will deliver whatever they have with them to almost anywhere into the Gulf and down the coast. It also spreads out over the Gulf of Maine and is important in bringing buoyancy in the springtime.

Because Scotian shelf water is relatively fresh, it is lighter than water beneath, even though it is very cold. The flow of this water into the Gulf of Maine tends to be maximal in winter and spreads out over the Gulf of Maine. During a cruise in the spring of 2000, a temperature inversion was recorded, i.e., the water was colder at the surface, but it was low-salinity Scotian shelf water so it set up the buoyant upper mixed layer that led to initiation of the spring phytoplankton bloom beginning much earlier than expected. The spring bloom of phytoplankton was postulated to begin first where the waters begin to warm, and indeed surface water is warm in the west and cold in the east. According to Sverdrup et al. (1942), the bloom is expected to occur first in the *west*, not the *east*, but on the spring 2000 cruise it was observed the other way around, which may in fact be the case every year. The water that comes in around Nova Scotia spreads slowly across the Gulf of Maine. Dave Mountain (NMFS, Woods Hole, pers. comm.) analyzed the time of year that the minimum surface salinity (from water coming in) spreads across the Gulf. It takes the better part of nine months to spread around the Gulf.

One reason to understand the nature of water mass flows is that it affects the ecosystem. First of all, the flow dynamics vary, especially in response to the North Atlantic Oscillation (NAO). The NAO is the differences in atmospheric pressure between Iceland and the Azores and plotted as an anomaly over the long-term trend (Figure 8). Differences in atmospheric pressure over time, fluctuate between periods where they are quite low (in the 1960s) followed

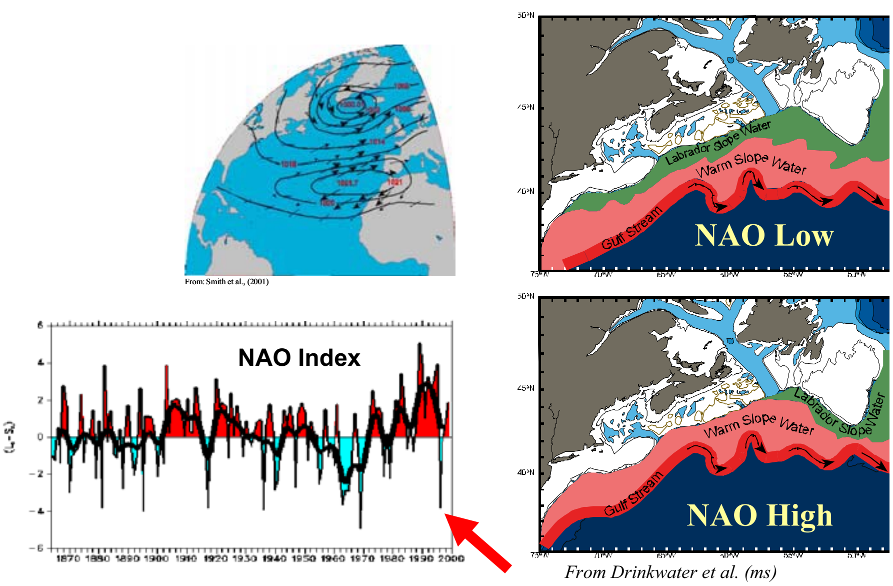

Figure 8. The North Atlantic Oscillation and its impacts on surface and deep water masses in the Gulf of Maine (from Smith et al., 2001). The red arrow points to a 1996-1997 NAO low event. *Reprinted with permission of Peter C. Smith, Bedford Institute of Oceanography.*

by a period when they are quite high. The red arrow in Figure 8 indicates a 1996-97 NAO low event. This is important because when there is an NAO low, the north wall of the Gulf Stream, is pushed farther to the south and it allows a penetration of Labrador slope water all the way down the coast as far as New Jersey (Figure 9). In fact, there is a very famous tile fish kill back in 1882 off the New Jersey coast that is thought to have been caused by this cold Labrador slope water that penetrated to New Jersey and resulted in the lower, lethal temperatures for those fish. But during an NAO high the cold waters do not make it as far (note Figure 8, which is cut off at the 200 meter isobath to show how the deep slope waters behave). Thus, the Labrador slope water flows all the way down during an NAO low year, but in an NAO high year it stops near the Laurentian Channel.

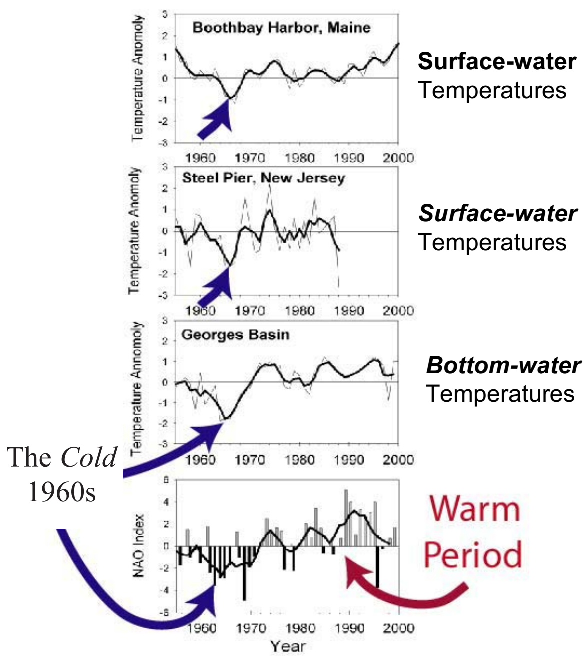

Figure 9. Far-ranging North Atlantic Oscillations that have connections to the Gulf of Maine surface and bottom water temperatures.

Concluding Thoughts

On the one hand, the Labrador slope water that is available to penetrate through the Northeast Channel and fill the Gulf of Maine during a low NAO, but it stops near the Laurentian Channel during a NAO high. Normally, with a high NAO, North Atlantic central water (or warm slope water) is available to enter the Gulf. The importance of the observed NAO relates differences in the water properties under high and low events. The Labrador slope water is very cold and not very salty. From 1998 when it penetrated the Gulf of Maine, very cold temperatures and fairly low salinities were measured, but more importantly, the concentrations of nutrients, (as nitrate) was very low, only reaching 15 micromoles at 200 meters depth. During a warm year, the temperature and salinity is very high, and the nitrate levels and silicates are very high, somewhere around 23 to 24 micromoles. That is a big difference in the nutrient injections that enter and then reside in the Gulf of Maine for as long as a year before they are flushed out again. The nutrient concentrations could set the stage for the overall production and whatever happens subsequently, and in fact low levels of production were observed in ocean color chlorophyll images in 1998, which was a cold-water year. The following year where the deep water was high-nutrient warm slope water, there was much higher chlorophyll production going on at the same time of year, both in the spring and in the summer, i.e., higher again in July 1999. These higher-nutrient loads enter the Gulf and influence the overall productivity of the Gulf of Maine. The Gulf of Maine is a complex system influenced by tides, currents, the Atlantic Ocean and climate events that affects productivity and dispersion of plankton and particles.

Audience Question and Response

A question from the audience was whether one could predict where particles would go ashore if a vessel discharged ballast water within 50 km of the shore. Townsend responded, yes and no. By way of explanation, he pointed out that to some extent the indented shoreline model discussed is very naïve. What really is most important along the coastline is the freshwater buoyant coastal current, and anything that is going to go from offshore to inshore has to pass through that front. Such materials in waters from offshore are more likely to go under the nearshore buoyant plume which means that materials are not going to reach the coast through the surface waters except in unusual circumstances. This could occur for example if the surface water were removed (perhaps by submergence) and offshore water entered. This does not usually happen and it is one of the dilemmas scientists face in explaining how *Alexandrium* sp. cells get into the coastal current. There must be mixing of coastal waters but how that happens is not clear. So there is a considerable blessing in that freshwater ribbon (the coastal current) along the coast which more or less protects the nearshore surface water.

Literature Cited

Hurst, J.W. and C.M. Yentch. 1981. Patterns of intoxication of shellfish in the Gulf of Maine coastal waters. *Canadian Journal of Fisheries and Aquatic Sciences*. 38: 151-156.

Signell, R. http://woodshole.er.usgs.gov/operations/modeling/index.html, last accessed 8/24/04

Smith, P.C., R.W. Houghton, R.G. Fairbanks and D.G. Mountain. 2001.Interannual variability of boundary fluxes and water mass properties in the Gulf of Maine and on Georges Bank: 1993–1997, *Deep-Sea Research Part II Topical Studies in Oceanography*, 48: 37-70.

Sverdrup, H.U., M.W. Johnson and R.H. Fleming. 1942. *The Oeans*. Englewood Cliffs, NJ: Prentice Hall Inc.

Physical Oceanographic Conditions on the Eastern Canadian Shelves

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Introduction

I would like to describe to you some characteristics of the waters off the east coast of North America that relate to the alternate ballast water exchange (ABWE) problem. I should emphasize at the outset that I am not the author of these results, which have been derived by my colleague at the Bedford Institute Oceanography, Brian Petrie. Unfortunately, Brian had a previous commitment in Seattle, Washington, and is unable to be here, so I am the messenger. Also if you would like to read more details about the results, I would refer you to two comprehensive reports by Brian and others (Petrie et al. 2001, and Petrie and Soukhovtsev 2002) which were contained in the information package you received on your arrival.

Today, I would like to give you a little bit of background for this project and describe some of the physical factors controlling the fate of ballast water released in our offshore waters. Then I will outline the methodology we have used to estimate the risk of ballast water contaminants or foreign species affecting sensitive marine resources and describe the results of our analysis.

Background/Motivation

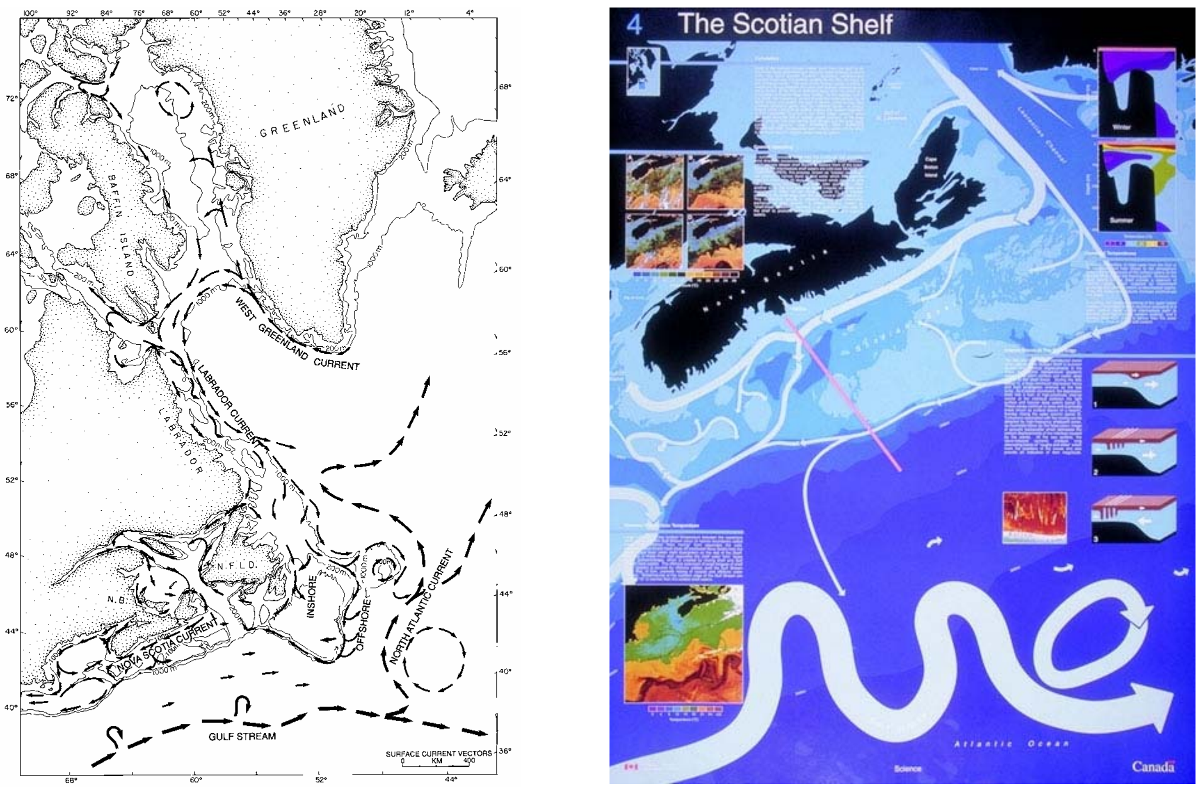
Original discussions of the alternate ballast water exchange problem between Transport Canada (responsible agency) and Department of Fisheries and Oceans (DFO) scientists at the Bedford Institute of Oceanography (BIO) resulted in a presentation describing our current understanding of the physical oceanography off Canada's east coast in the fall of 2000. This work was further documented in DFO's first report to Transport Canada (Petrie et al. 2001), which recommended, among other things, additional drifter studies and trials in areas of potential alternate ballast water exchange. Discussion of the results of these trials and the analysis of extensive historical drifter databases were contained in the second (and final) report to Transport Canada in April, 2002 (Petrie and Soukhovtsev 2002). The overall goals of these projects were:

a) careful assessment of the risks of bioinvasions from alternate ballast water exchange in proposed zones off the east coast, and
b) the protection of sensitive marine living resources.

Important classes of living resources requiring protection range from the widespread and diverse plankton communities, which may be detected in the surface layer by multi-spectral remote sensing imagery (e.g. SeaWiFS), to fisheries resources at higher trophic levels, such as the lucrative invertebrate species on the Scotian Shelf and Gulf of St. Lawrence.

Near-surface Circulation

The near-surface circulation off the northeast coast of North America (i.e. north of Cape Hatteras) consists of two primary opposing flows (Fig. 1a). As may be seen from the schematic circulation on the Scotian Shelf (Fig. 1b), a broad, complex southwestward current exists over the contental shelf and slope regions, punctuated by localized, gyre-like flows around isolated banks and other topographic features. This shelf water is generally colder and fresher than the offshore waters. Prominent features include the Nova Scotian Current, which emanates from the Gulf of St. Lawrence and flows along the coast of Nova Scotia. At Halifax, the Current splits, with one branch continuing along the coast and a second moving across the shelf to join the shelf break current near the 200 m isobath on the outer shelf. At the eastern edge of



(a) (b)

Figure 1. (a) Schematic diagram of near-surface circulation in the Northwest Atlantic showing two major and opposing current systems: the north-to-south flow along the continental margin and the south-to-north flow in the Gulf Stream and North Atlantic Current. (b) A more detailed schematic of the near-surface flow on the Scotian Shelf and surrounding waters.

the Northeast Channel, the main branch of the shelfbreak current turns shoreward into the Gulf of Maine following the eastern side of the Channel. An eastward flow along the northern flank of Georges Bank passes clockwise around the Northeast Peak of the Bank and feeds into another shelfbreak current which flows south-westward to the New England Shelf and into the Mid-Atlantic Bight.

In the deeper waters off the shelf, the primary current is the Gulf Stream, which carries warm, saline waters from the southwest to the north-east. At the Tail of the Grand Bank (~50^{o}W), the Gulf Stream splits into two branches (Fig. 1a), one of which continues eastward to close the subtropical gyre of the North Atlantic, and another which turns northward to form the North Atlantic Current that crosses the Atlantic at more northerly latitudes. Between the Gulf Stream and the shelf waters lie the moderately warm and saline slope waters, which are separated from the shelf waters by a sharp discontinuity known as the shelf-slope front (SSF). The prevailing mean currents in the slope waters are eastward, as in the Gulf Stream, but much weaker. However, the slope waters are populated by strong eddy-like structures and other mesoscale features, such as warm-core rings which are shed by the Gulf Stream. As a result, the energy of the variable flows at the surface, the so-called eddy kinetic energy, is much higher in the slope waters than on the shelf.

Circulation models, validated by direct observations, are useful in testing and assessing drift pathways in the surface layers, especially for the shelf environments. These observations and models show that strong annual cycles in the shelf circulation affect both the magnitude of the currents and the drift pathways for passive tracers in the flow. However, although the general drift rates may be assessed by models, the effects of horizontal dispersion in the surface layer are

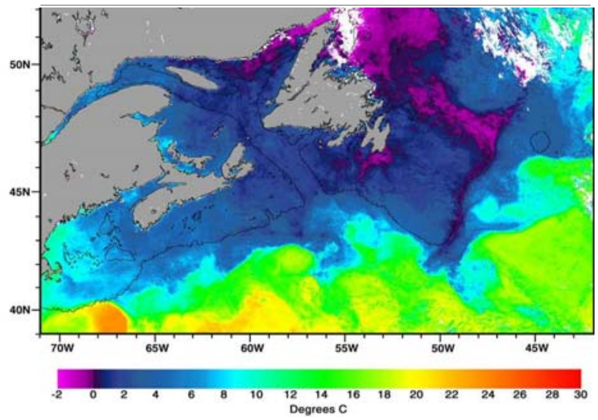


Figure 2. Composite satellite image of sea surface temperature for the period 1-15 May, 1999, indicating the complexity of the mesoscale eddy field in Atlantic Canadian waters, especially the slope waters.

more difficult to simulate, especially in the slope waters where the eddy kinetic energy is high.

Satellite imagery of the sea-surface temperature (Fig. 2) confirms the complexity of the near-surface circulation at all scales. The small-scale eddies which populate the coastal, slope, and temperate waters contribute strongly to the horizontal dispersion of all planktonic organisms, including those which might be contained in ballast water released in any of these areas. Because of the difficulties in modeling the effects of this turbulent process, Lagrangian drift observations (which follow a surface water parcel rather than measuring currents at a fixed point) are required to assess the risks of ballast water contaminants released in offshore waters. Furthermore, because of the chaotic nature of the flow, there must be a sufficient number of such observations to ensure the statistical significance of the results.

Lagrangian Drift Statistics and Vertical Mixing

Woods Hole researcher, David Fratantoni, has analyzed a large volume of historical drift tracks from the 1990s and has summarized his results on a $0.5^{o} \times 0.5^{o}$ grid of the northwest Atlantic (Fig. 3). These results show mean drifts ranging from near 0 m/s in the slope water areas to >1.0 m/s in and around the Gulf Stream (Fig. 3a). More importantly, they reveal a strong offshore gradient of eddy kinetic energy (EKE) in the slope waters, especially in the regions off the Scotian Shelf and the southeast Grand Banks. Increased EKE implies stronger horizontal dispersion and mixing and suggests that these may be the primary mechanisms for transporting ballast water contaminants in the slope waters that are under consideration as regions potentially suitable for alternate ballast water exchange.

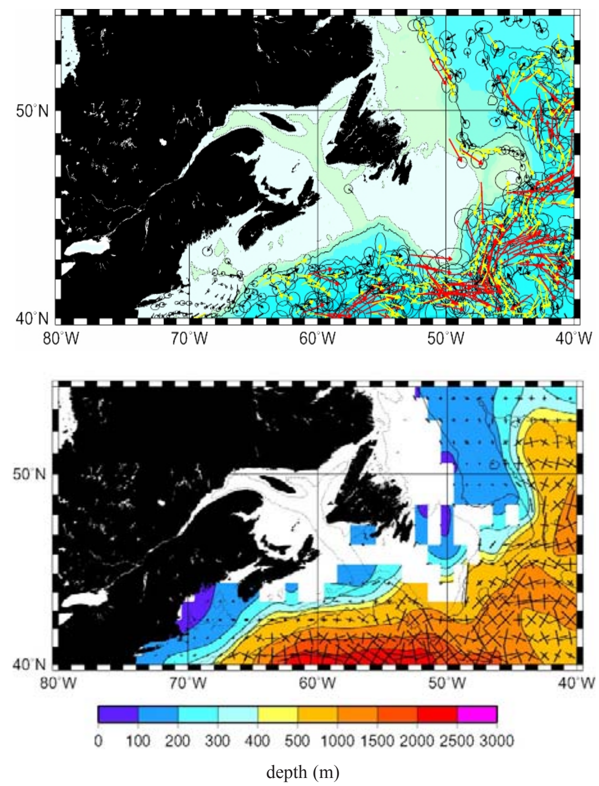


Figure 3. Drift statistics from historical data in the 1990's decadal mean currents in the ranges: 0-15 cm/s (black), 15-30 cm/s (yellow), and 30-100 cm/s (red); ellipse centered on the head of each vectors represents the standard errors in the zonal and meridional directions, and major and minor axes of the eddy kinetic energy (from Fratantoni, 2001).

Another factor to consider in assessing the suitability of the slope water regime is vertical mixing. This process not only dilutes the concentration of contaminants in the surface layer, but may also inject bioinvaders into different current regimes, water masses, and/or ecosystems that lie below the surface layer. To estimate vertical mixing rates in the near-surface slope waters, Brian Petrie fit a simple 1-D model to the observed amplitudes and phases of the ocean temperatures versus depth from BIO's historical database, following a method developed for the eastern Newfoundland shelf (Petrie et al. 1991). The rate of vertical mixing in this model is controlled by the vertical eddy diffusivity, K_v, which was found to lie in the range: $4<K_v<24$ cm^2/s for the Scotian Slope Water (Fig. 4). To put these numbers in perspective, in 10 days time, a passive tracer would mix from the surface down to a depth of roughly 45 (10) m if the eddy diffusivity had a value of K_v = 20 (1) cm^2/s. Thus the contents of the ballast water exchanged in the Scotian Slope Water regime could mix to a depth of roughly 50 m in 1-2 weeks.

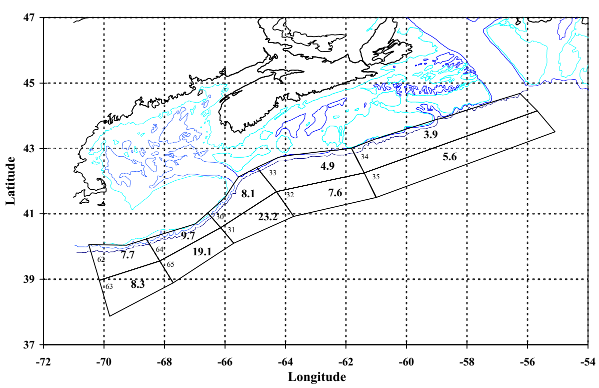
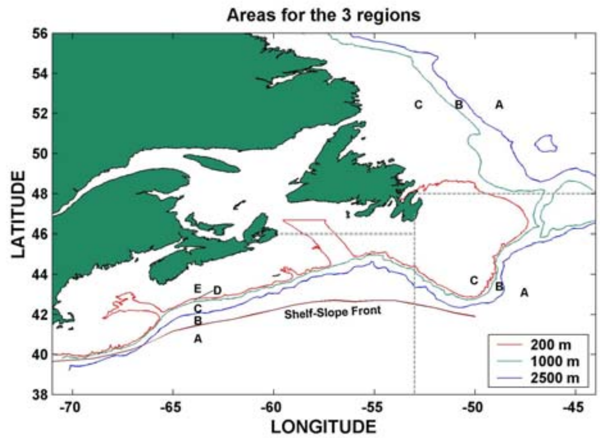


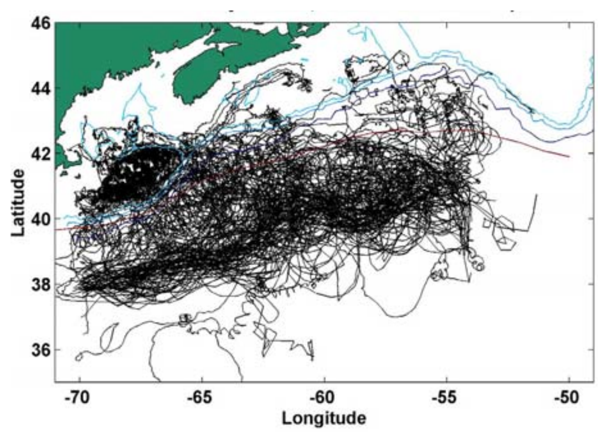
Figure 4. Estimates of vertical eddy diffusivity derived from annual cycles in ocean temperatures in offshore waters of the Gulf of Maine and Scotian Shelf (see text).

Evaluating Risks of Horizontal Dispersion in Potential Zones of ABWE

The assessment of the risk of bioinvasions from proposed regions of ABWE in Atlantic Canada was based on the presumption that the chances of surface-layer transport from the zone of interest to the nearshore waters within a reasonably short timescale (10-20 days) was to be minimized. Three different proposed zones were considered in the offshore regions of the Scotian Shelf, the southeastern Grand Banks, and the



(a)



(b)

Figure 5. (a) Zones of potential ABWE in three regions, including the Scotian Shelf (SS), southeastern Grand Banks (SEGB), and northern Newfoundland Shelf (NNS). Sub-zones are delimited by isobaths, latitude, and the shelf-slope front (SSF):

SS	SEGB	NNS
40^{o}N>A>SSF	A>2500 m	A>2500 m
SSF>B>2500 m	2500>B>200 m	2500>B>1000 m
2500>C>1000 m	C<200 m	C<1000 m
1000>D>200 m		
E<200 m		

(b) "Spaghetti diagram" of historical drift tracks in the Scotian Shelf region.

northern Newfoundland Shelf (Fig. 5a). Historical surface drifter data from the archives of the Canadian Marine Environmental Data Service (MEDS) were used to estimate the likelihood that a passive particle released in any "subzone" of the region of interest would reach any

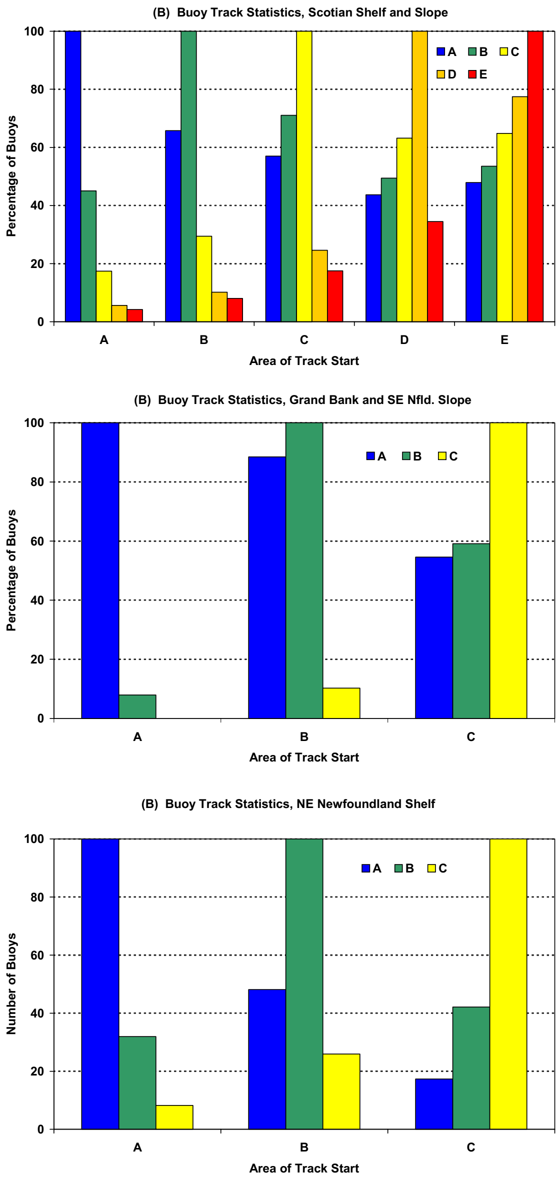


Figure 6 Transition statistics for surface drifters originating in each sub-zone of the three regions of interest for ABWE, expressed as a percentage of tracks tha intercepted that sub-zone. For example, in sub-zone A of the Scotian Shelf, 100% (blue bar) of those tracks that started in A intercepted A, but only 4% (red bar) intercepted sub-zone E.

other sub-zone of the same region, and the typical timescale over which this transition would occur. Specifically, for the Scotian Shelf example, the offshore was divided into five sub-zones, delimited by either an isobath or the historical position of the shelf-slope front (SSF). Similarly, three isobath-delimited sub-zones were identified in each of the two regions of the Newfoundland shelf and slope. Then, using the historical data (see Fig. 5b for the Scotian Shelf example), each drift track originating in a particular sub-zone was identified and used to estimate the both the residence times in the sub-zones of origin and the rates of transition between sub-zones.

The transition probabilities for all sub-zones, based on literally hundreds of tracks originating in each, show, for instance, that only 4% of the drifters launched in sub-zone A off the Scotian Shelf crossed the 200 m isobath onto the Scotian Shelf (sub-zone E) (Fig. 6). Similarly, tracks originating in sub-zones A off the Newfoundland Shelf regions showed 8(0) % probability of reaching the shelf waters in the northeastern (southeastern) zones, respectively. Thus, again assuming that the marine resources most sensitive to ballast water contaminants are found on the continental shelves, it would appear that the "safest" sub-zones for ABWE are beyond the 2500 m isobath or the SSF in the slope waters.

This conclusion is confirmed by examination of the transit and residence times calculated for

Table 1. Residence and transit times estimated from historical drift tracks for sub-zones A-E of the potential ABWE region off the Scotian Shelf. Sub-zone definitions are found in Fig. 5a. Residence times (average and range, in days) lie on the axis of the matrix; off-axis estimates are for transit times from one sub-zone to another.

Time (days) for buoy in	**To get to A**	**To get to B**	**To get to C**	**To get to D**	**To get to E**
Start in A	16.4 0.2-291.5	9.3 0.2-126	12.5 0.5-141	14.4 4.8-224.3	20.2 5.9-255.3
Start in B	2.1 0-54	2.6 0-61.4	3 0-40.9	5.1 0.3-56.4	6.8 1.3-87.4
Start in C	5.5 0.8-35.1	3.8 0.2-29.4	3.6 0.2-29.4	1.4 0-28.7	5 1.3-46.5
Start in D	7.2 1.3-35.6	6 0.6-31.3	1.4 0-28.7	1.2 0-31	1 0-31
Start in E	28.5 3.4-131.5	24 2.4-131.5	21.1 1.1-192.5	16.3 0.2-191.7	19.7 0.2-191.7

the individual sub-zones. For the Scotian Shelf zone (Table 1), the median residence time in sub-zone A is roughly 16 days (though the range is 0.2 to 291 days) and the transit time from A to E is in excess of 20 days. These timescales of 2-3 weeks are sufficient for ballast water contaminants or foreign species to dilute to very low concentrations, both horizontally and vertically within the water column, and therefore to present much less serious risk than they did at the time of the original exchange. Similar tables for drift statistics in the proposed ABWE zones off Newfoundland may be found in Petrie and Soukhovtsev (2002).

Conclusions

The major conclusions of this study are as follows:

- The risk of establishing ABWE zones in Atlantic Canadian waters deeper than 2500 m, especially outside of the SSF off Nova Scotia, is low with regard to the probability of invasion into the shelf waters (0-8%), especially considering the the amount of dilution that would occur during such a transition;
- The average transit times between these offshore sub-zones and shelf waters ranges from roughly one to four weeks, but individual transit times vary widely.

We trust that this information will assist the appropriate authorities to make informed decisions regarding the establishment of alternate ballast water exchange zones.

References

Fratantoni, D. 2001. North Atlantic surface circulation during the 1990’s observed with satellite-tracked drifters. *J. Geophys. Res*. 106(C10): 22,067-22,093.

Petrie, B., J.W. Loder, S. Akenhead and J. Lazier. 1991. Temperature and salinity variability on the eastern Newfoundland Shelf. *Atmosphere-Ocean*. 29(1): 14-36.

Petrie, B., J. Loder, J. Chasse and G. Han. 2001. Review of the Physical Oceanography of the Newfoundland and Scotian Shelf Regions for Transport Canada in reference to Alternate Ballast Water Exchange Zones. Unpublished Report to Transport Canada

Petrie, B. and V. Soukhovtsev. 2002. Report on Oceanographic Studies related to Alternate Ballast Water Exchange Zones. Unpublished Report to Transport Canada

Circulation and Dispersion on the Southern New England Shelf: Implications for Ballast Water Exchange in the U.S. Exclusive Economic Zone

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An edited transcript of the presentation

In this paper, I first introduce some of the topic and language. Most of what I will be discussing requires an understanding of Lagrangian velocity and dispersion. Then I am going to tell you some of what is known about the circulation in the Mid-Atlantic. It is clear that is an important aspect of managing ballast water exchange. I will show you some data from drifters and will conclude with some speculations as to what might be alternative ballast water exchange zones.

Alhough we have been measuring the character of the physical oceanography in Middle Atlantic for the last hundred years, it is not all that relevant to the problem you are interested in addressing today. Unfortunately, we can not really measure across-shelf transport of materials very well yet. And, therefore, we do not have a good predictive capability for the rates at which transfer across shelves occurs. That may be one of the most important messages I convey in this presentation.

Discharge zone definitions based on water depth are just not very sensible, it seems to me. Although we do not understand very much about cross-shelf transport in a quantitative way, we do know qualitatively that it does not depend upon the depth very much. The locations of the discharge zones should be defined by the character of the circulation.

A picture of the surface *chlorophylla* distribution in southern New England and the continental shelf area is shown in Figure 1, a map created by David Ullman of the University of Rhode Island (pers. comm.) from chlorophyll estimates derived from satellite imagery. I am showing it mostly to identify the geography. The boxed area shows the Connecticut River and the eastern end of Long Island Sound (LIS), and Long Island. LIS is connected to New York Harbor and the mouth of the Hudson River by the East River, which is a sea-level canal really, not a river. The East River was blasted in the 19th century to make it deeper for navigation. A substantial amount of fresh water gets from the Hudson into the western part of Long Island Sound and the western part of Long Island Sound is fresher than the eastern part, notwithstanding the fact that the Connecticut River, the primary tributary for Long Island Sound, discharges into the eastern end. Another curious thing about Long Island Sound is that the vertically averaged mean flow in the East River goes to the west. Water comes from the relatively salty part of LIS into New York Harbor.

Yet the western end of LIS is fresher than

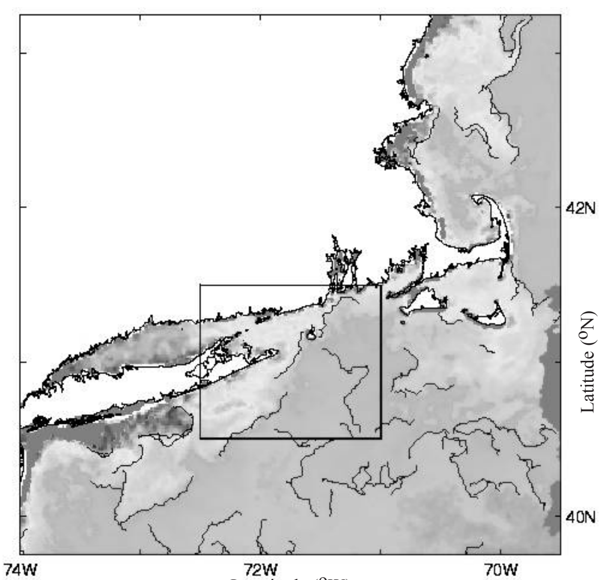

Figure 1. Surface *chlorophylla* distribution in southern New England and the continental shelf area. The boxed area shows the Connecticut River and Long Island Sound, darker areas have more *chlorophylla.*

the eastern end. How can this be? It is because of "dispersion". Though the mean flow is westward in the East River, the tidal motion moves both east and west. When it flows eastward, water comes from the Hudson into LIS and mixes with some water there. On the opposite phase of the tide a blob of almost equal volume goes the other way and that water mixes with the water of New York Harbor. What has happened over the tidal cycle is that some salt has been transported from Long Island Sound into the East River because the water that went west was saltier than the water that came east.

Salt has been transported from where the water is salty to where it is fresher, the opposite direction to the mean flow. This is an important principle. The dispersion flux of salt can be directed in the opposite direction to the mean flow or in the same direction. In this example a regulation that only focused on the Hudson would not make any sense because of the circulation and dispersion.

The circulation in the Northeast United States is shown in Figure 2. This diagram is published quite a lot because we know it is pretty good. Circulation on this scale can be estimated by oxygen isotope ratios. What you see is that on the southern New England shelf the water is going to the west and at about 0.25 Sverdups (million cubic meters per second) between the coast and 100 meter isobath. Another 0.25 Sverdrups (roughly) goes west in a narrow jet that flows along the edge of the shelf. So it is roughly half a Sverdrup total and we consider that a fairly reliable measurement.

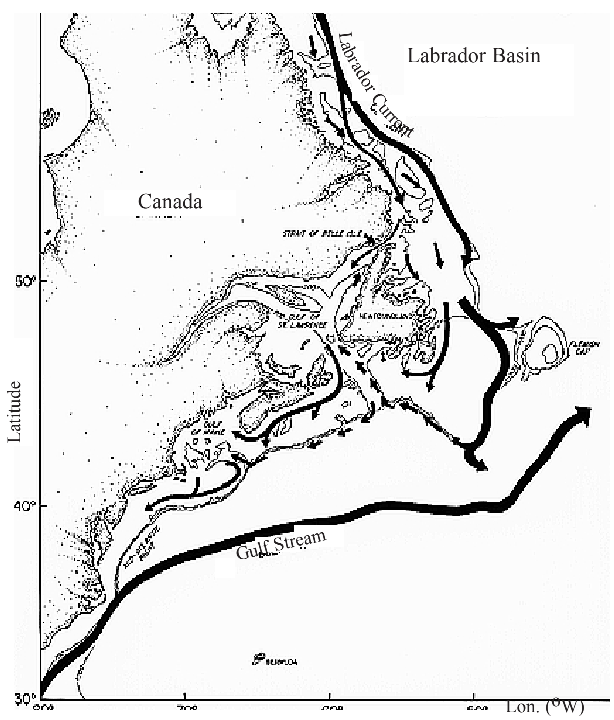

Figure 2. A water circulation diagram for the Northeast United States (from Chapman and Beardsley, 1989).

Because we can measure it pretty well, we know the fresh water discharge into the Mid-Atlantic from the Connecticut River is 627 m^3/s. This fresh water mixes with ocean water in Long Island Sound and it all shoots out onto the inner shelf off southern New England.

The discharge from LIS results in a circulation that can be represented by velocity vectors at a particular time. An example from measurements by a surface current radar system that is operated by the University of Connecticut (UConn) and the University of Rhode Island (URI) is shown in Figure 3. This involves some interesting technology that I have been working with, but will not discuss now. The point is, if you measure the velocity of a particular location as a function of time then you can show the pattern with vectors. This is called the Eulerian velocity.

An alternative way to describe the circulation is by tracing the path of a particle in time.

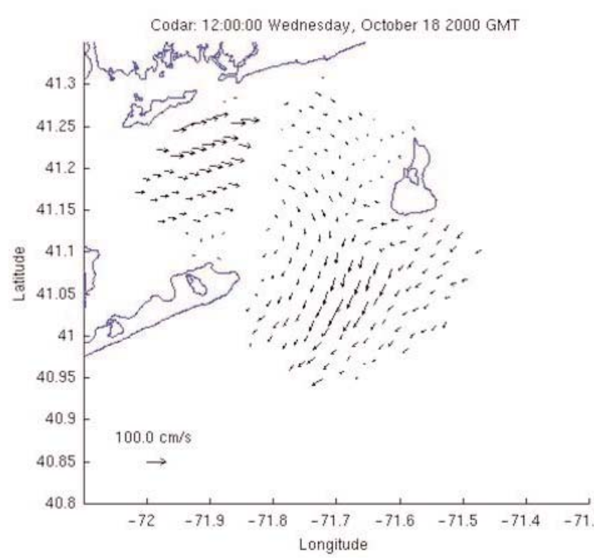

Figure 3. A sample of measurements from a surface current radar system; arrows indicate velocity vectors.

We do this by dropping a drifter that locates itself using Geographic Positioning System (GPS). These units transmit their position to a satellite. Figure 4 shows the track of a drifter launched in 2002 (heavy lines) with some simulations of the path (light lines). We can follow a particular drifter into LIS when the tide floods and out again when it ebbs. The pattern is not quite symmetrical so the drifter trajectory tends to move out eventually. These tracks are called “Lagrangian trajectories”.

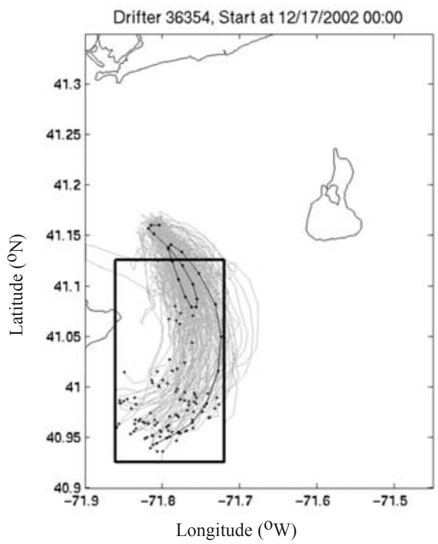

Figure 4. The track of a drifter (dark curved line inside box) with some simulations of the path (light lines).

The simulations show that multiple drifters that begin close together, but sample slightly different Eulerian velocity fields, can have quite different Lagrangian trajectories. It is the rate of separation of Lagrangian trajectories that indicates the magnitude of dispersion. Clearly, some areas will have more complicated patterns of Eulerian flow and, consequently, more rapid dispersion.

Now I am going to talk a little bit about the circulation on the Southern New England shelf. This information is based on a paper by Linder and Gawarkiewicz (1998). In Figure 5, the middle box is called the Nantucket Shoals area. They took all the data that was available in the archives for this area and plotted it as a cross-section, based on how far it was from the shelf break, the 100 m isobath according to their definition.

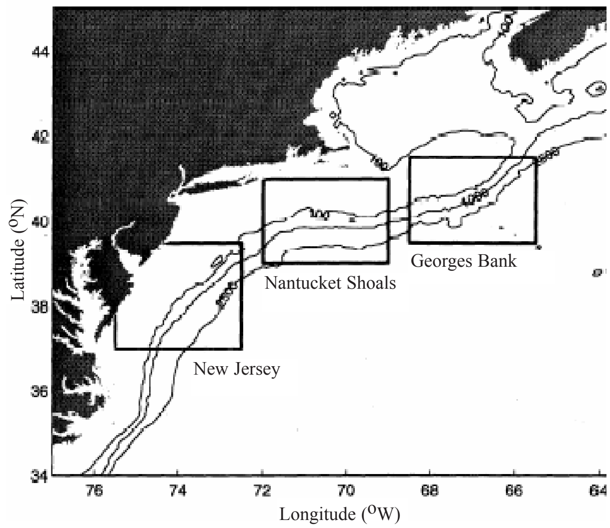

Figure 5. The New England shelf hydographic structure (from Linder and Gawarkiewicz, 1998).

Figure 6 shows the mean summer and winter temperature sections across the shelf. What you see is that the water column has been vertically stratified by heating in the summer. In the winter the temperature is homogeneous because there is less heating and more stirring by wind. Figure 7 shows the corresponding salinity distributions in the summer and winter. The higher salinity values are characteristic of the ocean water. Notice that even though heating does not affect the salinity of water, there is a substantial vertical gradient of salinity over the shelf in the summer.

This suggests that across shelf exchange of salt from the salty ocean and fresh water from the estuaries is higher in the summer. It is plausible that across shelf transport is enhanced by the thermal stratification which isolates the effect of bottom friction from the surface waters.

Part of the velocity field that can be inferred from the temperature and salinity observations, however, is along shelf component. Figure 8, from Linder and Gawarkiewicz (1998), shows what is called the geostrophic flow. Clearly, in the summer there is a very strong jet-like structure right at the shelf break. This narrow jet is about 20 to 40 km wide and carries about half of the along shelf transport in the Southern New England shelf. The other half is distributed across the rest of the shelf. In the winter the jet is weaker with maximum values of about 10 cm/s.

Though all this is interesting, it does not tell

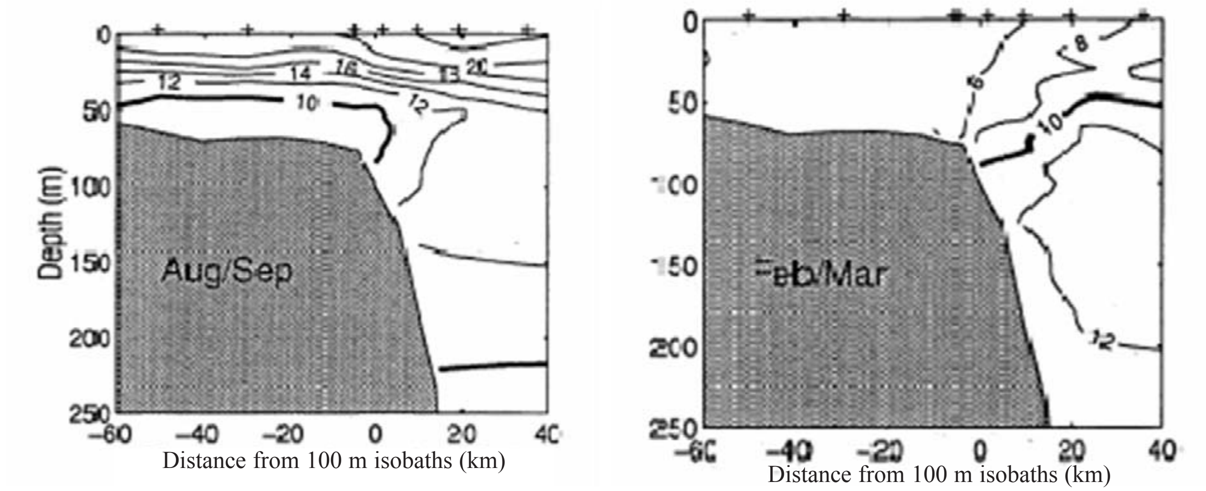

Figure 6. The mean summer and winter temperature sections (^{o}C) across the shelf (Linder and Gawarkiewicz, 1998).

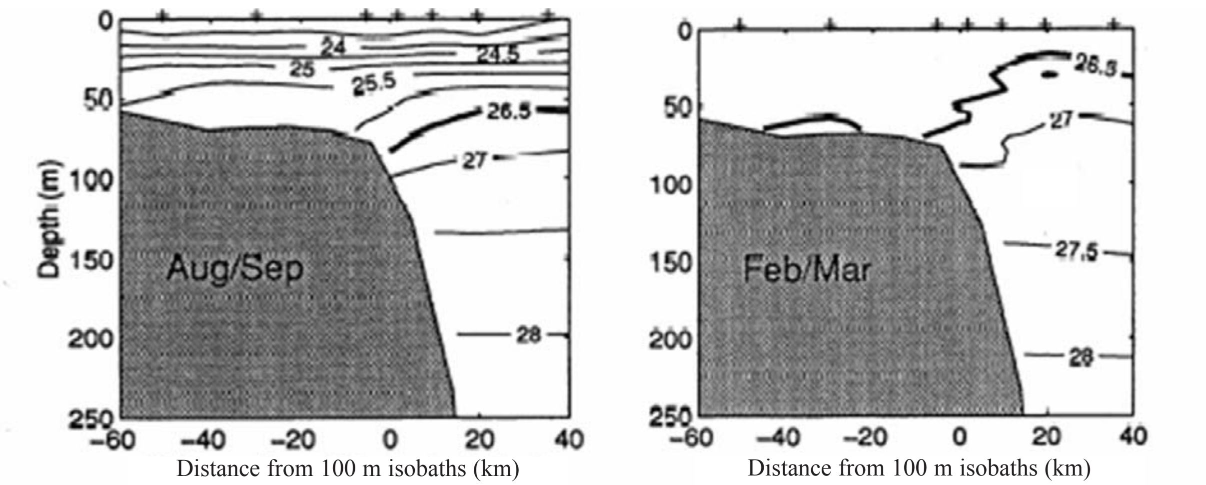

Figure 7. The mean summer and winter salinity sections (ppt) across the shelf (Linder and Gawarkiewicz, 1998).

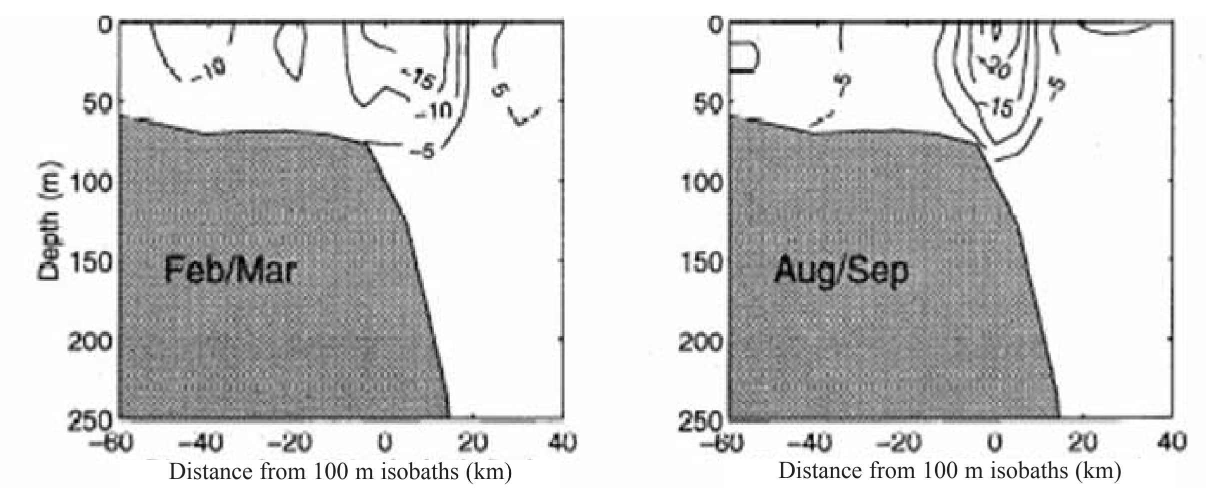

Figure 8. The geostrophic flow, in cm/s (Linder and Gawarkiewicz, 1998). Shelf flow is ~10 cm/s over the shelf with a narrow shelf-edge jet.

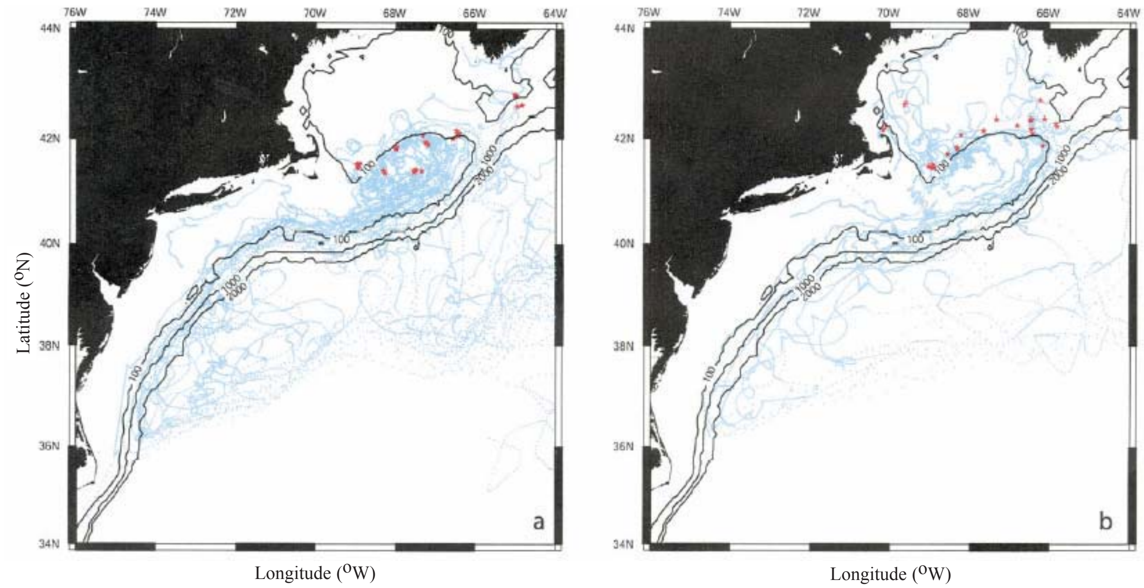

Figure 9. A compilation drifter trajectories following release on Georges Bank. The drifters were drogued below the surface of (a) 10 m (1996) and (b) 40 m (1995-1997) (Lozier and Gawarkiewicz, 2001).

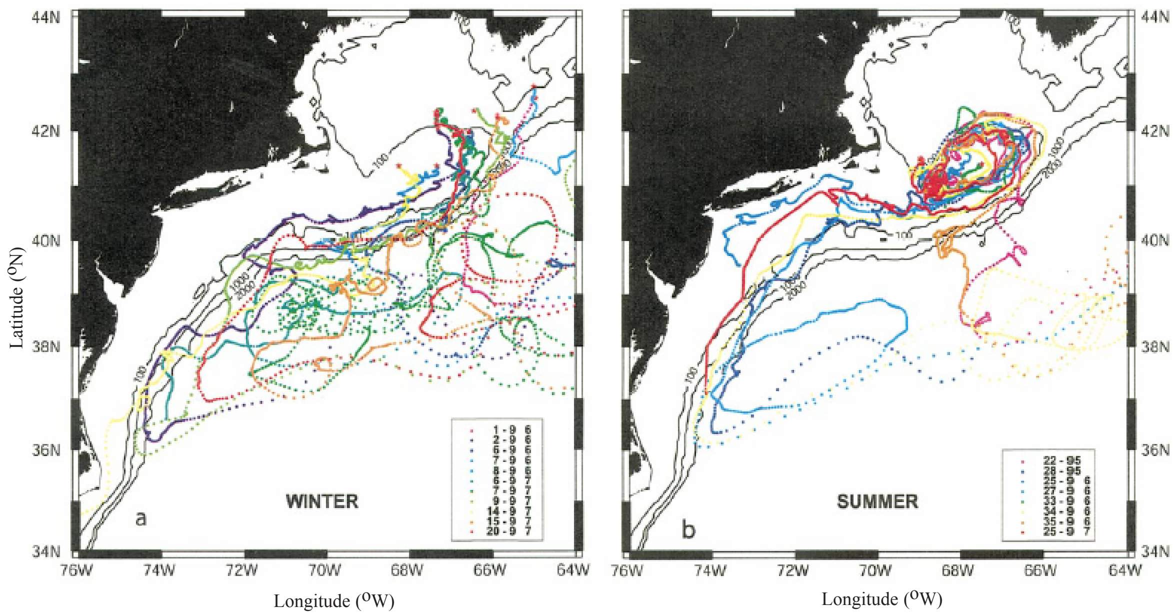

Figure 10. The compilation of tracts from drifters released on Georges Bank drogued at 10 m below the surface, segregated into winter and summer deployments (Lozier and Gawarkiewicz, 2001).

you anything about the impact of ballast water exchanged at the edge of the Continental Shelf. For that you need to know the across shelf velocities. These are small and hard to measure so we do not talk about them very much.

The only way these small velocities can be reliably observed at the moment is through the tracking of drifters. Figure 9 shows a compilation of tracks from drifters released on Georges Bank in 1996 (see Lozier and Gawarkiewicz, 2001). One set were drogued at 10 m below the surface and another set at 40 m. The data suggest that water at both levels circulates around Georges Bank and then leaks on to the mid-Atlantic Shelf at the southwest corner. They then track the edge of the shelf (approximately the 100 m isobath). Of those drifters that leak from the edge of the shelf, very few move across the

Figure 10 shows the 10 m data segregated into summer and winter deployments. None of the drifters crosses the shelf towards shore during the winter. But in the summer, there are four or five going across the shelf, and some go very close to Block Island. This is consistent with the notion that the across shelf flux (dispersion) is larger in summer. The stratification might make the surface motion "slippy."

There are very few drifter releases in the middle of the shelf. With David Ullman, Chris Edwards, and Art Allen, we deployed some in the winter of 2003 to assess how well our CODAR current measuring system was performing. Figure 11 shows the tracks of 13 drifters released in December 2002 and March 2003. The black circles are the starting locations and the lines show the paths over a thirty-day period. Most of the drifters traveled southwestward at about mid-shelf. I want to point out two things: one is that there is a persistent and substantial mean flow along the shelf as described by Linder and Gawarkiewicz (1998), and there are occasional reversals of motion due to winds. It is fairly well established that southeast winds cause the surface waters to move offshore. There is also a compensating flow onshore at depth. Strong wind, around 20 m/s, can cause water to move about 30 km across the shelf.

Translating drifter trajectories to dispersion coefficient estimates is quite straightforward. The hard thing is getting enough data to make the estimates meaningful statistically. Dye can be used but it is also labor-intensive and difficult to reproduce. Radiochemical tracers have also been used.

Torgersen et al. (1997) used radium distributions in Long Island Sound to obtain a dispersion rate of about 30 m^2/s. Sundermeyer and Ledwell (2001) did a similar dye experiment south of Nantucket in about 60 m of water. Twelve hours after dye had been pumped into the water near the bottom, it had spread vertically. After 60 hours it had spread over 6 km. The calculated spreading dispersion area is 5 m^2/s.

Recently I have been trying to do a similar experiment in the East River because I want to know about exchange between the Hudson/New York Harbor, and the western part of Long

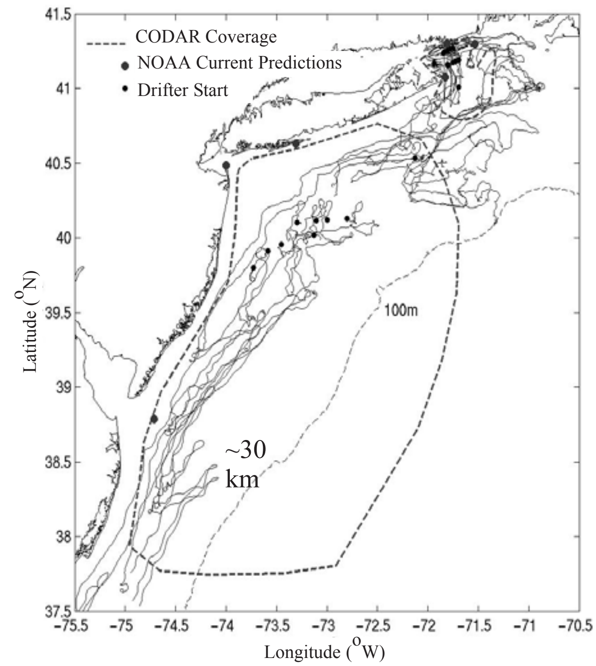

Figure 11. Front Resolving Observational Network and Short Term Prediction System drifter deployments. The Block Island Sound Region is from Dec. 2002 and March 2003 releases; the New Jersey Shelf Region is from March 2003 drifter release (O'Donnell, Ullman, Edwards and Allen (unpublished data)).

Island Sound. There are a lot of waste water treatment plants in the East River and in Connecticut and we want to know how much effluent ends up in our waters. I have estimated, using a variety of techniques, that the dispersion coefficient, K, could be as much as 500 to 1,000 m^2/s. Literature estimates in other big estuaries with vigorous tidal currents are several hundred m^2/s. In summary, a hundred is big and characteristic of a flow in an estuary, a thousand is really big and might be found in complex channels with strong tides, and 5 is tiny.

If you are more interested in what happens to something that you eject into the water that disperses like dye and decays (or dies) with a half life of T (perhaps ten days), you can estimate what the scale of the patch would be using the dispersion coefficient estimate K. This is not a bad model of plankton in water of inappropriate salinity or temperature. Approximately the size of the patch would be $L \sim (KT)^{1/2}$, where L=dispersal distance, K=dispersion, and T=half life of plankton.

For K=30 m^2/s and T=10 days (~10^6 s), then L~6 km. But if T is 100 days, then L goes up by the square root of 10, which is ~3 so it would go up to ~20 km. These scales are really quite small relative to the width of the shelf. So I think that the scale of discharge impacts might be only 10-30 km. That would be, I think, the best estimate I can provide at the moment.

The real weakness in all of this is that there are very few measurements of across-shelf motion in the summer when the water is stratified. There may be mechanisms that transport water onshore quite rapidly and into estuaries. There are some ideas and preliminary observations, but we just don't know. And all of my discussion has assumed that the pollutant behaves like water, but we know some organisms have behavior, they sink and swim in response to salinity and temperature variations. We just do not know how fast and they do it in the ocean. Much remains to be understood; I have attempted to summarize what we know and how it can be used.

Literature Cited

Chapman, D.C. and R.C. Beardsley. 1989. On the origin of the shelf water the Middle Atlantic Bight. *J. Phys. Oceanogr.* 19: 384-391.

Linder, C.A. and G. Gawarkiewicz. 1998. A climatology of the shelfbreak front in the Middle Atlantic Bight. *J. Geophys. Res.* 103(C9): 18405-18423.

Lozier, M.S. and G. Gawarkiewicz. 2001. Cross-frontal exchange in the Middle Atlantic Bight as evidenced by surface drifters. *J. Phys. Oceanogr.* 31(8): 2498-2510.

Sundermeyer, M.A. and J.R. Ledwell. 2001. Lateral dispersion over the continental shelf: Analysis of a dye release experiment. *J. Geophys. Res.* 106: 9603-9621.

Torgersen, T., E. A. DeAngelo, and J. O'Donnell. 1997. Calculations of horizontal mixing rates using ^{222}Rn and the controls on hypoxia in western Long Island Sound, 1991. *Estuaries.* 20(2): 328-345.

Biological Oceanography

Estimating Domestic and Foreign Ballast Water as a Vector for Invasive Species: Regional Analysis for New England, Northeast North America

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Abstract

Biological invasions of coastal ecosystems are increasing at an alarming rate, with the increases attributed primarily to shipping, especially plankton in ballast water discharge. Although regulations of ballast water discharge have focused primarily on arrivals from foreign last ports of call, domestic arrivals also transfer ballast water and associated organisms within and among regions on coastwise voyages. However, to date there has been little effort to measure patterns of domestic ballast water discharge for any region of the U.S. We examined shipping patterns and estimated volumes of ballast water discharged by domestic compared to foreign arrivals for ports of the New England region using nationwide data on U.S. shipping arrivals and ballast water discharge by ship type for a three-year period (July 1999-June 2002). Overall, New England ports combined receive similar numbers of domestic and foreign arrivals, although the number and composition of domestic versus foreign arrivals differ greatly among ports. Domestic arrivals differed from foreign arrivals by composition of Ship Type (Bulk Carrier, Container, General Cargo, Passenger, Tanker and Other), and the composition of Ship Type differed among ports within the region. Estimates of ballast water discharge also differed greatly by Ship Type, with Bulk Carriers and Tankers discharging 4-6 times the volume of other types. In combination, domestic arrivals contributed about 35% of the estimated 24.8 million metric tons of the total ballast water discharged into ports of the New England region. In general, domestic ballast water often has high densities of plankton, because domestic voyages are of short duration and survival of entrained organisms in ballast tanks is high. Based on the patterns of ship arrivals, many New England ports are receiving discharges of domestic ballast water at high frequencies on a repeated basis from the same source ports along the East Coast of North America. This combination of large volume, high density of entrained organisms, and repeated discharge from the same ports, creates a high risk of introduction and invasion by nonindigenous species. Although our comparison of domestic and foreign ballast water discharge for New England is extrapolated from limited data, our estimates indicate that domestic ballast water is an important component of invasion risk that requires more accurate measurement.

Introduction

Biological invasions of coastal ecosystems result globally in serious ecological and economic consequences (Carlton 1989; Carlton and Geller 1993; Ruiz et al. 1997, 1999). Marine invasions have received relatively little attention compared to terrestrial and freshwater communities, but the consequences of invasions are no less evident in marine systems than in freshwater and terrestrial systems (Carlton 1989, 2001; Pew Ocean Commission 2002). Approximately 500 marine and estuarine NIS are known for the coastal U.S., and over 200 of these can occur in a single estuary (Cohen and Carlton 1995; Ruiz et al. 1997, 2000). The number of nonindigenous species and their documented rates of invasions are increasing at an alarming pace in many U.S. ports as well as along all three coasts of North America (Cohen and Carlton 1998; Ruiz et al. 2000). Although many vectors cumulatively are responsible for the transport and introduction of non-native species into coastal waters, commercial shipping—particularly release of plankton in ballast water—is a primary cause of the rapidly increasing rate of invasion (Ruiz et al. 2000). The United States and Australia each receive >79 million metric tons of ballast water annually on ships arriving from foreign ports (Kerr 1994; Carlton et al. 1995). A taxonomically diverse community of organisms is entrained and transported within ballast tanks, resulting in many successful invasions of nonindigenous species at ports throughout the world (e.g., Carlton and Geller 1993; Cohen and Carlton 1995; Smith et al. 1999; Hines and Ruiz 2000).

A number of legislative and regulatory actions have attempted to reduce the risk of invasion associated with ballast water transport. In 1991, the International Maritime Organization (IMO) established voluntary guidelines for ships to perform mid-ocean ballast water exchange (BWE). BWE reduces risk of invasion by discharging a large percentage of the entrained coastal plankton into inhospitable mid-ocean ecosystems, and by increasing salinity within ballast tanks to a level that many freshwater and brackish water species cannot survive (Taylor et al. 2002; Murphy et al. 2004; Ruiz et al. 2004). BWE is now the primary method for reducing the risk of species transfer and introduction by ships. To prevent further invasion of the freshwater ecosystems of the Great Lakes, the U.S. and Canada mandated mid-ocean ballast water exchange for all ships entering the St. Lawrence seaway. The National Invasive Species Act of 1996 established the National Ballast Information Clearinghouse (NBIC) and required that vessels arriving to all U.S. ports from foreign ports outside the exclusive economic zone (EEZ) report their ballast water management practices to the NBIC. However, voluntary compliance to conduct mid-ocean exchange is low (NBIC 2001). In addition, several U.S. states (California, Oregon, Washington) now require BWE for all vessels intending to discharge ballast water from foreign voyages. Moreover, the U.S. Coast Guard intends to extend mandatory BWE regulations to all discharge of ballast water from foreign arrivals.

Ballast water is also carried by ships on domestic voyages, which may be a significant source of coastwise transport and spread of nonindigenous species (Hines and Ruiz 2000; Lavoie et al. 1999). Domestic, coastwise voyages are often of shorter duration (12-72 hr) than foreign, transoceanic voyages (6-30 days), and survival of entrained plankton within ballast tanks is much higher on short voyages (Hines and Ruiz 2000, Ruiz et al., unpublished data). However, the quantity and discharge pattern of domestic ballast water is poorly understood.

In this paper we provide a first quantitative estimate of ballast water delivered by domestic (including voyages originating in Canada, as defined by NISA 1996) and by foreign arrivals of shipping on a regional basis, using New England as a test region. Because ballast water management practices differ greatly among types of vessels, we present summaries of foreign and domestic arrivals, quantities of ballast water and their sources (ports of last call) for New England ports by ship type.

Methods

Ship Arrivals

Ship arrivals information was provided by the U.S. Department of Transportation's Maritime Administration (MARAD). MARAD compiles U.S. Customs and U.S. Army Corps of Engineers data on ships arriving to the coastal United States. These data are used to characterize both foreign (overseas) arrivals as well as domestic (coastwise) traffic. The National Invasive Species Act of 1996 (NISA) and associated federal regulations characterize foreign arrivals as ships that visit U.S. ports immediately following time spent outside the Exclusive Economic Zone (see NBIC 2001). Because all ships arriving to the Atlantic coast of the United States from the Atlantic Canadian Maritime and Atlantic provinces are considered domestic coastwise arrivals under NISA, they are included here as such. Arrivals from other North American countries (Mexico and Central America) are considered by NISA and here as foreign. All ship arrivals data refer to the 3-year time period from July 1, 1999 to June 30, 2002.

BALLAST WATER VOLUMES

Foreign Traffic

Ballast water discharge volumes are estimated by querying the National Ballast Information Clearinghouse database. The National Invasive Species Act requires that all foreign ship arrivals report ballast practices with NBIC. However, it has been shown at the national level that only about 30% of qualifying vessels in fact reported (N = 12,015) (NBIC 2001). For this reason, we chose to estimate a projected foreign arrival discharge volume to selected New England ports by calculating average discharge volume per ship based upon foreign arrivals across the United States for each of six ship types: Bulk Carrier, Container, General Cargo, Tanker, Passenger, and Other. The category "Other" includes many unidentified ships that were likely Bulk Carriers and Tankers.Clearly, not all ship arrivals discharge ballast (e.g., many arrive full of cargo and little ballast water), so only the subset of ballast water reports that indicated ballast discharge was included in the mean volume discharge for ship types. To avoid inflating discharge volumes by including all arrivals (some of which do not discharge), the number of dischargers was estimated to be 26.4% of overall arrivals as calculated by NBIC (2001).

Domestic Traffic

Domestic coastwise traffic has not been required under federal law to report ballasting activities, so such data are not systematically compiled. However, significant numbers of domestic arrivals did report to the NBIC during the July 1999 to June 2002 time period (N = 1,219). Using these data, average discharge volumes per ship were calculated for the nation as a whole for each ship type and multiplied by the number of overall arrivals to New England ports. In the absence of more comprehensive domestic data, we also applied the proportion of discharging foreign arrivals (26.4%) to estimate the fraction of total domestic arrivals that discharged ballast water.

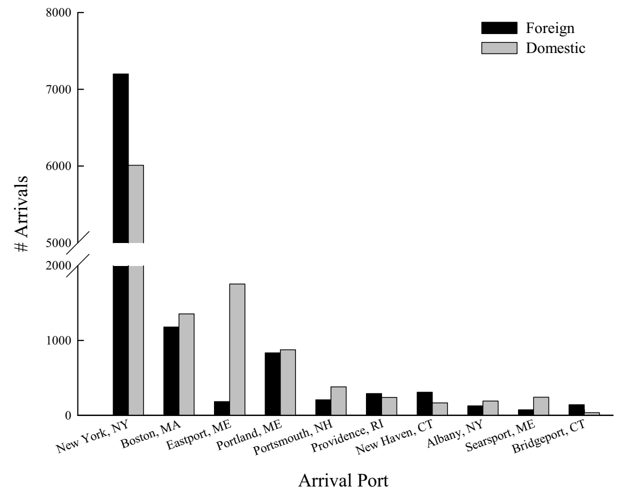

Figure 1. Number of foreign and domestic (coastwise) ship arrivals to selected New England ports. Data were provided by the Maritime Administration (MARAD) and cover the time period from July 1999 to June 2002.

RESULTS

The number of domestic arrivals (11,248) was similar to the number of foreign arrivals (10,544) for all ships coming to New England over the three-year period (1999-2002) of analysis (Fig. 1). Based on the national average of 26.4% of foreign arrivals reporting ballast water discharge in U.S. ports, we estimated that 2,784 foreign arrivals and 2,969 domestic arrivals discharged ballast water into New England ports during this period. However, individual ports differed substantially in the number and pattern of foreign and domestic arrivals, with New York receiving six to seven times the number of ship arrivals than ports such as Boston or Portland. New York had about 17% more foreign than domestic arrivals; whereas Eastport had about 600% more domestic than foreign arrivals; most other ports had similar numbers of domestic and foreign arrivals.

The composition of ship types differed between foreign and domestic arrivals to New England as a region (Fig. 2). Overall, arrivals of Container Ships and Tankers were most abundant, followed by General Cargo, Bulk Carriers, Passenger Ships and Others. Numbers of foreign and domestic arrivals were similar for Bulk Carriers, Container Ships, Passenger Ships and

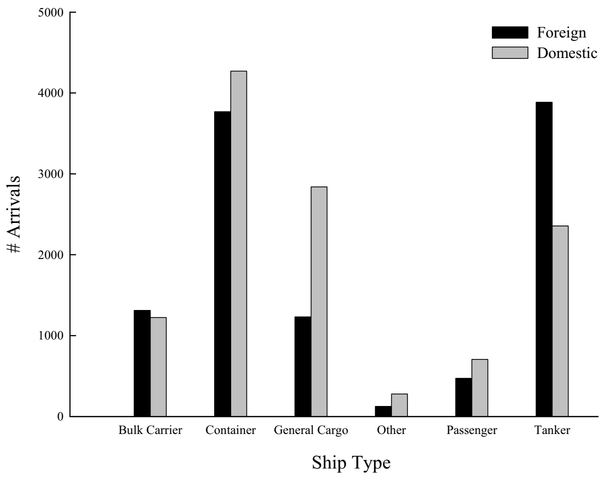

Figure 2. Number of foreign and domestic (coastwise) ship arrivals to New England ports (see Fig. 1) by ship type. Data were provided by MARAD and cover the time period from July 1999 to June 2002.

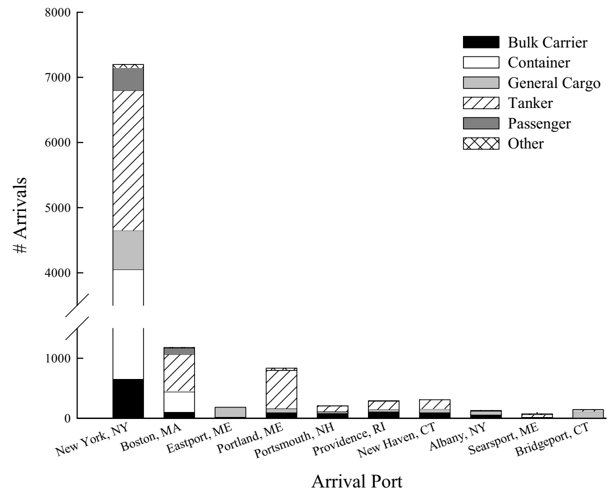

Figure 3. Foreign ship arrivals to New England ports by ship type. Data were provided by MARAD and cover the time period from July 1999 to June 2002.

Others; while foreign arrivals were greater for Tankers, but domestic arrivals were greater for General Cargo Ships.

The composition of ship types also differed among New England ports for both foreign arrivals (Fig. 3) and domestic (coastwise) arrivals (Fig. 4). For example, New York received large numbers of Container Ships for both foreign and domestic arrivals, but nearly three times as many foreign as domestic arrivals for Tankers. Eastport received General Cargo ships almost exclusively as foreign arrivals, but both General Cargo and Bulk Carriers as domestic arrivals.

The reported volumes of ballast water discharged differed substantially by Ship Type for both foreign and domestic arrivals reporting nationally (Table 1). Generally, Bulk Carriers and Tankers have the greatest capacity of ballast water and discharge four to six times the volume of ballast water of Container, General Cargo and Passenger Ships. Ballasting practices for domestic arrivals differed from foreign arrivals. For most types of ships (except the "Other" category), domestic arrivals discharged only 50-70% of the volume of foreign arrivals. Thus, in addition to the number of arrivals, the type of ships and whether they were foreign versus domestic arrivals had great influence on the volume of ballast water discharged.

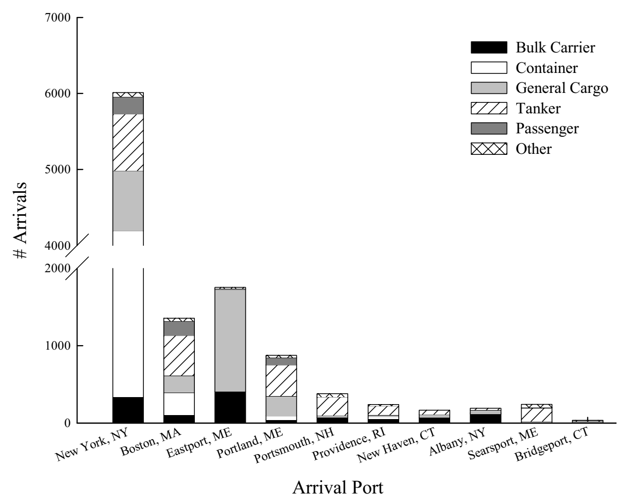

Figure 4. Domestic (coastwise) ship arrivals to New England ports by ship type. Data were provided by MARAD and cover the time period from July 1999 to June 2002.

In combination, foreign and domestic arrivals discharged a total extrapolated ballast water volume of about 24.8 million metric tons of ballast water into the ports of the New England region during the three year period (1999-2002). The estimated volume of ballast waster discharged from foreign arrivals totalled about 16.2 million metric tons (65.3% of total), whereas ballast water discharge from domestic arrivals totalled about 8.6 million metric tons (34.7% of total). However, the composition of

Table 1. Comparison of mean volume of ballast water discharge reported per ship for domestic (coastwise) and foreign arrivals by Ship Type. Volumes are in metric tons (MT), with standard error of the mean (SE) and number of ships (N) indicated. Data were provided by the NBIC and cover the time period from July 1999 to June 2002.

Ship Type	Domestic			Foreign		
	Mean Vol. Discharged [MT]	SE	N	Mean Vol. Discharged [MT]	SE	N
Bulker	6,660	582	197	12,328	228	2,706
Container	969	268	586	1,942	63	3,236
General Cargo	1,113	207	101	1,992	144	1,151
Other	8,268	1,050	48	5,677	687	168
Passenger	495	241	73	753	12	3,379
Tanker	6,566	545	214	9,251	486	1,375
Total			1,219			12,015

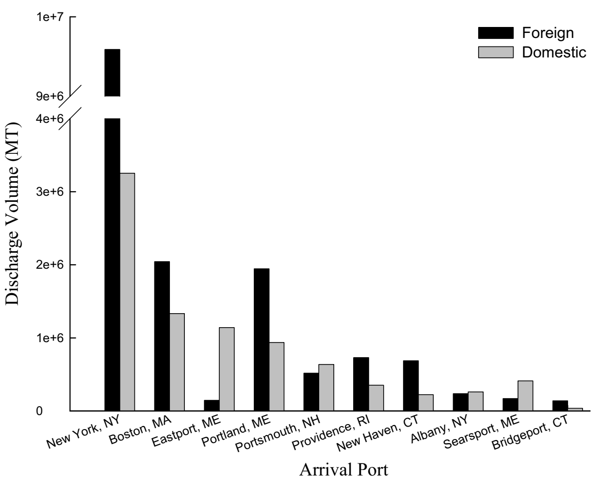

Figure 5. Total projected discharge volumes (in millions of metric tons) to New England ports by foreign and domestic arrivals. Mean, per ship, discharge volumes were estimated using the National Ballast Information Clearinghouse database for the time period from June 1999 to July 2002. Mean estimates were based on all ballast water reporting forms indicating ballast discharge. Foreign and domestic arrival discharge averages were multiplied by the number of MARAD arrivals and summed for each port to determine volume (see Methods for details).

foreign and domestic ballast water discharge differed substantially among ports (Fig. 5). For example, New York received three times the volume of foreign ballast water as domestic ballast water, while Eastport received six times the volume of domestic ballast water as foreign ballast water, and Albany received similar volumes of both foreign and domestic ballast water.

For foreign arrivals, the Last Ports of Call, which are often—but not always—the main sources of ballast water, were primarily in Europe, but included disparate ports from South America, North America (Mexico), Caribbean, Africa and Asia, as well as many others (Fig. 6). For domestic arrivals, the Last Ports of Call

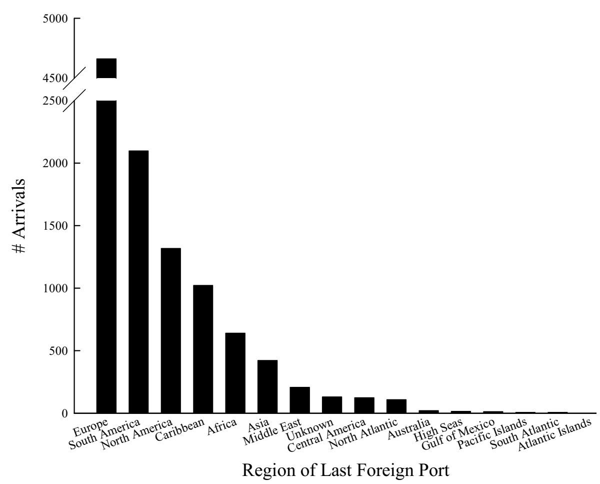

Figure 6. Number of foreign arrivals to New England ports (see Fig. 1) from regions of last port of call. Data were provided by MARAD and cover the time period from July 1999 to June 2002.

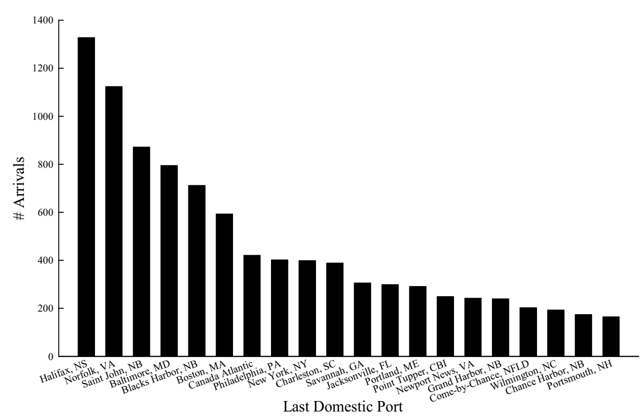

Figure 7. Number of domestic arrivals to New England ports (see Fig. 1) from twenty most common last ports of call. Data were provided by MARAD and cover the time period from July 1999 to June 2002.

were primarily in the Canadian Maritime Provinces,(namely, NB, NS, PEI), the Chesapeake ports of Baltimore and Norfolk, as well as Boston, plus many other ports both within and far outside the New England region along the East Coast (Fig. 7).

Discussion

As a first approximation on a regional scale for New England ports, ballast water from domestic arrivals appears to comprise nearly 35% of the total ballast water discharged by commercial ships. Domestic ballast water discharges often include high densities of plankton, because domestic voyages are of short duration and survival of entrained organisms in ballast tanks is high (Lavoie et al. 1999, Hines and Ruiz 2000). Based on the patterns of ship arrivals, many New England ports are receiving discharges of domestic ballast water at high frequencies on a repeated basis from the same source ports along the East Coast of North America. While we recognize that the origin of ballast water does not always equate to the last port of call, the combination of large volume, high density of viable entrained plankton, and frequent, repeated discharge, creates a high risk of introduction and invasion by nonindigenous species. Moreover, since a significant percentage of foreign arrivals have undergone ballast water exchange, while domestic arrivals have not, the contribution of coastal plankton in domestic ballast water discharge may be significantly greater than foreign ballast water based on calculations of volume alone.

Our estimates of the quantities and patterns of domestic and foreign ballast water discharged in New England ports include a number of uncertainties, because they are based on extrapolations from relatively small fraction of ship arrivals actually reporting (NBIC 2001). This is especially the case for domestic voyages, because there has been no federal requirement that domestic traffic report their ballast activities. Our extrapolations are based on reported discharges by ship type nation-wide, because that appears to provide the most integrative and inclusive use of the limited data available. Our extrapolations incorporated the national average of 26.4% of foreign arrivals that actually discharged ballast water. However, the larger dataset for foreign arrivals indicates first that only about 30% of arrivals report, and that ballast management practices may vary among regions. For the New England region, only about 25% of foreign arrivals reported to NBIC during the three-year period (1999-2002), and of these only about 10% of foreign arrivals claimed to discharge ballast water. Other regions have much more complete data for both foreign and domestic ballast water discharges, because of state requirements (e.g., California, Oregon, Washington) or types of shipping (e.g., oil tanker trade transiting from West Coast ports to Port Valdez, Alaska (Hines and Ruiz 2000, NBIC 2001). Until the data are more comprehensive, we rely on estimates derived from larger sample sizes that integrate across regions. The U.S. Coast Guard has initiated new regulations to increase reporting for both foreign and domestic arrivals that should increase the scope and quality at national, regional, and port levels of shipping activity. At the present time, however, we readily acknowledge both the uncertainties and that ballasting practices certainly differ among regions and ports, as well as between types of voyages (domestic versus foreign).

While we have only limited estimates of the volumes and management practices for ballast water on coastwise voyages, it is clear that the composition of ship types differs markedly among ports within New England. The volume and management practices of ballast water differ greatly among ship types, with Bulk Carriers and Tankers having much greater ballast water capacity than other ship types. Ports that export bulk cargo (e.g., coal, grain, oil) receive the greatest volume of ballast water discharged by ships arriving in ballast to take on loads. However, while Container Ships tend to carry small volumes of ballast water, the frequency of their arrivals may be much greater than Bulk Carriers (e.g., New York). We still have poor understanding of the relative contributions of volume compared to repetition of inoculations in the success of invasions, although both are probably important (Ruiz et al. 2000).

It is evident that the composition of ship types differs markedly among regions. For example, ballast water discharged by ships arriving in Alaska derives mainly from domestic voyages of oil tankers picking up crude oil from the trans-Alaska Pipeline (Hines and Ruiz 2000). The volume of foreign ballast water discharged into Chesapeake Bay is more than ten-fold than of any other U.S. port along the East Coast, primarily as a result of the large number of Bulk Carriers coming in ballast to the ports of Norfolk and Baltimore from European and Mediterranean ports (Carlton et al. 1995, NBIC 2001, Ruiz et al., unpublished data). Although the volume of ballast water discharged into the New England region is considerably smaller than some other regions of North America, the pattern of discharge of nearly 25 million metric tons from both domestic and foreign voyages may create significant risks of invasion, including coastwise transfer from other sites that receive even larger quantities of ballast water.

Many of the source ports for domestic voyages extend past biogeographic barriers, such as Cape Hatteras, Cape Cod, and Nova Scotia, as well as from ports within the region. These coastwise voyages may facilitate rapid dispersal of foreign invaders within a region and from one region to another. Many non-native species in New England and the Canadian Maritimes—including crabs, tunicates, and bryozoans—appear to have spread coastwise, although it is difficult to determine the relative contribution of human-assisted and natural means of transport in the spread (Ruiz et al. 2000).

Given the well-recognized increase in rate of marine invasions and their consequesnces, it is clear that domestic as well as foreign ballast water needs to be incorporated as a risk component of any effective management strategy for reducing coastal invasions. A crucial first step is to include accurate measures of ballast water discharge on domestic arrivals, so that we can better understand spatial and temporal variation in this risk.

Acknowledgements

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Literature Cited

Carlton, J.T. 1989. Man's role in changing the face of the ocean: biological invasions and implications for conservation of near-shore environments. *Conservation Biology* 3: 265-273.

Carlton, J.T., D.M. Reid, and H. van Leuwen. 1995. 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. Report to the U.S. Coast Guard, Washington, D.C.

Carlton, J.T. 2001. Introduced species in U.S. coastal waters: Environmental impacts an management priorities. Pew Oceans Commission, Arlington, Virginia.

Carlton, J.T. and J.B. Geller. 1993. Ecological roulette: the global transport of nonindigenous marine organisms. *Science* 261: 78-82.

Cohen, A.N. and J.T. Carlton. 1995. Nonindigenous species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and Delta. U.S. Fish and Wildlife Service and National Sea Grant College Program (Connecticut Sea Grant).

Cohen, A.N. and J.T. Carlton. 1998. Accelerating invasion rate in a highly invaded estuary. *Science* 279: 555-558.

Hines, A.H. and G.M. Ruiz (editors). 2000. Biological invasions of cold-water coastal ecosystems: Ballast-mediated introductions in Port Valdez / Prince William Sound, Alaska. Final Report, Regional Citizens' Council of Prince William Sound. Anchorage, Alaska. 313 p. (Available at: www.pwsrcac.org).

Kerr, S. 1994. Ballast water ports and shipping study. Australian Quarantine Inspection Service. Report No. 5, Canberra.

Lavoie, D.M., L.D. Smith, and G.M. Ruiz. 1999. The potential for intracoastal transfer of nonindigenous species in the ballast water of ships. *Estuarine Coastal Shelf Science* 48:551-564.

Murphy, K, J. Boehme, P. Coble, J. Cullen, P. Field, W. Moore, E. Perry, R. Sherrell, and G. Ruiz. 2004. Verification of mid-ocean ballast water exchange using naturally occurring coastal tracers. *Marine Pollution Bulletin* 48:711-730.

NBIC (National Ballast Information Clearinghouse). 2001. Status and trends of ballast water management in the United States: First biennial report of the National Ballast Information Clearinghouse, 45 p. National Ballast Information Clearinghouse, Edgewater, MD, USA.

Pew Ocean Commission. 2002. America's living oceans. Charting a course for sea change. Arlington, VA. www.pewoceans.org. 36 p.

Ruiz, G.M., J.T. Carlton, E.D. Grosholz, and A.H. Hines. 1997. Global invasions of marine and estuarine habitats by non-indigenous species: mechanisms, extent, and consequences. *American Zoologist* 37:621-632.

Ruiz, G.M., P. Fofonoff, A.H. Hines, and E.D. Grosholz. 1999.

Nonindigenous species as stressors in estuarine and marine communities: asssessing invasion impacts and interactions. *Limnology and Oceanography* 44:950-972.
Ruiz, G.M., P.W. Fofonoff, J.T. Carlton, M.Wonham and A.H. Hines. 2000. Invasion of coastal marine communities of North America: patterns and processes. *Annual Reviews in Ecology and Systematics* 31:481-531.
Ruiz, G.M., K.R. Murphy, E. Verling, G. Smith, S. Chaves, and A.H. Hines. 2004. Ballast Water Exchange: Efficacy of treating ships' ballast water to reduce marine species transfers and invasion success? Technical Report, Prince William Sound Regional Citizens Advisory Council, Anchorage, AK. 17 p.
Smith, L.D., M.J. Wonham, L.D. McCann, G.M. Ruiz, A.H. Hines, and J.T. Carlton. 1999. Invasion pressure and inoculant survival in a ballast-flooded estuary. *Biological Invasions* 1: 67-87.
Taylor, A., G. Rigby, S. Gollasch, M. Voigt, G. Hallegraeff, T. McCollin, and A. Jelmert. 2002. In Peppakoski, E., S. Gollasch, and S. Olenin (eds.). Invasive aquatic species in Europe: Distribution, impacts, and management. Kluwer Academic Publishers, Dordrecht. Pp. 484-50.

Ballast Water Exchange

Alternate Areas or Alternative Methods? Lessons from the Gulf of St. Lawrence

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Note: The alternative treatment discussion is not an endorsement for this process (ed.).

INTRODUCTION

The problem of aquatic species introductions is certainly as old as the transport of goods and merchandise by ship. The replacement of "solid ballast" used in the old days by "liquid ballast" in modern ships has exacerbated the problem, such that ballast water discharge is now recognized as the main pathway of species introduction and transfer in aquatic ecosystems (Carlton 1985, 1996; Carlton and Geller 1993; Wiley and Claudi 2000). Although the importance of this vector is now widely accepted, there are still numerous questions and unverified statements relative to the mechanisms determining the success of species transport and transfer via ballast water. Notwithstanding these unknowns, ballast water management was rapidly foreseen by scientists, governments, international maritime agencies and the shipping industry as a necessary tool to resolve the environmental problem of aquatic species introductions (IMO 2004). Theoretically, ballast water can be managed either via ballast water exchange (BWE) at sea or via ballast water treatment methods. In practice, due to its ease of application and relatively inexpensive operational cost, BWE was adopted quickly by the shipping industry and it currently represents the main method of preventing the introduction and transfer of aquatic species.

BWE in mid-ocean may pose a risk to ship safety, so the use of alternate zones in coastal environments has been recommended in cases where BWE cannot be performed at offshore locations. Ideally, these alternate zones should be defined and delineated after rigorous assessment of their appropriateness to minimize the risk of introductions. Since the use of alternate zones should be minimal and restricted to particular cases, the option of using alternative methods to treat ballast water is worth considering. The present paper reviews information on the appropriateness, effectiveness and benefits of alternate zones versus alternative treatment technologies to manage ballast water, using the Gulf of St. Lawrence alternate exchange zone as an example. First, we present an historical overview of the "back-up" zone for BWE in the Gulf of St. Lawrence; secondly, we provide a preliminary assessment of the impact and effectiveness of BWE in the Great Lakes - St. Lawrence basin; and, finally, we discuss the use of alternative treatment methods in the foreseeable future.

THE "BACK-UP" EXCHANGE ZONE IN THE GULF OF ST. LAWRENCE

In response to the environmental crisis resulting from the introduction and invasion of the Laurentian Great Lakes by zebra mussels (*Dreissena polymorpha*) in the mid-1980s and at the urging of the Great Lakes Fishery Commission, the Canadian Coast Guard, with the scientific guidance of several departments and agencies, established in May 1989 "voluntary" interim guidelines for BWE for ships entering the Great Lakes. These guidelines were first set for ships going upbound of Montreal harbour only. These voluntary guidelines designated a secondary (or "alternate") BWE zone within the

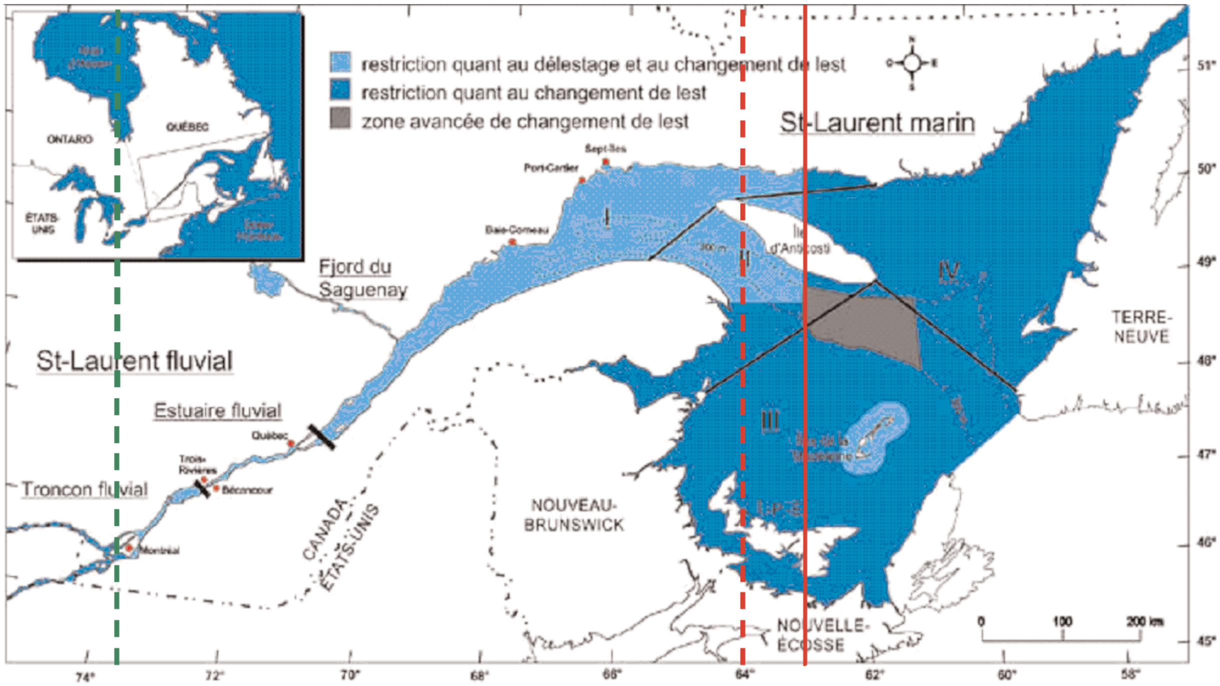

Figure 1. Map of the St. Lawrence River, the estuary and the Gulf of St. Lawrence. The shaded area corresponds to the alternative zone for ballast exchange and vertical lines indicate the various limits of application of the Canadian voluntary guidelines, (adapted from Bourgeois et al. 2001).

Gulf of St. Lawrence. The area was initially designated in the Laurentian Channel waters east of the Gaspé peninsula at 64°W longitude and over sounding depths >300 m (Figure 1). The eastern limit of the alternate exchange zone remained undefined but apparently extended into the Atlantic Ocean beyond Cabot Strait.

In 1990, a scientific expert group commissioned by the Department of Fisheries and Oceans recommended to redefine the boundaries of the alternate zone for exchange as the Laurentian Channel waters located between 63°W and 61°W longitude and over depths >300 m (Kerr 1990). Reasons for this proposed change were that the western boundary was considered too “risky”, due to the proximity of the Gaspé current which could potentially entrain surface water over the Magdalen Shallows and nearby coastal waters. The proposed eastern boundary was set at 61°W longitude was set to minimize the risk of entrainment of ballast water being discharged in Cabot Strait over the coastal waters of the Nova Scotian shelf (Kerr 1990). This proposition would have substantially reduced the size of the zone, so that ship transit time through it might be shorter than the amount of time required to complete BWE. On the other hand, the smaller size of the area would presumably minimize or eliminate its use on a “routine” basis, rather than under exceptional conditions only, as originally intended. The recommendation for an eastern limit to the alternate exchange zone never really came into force.

Ships steaming to ports in the St. Lawrence River (Montreal and downstream) as well as ports in the estuary and the Gulf of St. Lawrence were exempt from these guidelines and remained a risk with regards to non-indigenous species introduction. In 1993, the Canadian “voluntary” guidelines were changed to accommodate the U.S. mandatory regulation for ships entering the Great Lakes, so that all ships passing 63°W longitude were authorized to use the alternate exchange zone. This would presumably help protect the freshwater section of the St. Lawrence River downstream of Montreal. The Canada Shipping Act is currently under review and enforcement of new legislation should make BWE mandatory for ships entering the Great Lakes—St. Lawrence River system. The western limit of the alternate zone has remained unchanged at 63°W longitude.

The changes in the definition and application criteria of the voluntary guidelines and the limits of the alternate zone merely reflect the complexity of this issue. The problem arises principally from the desire to apply a single rule for protecting three different ecosystems: the Great Lakes, the freshwater St. Lawrence River and the marine sector comprising the estuary and the Gulf of St. Lawrence. In order to assess the potential risk of species introductions into each of these ecosystems, Bourgeois et al. (2001) compiled the information on foreign shipping traffic entering the Gulf of St. Lawrence between 1978 and 1996. Results on the number of ships, ballast capacity and effective volume of ballast being discharged into each ecosystem (Table 1) revealed that the risk of introduction would be obviously much higher within the marine sector. This sector accounted for over 50% of the estimated risk due to the presence of much larger ships (with much larger ballast capacity) potentially discharging at ports of destination. The freshwater sector of the St. Lawrence River ranked second with a risk estimate of 38%, while the risk for the Great Lakes sector was 8%. When considering the percentage of ships reported to carry ballast on board (BOB) during a survey made between 1994 and 1996 (Harvey et al. 1999), the total volume of ballast water discharged into the estuary and the Gulf was estimated to be approximately 10 million tons per year, or 78% of the total amount of ballast water discharged by foreign vessels in the Great Lakes and St. Lawrence basin. Paradoxically, the potential risk was lowest in the Great Lakes sector where the annual discharge of ballast water was 0.25 million tons (~2% of the total). The difference between sectors was essentially due to the percentage of ships without ballast on board. While the vast majority (87%) of ships stopping in the marine sector declared carrying ballast on board, the percentage dropped to 20% for ships at destinations along the St. Lawrence River and to 4% for ships entering the Great Lakes in years 1994-1996 (Table 1).

An analysis of the transoceanic shipping into the Great Lakes since the opening of the seaway in 1959 showed that the percentage of ships with no ballast on board or in partial ballast (NOBOB), has increased slightly since the establishment of the Canadian voluntary guidelines in 1989 and even more since that of the mandatory U.S. rules in 1993 (Grigorovich et al. 2003). Assuming that misreporting was not a problem, reasons for this increase could presumably be related either to economic pressure which forced the shipping industry to maximize cargo in recent years or to the fact that ships, in order to comply to guidelines and legislation, do discharge ballast water but not necessarily take new ballast on-board before entering the Great Lakes. Data from the U.S. Coast Guard on ship surveillance at the entrance of the Great Lakes indicated that full compliance with BWE rules and guidelines has been relatively high and exceeded 90% since 1993 (Figure 2). Depending on the year, up to 7% of ships were considered technically non-compliant. These ships did comply with salinity standards (>26 ppt), but not with the zone of exchange (>200 nautical miles offshore and over depth >2000 meters) and may therefore include ships using the alternate zone for salinity compliance. The above values are indeed very similar to the percentage of ships (7%) using the Gulf alternate zone for ballast exchange in 1989 immediately following the establishment of the voluntary guidelines (Kerr 1990). Given the number of foreign ships entering the Great Lakes, the number of ships that used the alternate exchange zone each year would probably be very small. The compliance rate varies seasonally and is usually lower in early spring and late fall, probably a result of harsh weather and poor sea conditions rendering

Table 1. Information on foreign shipping traffic to the Great Lakes and the St. Lawrence basin between 1978 and 1996 (data from Bourgeois et al. 2001 and Harvey et al. 1999).

	Ships		Ballast Capacity		Ballast discharged in 1994-1996	
Destination	(Nb. yr^{-1})	%	(10^6 T yr^{-1})	%	% BOB*	(10^6 T yr^{-1})
Great Lakes	249 ±39	13	2.3 ±0.5	8	4	0.25 (2%)
St. Lawrence River	1048 ±104	53	10.8 ±2.3	38	20	2.70 (20%)
Montréal	*735*	*70*	*6*	*60*		
Québec	*179*	*17*	*3*	*27*		
Other ports	*135*	*13*	*1.8*	*13*		
Estuary and Gulf	674 ±75	34	15.6 ±2.8	54	87	10.46 (78%)

* Ballast on board

ballast water exchange more difficult and risky (data not shown). Unfortunately, comparable data on ship compliance are lacking for other Canadian sectors (the St. Lawrence River, the estuary and Gulf of St. Lawrence). In the absence of mandatory rules for Canadian waters, monitoring or surveillance programs for ship ballast are still nonexistent and there is no formal checkpoint for ships entering the St. Lawrence River and the maritime sector in eastern Canada. Preliminary survey results from Transport Canada during year 2002 indicated that only 3 out of 573 foreign ships (0.7%) at destination ports in the Quebec region only (not including ships entering Gulf of St. Lawrence ports in the remaining provinces) did report exchanging ballast water in the alternate zone (D. Duranceau, Transport Canada, Quebec Region, pers. comm.). This would confirm that the alternate back-up zone in the Gulf of St. Lawrence is not frequently used for BWE.

Knowing the potential risk of species introductions associated with shipping traffic, we compiled the available information relative to the number of exotic species introduced into each of the three sectors in the Great Lakes – St. Lawrence basin in order to assess and compare the relative risk of species establishment among sectors. A recent analysis by de Lafontaine and Costan (2002) showed that the number of non-indigenous species introduced since 1820 in the upstream Great Lakes (160 species) was almost twice that reported in the downstream St. Lawrence River (85 species). The relative proportion of the various taxonomic groups (algae, vascular plants, invertebrates, fish) differed significantly between the two regions, suggesting different dynamics of introduction and establishment. Considering that the risk of introduction by shipping (simply based on traffic and ballast volume estimates) was presumably higher in the river than in the lakes, this result may be surprising and somewhat counterintuitive. From an ecological perspective, riverine systems are far more dynamic than lakes and would not necessarily favour the establishment of all forms of organisms. The rapid flow rate of the St. Lawrence River may indeed accelerate the drift of plankton and other larval forms toward the saline estuary, therefore reducing the risk of species establishment and invasion in the river. In fact, most introduced species reported in the river were either benthic organims (vascular plants and molluscs) or mobile animals (fish, benthic crustaceans). Moreover, nearly all species (98%) introduced in the St. Lawrence River since 1960 were first reported in the Great Lakes, suggesting that these species were introduced and established in the Great Lakes first before being subsequently transferred and spread into the St. Lawrence River by either passive or active transfer. Although several ecological reasons could be called for explaining this regional difference in the introduction and establishment success of non-indigenous species, it does not seem to parallel the potential risk associated with shipping (estimated on proportion of BOB ships and ballast capacity). In fact, these results support the hypothesis put forward by Grigorovich et al. (2003) that NOBOB ships after re-ballasting with water in the Great Lakes may indeed be the major cause of species introductions. This implies that untreated residual waters and sediments remaining at the bottom of tanks in NOBOB ships would present a higher risk factor and should be managed with adequate treatment methods.

On the positive side however, the number of species introductions associated with the shipping vector in freshwater (Great Lakes and St. Lawrence River) seems to have declined slightly over the last decade (1990-2000) since the implementation of the exchange guidelines by Canada and the U.S. during the early 1990s (de Lafontaine and Costan 2002; Grigorovich et al.

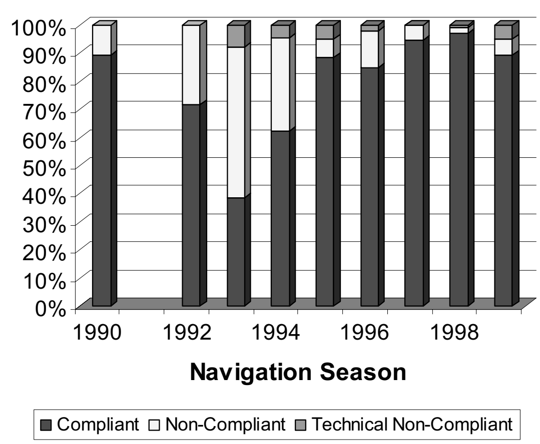

Figure 2. Ballast water compliance rates.

2003). If this decline is significant and persists over the next decade, it would strongly suggest that BWE does effectively help minimizing the input of new species. However, the objective of no new introductions is still far from being met.

Information on non-indigenous species introduction in Canadian marine environments is more scarce, in particular for the estuary and Gulf of St. Lawrence. Despite the presumably very high risk associated with the high proportion of BOB ships arriving at destinations in the Gulf of St. Lawrence harbours, the total reported number of exotic species in both marine and estuarine environments is 26 (Table 2), which is much less than that reported for the Great Lakes. Algae accounted for nearly half of that number. Shipping would account for 25% (6 species) of the total number of these introductions, which is close to the value of 33% estimated for the Great Lakes according to Wiley and Claudi (2002). Reports of introduced species are very localized, but the spatial coverage of sampling effort and inventory is much less thorough for the entire Gulf of St. Lawrence than that realized in the Great Lakes. Given the paucity of information available, no conclusions may be reached regarding the risk and the impact of BWE within the Gulf of St. Lawrence. Evidence indicates, however, that species introductions and establishment in the marine sector is not as important nor as frequent as in the upstream freshwater environments. Alternatively the theory that cummulative invaders facilitate new introductions might suggest that the Great Lakes is in the midst of "invasion meltdown," whereas the Gulf of St. Lawrence system may not have attained this phase of accelerating rates of invasion (Simberloff nad Von Halle, 1999).

Table 2. Introduced non-indigenous species reported in the Gulf of St Lawrence. Data compiled from various sources by N. Simard (DFO-Mont-Joli), and A. Locke and M. Hanson (DFO-Moncton).

Taxonomic group	Total	Presumed vector of introduction			
		Shipping	Natural or cryptic	Deliberate	Unknown
Algae	11	4	2	-	5
Invertebrates	9	2	2	2	3
Freshwater Fish	2	-	-	2	-
Parasites/ Pathogens	4	-	4	-	-

Alternative Treatment Methods

The above results highlight that BWE cannot be fully satisfactory to eliminate the risk of species introduction and protect the various aquatic environments. BWE at sea was originally recommended for protecting freshwater systems, by replacing freshwater in ballast tanks with oligotrophic marine waters to be discharged eventually in freshwater ports. The effectiveness of the method for protecting marine coastal waters is questionable, however. Shipping activities along the North American coastal waters represent a good example of ships transiting and transferring ballast water between different marine systems. In this regard, the possibility of using the Gulf alternate zone more frequently in the future would increase the risk of species introductions in the area. In scenarios where BWE would not be possible, the use of alternative treatment methods is recommended.

Excluding the use of on-shore treatment that would require the installation of treatment facilities in every port, various on-board ballast water treatment technologies have been developed but only a few have been tested adequately. These technologies can be grouped into either physical/mechanical or chemical processes, and the pros and cons of each method have been reviewed in different reports (Pollutech 1992; Hay et al. 1997; Mountfort et al. 1999; Calvé 2001; Tamburri et al. 2002). Most physical treatment methods require major re-fitting of ships and some may be unsafe to use. The proposed chemical methods are often based on the use of biocides and toxic chemicals which make them environmentally unacceptable because these treated waters have to be discharged in natural environments. A notable exception is the deoxygenation process by which the concentration of dissolved oxygen in ballast water is rapidly reduced to very low levels inducing a massive kill of most aquatic living organisms (Stalder and Marcus 1997; Mountfort et al. 1999; Tamburri et al. 2002). The anoxic environment in ballast tanks could also help prevent corrosion of a ship's structure, which could confer some advantage in using deoxygenation methods. Oxygen removal can be achieved either by saturating ballast waters with the addition of nitrogen gas as shown by Tamburri et al. (2002) or by bio-reactive processes as suggested by Mountfort et al. (1999).

While nitrogen addition has proven to be feasible and effective, its use is relatively costly, however, and might present some safety risk. Preliminary trials by Mountfort et al. (1999) suggested the potential of deoxygenating biological processes, but the development and use of such techniques can encounter many challenges. The treatment has to be effective in both fresh- and saltwater environments and at temperatures ranging from nearly 0 to ~30°C. The bio-reactive process has to be fully activated and completed over a short time period (<5 days) in order to be used during short voyages. The process should not release any toxic degradation product and treated ballast waters should be safe for release into the receiving environment. From a cost/benefit point of view, the technology should require no or minimal ship modification and it should be simple to handle and safe to use by the ship's crew.

Recent developments in biotechnological processes offer a new methodology that appears to be meeting the challenges of the criteria (see Table 1) and may become an effective and viable treatment alternative to ballast water exchange. Laboratory testing in 200 L vessels to assess the effectiveness and environmental impact of biological oxygenation, has shown promise in meeting Canadian discharge threshholds. Pilot-scale trials of this technique onboard ship are planned for the next year. We offer an example of one treatment to illustrate the type of data we expect from an alternative treatment prospective (Figure 3).

The development and testing of new techniques will eventually offer a variety of effective treatment methods to manage ballast water appropriately. The proposed existing techniques (including ballast water exchange) can be compared and evaluated with a list of different performance criteria. Based on literature information (Pollutech 1992; Hay et al. 1997; Calvé 2001; Moore and Ryan 2003; A. Valois, PolyGo,

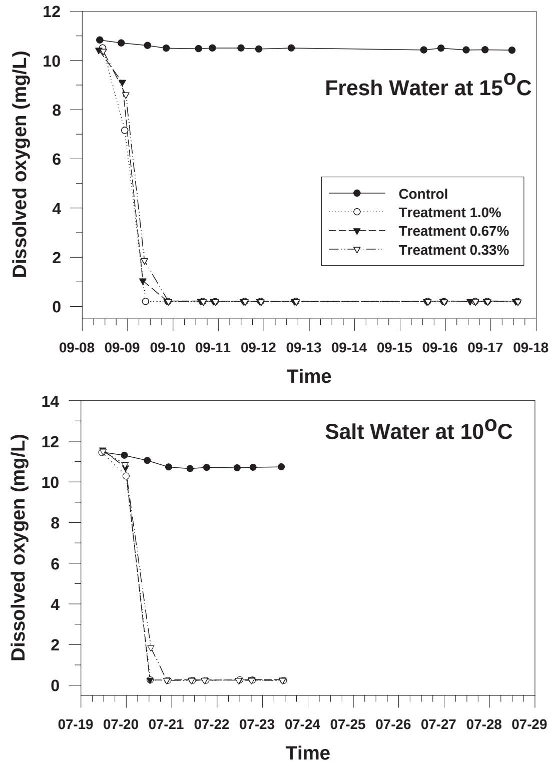

Figure 3. Concentration of dissolved oxygen as a function of time in both fresh- and saltwater experiments using a bio-technological process from 200 L vessel testing.

Montreal, pers. comm.), the characteristics of each method relative to each criterion were compiled in an information matrix (Tables 3 and 4). The estimated cost (in Canadian dollars) per trip was calculated for a 34,000 DWT vessel making 40 trips per year and carrying ballast 33% of the voyages. A 7-year depreciation time was assumed for capital investment. As expected, ballast water exchange was the least expensive method ($ 250 per trip) but its control effectiveness to treat and control species introductions is considered generally poor (Locke et al. 1991). On the other hand, the three deoxygenating techniques can meet a large number of criteria, and ranked very high in terms of control effectiveness. The deoxygenation techniques are presumably also capable of treating residual waters, which normally remained untreated after ballast water discharge (as in the NoBOB condition). The total cost per trip was quite variable between the different treatment methods, but the biological deoxygenating treatment method was the second least expensive ($ 1800 per trip)

Table 3. Comparative assessment of performance characteristics of different alternative technologies for treating ballast water.

Criteria	BWE	Filtration	UV	Ozone	Chlorine	Vacuum Deoxygenation	Nitrogen Deoxygenation	Biological Deoxygenation*
Energy cost	Small	High	High	High	Medium	High	Medium	Null
Risk to safety	Medium	Medium	High	High	High	High	High	Null
Training personnel	Low	Medium	High	High	High	High	High	Low
Effect on ship lifespan	Almost null	Null	Null	Corrosion	Corrosion	Positive	Positive ?	Positive
Possibility for change	Yes	No	No	No	No	No	No	Yes
Environmental impact	?	?	Null	Null	Unacceptable	Acceptable	Acceptable	Acceptable
Equipment space (m^2)	Null	10	4	15	2	8	4	Null
Perishable space (m^2)	Null	Some ?	0	0	?	0	0	0.4

*Based on 200 L vessel trials.

Table 4. Comparative assessment of performance characteristics of different alternative technologies for treating ballast water (suite from Table 3).

Criteria	BWE	Filtration	UV	Ozone	Chlorine	Vacuum Deoxygenation	Nitrogen Deoxygenation	Biological Deoxygenation*
Capital investment (K$CAD)	-	1000	1000	2000	500	1400	1000	?
Depreciation expenses (K$CAD)	-	3.6	3.6	7.1	1.7	5.0	3.6	?
Maintenance (K$CAD)	?	1.0	1.0	2.0	0.5	1.4	1.0	?
Perishables (K$CAD)	-	-	-	-	1.0	-	-	1.8 (est.)
Time loss	?	?	-	-	-	-	-	?
Total cost per trip (K$CAD)	0.30	4.6	4.6	9.1	3.2	6.4	4.6	1.8 (est.)
Control efectiveness	Poor	Partial	Medium	High	High	High	High	High
Residual waters treated	No	Partial	No	No	Partial	Yes ?	Yes ?	Yes ?

*Based on 200 L vessel trials.

after ballast water exchange. Of course, these calculations did not account for any socio-economic and environmental cost for controlling and mitigating the impact of species once they are introduced into an ecosystem.

Toward Better Management Practices

In summary, 15 years after the establishment of the Canadian voluntary guidelines for BWE, it is quite obvious that accurate information to adequately assess the control effectiveness of ballast water exchange is still largely limited. Circumstantial evidence suggests that BWE implementation has not resulted in an absolute decline in species introduction in freshwater systems and it cannot be truly effective for coastal shipping. Moreover, the problems of untreated residual waters after BWE and the lack of compliance monitoring and surveillance make difficult the management of ballast water to eventually stop the introduction and transfer of aquatic species via shipping. To meet this objective, BWE (even in alternate zones) may not represent the best method since the risk of introduction will always remain higher than with any alternative treatment method. Up to now, the switch to using other technologies for treating ballast water has been slow, primarily for two reasons. First, the lack of environmental standards for discharging the content of ballast tanks in aquatic systems does not provide a definition of reference criteria for comparing and testing the various treatment technologies, including BWE. It is hoped that the new convention proposed by the International Maritime Organization (IMO 2004) will be rapidly accepted in order to establish such standards at an international level. This will definitely serve as a first and essential step toward better management practices.

Second, in the absence of environmental standards, the shipping industry had no strong incentive to solve the problem of species introductions. Thus, BWE is still the best current practice due to its cheap operational cost. In order to meet our environmental objective of reducing the number of future introductions and to protect the integrity of our ecosystems, we must work toward finding and implementing effective treatment technologies that could also benefit the industry. With dedicated effort in this direction, the dream may come true more quickly than many think.

Literature Cited

Bourgeois, M., M. Gilbert, and B.Cusson. 2001. Évolution du trafic maritime en provenance de l'étranger dans le Saint-Laurent de 1978 à 1996 et implications pour les risques d'introduction d'espèces aquatiques non indigènes. Rapport technique canadien des sciences halieutiques et aquatiques No. 2338, 34 p.

Calvé, R. 2001. A review of potential alternative ballast water treatments. Pollution prevention. Year 1. Report presented to Environment Canada, Atlantic Region, 24 p.

Carlton, J.T. 1985. Transoceanic and interoceanic dispersal of coastal marine organisms: the biology of ballast water. *Oceanogr. Mar. Biol. Ann. Rev.* 23: 313-371.

Carlton, J.T. 1996. Biological invasions and cryptogenic species. *Ecology* 77: 1653-1655.

Carlton, J.T. and J.B. Geller. 1993. Ecological roulette: the global transport of nonindigenous marine organisms. *Science* 261: 78-82.

de Lafontaine, Y., and G. Costan. 2002. Introduction and transfer of alien aquatic species in the Great Lakes - St. Lawrence River drainage basin. In: R. Claudi, P. Nantel, and E. Muckle-Jeffs (eds), Alien Invaders in Canada's Waters, Wetlands, and Forests. Natural Resource Canada, Canadian Forestry Service, Science Branch, Ottawa, Canada. Pp. 73-92.

Grigorovich, I.A., R.I. Colautti, E.L. Mills, K. Holeck, A.G. Ballert and H.J. MacIsaac. 2003. Ballast-mediated animal introductions in the Laurentian Great lakes: retrospective and prospective analyses. *Can. J. Fish. Aquat. Sci.* 60: 740-756.

Harvey, M., M. Gilbert, D. Gauthier and D.M. Reid. 1999. A preliminary assessment of risks for the ballast water-mediated introduction of nonindigeneous marine organisms in the Estuary and Gulf of St. Lawrence. Canadian Technical Report of Fisheries and Aquatic Sciences. No. 2268, 56p.

Hay, C., S. Handley, T. Dodgshun, M. Taylor, and W. Gibbs. 1997. Cawthron's ballast water research: final report. Cawthron Institute Report No. 417, 135p.

IMO. 2004. Alien invaders in ballast water – new convention adopted at the International Maritime Organization. International Conference on Ballast water Management, 9-13 February 2004. http://www.imo.org/home.asp

Kerr, S.R. 1990. The risk to Atlantic Canadian waters of unwanted species introductions carried in ships' ballast. Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) Research Document 90/34, Ottawa, Canada, 11p.

Locke, A., D.M. Reid, W.G. Sprules, J.T. Carlton, and H.C. van Leeuwen. 1991. Effectiveness of mid-ocean exchange in controlling freshwater and coastal zooplankton in ballast water. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1822, 92p.

Moore, K. and E. Ryan. 2003. Shipping traffic analysis and cost assessment for ballast water exchange en route to the United States. Poster presented at the 12th International Conference on Aquatic Invasive Species, June 2003, Windsor, ON.

Mountfort, D.O., C. Hay, T. Dodgshun, S. Buchanan and W. Gibbs. 1999. Oxygen deprivation as a treatment for ships' ballast water - laboratory studies and evaluation. *J. Marine Env. Engg.* 5: 175-192.

Pollutech Environmental Ltd. 1992. 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. Appendix A - Ballast Water Characterization, Report to the Canadian Coast Guard, Ship safety Branch. Ottawa, March 1992.

Stalder, I.C. and N.H. Marcus. 1997. Zooplankton responses to hypoxia: behavioral patterns and survival of three species of calanoid copepods. *Mar. Biol.* 127: 599-607.

Tamburri, M.N., K. Wasson and M. Matsuda. 2002. Ballast deoxygenation can prevent aquatic introductions while reducing ship corrosion. *Biological Conservation* 103: 331-341.

Wiley, C.J. and R. Claudi. 2000. The role of ships as a vector of introduction for no-indigenous freshwater organisms, with focus on the Great Lakes. In: Claudi, R. and J.H. Leach (eds), Nonindigenous freshwater organisms. Vectors, biology and impacts. Lewis Publishers, Boca Raton, USA. Pp. 203-214.

Wiley, C.J. and R. Claudi. 2002. Alien species transported in ships' ballast water: from known impact to regulations. In: R. Claudi, P. Nantel, and E. Muckle-Jeffs (eds), Alien Invaders in Canada's Waters, Wetlands, and Forests. Natural Resource Canada, Canadian Forestry Service, Science Branch, Ottawa, Canada. Pp. 233-242.

Suitability of the Gulf of St. Lawrence as an Alternate Zone for Ballast Water Exchange by Foreign Ships Proceeding up the St. Lawrence Seaway

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Introduction

Voluntary Guidelines and Location of the Alternate Ballast Water Exchange Zone

Offshore ballast water exchanges are currently used as a voluntary and, in some cases, mandatory measure to reduce risks for the ballast water-mediated introduction of nonindigenous marine organisms in the coastal and inland waters of a growing number of countries. Some voluntary guidelines for offshore ballast water exchange make provision for an alternate exchange zone to protect as much as possible those particularly vulnerable receiving environments while at the same time allowing these exchanges to be conducted safely. The existing "Voluntary Guidelines for the Control of Ballast Water Discharges from Ships Proceeding to the St. Lawrence River and Great Lakes" provide for such an alternate zone, located in the Gulf of St. Lawrence (Figure 1).

The Voluntary Guidelines recommend that, if not feasible in the Atlantic Ocean, ships arriving from outside the Exclusive Economic Zone (EEZ) can exchange their ballast water in an alternate zone located in the Gulf of St. Lawrence, within the Laurentian Channel southeast of 63° W

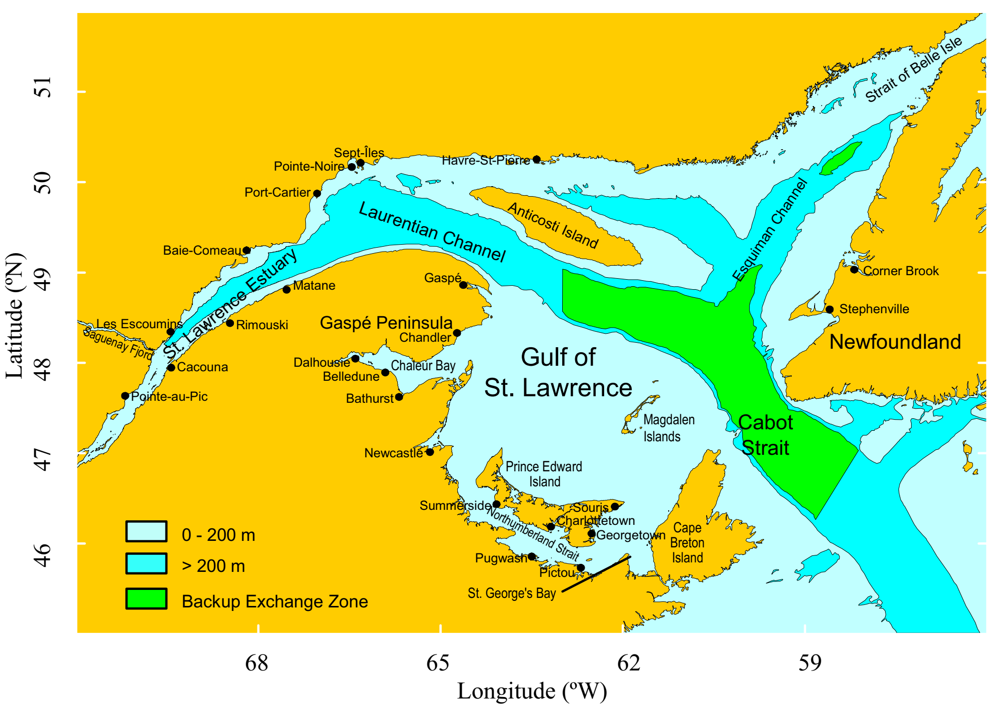

Figure 1. Current alternate ballast water exchange zone for ships proceeding up the Seaway.

longitude and at water depths exceeding 300 m. The Guidelines also recommend ballast water exchange for ships proceeding to Estuary and Gulf ports that are located west of 63° W longitude, which represents more than 80% of the entire maritime traffic from a foreign origin in the area on an annual basis.

An important oceanographic feature of the Gulf that has relevance for this study is the inward net transport of deep waters upstream to the head of the Laurentian Channel. The prescribed area is also located relatively close to the coastal waters of Anticosti Island, the Gaspé Peninsula and the Magdalen Islands which support important fisheries, including snow crab, lobster, and shrimp, in the Laurentian Channel. Thus, the location of the alternate exchange zone, particularly its upstream part, may represent and additional risk for the introduction of nonindigenous marine organisms in coastal areas of the Gulf of St. Lawrence.

Objectives

The objectives of this study were to assess risks for the introduction of nonindigenous marine organisms associated with ballast water exchange by foreign ships in the alternate zone of the Gulf of St. Lawrence and to minimize these risks in order to maintain an alternate ballast water exchange zone (ABWEZ) in the Gulf of St. Lawrence.

Methods

A three-dimensional model of circulation and thermodynamics in the Gulf of St. Lawrence (Saucier et al. 2003) was used to: (1) simulate the seasonal dispersion and fate of plankton inoculated with ballast water discharges in the ABWEZ and (2) identify areas from where surface waters are quickly flushed out of the Gulf so as to identify areas that could be used for alternate ballast water exchange (ABWE). The determination of these areas was put into context with other factors such as ballast water salinity and time of the year to derive a set of conditions under which backup exchanges could be allowed with an acceptable level of risk for the introduction of nonindigenous species in the Gulf of St. Lawrence.

Description of the Model

The model is a three-dimensional prognostic coastal model (Backhaus 1985) for currents, temperature, salinity, turbulence, and ice thickness and concentration in the Estuary and Gulf of St. Lawrence. The model has a horizontal resolution of 5 km and its vertical resolution is composed of 73 layers. Surface meteorological forcing is prescribed by six-hourly air temperature, winds, dew point, relative humidity, pressure, dry/liquid precipitation, and radiation. These data are provided by 20 virtual stations distributed throughout the Estuary and Gulf and derived from actual observations. Hydrological forcing is derived from monthly runoff at Quebec City and daily runoff for all major tributaries, and is adjusted to account for net basin drainage. An open boundary forcing at Belle-Isle Strait and Cabot Strait includes 15 water level tidal constituents and climatological water mass properties for entering Atlantic Ocean and Labrador Sea waters.

In terms of validation, the model was shown to reproduce well conditions that were observed in 1986 and 1987, including temperature and salinity profiles, current meter and tide gauge records, summer coastal temperature measurements, all of which with a relatively good precision. For example, the model was able to recreate freshwater pulses, storm events, and the formation, stability and dispersion of the Gaspé Current, which is one of the major features of circulation in the Gulf.

Simulations

All simulations of the dispersion of plankton were run by simultaneously releasing a predetermined number of particles over a given area that was limited to the upstream part of the alternate area for clarity purposes and to address greatest concerns. All particles were tracked by recording their position at the beginning of each day of simulation. Two-dimensional simulations were run to follow the discharge and surface dispersion of phytoplankton. A total of 8 simulations over 90 days were run, each starting at the beginning of the months of April to November. No simulations were run for winter months because of ice conditions which affect surface transport, particularily at small scales. For the dispersion of zooplankton, three-dimensional simulations integrating vertical migrations were run. However, given the CPU requirements for multi-variable simulations, these were limited to four, (starting in April, June, August, and October) and lasted for 60 days. For these simulations, the integration of daily vertical migrations was achieved by driving vertical movements of particles at dusk and dawn at a speed of 2 $cm \cdot s^{-1}$. Vertical migrations were forced down to 150 meters in the Laurentian Channel to allow particles to reach deep waters as usually observed, and to the bottom when water depths decreased to less than 150 m. Finally, to determine suitable areas for exchanges, simulations of the flushing of surface waters out of the Gulf were run in conjunction with phytoplankton dispersion simulations to identify initial positions of surface water particles that would be evacuated from the Gulf and these positions were recorded at 15-day intervals during these simulations.

Results and Discussion

Phytoplankton and Zooplankton Dispersion Simulations

Phytoplankton Surface Dispersion Simulations

The results of animations of two simulations of the surface dispersion of phytoplankton with contrasting results were presented to illustrate the large seasonal variability of transport and dispersion patterns. The first one started in April and shows the transport of particles first toward the Magdalen Islands, then upstream to coastal areas of Anticosti Island, and further upstream where some particles are caught up by the Anticosti Gyre. The patch is then transported downstream again with the arrival of the freshwater pulse around mid-May. The second started in September and shows a net downstream transport of inoculated particles, first towards the Magdalen Islands then further downstream to Cape Breton Island, as a result of typically dominant northwesterly winds at this time of the year. Most particles are ultimately flushed out of the Gulf through Cabot Strait and only a few remained at the end of the simulation.

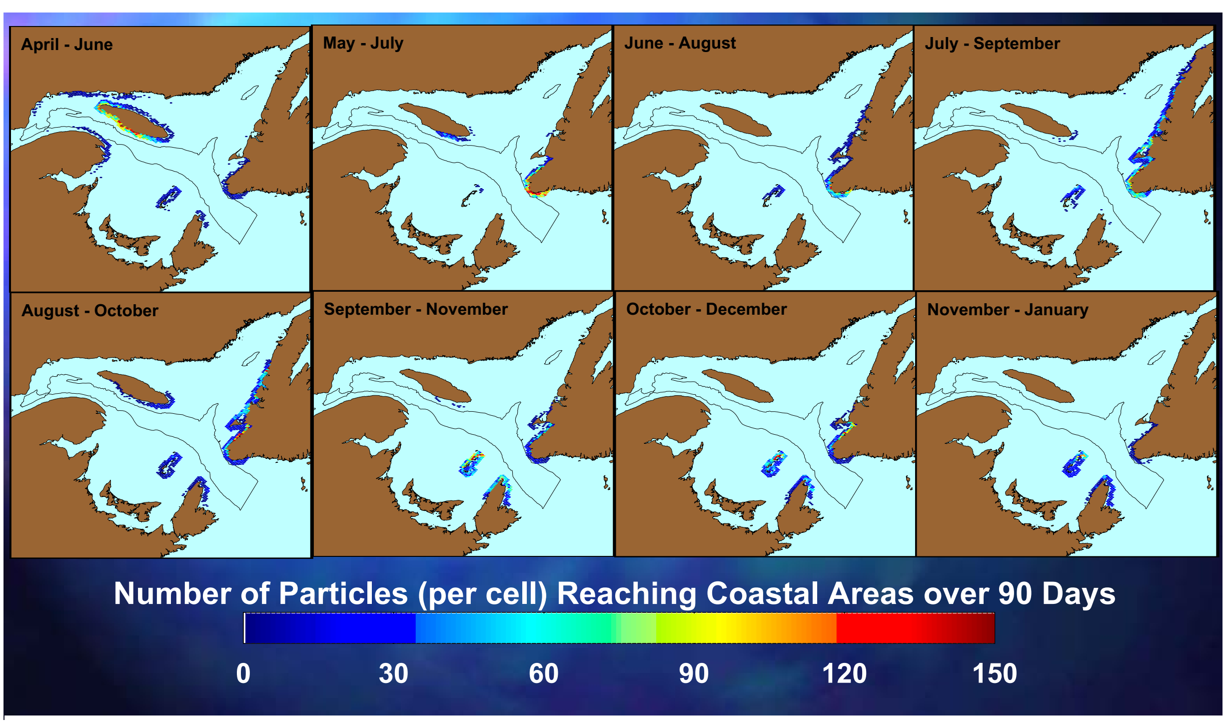

Figure 2. Estimated number of particles reaching coastal areas for 8 phytoplankton surface dispersion simulations.

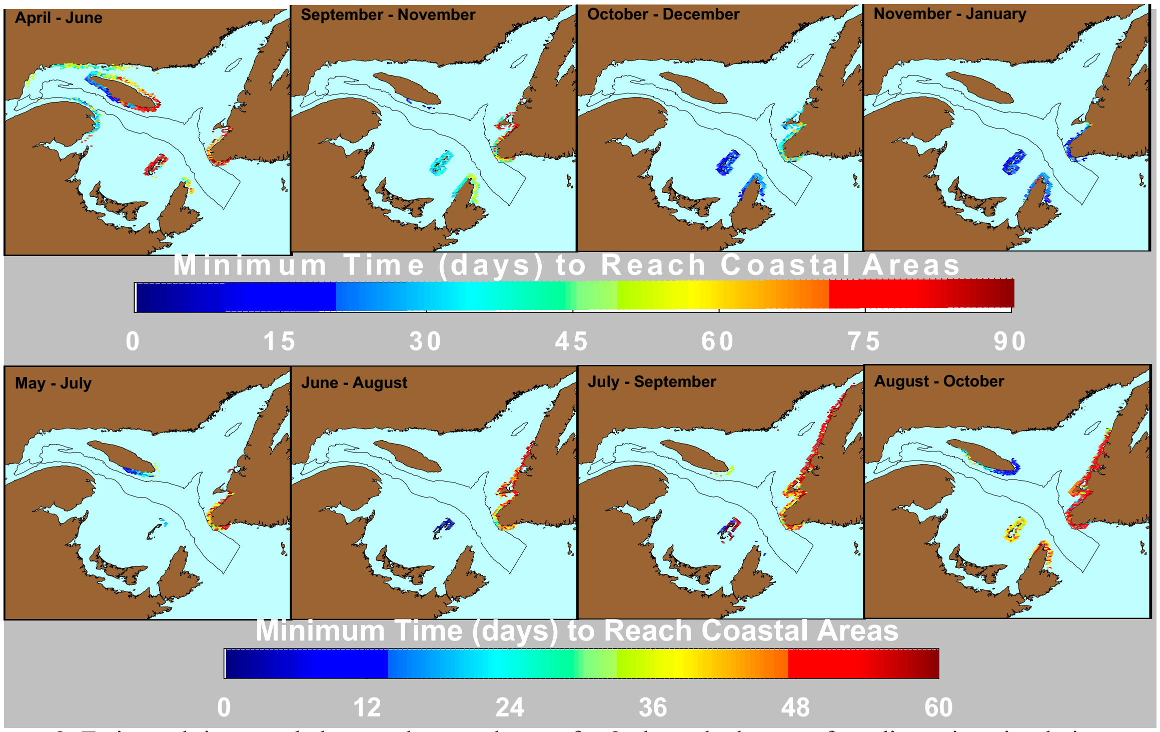

Figure 3. Estimated time needed to reach coastal areas for 8 phytoplankton surface dispersion simulations.

To illustrate coastal areas at risks in the Gulf of St. Lawrence, results of the eight simulations were summarized using three parameters: (1) the total number of particles reaching cells of the model that are adjacent to coastlines, (2) the minimum time required to reach the cells of the model that are adjacent to coaslines, and (3) the number of particles that are retained in the Gulf throughout the simulation.

1) Total number of particles. Results of all 8 phytoplankton surface dispersion simulations show that several coastal areas would be reached, some quite intensively, at different times of the year (Figure 2). Dispersion towards upstream areas such as Anticosti Island would occur in spring and late summer while downstream areas, namely the Magdalen Islands, southwestern Newfoundland and Cape Breton Island, would be reached in almost all cases. The entire west coast of Newfoundland would be particularily at risk in summer.
2) Time to reach coastal areas. In several cases, inoculated particles would reach coastal areas after 60 days, particularly on the west coast of Newfoundland (Figure 3). However, this is not the case in the fall and early winter for the Magdalen Islands and Cape Breton Island, which would be reached generally within 30 days. Anticosti Island would be reached within 45 days in spring/early summer and in early fall.
3) Retention in the Gulf. These figures show the change in retained particles with increasing time of simulation for the 8 seasonal runs (Figure 4). Most of the particles are still present in the Gulf after 45 days in spring and late summer, and at least half of the inoculated particles remain after completion of the 90-day simulations. This indicates that significant retention within the Gulf would occur for phytoplankton cells that would be inoculated with ballast water discharges in the upstream part of the ABWEZ during these periods. However, a significant number of surface particles would be flushed rapidly out of the Gulf in early summer and in fall; in extreme conditions (late fall), almost all of the inoculated particles would be lost to Atlantic waters. These times of the year are characterized by the passage of the spring freshwater runoff pulse in early summer, and

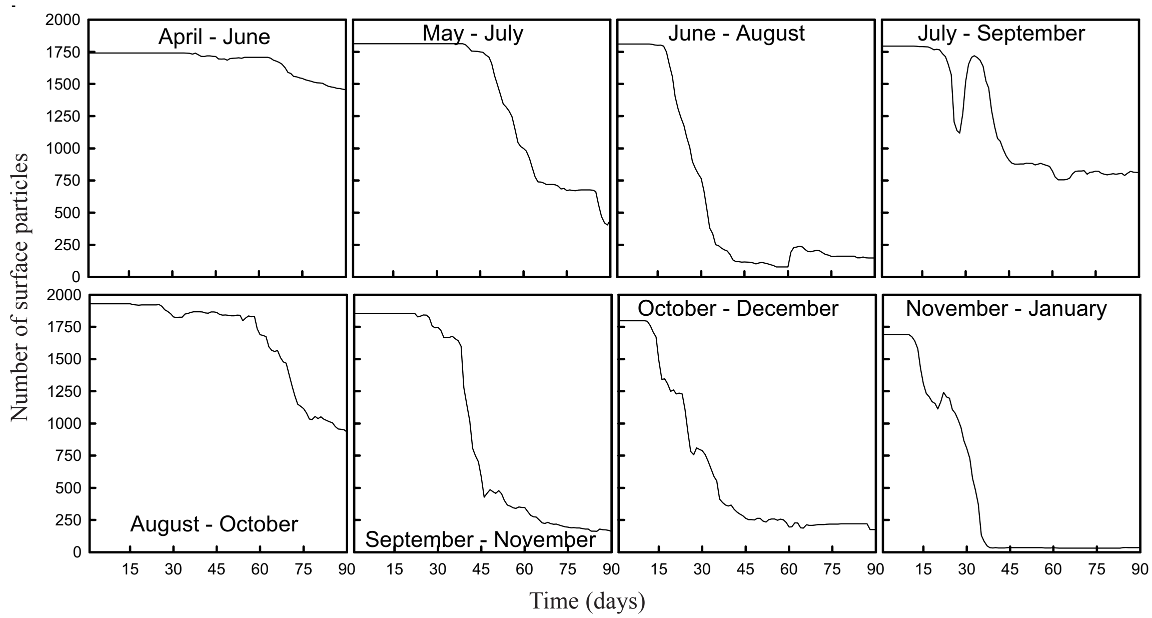

Figure 4. Estimated number of surface particles retained in the Gulf of St. Lawrence for 8 phytoplankton surface dispersion simulations.

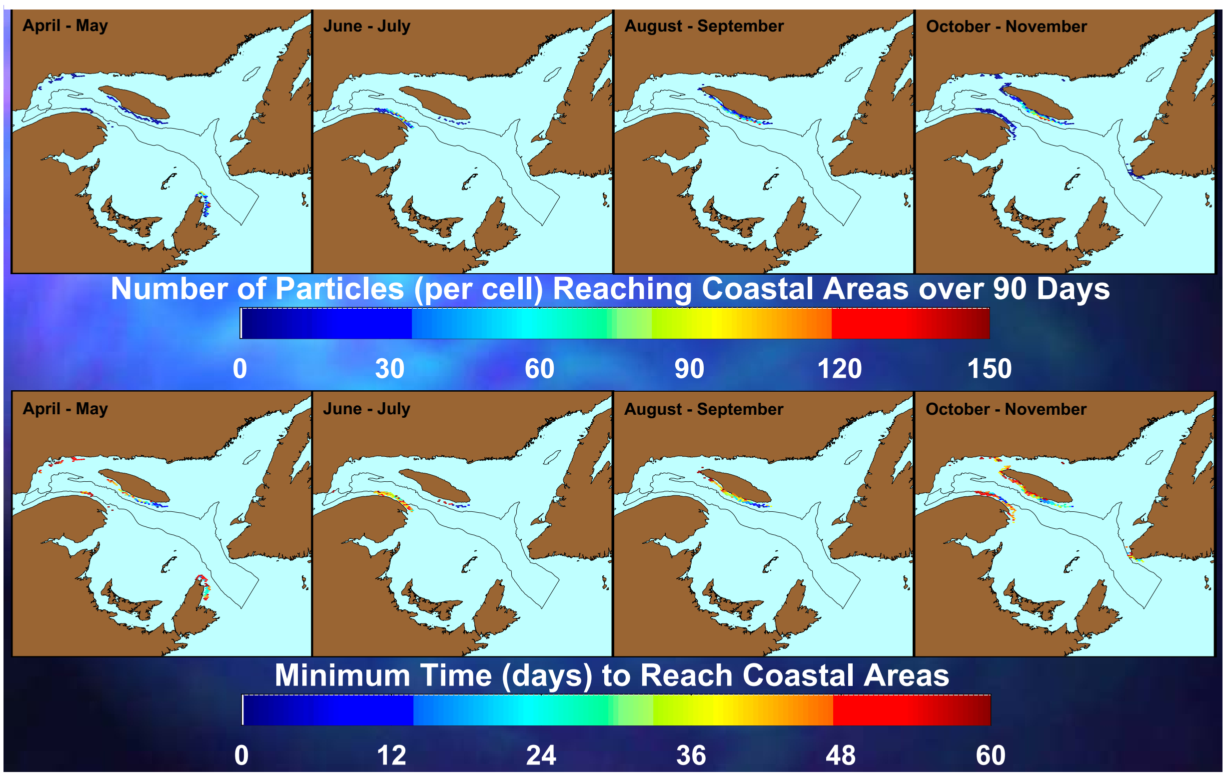

Figure 5. Estimated number of particles reaching coastal areas for 4 zooplankton dispersion simulations.

by strong northwesterly winds in fall which enhance the downstream transport of surface water towards the Atlantic Ocean.

Zooplankton Dispersion Simulations

The first four maps of the three-dimensional zooplankton dispersion simulations present the number of particles reaching coastal areas over the 4 simulations (Figure 5). These results show that dispersion patterns for zooplankton are clearly different from those observed for phytoplankton. In all cases, inoculated particles are dispersed upstream towards coastal areas of the Gaspé Peninsula, Anticosti Island and even the northwestern coast of the Gulf, whereas very few particles are dispersed towards downstream coastal areas. In contrast to phytoplankton simulations, the Magdalen Islands do not seem to be threatened by the inoculation of zooplankton in the upstream part of the ABWEZ. The four bottom maps show the minimum time required to reach these coastal areas and indicate that, in most cases, it takes at least 30 to 40 days for the inoculated particles to reach coastal areas except for the southeast coast of Anticosti Island. These different dispersion patterns are clearly related to daily migrations of zooplankton into deep waters of the Laurentian Channel, which show a net inward transport from Cabot Strait up to the head of the Laurentian Channel. This pattern is consistent with the observed zooplankton dynamics in the Gulf of St. Lawrence, where zooplankton is known to passively migrate upstream and accumulate at the head of the Laurentian Channel near Tadoussac. Thus, it can be assumed that zooplankton inoculated in the Laurentian Channel with ballast water discharges would be subjected to this passive upstream transport and ultimately could be incorporated in the observed zooplankton dynamics in this area, if conditions were favorable for their survival and reproduction.

Summary

In summary, phytoplankton dispersion simulations showed that several coastal areas are at risk from phytoplankton inoculation in the Laurentian Channel, including the Magdalen Islands, Southwest Newfoundland, Northern Cape Breton Island, and Anticosti Island. Some of these coastal areas, namely the Magdalen Islands, Anticosti Island, Cape Breton Island, would be reached within 30 days. A significant downstream transport would occur in late spring/ early summer, because of the spring freshet, and in fall as a result of predominant northwesterly winds, while a significant retention of surface phytoplankton within the Gulf would occur in spring and late summer.

Three-dimensional dispersion simulations of zooplankton yielded further retention of particles in the Gulf as a result of the net inward transport of deep waters in the Laurentian Channel. Thus, inoculated zooplankton would be mainly retained within the Laurentian Channel and upstream coastal areas would be particularly at risk (Gaspé Peninsula, Anticosti Island). Ultimately, inoculated zooplankton could be incorporated into the zooplankton dynamics of the Estuary and Gulf ecosystems.

ABWE southeast of Anticosti Island represents a risk from a Gulf perspective, because of the significant retention of inoculated planktonic organisms within the Gulf and for their dispersion towards coastal areas. However, it was recognized that there was a need for ballast water regulating agencies in Canada and the U.S. and for the industry to have an alternate zone in the Gulf of St. Lawrence, and the authors tried to identify such a ABWEZ by looking at areas from where surface waters would be quickly flushed out of the Gulf.

Flushing of Surface Waters out of the Gulf (90 Days)

Figure 6 shows the initial position of surface particles that would be flushed out of the Gulf at two week intervals during the simulations for the 8 phytoplankton surface dispersion simulations. Deep blue and blue areas represent areas flushed out within 15 and 30 days respectively, light blue and green areas represent areas flushed after 30 and 45 days, and yellow and red areas are for 75 and 90-day flushing time. These maps clearly show that surface waters in the Cabot Strait area of the Gulf are rapidly flushed out to the Atlantic, usually within 30 days. This is particularly the case in summer, when high surface temperature would allow survival of a greater number of inoculated species, and in late fall when the need for a ABWEZ is highest because of bad weather conditions in the North Atlantic at this time of the year.

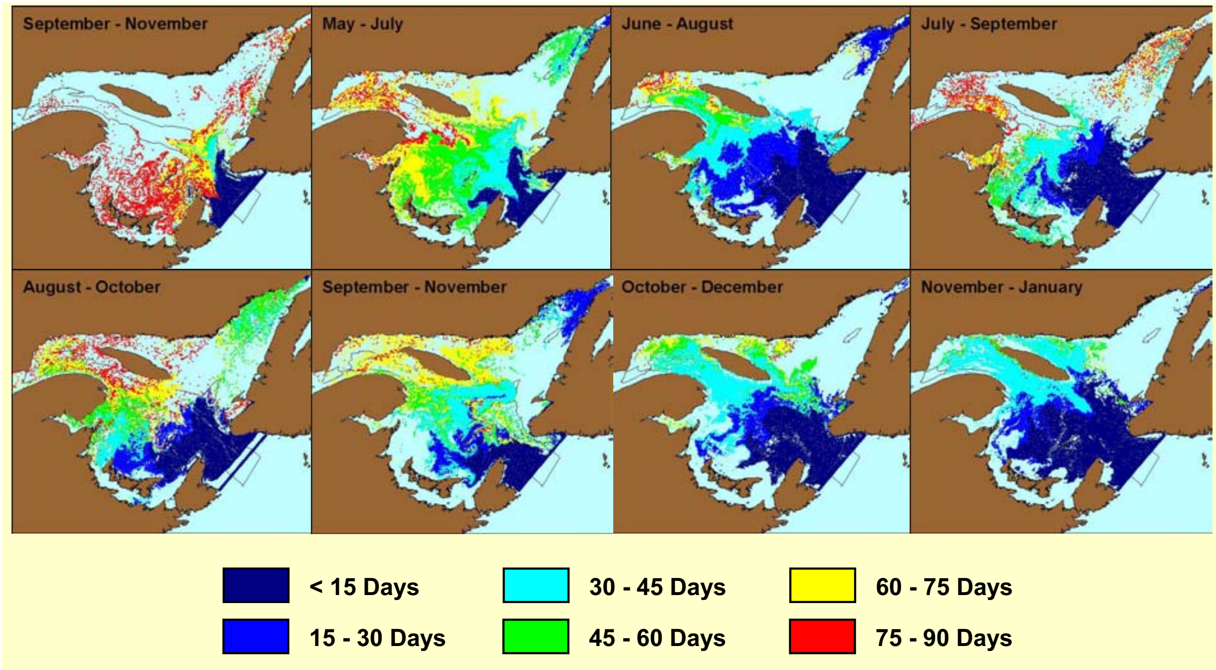

Figure 6. Estimated time required for flushing surface waters out of the Gulf of St. Lawrence for the phytoplankton dispersion simulations.

Conclusion and Recommendations

Conclusion

The Gulf area that is located around Cabot Strait east of the Magdalen Islands could be acceptable for ABWE from a Gulf perspective. However, zooplankton inoculations in this area would probably still be subjected to a net upstream transport and, more importantly, the fate of inoculated organisms that would be flushed out of the Gulf with surface waters is unknown, but may pose a threat to the Canadian Atlantic Coast. This hypothesis has been confirmed with recent studies. However, the approach presented in the present study should be applied to the Atlantic Coast in order to identify alternate zones for ballast water exchange.

Risk Analysis and Decision Support System

There is no ideal solution to this problem and some level of risk must be accepted. However, such an acceptable level of risk would have to be minimized as much as possible; the suitability of ballast water exchanges around Cabot Strait (or other areas) would have to be based also upon other conditions that influence the survival of inoculated organisms, which point to a risk analysis approach and a decision support system. For ships proceeding up the St. Lawrence River and to the Great Lakes, the first factor to be considered would be the salinity of ballast waters transported by ships. Exchanges in the Gulf of St. Lawrence could be allowed in the ABWEZ when ships are transporting freshwater in their ballast tanks. On the other hand, exchanges would not be required for ships transporting marine waters with salinity exceeding 30 PSU, because these exchanges would not further reduce risks for ships proceeding up to freshwater ports but could increase those for the Gulf of St. Lawrence. If brackish waters were transported in ballast tanks, then other factors would have to considered, the second most important being the time of the year. In this case, the need for ABWEZ would be particularly important during fall and winter because of stormy conditions in the North Atlantic. This is also a time of the year when surface temperature in the Gulf decreases significantly to near freezing temperatures, which limit the potential for survival of inoculated organisms. As a result, ABWE could be allowed from late fall through spring around Cabot Strait (or other areas) while for the rest of the year, a third factor would be incorporated in the risk analysis, namely the origin of the ship. If ships originate from tropical or subtropical areas, then ABWE would be allowed, whereas for ships originating from temperate and subarctic ports, other means such as storage facilities and treatment options or sealed tanks (exchanges not allowed) would have to be considered. Such a risk analysis, if incorporated in voluntary guidelines in conjunction with ABWEZ around Cabot Strait, would maintain risks for ballast water-mediated introductions in the Great Lakes at a low level, but would significantly reduce these risks for the Estuary and Gulf of St. Lawrence. A similar risk analysis could also be developed for ships proceeding to marine ports of the Estuary and Gulf. In conclusion, this approach would be consistent with a precautionary approach and would definitely facilitate the development of regulations for ballast water exchange at the national level in Canada.

Literature Cited

Backhaus, J. O. 1985. A three-dimensional model for the simulation of shelf-sea dynamics. *Dtsch. Hydrogr. Z.* 38: 165-187.
Saucier, F.J., F. Roy, D. Gilbert, P. Pellerin, H. Ritchie. 2003. Modeling the formation and circulation processes of water masses and sea ice in the Gulf of St. Lawrence. *J. Geophys. Res*. 108(C8): 3269-3289.

Risk Assessment for Species Introduced from Ballast Water Exchange

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Abstract

The geographical information system (GIS) mapping of geo-referenced ballast water exchange volume endpoints recorded on Ballast Water Report Forms submitted to Marine Safety, Transport Canada, provides insight in ballast activities reported off Eastern Canada during the year 2002.

Vessel movement tracks and seasonal computer-modelled potential (interpolation) surface thematic maps rendered location information on preferred vessel exchange corridors and delineated high-value areas for ballast exchange volumes (reported endpoints) for vessel traffic approaching Eastern Canada from the United States, Europe and other international departure points.

The same Transport Canada ballast water data provided for a comparative, statistical analysis of shipping trends and patterns for Eastern Canada, with years 1998 and 2000.

Please see the full 85-page report, *GIS Mapping of Marine Vessel Ballast Water Exchange Enpoint Data in Atlantic Canada, for the 2002 Shipping Season*, which appears in these proceedings as Appendix VII.

Shipping Industry Perspectives

Ballast Water Management:
A Marine Industry Perspective

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Introduction

The Shipping Federation of Canada is an association of shipowners, commercial operators and agents representing 90% of ocean traffic calling at East Coast, St. Lawrence and Great Lakes ports. The Federation has been an active player in the implementation of ballast water management guidelines and regulations in both Canada and the U.S.

The Economic Importance of the Marine Industry

According to statistics provided by Transport Canada, the value of Canada-U.S. marine trade in 2002 was $13.3 billion, while the value of Canada's international marine trade was a staggering $98.3 billion. Of the 61.9 million tons in total marine shipments recorded in 2002, more than half was attributable to cargo traffic along the east coast. More specifically, traffic moving from Canada's Atlantic coast to the U.S. Atlantic coast totaled 33.6 million tons, traffic moving from the U.S. Atlantic coast to the Canadian Atlantic coast totaled 3.8 million tons, and traffic moving from the St. Lawrence to the U.S. Atlantic coast totaled 3.6 million tons.

The marine industry creates 9,500 direct jobs in Atlantic Canada and 26,500 jobs in the Quebec region. Moreover, shipping is essential to the development of a number of major industries, including iron ore and steel, oil (offshore and refineries), agricultural products, mineral and concentrates, and wood and paper products.

Main Areas of Concern Based on Trades

U.S. Coast Guard statistics for the Great Lakes for 2000 indicate that overseas traders reported that they were able to exchange their ballast water at sea in 95 to 97 percent of cases. Recent samplings and biological analysis from the Great Lakes Institute for Environmental Research (Reid et al. 2002) confirm that the actual compliance rate is in line with the reports received. Container, ro-ro, and cruise ships carry very small quantities of ballast water and often do not discharge it at all, while a few small tankers operating in liner services are able to discharge all their ballast (oiled ballast) at the refinery. Coastal traders from South and Central American and the southern U.S. are usually in partial ballast and have, in most cases, sufficient time to conduct an exchange before entering the EEZ. Some find it necessary to top off in 2-3 East Coast ports en route. Thus, bulk carriers (tankers and dry bulk carriers) engaged in coastal trades that do not have a return cargo on their regular routes discharge the major amount of remaining unexchanged ballast water into the East coast ports at this point.

How Much Water are we Talking about and Where?

Estimates based on the main cargo trades indicate that approximately 0.9 to 1.1 million tons of coastal ballast water are discharged in the Laurentian Channel annually, mainly from iron ore carriers bound for Port Cartier and Sept-Isles. In the Atlantic region, between 9.3 and 9.8 million tons of coastal ballast water are discharged annually, mainly from tankers bound for Come by Chance and Halifax, and from non-mineral bulk carriers bound for ports in the Bay of Fundy and St. John.

Technical Constraints of Treatment Systems

The ideal treatment system would meet standards that are accepted globally, or in the least, that are accepted in the main countries in which vessels trade. The ideal treatment system would also be safe, easy to install, time-efficient, simple for the crew to operate, and non-hazardous.

Current Preventative Measures and Costs

The annual cost of exchanging ballast water at sea for a dry bulk carrier en route to the U.S. is $2.09 million (or $3,875 per vessel) for a Handymax and $1.1 million (or $7,830 per vessel) for a Panamax. In the tanker trades, the cost increases to $4.64 million (or $2,622 per vessel) for a Handymax, and $2.74 million (or $3,982 per vessel) for a Panamax. This does not include the costs associated with approved ballast water management plans, hull fatigue and increased safety concerns.

The shipping industry has been highly proactive on the ballast water issue. For example, the Shipping Federation played the lead role in developing the Code of Best Practices for Ballast Water Management (see Appendix), and continues to raise awareness through information sessions for industry and the publication of circular letters, reports and other written material. A number of shipping companies also participate in research, and take part in on-board trials and permanent installations of treatment systems.

Coastal Traders

Coastal vessels are restricted by their trade limitations to transits within the EEZ. Full exchange for such vessel takes 24 to 36 hours, and deviating to 200 nautical miles could take longer then the actual voyages in which they are engaged. One of the most extreme examples of this would occur with a ship in full ballast condition undertaking a voyage from New York to Point Tupper (approximately 43 hours in length). Such a vessel would add 40 extra hours to its voyage in order to do an exchange at 200 nautical miles offshore; 36 extra hours to do an exchange at a depth of 2000 metres, and 20 extra hours to do an exchange 100 nautical miles offshore. For the same vessel transiting from New York to Placentia Bay (a voyage of approximately 80 hours), the extra voyage times would be 10 hours, two hours, and 0 hours, respectively.

Meanwhile, a dry bulk carrier in full ballast condition engaged in a voyage from Savannah to Belledune (approximately 130 hours in length), would add 21 extra hours to do an exchange at 200 nautical miles offshore and 12 extra hours to do an exchange 100 nautical miles offshore. If that same vessel were traveling from Norfolk to Halifax, it would add 23 hours to its voyage for a 200 mile exchange and 14 hours for a 100 mile exchange.

As illustrated in Table 1 by these examples, the largest deviations are for vessels originating from U.S. East Coast ports and bound for Nova Scotia, New Brunswick or the Gulf, with the major impact from deviations occurring when vessels are in full ballast and transiting short distances.

Cost of Deviations

The financial impact of deviations can be extremely high. For tankers, the hourly cost of deviation amounts to $1,000 (USD) in additional time charter fees and $300 in additional fuel fees. Thus, a tanker that incurs a 20-hour deviation in a given voyage will incur an additional cost of $26,000 for that voyage only. For a tanker operator doing 200 voyages per year, the annual costs of deviation would amount to a substantial $5.2 million.

In a market where the overall profit margin per voyage is often less than $10,000 USD, it is quite possible for a company to change ports due to a cost differential of less than $2,000 USD per call. There exists, therefore, a risk that deviations could cause some ports to become less competitive and potentially lose long-term contracts. Ultimately, of course, any increase in the cost of transportation will be passed on to the consumer.

Commercial Considerations

It is important to remember that deep-sea ships are engaged in international trades, subject

Table 1. Summary of deviations from route to meet 200nm, 2000m depth and 100 nm for tankers and bulk carriers based on two different routes. Daily additional costs for tanks is approximates $1000 for time charter and $300 for fuel for each hour; data not provided for bulk carriers.

Case 1: Tanker (full ballast condition) Time to exchange=24 hrs Distance=360 nm	Approximate Cost (time charter and extra fuel)
Deviations	
Route A – New York to Point Tupper (approx. 43 hrs)	$26,000 USD
200 nm	+ 40 hrs
2000 m depth	+ 36 hrs
100 nm	+ 20 hrs
Route B - New York to Placentia Bay (approx. 80 hrs)	
200 nm	+ 10 hrs
2000 m depth	+ 2 hrs
100 nm	none
Case 2: Bulk carrier (full ballast condition)[1,2] Time to exchange=36 hrs Distance=504 nm	
Deviations	
Route A - Savannah to Belledune (approx. 130 hrs)	
200 nm	+ 21 hrs
100 nm	+ 12 hrs
Route B - Norfolk to Halifax	
200 nm	+ 23 hrs
100 nm	+ 14 hrs

[1]Bigger deviations if bound for NS, NB or the Gulf
[2]Major impact from deviations occur in full ballast, when transiting short distances

to international and multi-national standards and regulations. Given the strong competition that exists among the various routes by which a given cargo can travel, the imposition of a new requirement in one area could result in cargo transferred to other shipping routes or transported by other modes.

An international or national standard for ballast water treatment must still be defined. However, as far as individual ships are concerned, an acceptable level of investment will be closely linked to the remaining lifetime of a given ship. Additionally, some types of treatment systems will be inherently better suited to certain types of ships or trades.

Conclusion

Research and on-board trials of ballast water treatment systems must continue to be pursued, as must the provision of incentives for industry participation in such initiatives. In the meantime, however, it is important that coastal traders be provided with an alternative to ocean exchange. From our perspective, the ideal features of an alternative exchange zone should include: (a) 50 nautical miles or less from shore; (b) more than 500 nautical miles long; (c) applies for coastwise ships with ballast water intake originating south of the Chesapeake Bay. And finally, it is absolutely imperative that national regulations are in line with developments at the international level.

Literature Cited

Reid, D., H.J. MacIsaac, M. Dochoda, J. Gannon, M. Burrows and J. Hartig. 2002. Research and Management Priorities for Invasive Species in the Great Lakes. Prepared for: International Association of Great Lakes Researchers. 17 pp.

Maritime Industry Approaches to Reduction of Aquatic Nuisance Species: Actions and Activities

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Introduction

As an employee of a trade association which represents owners and operators of all ship types flying both U.S. and non-U.S. flags, I rarely attend a conference in which the concept of "polluter pays" does not arise. Since the validity of this concept and the deliberations necessary to determine what is pollution and who is the polluter in a given scenario could be the sole subject of a lengthy conference, I do not pretend to encompass this debate in this paper. However, as related to any scenario, the key to solutions for today's environmental challenges is to ensure that whomever is paying for whatever type of pollution is actually paying for something that benefits the marine environment while preserving the necessary flow of international commerce. As related to the control and mitigation of the impacts of aquatic nuisance species, this requires a clear definition of the problem, an understanding of the commercial industry to be regulated, and a collaborative effort to identify and quantify technologies that will achieve real results in an environmentally, operationally and economically viable manner.

Irregardless of our affiliations or backgrounds, when we discuss aquatic nuisance species management and the shipping industry, we are all tied to a single set of train tracks on which a number of different trains are bearing down on us at the same time. A number of initiatives, completed or proposed, at the international, national, sub-national (regional) and local levels seek to regulate ballast water discharges from ships; most if not all regulations are inconsistent one with the other. In discussing what part industry is playing, one thing is clear: this problem with all its scientific, technological, political and legal complexities is not going to be solved by any one of the interested parties. It will be solved only as a collaborative effort among the shipping industry, ports, environmental groups, technology developers and governments at all levels. Such collaborative efforts have resulted in real progress at the International Maritime Organization (IMO), which will likely finalize an international ballast water treaty in February 2004, and within the U.S. legislative and regulatory process at some time in the near future.

Specific Industry Activities

My organization, along with a number of national and international shipowner organizations have been participants in the IMO deliberations for a number of years both as members of national delegations and as non-governmental members of the IMO. In addition, my organization has participated in the deliberations of the U.S. Invasive Species Advisory Council, several U.S. Coast Guard subcommittees addressing technology and standards development associated with ballast water management, a U.S. Environmental Protection Agency sponsored group which is attempting to develop and finalize a standardized test protocol for measuring the effectiveness of various ballast water treatment technologies, and a science and technology development based grant program funded by the U.S. government. In addition, we have carried out numerous briefings to members of the U.S. Congress, their staffs and other governmental agencies. But perhaps most importantly has been our work within the industry in educating our colleagues that there is a real problem that needs fixing. We have also served as an information clearinghouse which a number of technology developers are using to get their message out to our members, their potential customers. We are long past the point of arguing that there is no problem with ballast water discharges from ships. Briefing our industry colleagues on the continuing saga of the zebra mussel, the Asian carp and the snakehead, replete with all the gory teeth-filled photographs we can muster has made our educational mission much easier. But the solution remains far less certain and far more challenging.

Costs, Concerns and Perceived Risks Associated with Ballast Water Management

Accepting the premise that ballast water management is the only viable legally recognized alternative for ballast water management to date is not necessarily to accept its permanence as a means for compliance. Large numbers of entrepreneurs are in various stages of developing and testing a number of ballast water treatment technologies utilizing ozone, physical separation, filtration, ultraviolet, heat, chemical biocides or some combination of these methods. In order to accurately assess the scientific and economic viability of these alternative ballast water treatment methods they need to be compared to the same implementation viability standards as ballast water exchange.

For example, with exchange comes a number of costs and concerns with its implementation including increased labor costs, crew safety issues associated with flushing large volumes of water over occupied main decks in mid-ocean, vessel trim and stability, energy costs and environmental impacts associated with increased use of fuels to drive the pumping systems, additional maintenance requirements and the potential diversion costs for vessels which do not transit mid-ocean areas for sufficient time to carry out the exchange during the normal transit (Table 1). Countering these costs and concerns are those associated with treatment systems which include the costs associated with experimental shipboard programs and the certification process, initial capital outlay for systems (estimated at a minimum of USD $150,000 with an already documented installation and test program exceeding USD $5,000,000), ongoing operating and maintenance costs (including treatment agents in some cases) and the potential for multiple capital outlays if future legal requirements require existing ships to continue to retrofit new systems when new standards are promulgated.

Considering these costs and concerns, each and every shipowner will be required to compare the impacts of exchange versus treatment, including integration of the uncertain legal structure in which requirements will be enforced to determine the "best" method of compliance for their particular ship and voyage parameters. When all is said and done, assuming that at some point in time exchange per se will not be an acceptable method of compliance, a treatment system that costs one million U.S. dollars may be quite affordable if, in the absence of that system, the vessel is required to add 3 days diversion to every 4 week period so as to conduct a "compliant" mid-ocean exchange, or worse yet is refused entry into its destination port. Factoring a very conservative charter rate of $30,000 per day and assuming a need for diversion, the vessel's treatment system would pay for itself in less than one calendar year. Unfortunately, this calculus is significantly impacted if that same vessel would require retrofitting with new systems every time the standard is made more stringent.

Table 1: Ship board costs, in USD, for ballast water exchange, treatment and experimental treatments.

Labor	Exchange	Treatment[1]	Experimental
Crew safety	No Data	Training, USCG	Training, USCG
Fuel to drive pumps, trim stability	Some costs incorporated into additional maintenance	Additional costs associated with equipment	Fuel cost associated with equipment
Maintenance	No Data	No Data	No Data monitoring
Diversion	$25-40 K per day	Not applicable	Not applicable
Capital costs	Not applicable	$150 K minimum	$250 K minimum
Retrofitting	Not applicable	No data	No data
[1]assumed approved			

Finally, the policy and political risks associated with management of ballast water from ships is a critical element in the calculations. These risks include the potential for inconsistency among international, national and sub-national programs which require multiple compliance strategies for each program (or in the worst possible case, make compliance with all impossible due to the inconsistency of one), inadequate incentive programs for the early implementation of experimental shipboard testing programs, and the potential for "continuous" retrofit for existing ships when final standards are changed over time.

The Bottom Line

Based on the considerations discussed and the inconsistencies among international and national programs detailed in my presentation, the following recommendations need to be implemented as soon as reasonably possible:

- Create a robust international program for ballast water management aboard vessels.
- Such international program should be of sufficient stringency to obviate the need for national/sub-national programs.
- Where nations do not believe the international program is sufficiently stringent, more stringent provisions may be acceptable as long as they are defined within the framework of the international convention.
- The international and national programs must contain vigorous reporting requirements for vessels so that much needed data is collected for ballast water research.
- International and national programs should focus on treatment as the long-term compliance method; however, exchange should be permitted where it meets the performance standards to which the treatment systems are subject.
- International and national programs should support the identification of alternate ballast water exchange zones as a short term compliance method.
- International and national programs must include the critical elements of performance standards, criteria for experimental shipboard testing programs, creation of standardized testing protocols and adequate grandfathering provisions to promote early participation and compliance with both the experimental program and the final performance standard.

Risk Assessment

Risk Assessment Systems for Ballast Water

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INTRODUCTION

The overall goal of this workshop, the identification of "safe zones" in which to conduct ballast water exchanges or releases, requires that we conduct some form of risk assessment of ballast water that is transported within our Atlantic Canada/northeastern U.S. waters. Risk assessment, whether formally stated or implicit, is associated with every recommendation or decision on the management of ballast water. Therefore, it is useful to review the process of risk assessment, and the approaches that have been taken to risk assessment of ballast water.

My objectives in this talk are to provide a general introduction to the science of risk assessment, an overview of the formalized systems that have been or are now being developed for risk assessment of ballast water worldwide, and a summary of existing information (e.g., biology, oceanography, vessel traffic patterns, methodologies) that is relevant to risk assessments of ballast water in Atlantic Canada and the northeastern USA. Two examples from the Laurentian Channel will be used to illustrate how different approaches to risk assessment can result in highly divergent conclusions.

GENERAL PRINCIPLES OF RISK ASSESSMENT

WHAT IS "RISK"?

The term "risk" expresses the chance of an undesirable event occurring as a result of some activity or action. In the context of risk assessment of ballast water, risk may be defined as "the likelihood of undesired/unwanted invasive species establishing and causing biological, economical, safety-related or social damage in areas where the species did not occur naturally/historically" (Haugom et al. 2002).

WHAT IS RISK ASSESSMENT?

The United States Environmental Protection Agency defines risk assessment as "a process for organizing and analyzing data, information, assumptions, and uncertainties to evaluate the likelihood of adverse ecological effects". The rationale for undertaking risk assessment is that it "provides a critical element for environmental decision making by giving risk managers an approach for considering scientific information along with the other factors they need to consider (e.g., social, legal, political or economic) in selecting a course of action" (US EPA 1998).

WHY USE RISK ASSESSMENT FOR BALLAST WATER?

Ballast water management can be undertaken as either a selective (risk-based) or a blanket (all ships) procedure. Regardless of which approach is selected, some form of initial risk assessment (either formal or informal) must have been conducted in order to determine if management is warranted.

Following the initial decision to undertake ballast water management, the blanket approach requires that the same management practices be undertaken by all ships. No further risk assessment is undertaken. For a regulatory agency, the blanket policy approach is simpler and less labour-intensive, requiring no ongoing investment in risk assessment. The disadvantage of this approach, however, is that it may impose unnecessary restrictions on low-risk ships (higher costs to the shipping industry), or that the requirements may be insufficient for high-risk ships (higher costs to the environment).

Risk-based management permits much more flexibility, allowing for specific restrictions or requirements to be imposed on individual ships, at the level warranted by the degree of risk associated with that ship. The goal is to make management more cost-efficient, by achieving the maximum risk reduction per unit cost. A disadvantage of this approach is that it is labour- and data-intensive for the managing agency, both to develop, and to use on an ongoing basis.

How many countries use risk assessment vs. blanket policies for ongoing management?

Strategies have been adopted by a number of countries for management of foreign ballast water. With the exception of New Zealand and Australia, management applies only to commercial vessels which originate from outside the Exclusive Economic Zone (EEZ). I have separated the strategies into five major categories. The lists of countries currently following each strategy are based on information obtained from the Intertanko web site in October 2003 (www.intertanko.com/tankerfacts/environmental/ballast/ballastreq.htm).

(1) Voluntary blanket ballast water management Formerly, this was the approach used by Canada. I am not aware of any country that publishes a ballast water management strategy for the use of mariners, and continues to use a solely voluntary approach.

(2) Mix of voluntary and mandatory blanket policies
   - Canada (mandatory in Vancouver, voluntary elsewhere as of October 2003 but with a regulatory reform underway which is expected to expand the area of mandatory ballast water management).
   - USA (mandatory in Great Lakes, Hudson River, California, and Valdez AL, again with the expectation that a regulatory reform now underway will result in a wider application of this approach).
   - Argentina (mandatory policy applies only to ships coming from locations with cholera)
   - Great Britain (mandatory in the port of Scapa Flow, Orkney Islands)

(3) Mandatory blanket management
   - Chile (applies to all shipping from outside EEZ)
   - Israel (applies to all shipping from outside EEZ)
   - New Zealand (applies to all shipping, including that which originates within the EEZ)

(4) Risk-based management under development
   - Norway (EMBLA project)

(5) Risk-based management in use
   - Australia (applies to all ships entering Australian waters from outside the EEZ, and to ships entering waters of the state of Victoria, including vessels originating from other Australian states).

What are the features of an effective risk assessment?

Almost every document on risk assessment discusses the characteristics that contribute to the development of an effective procedure. The features which are listed below are based on the recommendations of Hayes (1998a), Haugom et al. (2002), and US EPA (1998).

(1) The assessment should be quantitative, with measurable endpoints (quantifying the likelihood of occurrence of the "undesirable event", which might be inoculation of an exotic species, or its establishment, economic impact, etc.). Subjective risk-assessment perceptions are seen as the most serious obstacle of risk management. Low probability/high consequence events tend to be overestimated, and high probability/low consequence events tend to be underestimated (WHO CEMP 1992).

(2)Uncertainty in the estimate of risk is clearly described.

(3) Invasion success is determined as a function of both species-specific and site-specific attributes (i.e., an invasion cannot be successful unless a species is available to be picked up and transported by the vector (ballast water) and deposited into an appropriate receiving environment).

(4) The assessment may be improved as groundtruthing progresses, as an iterative process.

(5) It is essential that the risk assessment be understandable to stakeholders.

Risk Assessment Systems for Ballast Water

Currently, three formalized risk assessment systems exist or are under development in the international ballast water community.

- Australian Decision Support System
- Environmental Risk Management System for Ballast Water Assessment
- GloBallast Risk Assessment System

The Australian Ballast Water Decision Support System (DSS)

The Australian DSS was developed at CRIMP (Centre for Research on Introduced Marine Pests), from 1993 to 2001 (Hayes 1997, 1998a, 1998b; Hayes and Hewitt 1998, 2000; Hewitt and Hayes 2002). It has been in use by the Australian Quarantine Inspection Service since July 2001.

Import Risk Assessment and Quantitative Risk Assessment paradigms, familiar to Australian scientists from earlier screening procedures of the quarantine service, form the basic framework of the ballast water DSS. The steps in the Quantitative Risk Assessment paradigm were summarized by Hayes (1998a) as:

(1) Identify potential undesirable events (hazards)
(2) Analyse their frequency / likelihood of occurrence
(3) Assess potential effects or impacts
(4) Calculate risk, expressed as a product of the probability of an undesired event and its consequences
(5) Examine the significance of the results; this may be in the wider context of other social, economic or political concerns.

The risk assessment is based on a target list of marine pests to be avoided, so it is species-specific but not site-specific (unless all waters of Australia are considered as a single site). The endpoint of the assessment is the introduction and survival of non-native species.

A quantitative risk assessment is provided for each tank of the vessel. High-risk vessels are required to exchange or treat ballast water, or retain it on board.

Environmental Risk Management System for Ballast Water Assessment (EMBLA)

The EMBLA decision support system was developed by DNV (Det Norske Veritas), starting in 1998 (research.dnv.com/marmil/ballast/) (Haugom et al. 2002). The system was to have been completed by 2002 but there was no indication of its present status on the project web site in October 2003. The program was funded by the Norwegian and other Nordic governments and shipping interests. The project was also coordinated with the EU Concerned Action Group on Ballast Water. The questions addressed were:

- Which phase(s) of the ballast water transfer process is critical to the risk level?
- Where is it most efficient to introduce risk control measures?

Data and analytical requirements of the system include:

- Development of a Ballast Water Transfer Atlas (a summary of biogeographic compatibility, see Figure 1)
- Lists of risky species
- Determination of the environmental compatibility of risky species with the recipient port
- Hazard analysis to determine the probability of survival of viable populations of hazard species through the process of ballasting/transfer/de-ballasting

From these data inputs, the DSS estimates ecological, economic and safety impacts and determines whether these are at an acceptable level. If not, a reassessment can be run, taking into account the effect of different risk-reducing measures, and resulting in recommendations for ballast water treatment (Figure 2).

The GloBallast Risk Assessment System

The GloBallast (Global Ballast Water Management Programme) risk assessment system was supported by GEF/UNDP/IMO (Global Environment Facility/ United Nations Development Programme / International Maritime Organization). Pilot systems have been or are still in development in Brazil, China, India, Iran, South Africa, and Ukraine (globallast.imo.org). Development began in 2000 and is

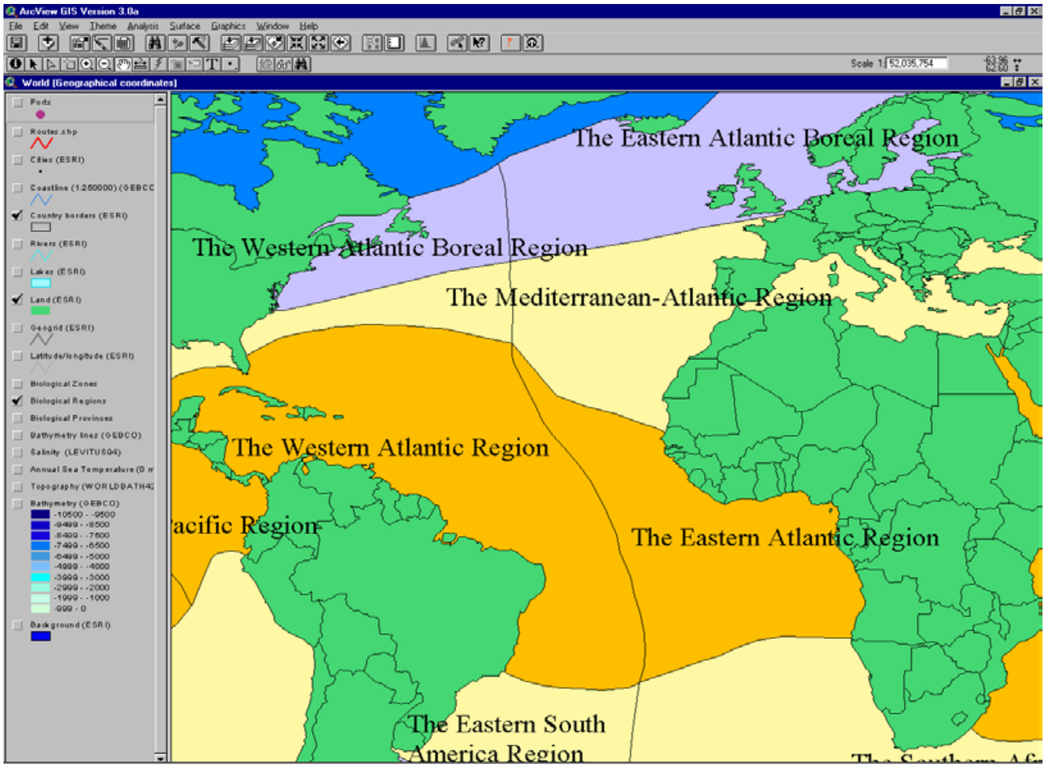

Figure 1. Biogeographic regions identified in EMBLA's Ballast Water Transfer Atlas. Source: EMBLA web site (see text).

scheduled to continue until 2004. The final project report for the Iranian site has recently been published, and explains the methodology in detail (Clarke et al. 2003).

The assessment is semi-quantitative. It identifies the riskiest trading routes for each recipient site, but does not identify the specific risk associated with an individual ballast tank. The major question that is addressed is: "Which ballast water sources and destinations need more vessel monitoring and management?"

The general approach has many parallels with that of EMBLA (Figure 3), and the data and analytical requirements are similar:

- Environmental matching
- Lists of risky species
- Ship-based risk factors (days in transit, tank size).

Elements of Risk Assessment in our Region

There have been no risk assessments of ballast water in the Atlantic Canada/northeastern US region, that come close to meeting the requirements of the formalized risk assessment protocols described above. Several studies (listed below) fulfill some requirements of risk assessment, but generally utilize approaches that are very different from those of the Australian, EMBLA, or GloBallast protocols.

From the three international examples in the preceding section, it is possible to identify some data requirements that are essential components of risk assessment. At a minimum, these common data requirements include: a list of risky species to be excluded from the recipient area, data on the biota and environmental conditions of both the donor and recipient areas (required for environmental matching), and information about the voyage (duration, origin, destination, type of ballast water management, etc.). In order to identify suitable exchange zones, it is further necessary to have understand the physical oceanography of the region. Many elements that could be used as the initial inputs to such a risk assessment do currently exist in our area. In the following list, I have included only reports

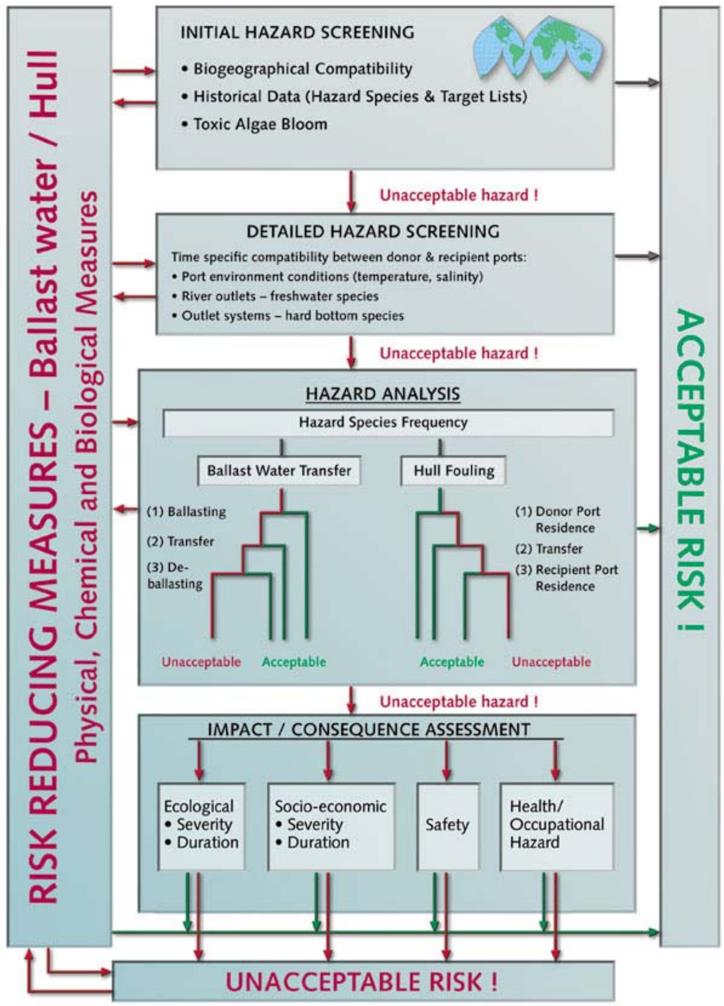

Figure 2. A flowchart of the major components of the EMBLA ballast water management system. Source: EMBLA website (see text).

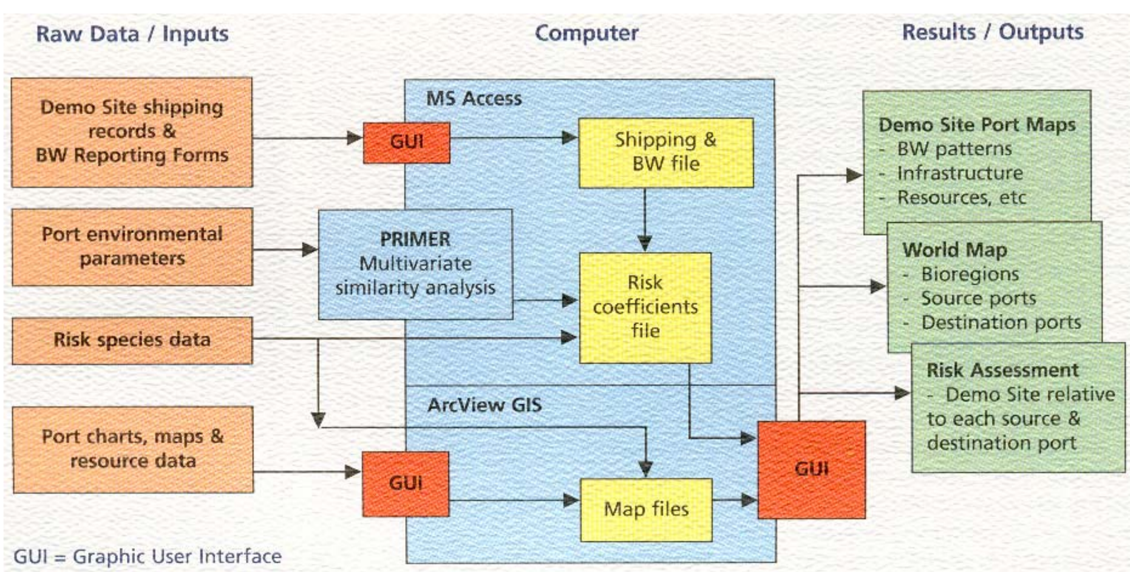

Figure 3. A flowchart of the major components of the GloBallast risk assessment procedure (GloBallast 2002).

dealing exclusively with ballast water. In addition, many reports in the general scientific literature contain relevant information, especially on biology and oceanography.

- Reports on biota in incoming ballast water, combined with oceanography and/or traffic patterns:
    - Magdalen Islands; Gosselin et al. (1995)
    - Ports of Estuary & Gulf of St. Lawrence; Harvey et al. (1999)
    - Laurentian Channel exchange zone; Gilbert and Saucier (2000)
    - Ports of NS; Carver and Mallet (2001)
    - Ports of NS, NB, PEI, NF; Carver and Mallet (2002)
- Hazard lists, or list of dangerous arrivals in incoming ballast water:
    - US State and Federal hazard lists; various datasets from SERC, SeaGrant, etc.
    - Atlantic provinces (algae); Subba Rao et al. (1994)
    - Invasive species lists for each FAO region; SNC/Lavalin (2003)
- Reports on oceanography, relative to ballast water exchange zones:
    - Potential for exchange zones in NE US; Beeton et al. (1998)
    - Potential for exchange zones off NF and Scotian Shelf; Petrie et al. (2001), Petrie and Soukhovtsev (2002)
- Reports on traffic patterns:
    - Maritimes, 1998; C.E.F Consultants (2000)
    - Maritimes, 2000; Balaban (2001)
    - St. Lawrence, 1978-1996; Bourgeois et al. (2001)
- Other related report (quantitative risk assessment based on traffic patterns):
    - Laurentian Channel exchange zone; RNT Consulting (2002)

Examples of two "risk assessment" approaches used in the Laurentian Channel

As with many things, what you get out of a risk assessment depends very much on what you put in, as well as how you go about the process and which question you are attempting to answer. One very controversial issue in ballast water management on the east coast has been the designation of the Laurentian Channel as an alternative ballast water exchange zone for the Great Lakes/St. Lawrence River traffic since 1989. Two very different forms of risk assessment, neither fulfilling all the requirements of an "ideal" risk assessment, have been conducted and have reached very different conclusions about the suitability of this area as an exchange zone.

The Circulation Study (Gilbert and Saucier, 2000)

Table 1. The goals and method used in the circulation study by Gilbert and Saucier (2000).

Goal	Method
Simulate the dispersal and fate of plankton (zoo- and phyto-) in ballast water discharges in the exchange zone.	Model the Gulf of St. Lawrence using a three-dimensional model of circulation and thermodynamics. Conduct simulations of the movements of zooplankton and phytoplankton particles released in the Laurentian Channel.
Identify areas where waters are flushed/retained.	

In this study by Gilbert and Saucier (2000) "risk" was not explicitly estimated, but it is assumed that areas where planktonic organisms are expected to be carried to the coast, or where they are retained for long periods of time, are "riskier" than areas from which the particles will be flushed and dispersed. Further assumptions, and a more complete description of the results, may be found in de Lafontaine and Simard (this volume).

The simulation model indicated that zooplankton and phytoplankton released in the Laurentian Channel would be advected throughout the Gulf and lower Estuary of St. Lawrence. Furthermore, many areas within the Gulf retain particles for > 45 days, and in some areas and seasons, particles may be retained for 90 days or more. Retention areas occur mainly in the southern Gulf over the Magdalen Shallows, and in the lower Estuary, and with lesser frequency in the northeastern portion of the Gulf. The high probability of advection of planktonic particles to, and retention in, these important zones of wild fisheries and aquaculture was considered risky. The only area in the Gulf where retention does not occur is the Cabot Strait. Thus, Gilbert and Saucier concluded that the lowest risk area (to the Gulf) for ballast water release was the Cabot Strait. However, their model does not model whatever happens to this water after it exits Cabot Strait, and they noted the possibility that ballast waters released in the Cabot Strait would affect the Atlantic Coast.

Recommendations, comprising the basis of a risk-based management strategy, were made to reduce the risk to Gulf marine waters of ongoing ballast water releases in the Laurentian Channel. Species-specific and site-specific considerations are implicit in this process.

Table 2. Recommendations made to reduce risk to Gulf waters, from Gilbert and Saucier (2000).

Allow exchange	Do not allow exchange	Consider other factors in decision
Freshwater BW	BW of salinity>30	Brackish BW
Late fall through spring		Other seasons
Last port tropical or subtropical	Last port temperate or subarctic	

The traffic patterns study of RNT Consulting (2002)

The goal of this study was to evaluate the risk of Laurentian Channel exchange relative to the risk from ballast water discharges elsewhere in the Gulf, Estuary and River. Note that the geographic scope of the study is much larger than that of Gilbert and Saucier, who did not investigate the effects of ballast water releases outside of the Laurentian Channel. Another major difference is that the RNT Consulting assessment did not consider the movement of any introduced species following release of the ballast water, while this is an integral part of the Gilbert and Saucier model.

In this study, a Probabilistic Risk Assessment procedure was followed. The endpoint was the introduction of a non-indigenous species. The model was developed to express the "relative risk" of ballast water release in Laurentian Channel, Gulf, Estuary or River, as a proportion of the invasive species that might have been present in the ballast water at the time of uptake, and that would be released upon ballast water discharge.

The method was based on an "Event Tree", which was used to break down the risk factors for ships entering each destination zone (e.g., transit time, mid-ocean exchange, Laurentian Channel exchange). It was assumed that mortality was 0% for voyage < 5 days, subsequently increasing to 50%. Exchange was assumed to replace 80% of the ballast water. Either 13 or 43 ships exchanged ballast water annually in the Gulf. The number of ships releasing ballast water in the other zones was based on historical traffic patterns. Finally, it was assumed that brackish-water species do not survive in marine salinities.

The result was the sum (for each arrival zone) of the product of probabilities of introduction associated with transit time, mid-ocean exchange, Laurentian Channel exchange, and ship traffic patterns. Only mean estimates (point estimates) were obtained. No uncertainty analyses were conducted, and therefore, no confidence limits were obtained.

The total risk to the Gulf, Estuary and River was estimated to be 25% (i.e., 25% of any alien species contained in the ballast at the point of origin will be introduced). The risk associated with FAO region of origin was 9% for region A (Northwestern Atlantic), 8% for region B (Northeastern Atlantic), and 6% for region G (Southeastern USA and Caribbean). The risks for the various destinations of the ballast water within the St. Lawrence system were: 13% for the marine/brackish Estuary, 8% for the River, 2% for the freshwater Estuary, 0.3% for the Gulf exclusive of the Laurentian Channel, and 0.2%

for the Laurentian Channel. Thus, the relative risk of ballast water exchanges in the Laurentian Channel was determined to be 0.5% of the total risk to the St. Lawrence River, Estuary and Gulf system.

Conclusions

Clearly, risk assessment can give very different answers, depending on exactly what question is being asked and how it is approached. In the examples for the Laurentian Channel, one might choose very different management strategies based on the results of the two models. Which one is correct? Probably both contain some elements of the truth, but neither is complete.

In terms of a general approach to risk management for ballast water, we must consider the following questions:

- Is it better to undertake a selective (risk-based) or a blanket (all ships) approach to ballast water management, considering the pros and cons of each?
- If risk-based management is chosen, which model is best?
- Should the same ballast water risk assessment standards apply to domestic and international shipping?
- And finally, who pays? This question could be applied equally to the cost of management, and to the cost of failure of management.

Literature Cited

Balaban, M. 2001. Vessel traffic/vessel shipping patterns on the east coast of Canada, 2000 shipping season. Transport Canada, Dartmouth, NS.

Beeton, A.M., J.T. Carlton, B.A. Holohan, G.H. Wheless, A. Valle-Levinson, L.A. Drake, G. Ruiz, L. McCann, W. Walton, A. Frese, P. Fofonoff, S. Goodwin, J. Toft, L. Hartman and E. von Holle. 1998. Ballast exchange study: Consideration of back-up exchange zones and environmental effects of ballast exchange and ballast release. Cooperative Institute for Limnology and Ecosystems Research, Ann Arbor, MI. Report to National Sea Grant Program, National Oceanic and Atmospheric Administration, Washington DC, and the Environmental Protection Agency, Washington, DC.

Bourgeois, M., M. Gilbert and B. Cusson. 2001. Evolution du trafic maritime en provenance de l'étranger dans le Saint-Laurent de 1978 à 1996 et implications pour les risques d'introduction d'espèces aquatiques non indigènes. Rapp. Tech. Can. Sci. Halieut. Aquat. 2338.

Carver, C.E. and A.L. Mallet. 2001. A preliminary assessment of the risks of ballast water-mediated introduction of non-indigenous phytoplankton and zooplankton species into Nova Scotian waters. Mallet Research Services Ltd. Report to Transport Canada, Dartmouth, NS.

Carver, C.E. and A.L. Mallet. 2002. An assessment of the risk of ballast water-mediated introduction of non-indigenous phytoplankton and zooplankton into Atlantic Canadian waters. Mallet Research Services, Dartmouth, NS. Report to Transport Canada, Dartmouth, NS.

C.E.F. Consultants. 2000. Vessel traffic/shipping patterns on the east coast of Canada. Report to Transport Canada.

Clarke, C., T. Hayes, R. Hilliard, N. Kayvanrad, A. Parhizi, H. Taymourtash, V. Yavari, and S. Raaymakers. 2003. Ballast water risk assessment: Port of Khark Island, Islamic Republic of Iran. Globallast Monograph Series No. 8. International Maritime Organisation, London.

Gilbert, M. and F.J. Saucier. 2000. Suitability of the Gulf of St. Lawrence as a backup zone for ballast water exchanges by foreign ships proce3eding up the St. Lawrence Seaway. From 10th International Aquatic Nuisance Species and Zebra Mussel Conference, Toronto, Canada. 13-17 February 2000.

Global Ballast Water Management Programme (GloBallast). 2002. Ballast Water News. Issue 8, January-March 2002.

Gosselin, S., M. Lavasseur and D. Gauthier. 1995. Transport and deballasting of toxic dinoflagellates via ships in the Grande Entrée Lagoon of the Iles-de-la-Madeleine (Gulf of St. Lawrence, Canada). Pages 591-596 in: Lassus, P., G. Arzul, E. Erard, P. Gentien and C. Marcaillou (eds.) Harmful Marine Algal Blooms. Lavoisier, Intercept Ltd..

Harvey, M., M. Gilbert, D. Gauthier and D.M. Reid. 1999. A preliminary assessment of risks for the ballast water-mediated introduction of nonindigenous marine organisms in the Estuary and Gulf of St. Lawrence. Can. Tech. Rept. Fish. Aquat. Sci. 2268.

Haugom, G.P., H.L. Behrens and A.B. Anderson. 2002. Risk based methodology to assess invasive aquatic species in ballast water. Pages 467-476 in: Leppakoski, E., S. Gollasch and S. Olenin (ed.) Invasive aquatic species of Europe: Distribution, impacts and management. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Hayes, K.R. 1997. A review of ecological risk assessment methodologies. CRIMP Technical Report 13.

Hayes, K.R. 1998a. Ecological risk assessment for ballast water introductions: A suggested approach. ICES Journal of Marine Science 55: 201-212.

Hayes, K.R. 1998b. Bayesian statistical inference in ecological risk assessment. CRIMP (Centre for Research on Introduced Marine Pests) Technical Report 17.

Hayes, K.R. and C.L. Hewitt. 1998. Risk assessment framework for ballast water introductions. CRIMP Technical Report 14.

Hayes, K.R. and C.L. Hewitt. 2000. Risk assessment framework for ballast water introductions – Volume II. CRIMP Technical Report 21.

Hewitt, C.L. and K.R. Hayes. 2002. Risk assessment of marine biological invasions. Pages 456-466 in: Leppakoski, E., S. Gollasch and S. Olenin (ed.) Invasive aquatic species of Europe: Distribution, impacts and management. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Petrie, B., J. Loder, J. Chasse and G. Han. 2001. Review of the physical oceanography of the Newfoundland and Scotian Shelf regions for Transport Canada in reference to Alternate Ballast Water Exchange Zones. Fisheries and Oceans Canada. Report to Transport Canada.

Petrie, B. and V. Soukhovtsev. 2002. Report on oceanographic studies related to Alternate Ballast Water Exchange Zones. Fisheries and Oceans Canada. Report to Transport Canada.

RNT Consulting. 2002. Quantification of risks of alien species introductions associated with alternative area for ballast water exchange in the Laurentian Channel of the Gulf of St. Lawrence. RNT Consulting Report 108. Prepared for Transport Canada.

SNC/Lavalin Inc. 2003. Management of marine invasive species in Canadian Naval Operations Atlantic (MARLANT). SNC/Lavalin Inc. Project No. 014807, Dartmouth, NS. Prepared for Defence Construction Canada, Halifax, NS.

Subba Rao, D.V., W.G. Sprules, A. Locke and J.T. Carlton. 1994. Exotic phytoplankton from ship's ballast waters: Risk of potential spread to mariculture sites on Canada's east coast. Can. Data Rept. Fish. Aquat. Sci. 937.

United States Environmental Protection Agency (US EPA). 1998. Guidelines for Ecological Risk Assessment. EPA/630/R95/002F.

World Health Organization, Centre for Environmental Management and Planning (WHO CEMP). 1992. Environmental and health impact assessment of development projects: A handbook for practitioners. Elsevier, NY.

Open Discussion

Workshop Panel Discussion

MODERATOR:

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Bivan Patnaik, Regulatory Coordinator, U.S. Coast Guard Headquarters, moderated the session. He identified this as an open forum between the audience and today's speakers on the issues of developing an alternate ballast water exchange zone.

QUESTION FROM AUDIENCE: This question is for Bernie Kelly. When you were giving your presentation and we were looking at the maps of the ballast end points, I was talking with someone else, and we were thinking that it paralleled some of the physical oceanographic currents in the Northwest Atlantic. I was wondering if you had looked at any correlations between the current systems and where the ships are exchanging ballast water and, what have your analyses found. Or is this a future project you foresee undertaking?

KELLY: I would have to say it is something for future exploration. My mandate is basically to provide location data and information along with ballast water information. I think that this is probably a future question. Having seen some of the physical oceanography presentations this morning, I can see that there is some correlation.
SMITH: I believe using the GIS system you could superimpose a cartoon of currents with the ballast water information. My point was that with the GIS system, you can take the schematic of currents that we showed this morning and superimpose it on event points, and you will have an idea of where they lie relative to the major currents. However, you have to take into consideration the position of seasons and inter-annual events, so there are other impacts to consider. One of the things we were talking about earlier was, do the end points correspond with currents that would be relatively safe with regards to invasions or inoculations? And by safe, I mean where they tend to be along the shelf edge or further offshore as opposed to the inshore zone. So, that way, you can try to make the correspondence between a ballast water discharge zone and the perceived danger of onshore advection as one place to start in terms of developing regulations.

LOCKE: Just one more comment to that. I would caution that if we superimpose those endpoints onto a currents map, we do not mix what is actually endpoint and the times to do the exchange and the route, which may be far from the point that we are on the map.

SMITH: The point was that the exchange is occurring over the whole track, not just at the endpoints so you really need a definition of where the water is being exchanged, not just the endpoints.

QUESTION FROM AUDIENCE: It seems to me that what we have concluded that a risk assessment needs to be conducted, and one of the major problems with any kind of risk assessment is you need a fair amount of data to really do a good job in terms of being very specific. So, we are talking about a situation right now where we really do not have a lot of that site-specific data, we do not have a lot of information about being able to predict which organisms are going to invade and so forth, so I guess I would ask a general question to the panel on some of things we really should be thinking about. When do you conduct a formal risk assessment and how would we define this? What are some of the important issues that we need to be thinking about for tomorrow?

O'DONNELL: I am not sure if I am the right person to ask, but one thing to consider is we need to know how long organisms survive in the receiving environment where they are discharged. Ballast water is a major source of introductions. Therefore, killing everything is the only truly effective way to zero the risk, but I think that is technically unachievable. Then to predict risk one needs to know how long the organisms are viable.

HINES: That question is insane. First of all, you assume that you know what species you have. All the taxonomy of marine organisms is based on adult characteristics. It has nothing to do with larval characteristics by and large, so we do not know what species we have. Then you are assuming that organisms such as zebra mussels do not occur in the Arctic, and saying that they are not a problem if you have a ship coming from Panama into I do not know where, let us say Halifax is okay, but the fact is most of the ships coming into Halifax are not from Panama. So, it gets really crazy. Even the issue about what invasive species is the highest risk of invasion. Look at green crabs, the poster child for marine invasions now. Green crabs invaded New England long ago and they are widely distributed on outer coasts and rocky intertidal systems, but on the West Coast, there are only invasions in estuaries and non-rocky intertidal systems, so what would you predict on that? If you look at the list of invasive species out there, almost none of them was predicted.

O'DONNELL: Predictions are often wrong, but that does not mean one stops trying to predict. I think that there is a philosophical difference we may have.

DE LAFONTAINE: I am in perfect agreement that we need a lot more data before we do risk assessment. We have a massive collection and analytical system and a lot of funds going into predicting weather, but almost nothing has gone into predicting marine invasions to this point and to suddenly state that we are going to arrive at a reasonable risk assessment is not likely. I just do not see it happening right away. Does that mean we should stop? No, I mean we should start pursuing that because the consequences are pretty great if we do not try.

BALABAN: I would like to comment on that. While I think that resources are short and we do have a limited amount of data, I do not see why we should focus on all the regions of the world. They are addressed at least partly now by vessels conducting ballast water exchange at sea, so I think vessels coming from outside should continue to do their exchange until we find a better option.

We should focus on coastwise trade and I think we have much data from the coastal traders: to know from where they are coming, exactly from which ports, and to which ports they are going to, and also we have data on what the main quantity of water is and where it is coming from. You have the rare case of some ships on random trips along the East Coast and stopping at three different ports, but these do not involve a major quantity of water. So, I would suggest that we focus our resources and limited amount of data on what is the main risk here as opposed to waiting until we have lots of data and all the possible information to implement the system that is like the one that is implemented in Australia. I personally do not want to wait four years before we have this system in place. I would like to see something done before that. We are in the regulation reform process now in Canada and we have a chance here to develop national regulations. If we miss this chance, the next time Canada under goes regulatory reforms will be not before 2006.

QUESTION FROM AUDIENCE: I just recalled in 1989, when the alternate ballast water exchange zone was set in the Gulf. It was set up on a temporary basis. Everyone agreed that let us try it for one year, and then reassess given the shipping traffic patterns. In 1999, they reassessed and just moved the zone. We have been living with it for 15 years without further data. We have a model, but it is not data. We have to wait for data. I would say at that time, in

1990, basically it was an expert judgment. People sat down and, to the best of their knowledge, they came up with a zone, and thus, we are still living with that. Are we satisfied with that? No, but there are pro and cons, and if we wish to develop a full risk assessment, we may wait forever without having any alternate zones. We need alternate zones and we might have to rely on an expert judgement like it was done 10-15 years ago.

SMITH: It is pretty clear that ballast water is producing a lot of invasions, so there is a very high risk associated with that. You could say that the risk of an individual, for example, 0.5% or something, might be low, but that is still enough of a risk for invasions to take place. But even so, we need a commitment to make a change because we also know that aquaculture and stock enhancement programs are also producing lots of invasions. And, even though we know that, people are still going forward and proposing to do it. Chesapeake Bay is going to have Asian oysters purposely introduced into it; it is inevitable, no matter how much risk is there. I do not think that having a detailed risk assessment that requires some elaborate matrix of all organisms that a ship coming from some country across the Atlantic Ocean is suddenly going to improve our risk assessment. I do not know, this all seems insane to me.

O'DONNELL: I think I agree with that. The risk assessment approach does not seem to me to be too profitable given the amount of data that is necessary to make it defensible. I do think, though, that it is time to do something and some simple regulations would do a lot. One regulation would be where everything, under normal conditions, no discharge of ballast water in Chesapeake Bay. However, one could also allow the discharge of ballast on the shelf within the Bay out to 40 or 50 km from the shore. I think that is pretty defensible too. But, it is a judgment call just now because the experiments that would need to be done to prove the results of the numerical model of the tact that you described earlier are very expensive, would need to be done at each site, and would need to be done dozens of times because there is natural variability when you do an experiment. You get the conditions that are occurring when you actually launch the drifters or release a tracer dye. So, you need to do it tens of times to be robust. So, it is going to come down to the professional judgment of such interested scientists, I think.

METCALF: I would like to throw another ratchet into this mess here too. When I think about the number of permutations that we have— just look at the number of species that are in the world, and the number of aquatic ecosystems— this is hard enough to fathom. A third factor is the variety of potential treatment systems or ballast water management techniques, in lieu of exchange, and the uniqueness of those methods applied on every single ship. An ultraviolet technology on the same ship may work with variable effectiveness from one voyage to the next. The same system on two different ships may produce a net risk that is different in the same port. And as mentioned earlier, with the limited resources and with the fact that it is doubtful we are going to be able to identify every species and their full distribution in all the receiving ports in the world, it just seems to me, this is why we are trying to make exchange more effective in the short term and trying to find effective treatment systems in the long term.

Because we are going to spend a lot of money on surveying probably what would amount to a tenth of the biological inventory for the world, we need to be able to do a risk assessment that is scientifically valid. Countries within IMO are conducting risk assessments, Australia probably is the only country that I know of right now that would say, "We have a good system." Australia is the only nation that has got a real system that is in operation, and that is a positive. But for the long-term, a number of countries just do not believe that they have enough resources to generate the data in a scientifically valid way.

PEDERSON: And I think the advantage of having a good model is that it could really show what organisms are being transported.

O'DONNELL: One problem with risk assessments is that a different group of people may use the same variables using a similar approach and could come up with substantially different results.

LOCKE: You really have to think about what you are assessing in terms of your assumptions and the way you evaluate is.

O'DONNELL: Yes, then there is also a certain arbitrariness to the choice of each variable and when you multiply them up you can get in trouble. It is well known that your multiplier in certain numbers can increase the uncertainty. Richard Fineman effectively criticized the National Aeronautical Space Administration's (NASA) use of that analysis during the investigation into the Challenger disaster. He really showed it and we could face the same criticism here too, I guess. The probability of a space launch blowing up is easily calculated by the number of times it happens divided by the number of launches and it turned out to be about 5% to 10% However, NASA's prediction was that it would be like 10 to minus five. So Fineman said that clearly the methodology was clearly wrong. So, here in this case, we know about how many times an invasion occurs, we know the rate of invasive species success, and we can estimate how many invasive species are getting inoculated into a particular ecosystem. Those numbers should be consistent with the results of risk analysis and I do not know if they are or not.

DE LAFONTAINE: At the risk of stating the obvious and putting this in laymen terms, I have seen many of the articles on that and you are absolutely right, that acceptable risk level is perfectly fine if you are NASA in general, but not so good if you are the astronaut on that launch where the odds are not in your favor. And I think that is the approach the industry seems to be taking, that we will never get to zero anything, but we believe we can get progressively better and better at what we are doing.

And again, who is going to pay for all this. There are limited funds the industry and government, the scientific community, and everywhere else. So trying to pool funds to achieve results, versus a system that is going to take centuries to perfect should be the way to go. If we wait for perfection it would be an unfortunate use of resources.

QUESTION FROM AUDIENCE: I noticed that most of the organisms in this little booklet, "Assess our Organisms," and I just wondered how confident are we that the vector of introduction is actually ballast water, rather than mere attachment to holds and anchors, etc.?

METCALF: Globally, Stephan Gollacsh from Germany, has been very active, and he provided, I cannot remember precise numbers, but it was an astonishingly huge number of introductions that he associated with hull. It is not like 1% with attachments to the hull and 99% via ballast water, it was a high percentage, which is another issue the industry must deal with because tributyltin (TBT) has been banned. TBT is a great antifoulant, but it may not be so good for the environment, particularly for vessels that are sitting in marinas day in and day out. Now the industry is searching for a viable alternative. Some are out there and some are very expensive, but most have not yet proven themselves for the time period and so forth.

DE LAFONTAINE: If I remember it was 98% of the vessels coming into the North Sea had some sort of nonindigenous species on the hulls of the ships generally, but approximately 50% of the vessels had nonindigenous species in their ballast water.

METCALF: And there was some discussion on whether or not they were actually detaching from the hull. They were riding in, but whether they decided to stay was another question. The potential was there for introduction.

HINES: We did some rough calculations of the size of ships and their surface areas and the number of ships that arrive and estimated that annually, the hull bottom surface area the size of Connecticut arrives at U.S. ports every year. These are not very evenly distributed in their hull fouling. Sea chests and moorings are much more frequently fouled than some of the exposed surfaces due to high speeds, anti-fouling paints, and they are very uneven as to how much maintenance is applied to them. Oil tankers on the West Coast have their hulls repainted about every two years, whereas who knows about your proverbial tramp streamer and the full spectrum of organisms they are bringing here. But, the bottom line is that we are recognizing that hull fouling as well as ballast water is potentially a major source of introduction of nonindigenous species.

QUESTION FROM AUDIENCE: Has hull fouling been addressed legislatively?

METCALF: I think historically we have focused more on ballast water because the invasive species problems in North America were recognized more in connection with the Great Lakes: zebra mussels, and ballast water. Hull fouling has been much less of an issue because if a vessel is coming from freshwater, going through salt water, and then going back to freshwater, you are less likely to have organisms living on your hull that can survive in their freshwater destinations. In fact, if you look at the distribution of species that have been inventoried in the Great Lakes, there has been a much larger proportion of ballast water species there than were found in places like San Francisco Bay. Hull fouling is probably going to be the key for the Northeast Atlantic region. So, we were influenced, I guess, by the Great Lakes agenda into looking extensively at the ballast water issue and much less so on the hull fouling issue, although for our waters the latter may well be a very large proportion of our problem.

MODERATOR: The proposed National Aquatic Invasive Species Act has language in it that addresses hull fouling. And although hull fouling is an important issue the purpose of this panel and workshop is to discuss alternative ballast water exchange zones.

PEDERSON: If you look at this environmental issue regarding ballast water, it is probably one that carries a huge amount of speculation and uncertainty. A focus on one issue is which process introduces an organism. We all believe it is ballast water, but the evidence is simply not there. We do not know if it is coming from the sea chest pushing backwards with the pump or if it was in the tank versus the sediment. We have a list of species that we keep adding on and adding on, but we have no clue as to the actual process of how species are introduced, whether it is ballast water, hull fouling, or by some other means.

SIMARD: Except for plankton introductions, the process would have to be ballast water.

METCALF: Well, I am an optimist, and there is good news. The good news is that the hull fouling cleaning of Alaskan tankers stated earlier is not because of hull fouling, that is because of some other internal U.S. regulations. The average foreign-flag ship, with a foreign flag and a classification that is trading into U.S. ports is dry-docking approximately every five years. That does not include passenger carriers and some of the more high-speed vessels. But the good news, is that the International Maritime Organization (IMO) is bringing different vessel types very slowly into a program called Enhanced Survey Inspection and a much larger number of the foreign flagships coming into North American countries are going to be undergoing more frequent dry-docking schedules. The other piece of good news is as a ship owner, it is not good to have stuff crusted on your hull because it is bad for your fuel consumption, so there is a real economic incentive for a ship owner to try and minimize the hull fouling as much as possible so we are all working towards the same goal.

QUESTION FROM THE AUDIENCE: It occurred to me when I just heard of this issue, I was just wondering if anybody had done a scientific or economic analysis of why are ships traveling in ballast anyway? Are ships looking into traveling without ballast?

MODERATOR: There is research being conducted now for ships to be ballastless as well as moving ballast water internally so there is no discharge.

LANGEVIN: I can tell you we are trying that every day and when a vessel is on route there are looking for returning cargo with no empty voyages, but in some trades, it is nearly impossible. Some ships just have fixed contracts and one destination and no return cargo because there is simply no production to go the other way so if there is a better way to find return cargo for every ship, I would be glad to hear about it.

HINES: True, but Port Valdez does not want what Los Angeles has to offer.

DE LAFONTAINE: It is true. I think first of all it is a matter of safety. They feel the ship has to be stable at sea so if they do not carry cargo, they are going to carry ballast water. What is difficult to understand is that the proportion of no-ballast ships has increased in the Great Lakes dramatically since Canada established some of the guidelines. Something happened: how come suddenly the shipping industry has found a way to fill their cargo and not carry ballast anymore? How come in the 1960s and 1970s they were carrying large amounts of ballast and they do not do that anymore? I mean no one has seemed to have an explanation for that, but that is the actual data and this is what we have been observing.

SIMARD: Well, I do not have an answer for that, but I have a question. Before ballast water reporting was mandatory, where did the data on ballast water or no-ballast come from?

DE LAFONTAINE: I am referring to Jenson, he has compiled a lot of data from everywhere and come up with figures.

SIMARD: I am going to ask him about that; I am curious.

METCALF: Do you want some more good news because there is some more good news. For a long time, we had oil tankers and bulk carriers and solely in the 1950s through the 1970s, people began to create a ship that could carry both. So, by doing that you maximize the flexibility to have cargo in both sides of the voyage. The more traditional huge volume of ballast, at least to the United States, is large crude oil tankers that are loading in West Africa. Now obviously, they are coming in loaded so, in this case, they are an exporter of ballast water unfortunately, back to their originating countries that should probably have at least a control program. But that is the scenario. And as far-fetched as it seems, we would love to have back-load cargo because the shipping industry does not get paid for carrying water, but the good news is, people are starting to do some smart ballast design such as the case of some railroad ships that are being built on the West Coast, they are building permanent ballast. Now keep in mind that that permanent ballast is just that, it is always there, therefore the whole dead-weighted cargo-carrying capability of the ship has not been agreed upon, they have not said, 12% or 10% or 5% of the net dead-weight of the ship is now going to be always dedicated to ballast is acceptable, will not be designated to cargo handling. If you can get buy in from vessels such as container ships and passenger liners that may have the ability because they are doing ballast water operations very frequently, much more frequently than a crude oil tanker running from West Africa to the East Atlantic coast. However, they are operating with much smaller volumes so they have to dedicate less proportion of the carrying capacity of the ship to this function. That is one thing, and somebody is actually trying to design a no-ballast ship that Bivan stated earlier.

WELLOCK: The reason why the amount of ballast onboard vessels has gone down is because the trade has changed. North America has become more of an importer than an exporter. Where in the earlier times, we were exporters, both the United States and Canada. Mostly the goods were exported out, and now we import more. So the vessels doing the importing are not carrying ballast, they are bringing the goods in, off-loading them, and if they do not have enough goods to carry back out again, they carry ballast water. We have a trade imbalance in both the United States and Canada with Europe or Asia as we are importing more than we export. But, that is part of the answer without looking at the numbers. And again, I do not know but I find it hard to believe somebody can come up with very accurate numbers on how much ballast was actually carried onboard ships before there was any reporting requirement. I could see in a particular trade where you could derive numbers. For example, in the tanker business when prior to the 1960s you had to come up with an oil record book and as part of the data in that oil record book you had to report what was put into those tanks, whether it was ballast or oil, but most other industries did not report ballast unless it was used in their engine rooms. So that oil record book for freighters, passenger ships, and for other general cargos or containers, they did not maintain accurate records on what was kept onboard for ballast. Tankers might, but anything prior to a mandatory reporting is pretty skeptical to me. I have not read Jensen's report, but on face value, having been in the industry for a long time that is my history of shipping.

SIMARD: Something else we have to look at is the rate of invasions with respect to cargo practices.

WELLOCK: I can tell you this much, again, we have a lot of data from when I was in the private industry versus a trade association. Vessels were coming into our refineries from Pennsylvania and I narrowed it down to three companies. They were going to control vapor recovery from ballast tanks. So we did an extensive data search going back three years to look at every vessel that had come in to our refineries. This was made it easier by time charts with the refineries in place so we had the time factor. We started looking at the amount of ballast water those ships were bringing in. There was some complication involved with the air quality issues, but that is not relevant here. We found out is that large vessels that were coming in, (between 8000 dead-weight and 140-150,000 dead-weight) had anywhere between 17 to 23% of the carrying capacity of the vessel brought in as normal ballast capacity. We did see, from time to time, as high as 35%, when a vessel was running right through a hurricane. It was storm ballast, basically. But keep in mind, those vessels do not want to have to sit at the dock any longer than they have too. Their charterers do not want them, the refiners do not want them, and the vessel owner does not want to do it so a captain is going to try to minimize the amount of ballast the ship is bringing in. Sometimes it has been done in the extreme where vessels have bounced through the tail end of a hurricane and actually done damage because they tried to go as minimum with ballast as they can so that the minute they get into port they are ready to start the cargo. There is some economic incentive for the owners to minimize the amount of ballast discharging.

MODERATOR: Stimulating as this discussion is, we are going to have to wrap up now. It is time for the social hour and we can continue the discussion there. I would like to thank the speakers for their presentations and for their time.

Appendices

Appendix I	Adoption of the Final Act and any Instruments, Recommendations and Resolutions Resulting from the Work of the Conference, *International Convention for the Control and Management of Ships' Ballast Water and Sediments*
Appendix II	Mandatory Ballast Water Management Program for U.S. Waters, *U.S. Coast Guard*
Appendix III	Guidelines for the Control of Ballast Water Discharge from Ships in Waters under Canadian Jurisdiction, *Transport Canada, Marine Safety*
Appendix IV	National Ballast Water Management Regulations Under the Current Canada Shipping Act, *Tom Morris*
Appendix V	National Ballast Water Management Regulations under NISA, *Bivan Patnaik*
Appendix VI	An Assessment of the Risk of Ballast Water-Mediated Introduction of Non-Indigenous Phytoplankton and Zooplankton into Atlantic Canadian Waters, *C.E. Carver and A.L. Mallet*
Appendix VII	GIS Mapping of Marine Vessel Ballast Water Exchange Endpoint Data in Atlantic Canada, for the 2002 Shipping Season, *Bernard Kelly*
Appendix VIII	Code of Best Practices for Ballast Water Management, *The Shipping Federation of Canada*
Appendix IX	Ballast Water Exchange in the North Atlantic, *Judith Pederson and Benjamin Fertig*
Appendix X	Quantification of Risks of Alien Species Introductions Associated with Alternative Area for Ballast Water Exchange in the Laurentian Channel of the Gulf of St. Lawrence, *RNT Consulting*

Appendix I

INTERNATIONAL CONFERENCE ON BALLAST WATER MANAGEMENT FOR SHIPS
Agenda item 8

BWM/CONF/36
16 February 2004
Original: ENGLISH

ADOPTION OF THE FINAL ACT AND ANY INSTRUMENTS, RECOMMENDATIONS AND RESOLUTIONS RESULTING FROM THE WORK OF THE CONFERENCE

INTERNATIONAL CONVENTION FOR THE CONTROL AND MANAGEMENT OF SHIPS' BALLAST WATER AND SEDIMENTS, 2004

Text adopted by the Conference

1 As a result of its deliberations, as recorded in the Record of Decisions of the Plenary (BWM/CONF/RD/2/Rev.1) and the Final Act of the Conference (BWM/CONF/37), the Conference adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004.

2 The above-mentioned Convention, as adopted by the Conference, is annexed hereto.

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ANNEX

INTERNATIONAL CONVENTION FOR THE CONTROL AND MANAGEMENT OF SHIPS' BALLAST WATER AND SEDIMENTS, 2004

THE PARTIES TO THIS CONVENTION,

RECALLING Article 196(1) of the 1982 United Nations Convention on the Law of the Sea (UNCLOS), which provides that "States shall take all measures necessary to prevent, reduce and control pollution of the marine environment resulting from the use of technologies under their jurisdiction or control, or the intentional or accidental introduction of species, alien or new, to a particular part of the marine environment, which may cause significant and harmful changes thereto,"

NOTING the objectives of the 1992 Convention on Biological Diversity (CBD) and that the transfer and introduction of Harmful Aquatic Organisms and Pathogens via ships' ballast water threatens the conservation and sustainable use of biological diversity as well as decision IV/5 of the 1998 Conference of the Parties (COP 4) to the CBD concerning the conservation and sustainable use of marine and coastal ecosystems, as well as decision VI/23 of the 2002 Conference of the Parties (COP 6) to the CBD on alien species that threaten ecosystems, habitats or species, including guiding principles on invasive species,

NOTING FURTHER that the 1992 United Nations Conference on Environment and Development (UNCED) requested the International Maritime Organization (the Organization) to consider the adoption of appropriate rules on ballast water discharge,

MINDFUL of the precautionary approach set out in Principle 15 of the Rio Declaration on Environment and Development and referred to in resolution MEPC.67(37), adopted by the Organization's Marine Environment Protection Committee on 15 September 1995,

ALSO MINDFUL that the 2002 World Summit on Sustainable Development, in paragraph 34(b) of its Plan of Implementation, calls for action at all levels to accelerate the development of measures to address invasive alien species in ballast water,

CONSCIOUS that the uncontrolled discharge of Ballast Water and Sediments from ships has led to the transfer of Harmful Aquatic Organisms and Pathogens, causing injury or damage to the environment, human health, property and resources,

RECOGNIZING the importance placed on this issue by the Organization through Assembly resolutions A.774(18) in 1993 and A.868(20) in 1997, adopted for the purpose of addressing the transfer of Harmful Aquatic Organisms and Pathogens,

RECOGNIZING FURTHER that several States have taken individual action with a view to prevent, minimize and ultimately eliminate the risks of introduction of Harmful Aquatic Organisms and Pathogens through ships entering their ports, and also that this issue, being of worldwide concern, demands action based on globally applicable regulations together with guidelines for their effective implementation and uniform interpretation,

DESIRING to continue the development of safer and more effective Ballast Water Management options that will result in continued prevention, minimization and ultimate elimination of the transfer of Harmful Aquatic Organisms and Pathogens,

RESOLVED to prevent, minimize and ultimately eliminate the risks to the environment, human health, property and resources arising from the transfer of Harmful Aquatic Organisms and Pathogens through the control and management of ships' Ballast Water and Sediments, as well as to avoid unwanted side-effects from that control and to encourage developments in related knowledge and technology,

CONSIDERING that these objectives may best be achieved by the conclusion of an International Convention for the Control and Management of Ships' Ballast Water and Sediments,

HAVE AGREED as follows:

Article 1 *Definitions*

For the purpose of this Convention, unless expressly provided otherwise:

1 "Administration" means the Government of the State under whose authority the ship is operating. With respect to a ship entitled to fly a flag of any State, the Administration is the Government of that State. With respect to floating platforms engaged in exploration and exploitation of the sea-bed and subsoil thereof adjacent to the coast over which the coastal State exercises sovereign rights for the purposes of exploration and exploitation of its natural resources, including Floating Storage Units (FSUs) and Floating Production Storage and Offloading Units (FPSOs), the Administration is the Government of the coastal State concerned.

2 "Ballast Water" means water with its suspended matter taken on board a ship to control trim, list, draught, stability or stresses of the ship.

3 "Ballast Water Management" means mechanical, physical, chemical, and biological processes, either singularly or in combination, to remove, render harmless, or avoid the uptake or discharge of Harmful Aquatic Organisms and Pathogens within Ballast Water and Sediments.

4 "Certificate" means the International Ballast Water Management Certificate.

5 "Committee" means the Marine Environment Protection Committee of the Organization.

6 “Convention” means the International Convention for the Control and Management of Ships’ Ballast Water and Sediments.

7 “Gross tonnage” means the gross tonnage calculated in accordance with the tonnage measurement regulations contained in Annex I to the International Convention on Tonnage Measurement of Ships, 1969 or any successor Convention.

8 “Harmful Aquatic Organisms and Pathogens” means aquatic organisms or pathogens which, if introduced into the sea including estuaries, or into fresh water courses, may create hazards to the environment, human health, property or resources, impair biological diversity or interfere with other legitimate uses of such areas.

9 “Organization” means the International Maritime Organization.

10 “Secretary-General” means the Secretary-General of the Organization.

11 “Sediments” means matter settled out of Ballast Water within a ship.

12 “Ship” means a vessel of any type whatsoever operating in the aquatic environment and includes submersibles, floating craft, floating platforms, FSUs and FPSOs.

Article 2 *General Obligations*

1 Parties undertake to give full and complete effect to the provisions of this Convention and the Annex thereto in order to prevent, minimize and ultimately eliminate the transfer of Harmful Aquatic Organisms and Pathogens through the control and management of ships’ Ballast Water and Sediments.

2 The Annex forms an integral part of this Convention. Unless expressly provided otherwise, a reference to this Convention constitutes at the same time a reference to the Annex.

3 Nothing in this Convention shall be interpreted as preventing a Party from taking, individually or jointly with other Parties, more stringent measures with respect to the prevention, reduction or elimination of the transfer of Harmful Aquatic Organisms and Pathogens through the control and management of ships’ Ballast Water and Sediments, consistent with international law.

4 Parties shall endeavour to co-operate for the purpose of effective implementation, compliance and enforcement of this Convention.

5 Parties undertake to encourage the continued development of Ballast Water Management and standards to prevent, minimize and ultimately eliminate the transfer of Harmful Aquatic Organisms and Pathogens through the control and management of ships’ Ballast Water and Sediments.

6 Parties taking action pursuant to this Convention shall endeavour not to impair or damage their environment, human health, property or resources, or those of other States.

7 Parties should ensure that Ballast Water Management practices used to comply with this Convention do not cause greater harm than they prevent to their environment, human health, property or resources, or those of other States.

8 Parties shall encourage ships entitled to fly their flag, and to which this Convention applies, to avoid, as far as practicable, the uptake of Ballast Water with potentially Harmful Aquatic Organisms and Pathogens, as well as Sediments that may contain such organisms, including promoting the adequate implementation of recommendations developed by the Organization.

9 Parties shall endeavour to co-operate under the auspices of the Organization to address threats and risks to sensitive, vulnerable or threatened marine ecosystems and biodiversity in areas beyond the limits of national jurisdiction in relation to Ballast Water Management.

Article 3 *Application*

1 Except as expressly provided otherwise in this Convention, this Convention shall apply to:

(a) ships entitled to fly the flag of a Party; and

(b) ships not entitled to fly the flag of a Party but which operate under the authority of a Party.

2 This Convention shall not apply to:

(a) ships not designed or constructed to carry Ballast Water;

(b) ships of a Party which only operate in waters under the jurisdiction of that Party, unless the Party determines that the discharge of Ballast Water from such ships would impair or damage their environment, human health, property or resources, or those of adjacent or other States;

(c) ships of a Party which only operate in waters under the jurisdiction of another Party, subject to the authorization of the latter Party for such exclusion. No Party shall grant such authorization if doing so would impair or damage their environment, human health, property or resources, or those of adjacent or other States. Any Party not granting such authorization shall notify the Administration of the ship concerned that this Convention applies to such ship;

(d) ships which only operate in waters under the jurisdiction of one Party and on the high seas, except for ships not granted an authorization pursuant to sub-paragraph (c), unless such Party determines that the discharge of Ballast Water from such ships would impair or damage their environment, human health, property or resources, or those of adjacent of other States;

(e) any warship, naval auxiliary or other ship owned or operated by a State and used, for the time being, only on government non-commercial service. However, each Party shall ensure, by the adoption of appropriate measures not impairing operations or operational capabilities of such ships owned or operated by it, that such ships act in a manner consistent, so far as is reasonable and practicable, with this Convention; and

(f) permanent Ballast Water in sealed tanks on ships, that is not subject to discharge.

3 With respect to ships of non-Parties to this Convention, Parties shall apply the requirements of this Convention as may be necessary to ensure that no more favourable treatment is given to such ships.

Article 4 *Control of the Transfer of Harmful Aquatic Organisms and Pathogens Through Ships' Ballast Water and Sediments*

1 Each Party shall require that ships to which this Convention applies and which are entitled to fly its flag or operating under its authority comply with the requirements set forth in this Convention, including the applicable standards and requirements in the Annex, and shall take effective measures to ensure that those ships comply with those requirements.

2 Each Party shall, with due regard to its particular conditions and capabilities, develop national policies, strategies or programmes for Ballast Water Management in its ports and waters under its jurisdiction that accord with, and promote the attainment of the objectives of this Convention.

Article 5 *Sediment Reception Facilities*

1 Each Party undertakes to ensure that, in ports and terminals designated by that Party where cleaning or repair of ballast tanks occurs, adequate facilities are provided for the reception of Sediments, taking into account the Guidelines developed by the Organization. Such reception facilities shall operate without causing undue delay to ships and shall provide for the safe disposal of such Sediments that does not impair or damage their environment, human health, property or resources or those of other States.

2 Each Party shall notify the Organization for transmission to the other Parties concerned of all cases where the facilities provided under paragraph 1 are alleged to be inadequate.

Article 6 *Scientific and Technical Research and Monitoring*

1 Parties shall endeavour, individually or jointly, to:

(a) promote and facilitate scientific and technical research on Ballast Water Management; and

(b) monitor the effects of Ballast Water Management in waters under their jurisdiction.

Such research and monitoring should include observation, measurement, sampling, evaluation and analysis of the effectiveness and adverse impacts of any technology or methodology as well as any adverse impacts caused by such organisms and pathogens that have been identified to have been transferred through ships' Ballast Water.

2 Each Party shall, to further the objectives of this Convention, promote the availability of relevant information to other Parties who request it on:

(a) scientific and technology programmes and technical measures undertaken with respect to Ballast Water Management; and

(b) the effectiveness of Ballast Water Management deduced from any monitoring and assessment programmes.

Article 7 *Survey and certification*

1 Each Party shall ensure that ships flying its flag or operating under its authority and subject to survey and certification are so surveyed and certified in accordance with the regulations in the Annex.

2 A Party implementing measures pursuant to Article 2.3 and Section C of the Annex shall not require additional survey and certification of a ship of another Party, nor shall the Administration of the ship be obligated to survey and certify additional measures imposed by another Party. Verification of such additional measures shall be the responsibility of the Party implementing such measures and shall not cause undue delay to the ship.

Article 8 *Violations*

1 Any violation of the requirements of this Convention shall be prohibited and sanctions shall be established under the law of the Administration of the ship concerned, wherever the violation occurs. If the Administration is informed of such a violation, it shall investigate the matter and may request the reporting Party to furnish additional evidence of the alleged violation. If the Administration is satisfied that sufficient evidence is available to enable proceedings to be brought in respect of the alleged violation, it shall cause such proceedings to be taken as soon as possible, in accordance with its law. The Administration shall promptly inform the Party that reported the alleged violation, as well as the Organization, of any action taken. If the Administration has not taken any action within 1 year after receiving the information, it shall so inform the Party which reported the alleged violation.

2 Any violation of the requirements of this Convention within the jurisdiction of any Party shall be prohibited and sanctions shall be established under the law of that Party. Whenever such a violation occurs, that Party shall either:

(a) cause proceedings to be taken in accordance with its law; or

(b) furnish to the Administration of the ship such information and evidence as may be in its possession that a violation has occurred.

3 The sanctions provided for by the laws of a Party pursuant to this Article shall be adequate in severity to discourage violations of this Convention wherever they occur.

Article 9 *Inspection of Ships*

1 A ship to which this Convention applies may, in any port or offshore terminal of another Party, be subject to inspection by officers duly authorized by that Party for the purpose of determining whether the ship is in compliance with this Convention. Except as provided in paragraph 2 of this Article, any such inspection is limited to:

(a) verifying that there is onboard a valid Certificate, which, if valid shall be accepted; and

(b) inspection of the Ballast Water record book, and/or

(c) a sampling of the ship's Ballast Water, carried out in accordance with the guidelines to be developed by the Organization. However, the time required to analyse the samples shall not be used as a basis for unduly delaying the operation, movement or departure of the ship.

2 Where a ship does not carry a valid Certificate or there are clear grounds for believing that:

(a) the condition of the ship or its equipment does not correspond substantially with the particulars of the Certificate; or

(b) the master or the crew are not familiar with essential shipboard procedures relating to Ballast Water Management, or have not implemented such procedures;

a detailed inspection may be carried out.

3 In the circumstances given in paragraph 2 of this Article, the Party carrying out the inspection shall take such steps as will ensure that the ship shall not discharge Ballast Water until it can do so without presenting a threat of harm to the environment, human health, property or resources.

Article 10 *Detection of Violations and Control of Ships*

1 Parties shall co-operate in the detection of violations and the enforcement of the provisions of this Convention.

2 If a ship is detected to have violated this Convention, the Party whose flag the ship is entitled to fly, and/or the Party in whose port or offshore terminal the ship is operating, may, in addition to any sanctions described in Article 8 or any action described in Article 9, take steps to warn, detain, or exclude the ship. The Party in whose port or offshore terminal the ship is operating, however, may grant such a ship permission to leave the port or offshore terminal for the purpose of discharging Ballast Water or proceeding to the nearest appropriate repair yard or reception facility available, provided doing so does not present a threat of harm to the environment, human health, property or resources.

3 If the sampling described in Article 9.1(c) leads to a result, or supports information received from another port or offshore terminal, indicating that the ship poses a threat to the environment, human health, property or resources, the Party in whose waters the ship is operating shall prohibit such ship from discharging Ballast Water until the threat is removed.

4 A Party may also inspect a ship when it enters the ports or offshore terminals under its jurisdiction, if a request for an investigation is received from any Party, together with sufficient evidence that a ship is operating or has operated in violation of a provision in this Convention. The report of such investigation shall be sent to the Party requesting it and to the competent authority of the Administration of the ship concerned so that appropriate action may be taken.

Article 11 *Notification of Control Actions*

1 If an inspection conducted pursuant to Article 9 or 10 indicates a violation of this Convention, the ship shall be notified. A report shall be forwarded to the Administration, including any evidence of the violation.

2 In the event that any action is taken pursuant to Article 9.3, 10.2 or 10.3, the officer carrying out such action shall forthwith inform, in writing, the Administration of the ship concerned, or if this is not possible, the consul or diplomatic representative of the ship concerned, of all the circumstances in which the action was deemed necessary. In addition, the recognized organization responsible for the issue of certificates shall be notified.

3 The port State authority concerned shall, in addition to parties mentioned in paragraph 2, notify the next port of call of all relevant information about the violation, if it is unable to take action as specified in Article 9.3, 10.2 or 10.3 or if the ship has been allowed to proceed to the next port of call.

Article 12 *Undue Delay to Ships*

1 All possible efforts shall be made to avoid a ship being unduly detained or delayed under Article 7.2, 8, 9 or 10.

2 When a ship is unduly detained or delayed under Article 7.2, 8, 9 or 10, it shall be entitled to compensation for any loss or damage suffered.

Article 13 *Technical Assistance, Co-operation and Regional Co-operation*

1 Parties undertake, directly or through the Organization and other international bodies, as appropriate, in respect of the control and management of ships' Ballast Water and Sediments, to provide support for those Parties which request technical assistance:

(a) to train personnel;

(b) to ensure the availability of relevant technology, equipment and facilities;

(c) to initiate joint research and development programmes; and

(d) to undertake other action aimed at the effective implementation of this Convention and of guidance developed by the Organization related thereto.

2 Parties undertake to co-operate actively, subject to their national laws, regulations and policies, in the transfer of technology in respect of the control and management of ships' Ballast Water and Sediments.

3 In order to further the objectives of this Convention, Parties with common interests to protect the environment, human health, property and resources in a given geographical area, in particular, those Parties bordering enclosed and semi-enclosed seas, shall endeavour, taking into account characteristic regional features, to enhance regional co-operation, including through the

conclusion of regional agreements consistent with this Convention. Parties shall seek to co-operate with the Parties to regional agreements to develop harmonized procedures.

Article 14 *Communication of information*

1 Each Party shall report to the Organization and, where appropriate, make available to other Parties the following information:

(a) any requirements and procedures relating to Ballast Water Management, including its laws, regulations, and guidelines for implementation of this Convention;

(b) the availability and location of any reception facilities for the environmentally safe disposal of Ballast Water and Sediments; and

(c) any requirements for information from a ship which is unable to comply with the provisions of this Convention for reasons specified in regulations A-3 and B-4 of the Annex.

2 The Organization shall notify Parties of the receipt of any communications under the present Article and circulate to all Parties any information communicated to it under subparagraphs 1(b) and (c) of this Article.

Article 15 *Dispute Settlement*

Parties shall settle any dispute between them concerning the interpretation or application of this Convention by negotiation, enquiry, mediation, conciliation, arbitration, judicial settlement, resort to regional agencies or arrangements or other peaceful means of their own choice.

Article 16 *Relationship to International Law and Other Agreements*

Nothing in this Convention shall prejudice the rights and obligations of any State under customary international law as reflected in the United Nations Convention on the Law of the Sea.

Article 17 *Signature, Ratification, Acceptance, Approval and Accession*

1 This Convention shall be open for signature by any State at the Headquarters of the Organization from 1 June 2004 to 31 May 2005 and shall thereafter remain open for accession by any State.

2 States may become Parties to the Convention by:

(a) signature not subject to ratification, acceptance, or approval; or

(b) signature subject to ratification, acceptance, or approval, followed by ratification, acceptance or approval; or

(c) accession.

3 Ratification, acceptance, approval or accession shall be effected by the deposit of an instrument to that effect with the Secretary-General.

4 If a State comprises two or more territorial units in which different systems of law are applicable in relation to matters dealt with in this Convention, it may at the time of signature, ratification, acceptance, approval, or accession declare that this Convention shall extend to all its territorial units or only to one or more of them and may modify this declaration by submitting another declaration at any time.

5 Any such declaration shall be notified to the Depositary in writing and shall state expressly the territorial unit or units to which this Convention applies.

Article 18 *Entry into Force*

1 This Convention shall enter into force twelve months after the date on which not less than thirty States, the combined merchant fleets of which constitute not less than thirty-five percent of the gross tonnage of the world's merchant shipping, have either signed it without reservation as to ratification, acceptance or approval, or have deposited the requisite instrument of ratification, acceptance, approval or accession in accordance with Article 17.

2 For States which have deposited an instrument of ratification, acceptance, approval or accession in respect of this Convention after the requirements for entry into force thereof have been met, but prior to the date of entry in force, the ratification, acceptance, approval or accession shall take effect on the date of entry into force of this Convention or three months after the date of deposit of instrument, whichever is the later date.

3 Any instrument of ratification, acceptance, approval or accession deposited after the date on which this Convention enters into force shall take effect three months after the date of deposit.

4 After the date on which an amendment to this Convention is deemed to have been accepted under Article 19, any instrument of ratification, acceptance, approval or accession deposited shall apply to this Convention as amended.

Article 19 *Amendments*

1 This Convention may be amended by either of the procedures specified in the following paragraphs.

2 Amendments after consideration within the Organization:

(a) Any Party may propose an amendment to this Convention. A proposed amendment shall be submitted to the Secretary-General, who shall then circulate it to the Parties and Members of the Organization at least six months prior to its consideration.

(b) An amendment proposed and circulated as above shall be referred to the Committee for consideration. Parties, whether or not Members of the

Organization, shall be entitled to participate in the proceedings of the Committee for consideration and adoption of the amendment.

(c) Amendments shall be adopted by a two-thirds majority of the Parties present and voting in the Committee, on condition that at least one-third of the Parties shall be present at the time of voting.

(d) Amendments adopted in accordance with subparagraph (c) shall be communicated by the Secretary-General to the Parties for acceptance.

(e) An amendment shall be deemed to have been accepted in the following circumstances:

(i) An amendment to an article of this Convention shall be deemed to have been accepted on the date on which two-thirds of the Parties have notified the Secretary-General of their acceptance of it.

(ii) An amendment to the Annex shall be deemed to have been accepted at the end of twelve months after the date of adoption or such other date as determined by the Committee. However, if by that date more than one-third of the Parties notify the Secretary-General that they object to the amendment, it shall be deemed not to have been accepted.

(f) An amendment shall enter into force under the following conditions:

(i) An amendment to an article of this Convention shall enter into force for those Parties that have declared that they have accepted it six months after the date on which it is deemed to have been accepted in accordance with subparagraph (e)(i).

(ii) An amendment to the Annex shall enter into force with respect to all Parties six months after the date on which it is deemed to have been accepted, except for any Party that has:

(1) notified its objection to the amendment in accordance with subparagraph (e)(ii) and that has not withdrawn such objection; or

(2) notified the Secretary-General, prior to the entry into force of such amendment, that the amendment shall enter into force for it only after a subsequent notification of its acceptance.

(g) (i) A Party that has notified an objection under subparagraph (f)(ii)(1) may subsequently notify the Secretary-General that it accepts the amendment. Such amendment shall enter into force for such Party six months after the date of its notification of acceptance, or the date on which the amendment enters into force, whichever is the later date.

(ii) If a Party that has made a notification referred to in subparagraph (f)(ii)(2) notifies the Secretary-General of its acceptance with respect to an amendment, such amendment shall enter into force for such Party six months after the date of its notification of acceptance, or the date on which the amendment enters into force, whichever is the later date.

3 Amendment by a Conference:

(a) Upon the request of a Party concurred in by at least one-third of the Parties, the Organization shall convene a Conference of Parties to consider amendments to this Convention.

(b) An amendment adopted by such a Conference by a two-thirds majority of the Parties present and voting shall be communicated by the Secretary-General to all Parties for acceptance.

(c) Unless the Conference decides otherwise, the amendment shall be deemed to have been accepted and shall enter into force in accordance with the procedures specified in paragraphs 2(e) and (f) respectively.

4 Any Party that has declined to accept an amendment to the Annex shall be treated as a non-Party only for the purpose of application of that amendment.

5 Any notification under this Article shall be made in writing to the Secretary-General.

6 The Secretary-General shall inform the Parties and Members of the Organization of:

(a) any amendment that enters into force and the date of its entry into force generally and for each Party; and

(b) any notification made under this Article.

Article 20 *Denunciation*

1 This Convention may be denounced by any Party at any time after the expiry of two years from the date on which this Convention enters into force for that Party.

2 Denunciation shall be effected by written notification to the Depositary, to take effect one year after receipt or such longer period as may be specified in that notification.

Article 21 *Depositary*

1 This Convention shall be deposited with the Secretary-General, who shall transmit certified copies of this Convention to all States which have signed this Convention or acceded thereto.

2 In addition to the functions specified elsewhere in this Convention, the Secretary-General shall:

(a) inform all States that have signed this Convention, or acceded thereto, of:

(i) each new signature or deposit of an instrument of ratification, acceptance, approval or accession, together with the date thereof;

(ii) the date of entry into force of this Convention; and

(iii) the deposit of any instrument of denunciation from the Convention, together with the date on which it was received and the date on which the denunciation takes effect; and

(b) as soon as this Convention enters into force, transmit the text thereof to the Secretariat of the United Nations for registration and publication in accordance with Article 102 of the Charter of the United Nations.

Article 22 *Languages*

This Convention is established in a single original in the Arabic, Chinese, English, French, Russian and Spanish languages, each text being equally authentic.

DONE AT LONDON this thirteenth day of February, two thousand and four.

IN WITNESS WHEREOF the undersigned, being duly authorised by their respective Governments for that purpose, have signed this Convention.

ANNEX

REGULATIONS FOR THE CONTROL AND MANAGEMENT OF SHIPS' BALLAST WATER AND SEDIMENTS

SECTION A - GENERAL PROVISIONS

Regulation A-1 *Definitions*

For the purposes of this Annex:

1 "Anniversary date" means the day and the month of each year corresponding to the date of expiry of the Certificate.

2 "Ballast Water Capacity" means the total volumetric capacity of any tanks, spaces or compartments on a ship used for carrying, loading or discharging Ballast Water, including any multi-use tank, space or compartment designed to allow carriage of Ballast Water.

3 "Company" means the owner of the ship or any other organization or person such as the manager, or the bareboat charterer, who has assumed the responsibility for operation of the ship from the owner of the ship and who on assuming such responsibility has agreed to take over all the duties and responsibilities imposed by the International Safety Management Code[1].

4 "Constructed" in respect of a ship means a stage of construction where:

.1 the keel is laid; or

.2 construction identifiable with the specific ship begins;

.3 assembly of the ship has commenced comprising at least 50 tonnes or 1 percent of the estimated mass of all structural material, whichever is less; or

.4 the ship undergoes a major conversion.

5 "Major conversion" means a conversion of a ship:

.1 which changes its ballast water carrying capacity by 15 percent or greater, or

.2 which changes the ship type, or

.3 which, in the opinion of the Administration, is projected to prolong its life by ten years or more, or

.4 which results in modifications to its ballast water system other than component replacement-in-kind. Conversion of a ship to meet the provisions of regulation D-

1 Refer to the ISM Code adopted by the Organization by resolution A.741(18), as amended.

1 shall not be deemed to constitute a major conversion for the purpose of this Annex.

6 "From the nearest land" means from the baseline from which the territorial sea of the territory in question is established in accordance with international law except that, for the purposes of the Convention, "from the nearest land" off the north-eastern coast of Australia shall mean from a line drawn from a point on the coast of Australia in

latitude 11°00´ S, longitude 142°08´ E
to a point in latitude 10°35´ S, longitude 141°55´ E
thence to a point latitude 10°00´ S, longitude 142°00´ E
thence to a point latitude 9°10´ S, longitude 143°52´ E
thence to a point latitude 9°00´ S, longitude 144°30´ E
thence to a point latitude 10°41´ S, longitude 145°00´ E
thence to a point latitude 13°00´ S, longitude 145°00´ E
thence to a point latitude 15°00´ S, longitude 146°00´ E
thence to a point latitude 17°30´ S, longitude 147°00´ E
thence to a point latitude 21°00´ S, longitude 152°55´ E
thence to a point latitude 24°30´ S, longitude 154°00´ E
thence to a point on the coast of Australia
in latitude 24°42´ S, longitude 153°15´ E.

7 "Active Substance" means a substance or organism, including a virus or a fungus, that has a general or specific action on or against Harmful Aquatic Organisms and Pathogens.

Regulation A-2 *General Applicability*

Except where expressly provided otherwise, the discharge of Ballast Water shall only be conducted through Ballast Water Management in accordance with the provisions of this Annex.

Regulation A-3 *Exceptions*

The requirements of regulation B-3, or any measures adopted by a Party pursuant to Article 2.3 and Section C, shall not apply to:

1 the uptake or discharge of Ballast Water and Sediments necessary for the purpose of ensuring the safety of a ship in emergency situations or saving life at sea; or

2 the accidental discharge or ingress of Ballast Water and Sediments resulting from damage to a ship or its equipment:

.1 provided that all reasonable precautions have been taken before and after the occurrence of the damage or discovery of the damage or discharge for the purpose of preventing or minimizing the discharge; and

.2 unless the owner, Company or officer in charge wilfully or recklessly caused damage; or

3 the uptake and discharge of Ballast Water and Sediments when being used for the purpose of avoiding or minimizing pollution incidents from the ship; or

4 the uptake and subsequent discharge on the high seas of the same Ballast Water and Sediments; or

5 the discharge of Ballast Water and Sediments from a ship at the same location where the whole of that Ballast Water and those Sediments originated and provided that no mixing with unmanaged Ballast Water and Sediments from other areas has occurred. If mixing has occurred, the Ballast Water taken from other areas is subject to Ballast Water Management in accordance with this Annex.

Regulation A-4 *Exemptions*

1 A Party or Parties, in waters under their jurisdiction, may grant exemptions to any requirements to apply regulations B-3 or C-1, in addition to those exemptions contained elsewhere in this Convention, but only when they are:

.1 granted to a ship or ships on a voyage or voyages between specified ports or locations; or to a ship which operates exclusively between specified ports or locations;

.2 effective for a period of no more than five years subject to intermediate review;

.3 granted to ships that do not mix Ballast Water or Sediments other than between the ports or locations specified in paragraph 1.1; and

.4 granted based on the Guidelines on risk assessment developed by the Organization.

2 Exemptions granted pursuant to paragraph 1 shall not be effective until after communication to the Organization and circulation of relevant information to the Parties.

3 Any exemptions granted under this regulation shall not impair or damage the environment, human health, property or resources of adjacent or other States. Any State that the Party determines may be adversely affected shall be consulted, with a view to resolving any identified concerns.

4 Any exemptions granted under this regulation shall be recorded in the Ballast Water record book.

Regulation A-5 *Equivalent compliance*

Equivalent compliance with this Annex for pleasure craft used solely for recreation or competition or craft used primarily for search and rescue, less than 50 metres in length overall, and with a maximum Ballast Water capacity of 8 cubic metres, shall be determined by the Administration taking into account Guidelines developed by the Organization.

SECTION B – MANAGEMENT AND CONTROL REQUIREMENTS FOR SHIPS

Regulation B-1 *Ballast Water Management Plan*

Each ship shall have on board and implement a Ballast Water Management plan. Such a plan shall be approved by the Administration taking into account Guidelines developed by the Organization. The Ballast Water Management plan shall be specific to each ship and shall at least:

1 detail safety procedures for the ship and the crew associated with Ballast Water Management as required by this Convention;

2 provide a detailed description of the actions to be taken to implement the Ballast Water Management requirements and supplemental Ballast Water Management practices as set forth in this Convention;

3 detail the procedures for the disposal of Sediments:

.1 at sea; and

.2 to shore;

4 include the procedures for coordinating shipboard Ballast Water Management that involves discharge to the sea with the authorities of the State into whose waters such discharge will take place;

5 designate the officer on board in charge of ensuring that the plan is properly implemented;

6 contain the reporting requirements for ships provided for under this Convention; and

7 be written in the working language of the ship. If the language used is not English, French or Spanish, a translation into one of these languages shall be included.

Regulation B-2 *Ballast Water Record Book*

1 Each ship shall have on board a Ballast Water record book that may be an electronic record system, or that may be integrated into another record book or system and, which shall at least contain the information specified in Appendix II.

2 Ballast Water record book entries shall be maintained on board the ship for a minimum period of two years after the last entry has been made and thereafter in the Company's control for a minimum period of three years.

3 In the event of the discharge of Ballast Water pursuant to regulations A-3, A-4 or B-3.6 or in the event of other accidental or exceptional discharge of Ballast Water not otherwise exempted by this Convention, an entry shall be made in the Ballast Water record book describing the circumstances of, and the reason for, the discharge.

4 The Ballast Water record book shall be kept readily available for inspection at all reasonable times and, in the case of an unmanned ship under tow, may be kept on the towing ship.

5 Each operation concerning Ballast Water shall be fully recorded without delay in the Ballast Water record book. Each entry shall be signed by the officer in charge of the operation concerned and each completed page shall be signed by the master. The entries in the Ballast Water record book shall be in a working language of the ship. If that language is not English, French or Spanish the entries shall contain a translation into one of those languages. When entries in an official national language of the State whose flag the ship is entitled to fly are also used, these shall prevail in case of a dispute or discrepancy.

6 Officers duly authorized by a Party may inspect the Ballast Water record book on board any ship to which this regulation applies while the ship is in its port or offshore terminal, and may make a copy of any entry, and require the master to certify that the copy is a true copy. Any copy so certified shall be admissible in any judicial proceeding as evidence of the facts stated in the entry. The inspection of a Ballast Water record book and the taking of a certified copy shall be performed as expeditiously as possible without causing the ship to be unduly delayed.

Regulation B-3 *Ballast Water Management for Ships*

1 A ship constructed before 2009:

.1 with a Ballast Water Capacity of between 1500 and 5000 cubic metres, inclusive, shall conduct Ballast Water Management that at least meets the standard described in regulation D-1 or regulation D-2 until 2014, after which time it shall at least meet the standard described in regulation D-2;

.2 with a Ballast Water Capacity of less than 1500 or greater than 5000 cubic metres shall conduct Ballast Water Management that at least meets the standard described in regulation D-1 or regulation D-2 until 2016, after which time it shall at least meet the standard described in regulation D-2.

2 A ship to which paragraph 1 applies shall comply with paragraph 1 not later than the first intermediate or renewal survey, whichever occurs first, after the anniversary date of delivery of the ship in the year of compliance with the standard applicable to the ship.

3 A ship constructed in or after 2009 with a Ballast Water Capacity of less than 5000 cubic metres shall conduct Ballast Water Management that at least meets the standard described in regulation D-2.

4 A ship constructed in or after 2009, but before 2012, with a Ballast Water Capacity of 5000 cubic metres or more shall conduct Ballast Water Management in accordance with paragraph 1.2.

5 A ship constructed in or after 2012 with a Ballast Water Capacity of 5000 cubic metres or more shall conduct Ballast Water Management that at least meets the standard described in regulation D-2.

6 The requirements of this regulation do not apply to ships that discharge Ballast Water to a reception facility designed taking into account the Guidelines developed by the Organization for such facilities.

7 Other methods of Ballast Water Management may also be accepted as alternatives to the requirements described in paragraphs 1 to 5, provided that such methods ensure at least the same level of protection to the environment, human health, property or resources, and are approved in principle by the Committee.

Regulation B-4 *Ballast Water Exchange*

1 A ship conducting Ballast Water exchange to meet the standard in regulation D-1 shall:

.1 whenever possible, conduct such Ballast Water exchange at least 200 nautical miles from the nearest land and in water at least 200 metres in depth, taking into account the Guidelines developed by the Organization;

.2 in cases where the ship is unable to conduct Ballast Water exchange in accordance with paragraph 1.1, such Ballast Water exchange shall be conducted taking into account the Guidelines described in paragraph 1.1 and as far from the nearest land as possible, and in all cases at least 50 nautical miles from the nearest land and in water at least 200 metres in depth.

2 In sea areas where the distance from the nearest land or the depth does not meet the parameters described in paragraph 1.1 or 1.2, the port State may designate areas, in consultation with adjacent or other States, as appropriate, where a ship may conduct Ballast Water exchange, taking into account the Guidelines described in paragraph 1.1.

3 A ship shall not be required to deviate from its intended voyage, or delay the voyage, in order to comply with any particular requirement of paragraph 1.

4 A ship conducting Ballast Water exchange shall not be required to comply with paragraphs 1 or 2, as appropriate, if the master reasonably decides that such exchange would threaten the safety or stability of the ship, its crew, or its passengers because of adverse weather, ship design or stress, equipment failure, or any other extraordinary condition.

5 When a ship is required to conduct Ballast Water exchange and does not do so in accordance with this regulation, the reasons shall be entered in the Ballast Water record book.

Regulation B-5 *Sediment Management for Ships*

1 All ships shall remove and dispose of Sediments from spaces designated to carry Ballast Water in accordance with the provisions of the ship's Ballast Water Management plan.

2 Ships described in regulation B-3.3 to B-3.5 should, without compromising safety or operational efficiency, be designed and constructed with a view to minimize the uptake and

undesirable entrapment of Sediments, facilitate removal of Sediments, and provide safe access to allow for Sediment removal and sampling, taking into account guidelines developed by the Organization. Ships described in regulation B-3.1 should, to the extent practicable, comply with this paragraph.

Regulation B-6 *Duties of Officers and Crew*

Officers and crew shall be familiar with their duties in the implementation of Ballast Water Management particular to the ship on which they serve and shall, appropriate to their duties, be familiar with the ship's Ballast Water Management plan.

SECTION C – SPECIAL REQUIREMENTS IN CERTAIN AREAS

Regulation C-1 *Additional Measures*

1 If a Party, individually or jointly with other Parties, determines that measures in addition to those in Section B are necessary to prevent, reduce, or eliminate the transfer of Harmful Aquatic Organisms and Pathogens through ships' Ballast Water and Sediments, such Party or Parties may, consistent with international law, require ships to meet a specified standard or requirement.

2 Prior to establishing standards or requirements under paragraph 1, a Party or Parties should consult with adjacent or other States that may be affected by such standards or requirements.

3 A Party or Parties intending to introduce additional measures in accordance with paragraph 1 shall:

.1 take into account the Guidelines developed by the Organization.

.2 communicate their intention to establish additional measure(s) to the Organization at least 6 months, except in emergency or epidemic situations, prior to the projected date of implementation of the measure(s). Such communication shall include:

.1 the precise co-ordinates where additional measure(s) is/are applicable;

.2 the need and reasoning for the application of the additional measure(s), including, whenever possible, benefits;

.3 a description of the additional measure(s); and

.4 any arrangements that may be provided to facilitate ships' compliance with the additional measure(s).

. 3 to the extent required by customary international law as reflected in the United Nations Convention on the Law of the Sea, as appropriate, obtain the approval of the Organization.

4 A Party or Parties, in introducing such additional measures, shall endeavour to make available all appropriate services, which may include but are not limited to notification to mariners of areas, available and alternative routes or ports, as far as practicable, in order to ease the burden on the ship.

5 Any additional measures adopted by a Party or Parties shall not compromise the safety and security of the ship and in any circumstances not conflict with any other convention with which the ship must comply.

6 A Party or Parties introducing additional measures may waive these measures for a period of time or in specific circumstances as they deem fit.

Regulation C-2 *Warnings Concerning Ballast Water Uptake in Certain Areas and Related Flag State Measures*

1 A Party shall endeavour to notify mariners of areas under their jurisdiction where ships should not uptake Ballast Water due to known conditions. The Party shall include in such notices the precise coordinates of the area or areas, and, where possible, the location of any alternative area or areas for the uptake of Ballast Water. Warnings may be issued for areas:

.1 known to contain outbreaks, infestations, or populations of Harmful Aquatic Organisms and Pathogens (e.g., toxic algal blooms) which are likely to be of relevance to Ballast Water uptake or discharge;

.2 near sewage outfalls; or

.3 where tidal flushing is poor or times during which a tidal stream is known to be more turbid.

2 In addition to notifying mariners of areas in accordance with the provisions of paragraph 1, a Party shall notify the Organization and any potentially affected coastal States of any areas identified in paragraph 1 and the time period such warning is likely to be in effect. The notice to the Organization and any potentially affected coastal States shall include the precise coordinates of the area or areas, and, where possible, the location of any alternative area or areas for the uptake of Ballast Water. The notice shall include advice to ships needing to uptake Ballast Water in the area, describing arrangements made for alternative supplies. The Party shall also notify mariners, the Organization, and any potentially affected coastal States when a given warning is no longer applicable.

Regulation C-3 *Communication of Information*

The Organization shall make available, through any appropriate means, information communicated to it under regulations C-1 and C-2.

SECTION D - STANDARDS FOR BALLAST WATER MANAGEMENT

Regulation D-1 *Ballast Water Exchange Standard*

1 Ships performing Ballast Water exchange in accordance with this regulation shall do so with an efficiency of at least 95 percent volumetric exchange of Ballast Water.

2 For ships exchanging Ballast Water by the pumping-through method, pumping through three times the volume of each Ballast Water tank shall be considered to meet the standard described in paragraph 1. Pumping through less than three times the volume may be accepted provided the ship can demonstrate that at least 95 percent volumetric exchange is met.

Regulation D-2 *Ballast Water Performance Standard*

1 Ships conducting Ballast Water Management in accordance with this regulation shall discharge less than 10 viable organisms per cubic metre greater than or equal to 50 micrometres in minimum dimension and less than 10 viable organisms per milliliter less than 50 micrometres in minimum dimension and greater than or equal to 10 micrometres in minimum dimension; and discharge of the indicator microbes shall not exceed the specified concentrations described in paragraph 2.

2 Indicator microbes, as a human health standard, shall include:

.1 Toxicogenic *Vibrio cholerae* (O1 and O139) with less than 1 colony forming unit (cfu) per 100 milliliters or less than 1 cfu per 1 gram (wet weight) zooplankton samples ;

.2 *Escherichia coli* less than 250 cfu per 100 milliliters;

.3 Intestinal Enterococci less than 100 cfu per 100 milliliters.

Regulation D-3 *Approval requirements for Ballast Water Management systems*

1 Except as specified in paragraph 2, Ballast Water Management systems used to comply with this Convention must be approved by the Administration taking into account Guidelines developed by the Organization.

2 Ballast Water Management systems which make use of Active Substances or preparations containing one or more Active Substances to comply with this Convention shall be approved by the Organization, based on a procedure developed by the Organization. This procedure shall describe the approval and withdrawal of approval of Active Substances and their proposed manner of application. At withdrawal of approval, the use of the relevant Active Substance or Substances shall be prohibited within 1 year after the date of such withdrawal.

3 Ballast Water Management systems used to comply with this Convention must be safe in terms of the ship, its equipment and the crew.

Regulation D-4 *Prototype Ballast Water Treatment Technologies*

1 For any ship that, prior to the date that the standard in regulation D-2 would otherwise become effective for it, participates in a programme approved by the Administration to test and evaluate promising Ballast Water treatment technologies, the standard in regulation D-2 shall not apply to that ship until five years from the date on which the ship would otherwise be required to comply with such standard.

2 For any ship that, after the date on which the standard in regulation D-2 has become effective for it, participates in a programme approved by the Administration, taking into account Guidelines developed by the Organization, to test and evaluate promising Ballast Water technologies with the potential to result in treatment technologies achieving a standard higher than that in regulation D-2, the standard in regulation D-2 shall cease to apply to that ship for five years from the date of installation of such technology.

3 In establishing and carrying out any programme to test and evaluate promising Ballast Water technologies, Parties shall:

.1 take into account Guidelines developed by the Organization, and

.2 allow participation only by the minimum number of ships necessary to effectively test such technologies.

4 Throughout the test and evaluation period, the treatment system must be operated consistently and as designed.

Regulation D-5 *Review of Standards by the Organization*

1 At a meeting of the Committee held no later than three years before the earliest effective date of the standard set forth in regulation D-2, the Committee shall undertake a review which includes a determination of whether appropriate technologies are available to achieve the standard, an assessment of the criteria in paragraph 2, and an assessment of the socio-economic effect(s) specifically in relation to the developmental needs of developing countries, particularly small island developing States. The Committee shall also undertake periodic reviews, as appropriate, to examine the applicable requirements for ships described in regulation B-3.1 as well as any other aspect of Ballast Water Management addressed in this Annex, including any Guidelines developed by the Organization.

2 Such reviews of appropriate technologies shall also take into account:

.1 safety considerations relating to the ship and the crew;

.2 environmental acceptability, i.e., not causing more or greater environmental impacts than they solve;

.3 practicability, i.e., compatibility with ship design and operations;

.4 cost effectiveness, i.e., economics; and

.5 biological effectiveness in terms of removing, or otherwise rendering not viable, Harmful Aquatic Organisms and Pathogens in Ballast Water.

3 The Committee may form a group or groups to conduct the review(s) described in paragraph 1. The Committee shall determine the composition, terms of reference and specific issues to be addressed by any such group formed. Such groups may develop and recommend proposals for amendment of this Annex for consideration by the Parties. Only Parties may participate in the formulation of recommendations and amendment decisions taken by the Committee.

4 If, based on the reviews described in this regulation, the Parties decide to adopt amendments to this Annex, such amendments shall be adopted and enter into force in accordance with the procedures contained in Article 19 of this Convention.

SECTION E - SURVEY AND CERTIFICATION REQUIREMENTS FOR BALLAST WATER MANAGEMENT

Regulation E-1 *Surveys*

1 Ships of 400 gross tonnage and above to which this Convention applies, excluding floating platforms, FSUs and FPSOs, shall be subject to surveys specified below:

.1 An initial survey before the ship is put in service or before the Certificate required under regulation E-2 or E-3 is issued for the first time. This survey shall verify that the Ballast Water Management plan required by regulation B-1 and any associated structure, equipment, systems, fitting, arrangements and material or processes comply fully with the requirements of this Convention.

.2 A renewal survey at intervals specified by the Administration, but not exceeding five years, except where regulation E-5.2, E-5.5, E-5.6, or E-5.7 is applicable. This survey shall verify that the Ballast Water Management plan required by regulation B-1 and any associated structure, equipment, systems, fitting, arrangements and material or processes comply fully with the applicable requirements of this Convention.

.3 An intermediate survey within three months before or after the second Anniversary date or within three months before or after the third Anniversary date of the Certificate, which shall take the place of one of the annual surveys specified in paragraph 1.4. The intermediate surveys shall ensure that the equipment, associated systems and processes for Ballast Water Management fully comply with the applicable requirements of this Annex and are in good working order. Such intermediate surveys shall be endorsed on the Certificate issued under regulation E-2 or E-3.

.4 An annual survey within three months before or after each Anniversary date, including a general inspection of the structure, any equipment, systems, fittings, arrangements and material or processes associated with the Ballast Water

Management plan required by regulation B-1 to ensure that they have been maintained in accordance with paragraph 9 and remain satisfactory for the service for which the ship is intended. Such annual surveys shall be endorsed on the Certificate issued under regulation E-2 or E-3.

.5 An additional survey either general or partial, according to the circumstances, shall be made after a change, replacement, or significant repair of the structure, equipment, systems, fittings, arrangements and material necessary to achieve full compliance with this Convention. The survey shall be such as to ensure that any such change, replacement, or significant repair has been effectively made, so that the ship complies with the requirements of this Convention. Such surveys shall be endorsed on the Certificate issued under regulation E-2 or E-3.

2 The Administration shall establish appropriate measures for ships that are not subject to the provisions of paragraph 1 in order to ensure that the applicable provisions of this Convention are complied with.

3 Surveys of ships for the purpose of enforcement of the provisions of this Convention shall be carried out by officers of the Administration. The Administration may, however, entrust the surveys either to surveyors nominated for the purpose or to organizations recognized by it.

4 An Administration nominating surveyors or recognizing organizations to conduct surveys, as described in paragraph 3 shall, as a minimum, empower such nominated surveyors or recognized organizations[2] to:

.1 require a ship that they survey to comply with the provisions of this Convention; and

.2 carry out surveys and inspections if requested by the appropriate authorities of a port State that is a Party.

5 The Administration shall notify the Organization of the specific responsibilities and conditions of the authority delegated to the nominated surveyors or recognized organizations, for circulation to Parties for the information of their officers.

6 When the Administration, a nominated surveyor, or a recognized organization determines that the ship's Ballast Water Management does not conform to the particulars of the Certificate required under regulation E-2 or E-3 or is such that the ship is not fit to proceed to sea without presenting a threat of harm to the environment, human health, property or resources such surveyor or organization shall immediately ensure that corrective action is taken to bring the ship into compliance. A surveyor or organization shall be notified immediately, and it shall ensure that the Certificate is not issued or is withdrawn as appropriate. If the ship is in the port of another Party, the appropriate authorities of the port State shall be notified immediately. When an officer of the Administration, a nominated surveyor, or a recognized organization has notified the appropriate authorities of the port State, the Government of the port State concerned shall

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2 Refer to the guidelines adopted by the Organization by resolution A.739(18), as may be amended by the Organization, and the specifications adopted by the Organization by resolution A.789(19), as may be amended by the Organization.

give such officer, surveyor or organization any necessary assistance to carry out their obligations under this regulation, including any action described in Article 9.

7 Whenever an accident occurs to a ship or a defect is discovered which substantially affects the ability of the ship to conduct Ballast Water Management in accordance with this Convention, the owner, operator or other person in charge of the ship shall report at the earliest opportunity to the Administration, the recognized organization or the nominated surveyor responsible for issuing the relevant Certificate, who shall cause investigations to be initiated to determine whether a survey as required by paragraph 1 is necessary. If the ship is in a port of another Party, the owner, operator or other person in charge shall also report immediately to the appropriate authorities of the port State and the nominated surveyor or recognized organization shall ascertain that such report has been made.

8 In every case, the Administration concerned shall fully guarantee the completeness and efficiency of the survey and shall undertake to ensure the necessary arrangements to satisfy this obligation.

9 The condition of the ship and its equipment, systems and processes shall be maintained to conform with the provisions of this Convention to ensure that the ship in all respects will remain fit to proceed to sea without presenting a threat of harm to the environment, human health, property or resources.

10 After any survey of the ship under paragraph 1 has been completed, no change shall be made in the structure, any equipment, fittings, arrangements or material associated with the Ballast Water Management plan required by regulation B-1 and covered by the survey without the sanction of the Administration, except the direct replacement of such equipment or fittings.

Regulation E-2 *Issuance or Endorsement of a Certificate*

1 The Administration shall ensure that a ship to which regulation E-1 applies is issued a Certificate after successful completion of a survey conducted in accordance with regulation E-1. A Certificate issued under the authority of a Party shall be accepted by the other Parties and regarded for all purposes covered by this Convention as having the same validity as a Certificate issued by them.

2 Certificates shall be issued or endorsed either by the Administration or by any person or organization duly authorized by it. In every case, the Administration assumes full responsibility for the Certificate.

Regulation E-3 *Issuance or Endorsement of a Certificate by Another Party*

1 At the request of the Administration, another Party may cause a ship to be surveyed and, if satisfied that the provisions of this Convention are complied with, shall issue or authorize the issuance of a Certificate to the ship, and where appropriate, endorse or authorize the endorsement of that Certificate on the ship, in accordance with this Annex.

2 A copy of the Certificate and a copy of the survey report shall be transmitted as soon as possible to the requesting Administration.

3 A Certificate so issued shall contain a statement to the effect that it has been issued at the request of the Administration and it shall have the same force and receive the same recognition as a Certificate issued by the Administration.

4 No Certificate shall be issued to a ship entitled to fly the flag of a State which is not a Party.

Regulation E-4 *Form of the Certificate*

The Certificate shall be drawn up in the official language of the issuing Party, in the form set forth in Appendix I. If the language used is neither English, French nor Spanish, the text shall include a translation into one of these languages.

Regulation E-5 *Duration and Validity of the Certificate*

1 A Certificate shall be issued for a period specified by the Administration that shall not exceed five years.

2 For renewal surveys:

.1 Notwithstanding the requirements of paragraph 1, when the renewal survey is completed within three months before the expiry date of the existing Certificate, the new Certificate shall be valid from the date of completion of the renewal survey to a date not exceeding five years from the date of expiry of the existing Certificate.

.2 When the renewal survey is completed after the expiry date of the existing Certificate, the new Certificate shall be valid from the date of completion of the renewal survey to a date not exceeding five years from the date of expiry of the existing Certificate.

.3 When the renewal survey is completed more than three months before the expiry date of the existing Certificate, the new Certificate shall be valid from the date of completion of the renewal survey to a date not exceeding five years from the date of completion of the renewal survey.

3 If a Certificate is issued for a period of less than five years, the Administration may extend the validity of the Certificate beyond the expiry date to the maximum period specified in paragraph 1, provided that the surveys referred to in regulation E-1.1.3 applicable when a Certificate is issued for a period of five years are carried out as appropriate.

4 If a renewal survey has been completed and a new Certificate cannot be issued or placed on board the ship before the expiry date of the existing Certificate, the person or organization authorized by the Administration may endorse the existing Certificate and such a Certificate shall be accepted as valid for a further period which shall not exceed five months from the expiry date.

5 If a ship at the time when the Certificate expires is not in a port in which it is to be surveyed, the Administration may extend the period of validity of the Certificate but this extension shall be granted only for the purpose of allowing the ship to complete its voyage to the

port in which it is to be surveyed, and then only in cases where it appears proper and reasonable to do so. No Certificate shall be extended for a period longer than three months, and a ship to which such extension is granted shall not, on its arrival in the port in which it is to be surveyed, be entitled by virtue of such extension to leave that port without having a new Certificate. When the renewal survey is completed, the new Certificate shall be valid to a date not exceeding five years from the date of expiry of the existing Certificate before the extension was granted.

6 A Certificate issued to a ship engaged on short voyages which has not been extended under the foregoing provisions of this regulation may be extended by the Administration for a period of grace of up to one month from the date of expiry stated on it. When the renewal survey is completed, the new Certificate shall be valid to a date not exceeding five years from the date of expiry of the existing Certificate before the extension was granted.

7 In special circumstances, as determined by the Administration, a new Certificate need not be dated from the date of expiry of the existing Certificate as required by paragraph 2.2, 5 or 6 of this regulation. In these special circumstances, the new Certificate shall be valid to a date not exceeding five years from the date of completion of the renewal survey.

8 If an annual survey is completed before the period specified in regulation E-1, then:

.1 the Anniversary date shown on the Certificate shall be amended by endorsement to a date which shall not be more than three months later than the date on which the survey was completed;

.2 the subsequent annual or intermediate survey required by regulation E-1 shall be completed at the intervals prescribed by that regulation using the new Anniversary date;

.3 the expiry date may remain unchanged provided one or more annual surveys, as appropriate, are carried out so that the maximum intervals between the surveys prescribed by regulation E-1 are not exceeded.

9 A Certificate issued under regulation E-2 or E-3 shall cease to be valid in any of the following cases:

.1 if the structure, equipment, systems, fittings, arrangements and material necessary to comply fully with this Convention is changed, replaced or significantly repaired and the Certificate is not endorsed in accordance with this Annex;

.2 upon transfer of the ship to the flag of another State. A new Certificate shall only be issued when the Party issuing the new Certificate is fully satisfied that the ship is in compliance with the requirements of regulation E-1. In the case of a transfer between Parties, if requested within three months after the transfer has taken place, the Party whose flag the ship was formerly entitled to fly shall, as soon as possible, transmit to the Administration copies of the Certificates carried by the ship before the transfer and, if available, copies of the relevant survey reports;

.3 if the relevant surveys are not completed within the periods specified under regulation E-1.1; or

.4 if the Certificate is not endorsed in accordance with regulation E-1.1.

APPENDIX I

FORM OF INTERNATIONAL BALLAST WATER MANAGEMENT CERTIFICATE

INTERNATIONAL BALLAST WATER MANAGEMENT CERTIFICATE

Issued under the provisions of the International Convention for the Control and Management of Ships' Ballast Water and Sediments (hereinafter referred to as "the Convention") under the authority of the Government of

…………………………………………………………………………………………………
(full designation of the country)

by ………………………………………………………………………………………
(full designation of the competent person or organization authorized under the provisions of the Convention)

Particulars of ship[1]

Name of ship ....

Distinctive number or letters ....

Port of registry ....

Gross Tonnage ....

IMO number[2] ....

Date of Construction ……………………………………………………………

Ballast Water Capacity (in cubic metres) ....

Details of Ballast Water Management Method(s) Used

Method of Ballast Water Management used ……………………………………………...

Date installed (if applicable) ....

Name of manufacturer (if applicable) ....

[1] Alternatively, the particulars of the ship may be placed horizontally in boxes.
[2] IMO Ship Identification Number Scheme adopted by the Organization by resolution A.600(15).

The principal Ballast Water Management method(s) employed on this ship is/are:

☐ in accordance with regulation D-1

☐ in accordance with regulation D-2
(describe) ....

☐ the ship is subject to regulation D-4

THIS IS TO CERTIFY:

1 That the ship has been surveyed in accordance with regulation E-1 of the Annex to the Convention; and

2 That the survey shows that Ballast Water Management on the ship complies with the Annex to the Convention.

This certificate is valid until …………………………… subject to surveys in accordance with regulation E-1 of the Annex to the Convention.

Completion date of the survey on which this certificate is based: dd/mm/yyyy

Issued at ....
(Place of issue of certificate)

....
(*Date of issue*) *Signature of authorized official issuing the certificate)*

(Seal or stamp of the authority, as appropriate)

ENDORSEMENT FOR ANNUAL AND INTERMEDIATE SURVEY(S)

THIS IS TO CERTIFY that a survey required by regulation E-1 of the Annex to the Convention the ship was found to comply with the relevant provisions of the Convention:

Annual survey: Signed ....
(Signature of duly authorized official)

Place ....

Date.............................

(Seal or stamp of the authority, as appropriate)

Annual*/Intermediate survey*: Signed ....
(Signature of duly authorized official)

Place ....

Date.............................

(Seal or stamp of the authority, as appropriate)

Annual*/Intermediate survey*: Signed ....
(Signature of duly authorized official)

Place ....

Date.............................

(Seal or stamp of the authority, as appropriate)

Annual survey: Signed ....
(Signature of duly authorized official)

Place ....

Date.............................

(Seal or stamp of the authority, as appropriate)

---

* Delete as appropriate

ANNUAL / INTERMEDIATE SURVEY
IN ACCORDANCE WITH REGULATION E-5.8.3

THIS IS TO CERTIFY that, at an annual / intermediate* survey in accordance with regulation E-5.8.3 of the Annex to the Convention, the ship was found to comply with the relevant provisions of the Convention:

Signed ....
(Signature of authorized official)

Place ....

Date..........................…..

(Seal or stamp of the authority, as appropriate)

ENDORSEMENT TO EXTEND THE CERTIFICATE IF VALID
FOR LESS THAN 5 YEARS WHERE REGULATION E-5.3 APPLIES

The ship complies with the relevant provisions of the Convention, and this Certificate shall, in accordance with regulation E-5.3 of the Annex to the Convention, be accepted as valid until………………………

Signed ....
(Signature of authorized official)

Place ....

Date..........................…

(Seal or stamp of the authority, as appropriate)

ENDORSEMENT WHERE THE RENEWAL SURVEY HAS BEEN
COMPLETED AND REGULATION E-5.4 APPLIES

The ship complies with the relevant provisions of the Convention and this Certificate shall, in accordance with regulation E-5.4 of the Annex to the Convention, be accepted as valid until …………………

Signed ....
(Signature of authorized official)

Place ....

Date............................…

(Seal or stamp of the authority, as appropriate)

---

* Delete as appropriate

ENDORSEMENT TO EXTEND THE VALIDITY OF THE CERTIFICATE UNTIL REACHING THE PORT OF SURVEY OR FOR A PERIOD OF GRACE WHERE REGULATION E-5.5 OR E-5.6 APPLIES

This Certificate shall, in accordance with regulation E-5.5 or E-5.6* of the Annex to the Convention, be accepted as valid until …………………..

Signed ....
(Signature of authorized official)

Place ....

Date...........................…

(Seal or stamp of the authority, as appropriate)

ENDORSEMENT FOR ADVANCEMENT OF ANNIVERSARY DATE WHERE REGULATION E-5.8 APPLIES

In accordance with regulation E-5.8 of the Annex to the Convention the new Anniversary date is …………….

Signed ....
(Signature of authorized official)

Place ....

Date...........................…

(Seal or stamp of the authority, as appropriate)

In accordance with regulation E-5.8 of the Annex to the Convention the new Anniversary date is …………….

Signed ....
(Signature of duly authorized official)

Place ....

Date...........................…

(Seal or stamp of the authority, as appropriate)

* Delete as appropriate

APPENDIX II

FORM OF BALLAST WATER RECORD BOOK

INTERNATIONAL CONVENTION FOR THE CONTROL AND MANAGEMENT OF SHIPS' BALLAST WATER AND SEDIMENTS

Period From: …..…… To: ………..

Name of Ship ………………………………………..………………...

IMO number …………….…………………………………..……..…

Gross tonnage ……………………………………………………

Flag …………………………………………………………………

Total Ballast Water capacity (in cubic metres) ……………………..….

The ship is provided with a Ballast Water Management plan ☐

Diagram of ship indicating ballast tanks:

1 Introduction

In accordance with regulation B-2 of the Annex to the International Convention for the Control and Management of Ships' Ballast Water and Sediments, a record is to be kept of each Ballast Water operation. This includes discharges at sea and to reception facilities.

2 Ballast Water and Ballast Water Management

"Ballast Water" means water with its suspended matter taken on board a ship to control trim, list, draught, stability, or stresses of a ship. Management of Ballast Water shall be in accordance with an approved Ballast Water Management plan and taking into account Guidelines[3] developed by the Organization.

3 Entries in the Ballast Water Record Book

Entries in the Ballast Water record book shall be made on each of the following occasions:

3.1 When Ballast Water is taken on board:

.1 Date, time and location port or facility of uptake (port or lat/long), depth if outside port

[3] Refer to the Guidelines for the control and management of ships' ballast water to minimize the transfer of harmful aquatic organisms and pathogens adopted by the Organization by resolution A.868(20).

.2 Estimated volume of uptake in cubic metres

.3 Signature of the officer in charge of the operation.

3.2 Whenever Ballast Water is circulated or treated for Ballast Water Management purposes:

.1 Date and time of operation

.2 Estimated volume circulated or treated (in cubic metres)

.3 Whether conducted in accordance with the Ballast Water Management plan

.4 Signature of the officer in charge of the operation

3.3 When Ballast Water is discharged into the sea:

.1 Date, time and location port or facility of discharge (port or lat/long)

.2 Estimated volume discharged in cubic metres plus remaining volume in cubic metres

.3 Whether approved Ballast Water Management plan had been implemented prior to discharge

.4 Signature of the officer in charge of the operation.

3.4 When Ballast Water is discharged to a reception facility:

.1 Date, time, and location of uptake

.2 Date, time, and location of discharge

.3 Port or facility

.4 Estimated volume discharged or taken up, in cubic metres

.5 Whether approved Ballast Water Management plan had been implemented prior to discharge

.6 Signature of officer in charge of the operation

3.5 Accidental or other exceptional uptake or discharges of Ballast Water:

.1 Date and time of occurrence

.2 Port or position of the ship at time of occurrence

.3 Estimated volume of Ballast Water discharged

.4 Circumstances of uptake, discharge, escape or loss, the reason therefore and general remarks.

.5 Whether approved Ballast Water Management plan had been implemented prior to discharge

.6 Signature of officer in charge of the operation

3.6 Additional operational procedure and general remarks

4 Volume of Ballast Water

The volume of Ballast Water onboard should be estimated in cubic metres. The Ballast Water record book contains many references to estimated volume of Ballast Water. It is recognized that the accuracy of estimating volumes of ballast is left to interpretation.

RECORD OF BALLAST WATER OPERATIONS

SAMPLE BALLAST WATER RECORD BOOK PAGE

Name of Ship: ………………………………………………

Distinctive number or letters ……………………………….

Date	Item (number)	Record of operations/signature of officers in charge

Signature of master ………………………………..

designee determines necessary to adjudicate a specific claim.

(3) *ECHO provider exclusion or suspension.* A provider of ECHO services or items may be excluded or suspended for a pattern of discrimination on the basis of disability. Such exclusion or suspension shall be accomplished according to the provisions of § 199.9.

* * * * *

■ 7. Section 199.7 is amended by revising paragraphs (a)(2) and (b)(2)(xii) to read as follows:

§ 199.7 Claims submission, review, and payment.

(a) * * *

(2) *Claim required.* No benefit may be extended under the Basic Program or Extended Care Health Option (ECHO) Program without submission of an appropriate, complete and properly executed claim form.

* * * * *

(b) * * *

(2) * * *

(xii) *Other authorized providers.* For items from other authorized providers (such as medical supplies), an explanation as to the medical need must be attached to the appropriate claim form. For purchases of durable equipment and durable medical equipment under the ECHO, it is necessary also to attach a copy of the preauthorization.

* * * * *

■ 8. Section 199.8 is amended by revising paragraphs (d)(4) and (d)(5) to read as follows:

§ 199.8 Double coverage.

* * * * *

(d) * * *

(4) *Extended Care Health Option (ECHO).* For those services or supplies that require use of public facilities, an ECHO eligible beneficiary (or sponsor or guardian acting on behalf of the beneficiary) does not have the option of waiving the full use of public facilities which are determined by the Director, TRICARE Management Activity or designee to be available and adequate to meet a disability related need for which an ECHO benefit was requested. Benefits eligible for payment under a state plan for medical assistance under Title XIX of the Social Security Act (Medicaid) are never considered to be available in the adjudication of ECHO benefits.

(5) *Primary payer.* The requirements of paragraph (d)(4) of this section notwithstanding, TRICARE is primary payer for services and items that are provided in accordance with the Individualized Family Service Plan as required by Part C of the Individuals with Disabilities Education Act and that are medically or psychologically necessary and otherwise allowable under the TRICARE Basic Program or the Extended Care Health Option.

* * * * *

■ 9. Section 199.20 is amended by revising paragraph (p)(2)(i) to read as follows:

§ 199.20 Continued Health Care Benefits Program (CHCBP).

* * * * *

(p) * * *

(2) * * *

(i) The Extended Care Health Option (ECHO) under § 199.5.

* * * * *

■ 10. Appendix A to part 199 is amended by adding the term ''ECHO'' and removing the term ''PFPWD'' to read as follows:

Appendix A to Part 199—Acronyms

* * * * *

ECHO—Extended Care Health Option

* * * * *

Dated: July 20, 2004.

L.M. Bynum,

Alternate OSD Federal Register Liaison Officer, Department of Defense.

[FR Doc. 04–16932 Filed 7–27–04; 8:45 am]

BILLING CODE 5001–06–P

DEPARTMENT OF HOMELAND SECURITY

Coast Guard

33 CFR Part 151

[USCG–2003–14273]

RIN 1625–AA52

Mandatory Ballast Water Management Program for U.S. Waters

AGENCY: Coast Guard, DHS.

ACTION: Final rule.

SUMMARY: The Coast Guard is requiring mandatory ballast water management practices for all vessels equipped with ballast water tanks bound for ports or places within the U.S. or entering U.S. waters. This rule will increase the Coast Guard's ability to protect U.S. waters against the unintentional introduction of nonindigenous species via ballast water discharges, which have had significant impacts on the nation's marine and freshwater resources, biological diversity, and coastal infrastructure. It will also comply with the requirements of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 and the National Invasive Species Act of 1996. The Great Lakes ballast water management program remains unchanged.

DATES: This final rule is effective September 27, 2004.

ADDRESSES: Comments and material received from the public, as well as documents mentioned in this preamble as being available in the docket, are part of docket USCG–2003–14273 and are available for inspection or copying at the Docket Management Facility, U.S. Department of Transportation, room PL–401, 400 Seventh Street SW., Washington, DC, between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays. You may also find this docket on the Internet at *http://dms.dot.gov.*

FOR FURTHER INFORMATION CONTACT: If you have questions on this rule, call Mr. Bivan R. Patnaik, Project Manager, Environmental Standards Division, Coast Guard, telephone 202–267–1744, e-mail: *bpatnaik@comdt.uscg.mil.* If you have questions on viewing the docket, call Andrea M. Jenkins, Program Manager, Docket Operations, telephone 202–366–0271.

SUPPLEMENTARY INFORMATION:

Legislative and Regulatory History

The Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA) [Pub. L. 101–646], enacted by Congress on November 29, 1990, established the Coast Guard's regulatory jurisdiction over ballast water management (BWM). To fulfill the directives of NANPCA, the Coast Guard published a final rule on April 8, 1993, titled ''Ballast Water Management for Vessels Entering the Great Lakes'' in the **Federal Register** (58 FR 18330). This rule established mandatory BWM procedures for vessels entering the Great Lakes in 33 CFR part 151, subpart C.

A subsequent final rule titled ''Ballast Water Management for Vessels Entering the Hudson River'' was published on December 30, 1994, in the **Federal Register** (59 FR 67632). This final rule amended 33 CFR part 151 to extend the BWM requirements into portions of the Hudson River.

The National Invasive Species Act (NISA) [Pub. L. 104–332] enacted by Congress on October 26, 1996, reauthorized and amended NANPCA. NISA reemphasized the significant role of ships' ballast water in the introduction and spread of nonindigenous species (NIS). NISA authorized the Coast Guard to develop a voluntary national BWM program and mandated the submission of reporting forms without penalty provisions. On

May 17, 1999, the Coast Guard published an interim rule on this voluntary program titled, ''Implementation of the National Invasive Species Act of 1996 (NISA)'' (64 FR 26672) and finalized the rule on November 21, 2001 (66 FR 5838).

NISA also instructed the Secretary of the Department in which the Coast Guard is operating (the Coast Guard was operating under the Department of Transportation when NISA was enacted) to submit a Report to Congress evaluating the effectiveness of the voluntary BWM program. Congress anticipated that the Secretary might determine that either compliance with the voluntary guidelines was inadequate, or the rate of reporting was too low to allow for a valid assessment of compliance. In either case, Congress stipulated the development of additional regulations to make the voluntary guidelines a mandatory BWM program. The Secretary's Report to Congress, signed June 3, 2002, concluded that compliance with the voluntary guidelines, found in 33 CFR part 151, subpart D, was insufficient to allow for an accurate assessment of the voluntary BWM regime. Accordingly, the Secretary stated his intention to make the voluntary BWM guidelines mandatory. A copy of this Report to Congress can be found in the public docket (USCG–2002–13147) at *http://dms.dot.gov.*

On June 14, 2004 (69 FR 32864), we published a final rule titled ''Penalties for Non-submission of Ballast Water Management Reports'' that implemented penalties for failure to comply with the mandatory requirements found in 33 CFR part 151 and widened the applicability of the reporting and recordkeeping requirements to all vessels bound for ports or places within the U.S., with minor exceptions.

On July 30, 2003, we published a notice of proposed rulemaking titled ''Mandatory Ballast Water Management Program for U.S. Waters'' in the **Federal Register** (68 FR 44691). We received 38 letters commenting on the proposed rule. No public meeting was held on this rulemaking.

Background and Purpose

As directed by NISA and as stated in the Secretary of Transportation's Report to Congress in June 2002, the Coast Guard has determined that the voluntary BWM program is inadequate because sufficient compliance has not occurred. Therefore, as of the effective date of this rule, the Coast Guard has converted the voluntary BWM program into a mandatory program. This rule will increase the Coast Guard's ability to protect against introductions of NIS via ballast water discharges.

On March 1, 2003, the Coast Guard became a component of the Department of Homeland Security. As a result, the Secretary of the Department of Homeland Security assumed all duties once bestowed on the Secretary of the Department of Transportation with respect to this rule. The Secretary of Homeland Security concurs with the Coast Guard's rule regarding the mandatory BWM program.

This final rule revises 33 CFR part 151, subpart D, by requiring a mandatory BWM program for all vessels equipped with ballast water tanks bound for ports or places within the U.S. and/or entering U.S. waters. The mandatory BWM requirements for vessels entering the Great Lakes and Hudson River from outside the U.S. Exclusive Economic Zone (EEZ) remain unchanged.

The mandatory program requires all vessels equipped with ballast water tanks entering U.S. waters after operating beyond the EEZ to employ at least one of the following BWM practices:

(a) Prior to discharging ballast water in U.S. waters, perform complete ballast water exchange in an area no less than 200 nautical miles (nm) from any shore.

(b) Retain ballast water onboard the vessel.

(c) Prior to the vessel entering U.S. waters, use an alternative environmentally sound method of BWM that has been approved by the Coast Guard.

Although the national mandatory BWM program provides vessels with the option of using one of three BWM practices, ballast water exchange is likely to be the most used practice because—

• Some vessels engaged in trade are unlikely to hold their ballast water after arriving in U.S. waters from outside the EEZ, as this would mean they would not be able to conduct cargo operations;

• Alternative environmentally sound methods of BWM are still being developed and will likely be of limited availability in the near future; and

Therefore, under this rule, the BWM practice of conducting mid-ocean ballast water exchange prior to discharging ballast water in U.S. waters will be the practice used by the majority of vessels at this time.

Mid-ocean ballast water exchange is currently the most practicable method to help prevent the introductions of NIS into U.S. waters. Water in the open ocean contains certain physical, chemical, and biological conditions (such as high salinity). Organisms contained in ballast water that is exchanged in mid-ocean will not, or are unlikely to survive in an open ocean system. Likewise organisms that are contained in ballast water after a mid-ocean exchange is conducted will not, or are unlikely to survive if introduced into a freshwater or coastal system.

As mid-ocean ballast water exchange will be the most likely used BWM practice at this time, there are those vessels with voyage and/or safety concerns that will not be able to conduct ballast water exchange. Voyage and/or safety concerns may include security concerns since these issues have increased significantly due to recent events. NISA requires us to take into consideration different operating conditions in developing the mandatory BWM program. Therefore, a vessel that cannot practicably meet the requirements of paragraph (a) above due to a voyage that does not take it into waters at least 200 nm from any shore for a sufficient length of time or due to safety concerns will retain its ballast onboard. The vessel will not be prohibited from discharging the minimum amount of its ballast water necessary to maintain the safety of the vessel in areas other than the Great Lakes and the Hudson River. However, the vessel must discharge only the amount of ballast water operationally necessary for safety concerns. An entry must be made in the ballast water records supporting the reasons that the vessel could not comply with the regulatory requirements. Ballast water records must be made available to the local Captain of the Port (COTP) upon request.

This final rule also revises the criteria for a mid-ocean exchange by removing the constraints of exchanging ballast water in waters at a depth of 2,000 meters. Currently, there is no international consensus on a water-depth criterion for ballast water exchange. For example, Australian legislation has a depth requirement of 200 meters, and Israel's ballast water exchange requirement has no depth restriction, while the International Maritime Organization (IMO) Convention for the Control and Management of Ship's Ballast Water and Sediments, recently adopted on February 9, 2004, has a criterion of 200 meters. As there is no international consensus to mid-ocean ballast water exchange criteria, at this time, we believe defining mid-ocean ballast water exchange as taking place at least 200 nm from shore allows more vessels to conduct exchange and simplifies enforceability.

The Coast Guard recognizes that there are two currently feasible methods of conducting an exchange:

- An empty/refill exchange. The tank (or pair of tanks) is pumped down to the point where the pumps lose suction, and then the tank is pumped back up to the original level.
- A flow-through exchange. Mid-ocean water is pumped into a full tank while the existing coastal or fresh water is pumped or pushed out through another opening. As defined by the Coast Guard, a volume of water equal to three times the ballast tank capacity must be pumped for a flow-through exchange.

Failure to employ at least one of the BWM practices outlined above will result in a penalty, unless the vessel is exempt due to safety or voyage constraints or specifically exempted from the regulation.

Each vessel subject to this rule (33 CFR part 151 subpart D) will be required to develop and maintain a BWM plan. The plan shall be specific to each vessel and shall fulfill two purposes: (1) Show that there is a BWM strategy for the vessel; and (2) allow any master, or other ship's officer as appropriate, serving on that vessel to understand and follow the BWM strategy for the vessel. The IMO has issued guidelines on the content of BWM plans in IMO Resolution A.868(20) Annex 1, Chapter 7. Any plan meeting these IMO guidelines will meet the regulatory requirement laid out in § 151.2035(a)(7). This Resolution is available on the IMO's Global Ballast Water Management Programme Web site [*http://globallast.imo.org*]. For your reference, we have also placed a copy of the IMO guidelines in the docket for this rule at the location listed above under **ADDRESSES.** Failure to maintain a BWM plan onboard the vessel or to make the required ballast water reporting forms available will result in penalties.

Discussion of Comments and Changes

We received 38 letters on the proposed rulemaking for BWM. Most letters contained more than one comment. These included general comments as well as specific comments. We address the general comments first and then the specific comments.

General Comments

We received 16 comments in general support of the rule. One of these commenters supported the requirement that vessels must maintain BWM plans and that they should be modeled after IMO guidelines. One commenter supported the provisions of the rule that would not require vessels to deviate from their voyages or delay their voyages in order to conduct ballast water exchange.

One commenter stated that effective BWM and reporting are critical to maintaining the ecological and economic well being of coastal Alaska.

Three commenters stated that the U.S. mandatory BWM program should be consistent with IMO guidelines and supported our removal of the depth requirement for conducting ballast water exchange. One commenter stated that the Coast Guard did not adequately explain why ballast water exchange is acceptable in waters less than 2,000 meters deep.

We agree with the commenters. We have developed the BWM program to be as consistent with IMO guidelines as practicable. For example, and as recognized by the commenters, under the voluntary BWM program, we requested that ballast water exchange take place in an area 200 nm from shore and at a depth of 2,000 meters. To be consistent with IMO guidelines, we modified the mandatory program to require that ballast water exchange take place 200 nm from shore, without regard to water depth. We believe this harmonization will help vessel operators that must follow both IMO guidelines and U.S. requirements. As stated in the proposed rulemaking (68 FR 44691), there is not consensus on water depth criterion for ballast water exchange. Because there is no scientific consensus on a specific water depth that is suitable for exchange, and for the reasons stated above, we aligned our requirements with IMO guidelines.

One commenter stated that there should be no vessels exempt from the mandatory BWM program.

We disagree with the commenter. NISA authorizes specific exemptions for crude oil tankers engaged in coastwise trade and Department of Defense and Coast Guard vessels. Therefore, we do not currently have the authority to include these vessels in the applicability for the final rule.

One commenter requested that the Coast Guard host a public meeting on the Programmatic Environmental Assessment (PEA).

The Coast Guard does not intend to hold a public meeting for the PEA. We believe that the comment period provided ample opportunity for the public to suggest other alternatives to the one examined in the PEA.

Two commenters stated that there should be a publicly accessible database for nationwide ballast water discharges.

National ballast water discharge data is publicly available and can be found at the Web site for the National Ballast Information Clearinghouse at *http://invasions.si.edu/NBIC/ballast.html.*

One commenter asked if vessels discharging ballast water should be regulated under the Environmental Protection Agency's (EPA) National Pollution Discharge Elimination System (NPDES) Program.

This comment was the subject of a petition submitted to EPA on January 13, 1999. EPA responded to this petition on September 9, 2003 to comply with a court order (68 FR 53165). The Coast Guard opined, during the legal proceedings, that regulation of vessels discharging ballast water should remain under the authority of the Coast Guard. EPA, for the reasons set out in its September 9, 2003, petition denial, does not regulate vessels discharging ballast water under the NPDES program.

One commenter asked if the Coast Guard would identify ''high-risk vessels'' and if we would encourage their owners to install ballast water treatment systems. This commenter also asked if the Coast Guard has funding to conduct research onboard vessels.

The Coast Guard does not have the ability to identify ''high-risk vessels'' with respect to NIS, nor have we defined this term in our regulations. Further, the Coast Guard does not have funding to conduct research onboard vessels; however, we have developed a Shipboard Technology Evaluation Program (STEP) that encourages owners to install and test various technologies for ballast water treatment. This program was established in January 2004, through a Navigation and Inspection Circular (NVIC 01–04) and announced in a Notice of Availability published in the **Federal Register** on January 7, 2004 (69 FR 1082).

One commenter asked how the Coast Guard, in conjunction with EPA and the States, will develop education and outreach programs for BWM.

We intend to develop guidance regarding BWM procedures and recommended practices. This guidance will take into account coordination with EPA and other Federal and State agencies. Additionally, class societies and IMO have published guidance on best practices and procedures for BWM that is specific to ship type.

One commenter stated there has been a misunderstanding among mariners on what constitutes a ''full exchange.''

As defined in § 151.2025, there are two methods of exchange, either ''flow through'' or ''empty/refill.'' Both exchange methods, as defined in this section, describe what constitutes a full exchange. A ''full exchange'' using the ''flow through'' method means that three full tank volumes of water have been exchanged. A ''full exchange'' using the ''empty/refill'' method means that the ballast tanks are pumped down to the point where the pumps lose suction, and the tank is then refilled to the original level.

One commenter suggested we revise § 151.2030 to remove the distinction between U.S. waters and the Great Lakes. Another commenter stated that the national BWM program should be the same as the program on the Great Lakes.

We agree with these comments; however, the intent of this rule is simply to convert the voluntary national guidelines for BWM to a mandatory, national program. We intend to merge the Great Lakes program and the national program into a single program in a future rulemaking.

One commenter stated that § 151.2037 is not enforceable and is inconsistent with § 151.2035(b) and recommended removing the term ''voyage concerns.''

We disagree with this comment. If a vessel cannot comply with § 151.2035(b) because of ''voyage concerns,'' that vessel is responsible for documenting this action. If there is no documentation, the Coast Guard will assess a monetary penalty for failing to comply with § 151.2037.

One commenter stated that a minimum ballast water transfer quantity or capacity should be established and that BWM or reporting should not be required for volumes below these amounts.

We disagree with the commenter. As directed by NISA, we are required to analyze BWM operations for vessels, regardless of a vessel's ballast capacity or volume of ballast water carried on any particular voyage. Therefore, we are not establishing a minimum quantity or capacity requirement.

One commenter requested clarification on what is expected of vessels in innocent passage in terms of compliance with the rule.

As stated in § 151.2015 titled ''Is a vessel in innocent passage exempt from the mandatory requirements?'' vessels merely traversing the territorial seas of the U.S. (*i.e.*, not entering or departing a U.S. port, or not navigating the internal waters of the U.S.) are exempt from the requirements of 33 CFR part 151. Vessels merely traversing the territorial seas of the U.S. would be considered engaged in ''innocent passage.''

One commenter requested clarification on the definition of ''waters of the U.S.,'' asking if the term means ''territorial waters'' (12 nm from shore) or the U.S. EEZ (200 nm from shore).

''Waters of the U.S.,'' as stated in 33 CFR 151.2025, means waters subject to the jurisdiction of the United States as defined in 33 CFR 2.05–30, including the navigable waters of the United States. For this regulation, the navigable waters include the territorial sea as extended to 12 nautical miles from the baseline, pursuant to Presidential Proclamation No. 5928 of December 27, 1988. We are revising that definition to correct the citation from 33 CFR 2.05–30 to 33 CFR 2.38.

One commenter requested clarification on distance and depth requirements for ballast water exchange.

As stated in § 151.2035(b)(1), ballast water exchange must be performed in an area no less than 200 nm from any shore. Neither the proposed rulemaking nor the final rule for mandatory BWM contains a depth requirement for ballast water exchange.

Two commenters requested clarification for the term ''discharge only the amount operationally necessary.''

This term was intended to allow vessel operators some flexibility in their cargo operations and BWM practices, while protecting the receiving environment to the extent practicable. If ballast water exchange has not been conducted prior to entering U.S. waters, and a vessel operator must conduct cargo operations in a U.S. port, the operator may release the amount of ballast water necessary to conduct safe cargo operations. The vessel operator must make a note of the discharge into the U.S. port on the ballast water reporting form.

Four commenters expressed concern regarding the breadth of these regulations. Two commenters stated concern that some vessels are exempt from conducting ballast water exchange due to voyage constraints and suggested that these vessels employ alternative BWM methods. Two commenters stated that ballast water exchange is not an ''effective solution'' and should not be the ''default solution.'' The Coast Guard should instead focus on a ''zero discharge'' standard.

We understand that ballast water exchange is not the final answer in preventing the introduction of NIS. Currently, there are no alternative BWM methods to ballast water exchange that have been approved by the Coast Guard. We are exploring environmentally sound alternative BWM methods that are at least as effective as ballast water exchange and intend to approve those methods that meet the above criteria in the future. We are not mandating the use of alternative methods in this final rule. Additionally, the Coast Guard intends to establish ballast water discharge standards that prevent the introduction of NIS and are both environmentally protective and economically feasible. As described in the Notice of Intent for our Programmatic Environmental Impact Statement (68 FR 55559), one of the alternatives under consideration would ''result in the discharge of no detectable viable organisms larger than 0.1 microns,'' which is, in essence, a ''zero discharge'' alternative.

One commenter stated that it is premature to establish a mandatory BWM program without first establishing ballast water discharge standards.

We disagree with this commenter. The intent of this final rule is to convert the voluntary BWM program to a mandatory program if we deemed the voluntary BWM program inadequate, as required by NISA. We believe it is inefficient to develop discharge standards without first having an overarching BWM program in place. The Coast Guard is in the process of establishing ballast water discharge standards and evaluating shipboard treatment technologies that could be employed to meet these standards. Ballast water discharge standards will be the subject of a future rulemaking.

Three commenters stated that the mandatory BWM program does not address vessels with no ballast on board (NOBOBs) and that ballast water exchange is not a final answer to preventing the introduction of NIS.

While our final rule for mandatory BWM does not address NOBOBs, we believe that addressing these vessels is an important factor in the prevention of NIS introductions. As a first step, the Coast Guard now requires NOBOBs to submit ballast water reporting forms, as stated in the final rule titled ''Penalties for Non-submission of Ballast Water Management Reports'' published on June 14, 2004 (69 FR 32864). We will continue to explore the issue of NOBOBs entering U.S. waters, and these vessels may be included in a future rulemaking.

One commenter suggested removing the term ''voluntary guidelines'' in § 151.2015 and replacing it with ''mandatory program.''

We agree with the commenter and have amended § 151.2015 to reflect this change.

Three commenters suggested that the definition of ballast water tanks be clarified.

We have added the definition for ''ballast tank,'' currently found in § 151.1504 (151 subpart C) to § 151.2025 (151 subpart D). This definition will help clarify which vessels must comply with the rule.

One commenter recommended that language regarding the BWM plan in § 151.2035(a)(7) should be changed from ''ship's officer'' to ''those responsible for its implementation.''

We agree with the commenter and have amended § 151.2035(a)(7) to clarify the specificity needed in the BWM plan.

One commenter recommended that language in § 151.2035(b)(4) should state that reception facilities be approved by the Coast Guard for receipt and treatment of ballast water.

We disagree with the commenter. The Coast Guard does not currently have the statutory authority to approve reception facilities; therefore adding the language requested by the commenter would be inappropriate. In order to eliminate the confusion created by this provision, and for the reasons discussed in greater detail in the ''Environment'' section, below, we are deleting § 151.2035(b)(4).

Comments Regarding Coastwise Trade

Two commenters recommended that the Coast Guard, in consultation with Canada and IMO, adopt a single set of national or regional ballast water exchange zones along the West Coast to address concerns regarding coastwise voyages. An additional ten commenters asked the Coast Guard to adopt regulations addressing coastwise trade and recommended that we convene a panel of experts to develop alternative ballast water exchange zones within the EEZ.

The final rule does not address coastwise trade because vessels on these voyages cannot conduct a mid-ocean ballast water exchange, due to the fact that they do not travel outside 200 nm of any shore. The Coast Guard is examining the possibility of establishing alternative ballast water exchange zones. As part of this effort, we participated in a workshop for alternative ballast water exchange zones in October 2003, and believe the ideas exchanged at this and future workshops could provide a sound, scientific basis for establishing ballast water exchange zones within the EEZ.

One commenter stated that vessels engaged in coastwise trade should be required to submit ballast water reporting forms.

We agree. As stated in the final rule titled ''Penalties for Non-submission of Ballast Water Management Reports'' (69 FR 32864), as of August 13, 2004, these vessels are required to submit ballast water reporting forms.

One commenter stated that vessels on domestic voyages that do not conduct ballast water operations outside the EEZ should be exempt from this rule.

We agree and as stated in § 151.2005(b), only those vessels equipped with ballast tanks that enter U.S. waters from beyond the EEZ must conduct BWM, with the exception of those vessels exempted in §§ 151.2010 and 151.2015.

Comments on Barges and Towing Vessels

Four commenters asked the Coast Guard to recognize the uniqueness of domestic barges and towing operations by accepting different approaches to ballast water management.

The Coast Guard appreciates the uniqueness of all types of vessels. However, if a barge or tug vessel operates outside the EEZ, it will be required to conduct ballast water management, unless it meets the requirements under § 151.2037.

Three commenters asked the Coast Guard to exempt inland towing vessels and barges from BWM requirements, as they are not equipped with ballast water tanks.

We disagree. Inland towing vessels and barges may be covered even if they are not equipped with ballast water tanks. As stated in the definition for ''ballast tank,'' any vessel that carries ballast water must comply with these regulations. NISA, while allowing for exemptions from BWM, mandates that the BWM program be based on the best scientific information possible. We do not currently have information that would allow us to make specific exemptions for inland towing vessels and barges. We note, however, that those inland towing vessels and barges that never carry ballast water do not fall within the applicability section of this regulation; therefore, no specific exemption is needed. Additionally, vessels that do not transit outside the EEZ, such as most inland towing vessels and barges, are not subject to mandatory BWM requirements.

Four commenters asked the Coast Guard not to require BWM plans for barges and towing vessels that operate within the EEZ. One of these commenters also asked the Coast Guard to provide a template to assist them in developing their plans.

We believe that if towing vessels and barges are equipped with ballast water tanks or use other tanks to ballast and deballast water, these vessels will be required to maintain a BWM plan specific to those vessels. At this time, the Coast Guard does not intend to develop a template for a BWM plan. We recommend that these vessels seek assistance from their class societies or maritime associations. We also suggest that vessel owners refer to IMO guidelines for IMO Resolution A.868(20) Annex 1, which are available in the public docket for this rule.

We received four comments regarding the ballast water reporting form. Two commenters asked the Coast Guard to develop a new ballast water reporting form specific to barges and towing vessels. One commenter expressed concern with the ballast water reporting form. One commenter recommended that the ballast water reporting form include a listing of all locations where ballast water was discharged.

Comments regarding the ballast water reporting form were addressed in the Discussion of Comments section of the final rule for ''Penalties for Non-submission of Ballast Water Reporting Forms'' [69 FR 32864]. At this time we do not intend to develop a ballast water reporting form that is specific to barges and towing vessels; however, we are exploring a potential redesign of the reporting form. Additionally, we wish to note that the locations of all ballast water discharges are already part of the ballast water reporting form. Operators are required to log the coordinates (latitude/longitude) or port where the ballast water was discharged. Ballast water sources are required to be similarly reported on the form.

Two commenters asked the Coast Guard to allow tug and barge operators that carry ballast water and serve domestic coastwise trade to submit reports every 30 days, rather than 24 hours prior to arrival at the first U.S. port. These commenters argued that monthly reporting would ease the administrative burden on the vessel operator.

We disagree with this comment. To change the submission requirements of ballast water reports for tugs and barges from 24 hours to 30 days would delay the accounting of BWM practices, thus denying the Coast Guard the means of enforcing compliance with mandatory ballast water reporting requirements. If the operators of these vessels know their destinations in advance, they may submit multiple reports of their BWM practices to the Coast Guard prior to their arrival.

One commenter stated that coastwise barges will be unable to comply with § 151.2035(b)(1 through 3) because it is ''unsafe'' for barges to conduct ballast water operations in the open sea.

As previously stated, vessels engaged in coastwise trade will not be expected to conduct mandatory BWM under this final rule. Additionally, § 151.2037 states that a vessel that cannot meet the requirements of § 151.2035(b)(1–3) because of safety concerns will not be prohibited from discharging ballast water in areas other than the Great Lakes and Hudson River; however, the vessel must discharge only that amount that is operationally necessary and make ballast water records available to the local COTP upon request.

Comments on Compliance and Enforcement

Three commenters asked how the Coast Guard would ensure that a vessel has conducted BWM.

The vessel owner or operator must maintain accurate copies of the ballast water records onboard the vessel as required by 33 CFR 151.2045 and the forms must be readily available upon request. Additionally, we will use the ballast water reporting forms that must be submitted in advance of a vessel arriving at a U.S. port as required by 33 CFR 151.2040 to verify and ensure that the vessel has conducted BWM. We are actively pursuing ballast water exchange verification technologies, and when these technologies are available, we will employ them as appropriate.

One commenter requested a discussion on penalties, including failure to keep required records, failure to record why BWM was not conducted, and the range of potential penalties for these violations.

We addressed penalties for violations of BWM and non-submission of reporting forms at length in the preamble to the final rule titled ''Penalties for Non-submission of Ballast Water Reporting Forms'' [69 FR 32864].

Two commenters raised issues regarding penalties. One commenter asked if monetary penalties for violating these regulations would be based on a flat fee or a weighted fee based on ship size or amount of ballast water. One commenter asked that the Coast Guard assess penalties that deter inaccurate reporting or failure to report ballast water discharge information.

Monetary civil penalties associated with violations of this rule will not be based on a flat fee or based on ship size or ballast water amount. Penalties for failure to comply with any of the BWM regulations, including reporting requirements, will be assessed on a case-by-case basis. We have the discretion to issue a penalty of up to $27,500, depending on the facts of each individual case, and each day is considered a separate violation, pursuant to NISA.

One commenter urged the Coast Guard to use the existing Port State Control (PSC) program to enforce the BWM program.

We partially agree with the commenter. BWM reports will not be considered in the ''scoring matrix'' used to prioritize boardings and inspections under the Coast Guard's PSC program at this time. However, inspectors boarding vessels that arrive in U.S. ports may ask for any documentation regarding a vessel's BWM practices during the inspection process. Inspectors may also target specific vessels if they believe these vessels are not in compliance with the mandatory BWM provisions. As a result, BWM maybe become a future part of PSC. We intend to publish a NVIC that describes our intended enforcement activities for BWM. The NVIC will be available to all interested stakeholders through their local COTP or the Office of Operating and Environmental Standards at *http://www.uscg.mil/hq/gm/mso/index.html.*

Comments Beyond the Scope of This Rule

One commenter recommended that a fund be established from noncompliance fees to remediate ballast water-related impact areas.

We think this type of program is a novel concept; however, the Coast Guard does not currently have the authority to establish or administer such a program.

Five commenters stated that establishing ballast water discharge standards should be a priority for the Coast Guard.

We agree with commenters; however, ballast water discharge standards will be addressed in a future rulemaking.

One commenter stated that vessels on voyages outside the EEZ that do not perform any ballasting operations while outside the EEZ should not have to submit a ballast water reporting form.

We disagree with the commenter. As stated in the final rule titled ''Penalties for Non-submission of Ballast Water Management'' [69 FR 32864], vessels are required to submit a ballast water reporting form if they transit within U.S. waters, regardless of where they operate, with minor exceptions, such as a vessel in innocent passage.

Two commenters stated that the rule does not give any consideration to the National Aquatic Invasive Species Act (NAISA).

While introduced into Congress, NAISA has not yet been enacted. We will monitor NAISA's progress through Congress, but will not begin implementing any portions of the Act before it becomes law.

One commenter stated that the Coast Guard's highest priority should be establishing an experimental technology approval program.

On January 7, 2004, the Coast Guard published NVIC 01–04, as announced in the **Federal Register** (69 FR 1082), describing the STEP application process. We are actively reviewing and providing feedback on all applications received to date.

One commenter recommended that the Coast Guard consider a specific treatment technology.

The Coast Guard cannot recommend specific technologies without first evaluating their effectiveness and environmental soundness. We encourage any parties that believe they have shipboard technologies to prevent the introduction of NIS to participate in the Coast Guard's STEP.

One commenter suggested that the Coast Guard encourage the Canadian and Mexican governments to adopt BWM regulations similar to ours.

We agree that international coordination, particularly with Canada and Mexico, is essential for the successful prevention of NIS introductions. The U.S. is currently working with Canada under the auspices of the International Joint Commission to address the prevention of NIS. Both Canada and Mexico participate as invited observers to the Aquatic Nuisance Species Task Force. We will continue to work with all countries to address the challenges posed by invasive species.

Regulation Evaluation

This rule is a ''significant regulatory action'' under section 3(f) of Executive Order 12866, Regulatory Planning and Review. The Office of Management and Budget has reviewed it under that Order. It requires an assessment of potential costs and benefits under section 6(a)(3) of that Order. It is significant under the regulatory policies and procedures of the Department of Homeland Security. A final Regulatory Evaluation is available in the docket as indicated under **ADDRESSES.** A summary of the Regulatory Evaluation follows and is available in the public docket for this rule.

We received 5 comments on the Regulatory Evaluation. One commenter stated that annual costs for BWM should be explained in the final rule.

We have included a summary of the annual costs for BWM in this preamble to the final rule. A detailed analysis of annual costs for BWM can be found in the final Regulatory Evaluation, which is available in the public docket for this rule.

Two commenters stated that our estimated costs for ballast water exchange were too low. One commenter stated that a single exchange for a large bulk carrier would be several times more than our estimate. The second commenter stated that the annual cost for container ships would be higher than our estimate.

Our cost-per-exchange estimates are based on information from class societies, ballast water literature, and the U.S. Maritime Administration. We believe that the alternate estimates provided by the commenters greatly overstate, in one case by an order of magnitude, the costs of ballast water exchange. Additionally, these commenters did not provide documentation or substantiation for their alternate estimates. We have not, therefore, modified our cost estimates based on these comments.

One commenter generally agreed with the analysis, but expressed concern that costs to the environment were understated and more information should be provided. Another commenter stated that we must consider the costs to local communities and ecosystems if NIS continue to gain a foothold in Alaskan waters.

We did not estimate the annual benefit of BWM in monetary terms. Instead, we supplied a literature review providing estimated damages resulting from invasions. In this review, we discuss potential damages from NIS to local communities and ecosystems. Much of this literature revolves around the damages caused by the zebra mussel in the Great Lakes and Mississippi River basin. In our Regulatory Evaluation, we were careful to note that we do not believe that this rule will prevent a species as destructive as the zebra mussel from becoming established because the uncertainties surrounding invasions are numerous. We believe that ballast water exchange will provide a measure of protection to the environment. However, ballast water exchange is not the final answer to preventing invasions and, therefore, we do not wish to overstate the potential benefits of exchange. We will revisit environmental damages in our Regulatory Assessment and Environmental Impact Statement in a future rulemaking for ballast water discharge standards. A summary of the Regulatory Evaluation follows.

This Regulatory Evaluation identified the vessel population affected by the rule and provides cost and benefit models for the current principal option of BWM provided for under the rule-ballast water exchange. Any vessel equipped with ballast tanks entering U.S. waters from outside the EEZ must conduct BWM, with minor exceptions. The vessel population was categorized by vessel type under the assumption that vessels in different cargo services and of different sizes likely manage ballast water in different ways. We estimated that approximately 7,420 vessels will be affected and approximately 11,500 ballast water exchanges will be performed annually. Annual costs totaled approximately $15.8 million. The 10-year present value cost for this rule is $116.7 million. These costs do not account for the Great Lakes program, which was not part of this rule.

The benefit assessment expanded on the analysis conducted for costs by focusing on the probability of viable organisms being introduced into U.S. waters through ballast water discharge, both before the rule and following the implementation of mandatory BWM. A probability of a reduction in the number of invasions of NIS was calculated using data on voyages, vessel types, ballast water volumes, and exchange effectiveness, as well as order-of-magnitude assumptions about the probabilities of inoculations, introductions, and invasions resulting from ballast water discharges. The calculations indicated the rule may result in avoiding approximately 10 inoculations that result in invasions for each year the rule is in effect. While there is considerable uncertainty in these calculations and the order-of-magnitude assumptions (referred to as the ‘‘rule of 10s’’ in the Regulatory Evaluation) are admittedly an oversimplification of a complex problem, we believe their simplicity and transparency are compelling. To date, there is no national estimate of the invasion rate of NIS, and we cannot compare our baseline invasion estimate to other, more limited estimates regarding invasions. Our findings are broadly consistent, however, with other estimates of the rate of NIS invasions. One study finds that in the San Francisco Bay and Delta, invasions have increased from one new species every 55 weeks (1851–1960) to one new species every 14 weeks (1961–1995) (Cohen and Carlton, 1998). Another study posits that invasion rates may have increased in the San Francisco Bay and the Great Lakes over the past several decades (Mills, et al., 1993). Finally, some researchers believe that the increase of initial invasions is best described by an exponential function (Ruiz, et al., 2000). Using our simple methodology, we found that an invasion occurs about twice every 3 weeks somewhere in the U.S.

There is considerable difficulty in estimating monetized damages resulting from NIS invasions. Some species impose significant, long-term damages on marine industries and infrastructure. Other species may create subtle disturbances in ecosystems that are difficult to quantify. Still others may be relatively benign. There have been attempts to estimate monetized damages for a few species, most notably the zebra mussel. One study estimated costs to Great Lakes water users, mostly due to fouling of intake structures, of $120 million over the time period 1989 to 1994 (Hushak, 1996). Another estimated cumulative zebra mussel impacts of $750 million to $1 billion over the time period 1989 to 2000 (Carlton, 2001). Other species for which monetized damage estimates have been developed include the Asian clam ($1 billion per year, OTA, 1993) and European green crab ($44 million per year, CRS, 1999). Eight Federal agencies that sit on the National Invasive Species Council collectively spent $514 million in 1999 and $631 million in 2000 for the control and management of NIS (GAO, 2000).

We have not reviewed the methodologies used to produce these estimates in detail, though all of them (except expenditures by Federal agencies) involve considerable uncertainty. They are indicative, however, of the magnitude of damages that may result from particularly destructive invasions. It is likely, however, that most invasions would result in considerably lower damages than the numbers reported in these studies. Because of the lack of data on damages potentially associated with any but the most destructive invasions, we have not tried to monetize the benefits of the rule. If the rule resulted in avoiding even one invasion of this magnitude over the course of several decades, however, the benefits of the rule would most likely justify the costs.

Small Entities

We did not receive any comments on small entities. Of the affected population of all vessels arriving at U.S ports, we estimate that 21 vessels of the 171 U.S. flag vessels, are owned by 10 small businesses. Approximately 35 large companies own the remaining 150 U.S.-flagged vessels. We estimate all vessels will choose the alternative of conducting a mid-ocean ballast water exchange. The cost of complying with this rule is the cost of exchanges performed by the vessel added to the cost of additional maintenance required for the ballast water pumping system. The cost per exchange is a function of vessel type. Each vessel's costs will be a function of the cost of exchange for that vessel type multiplied by the number of trips into U.S. waters from outside the U.S. EEZ. Thus the annual impact on the revenue for a small business will vary with the number of entries the vessel makes from outside the U.S. EEZ. In order to estimate the upper bound of that impact, we calculated the cost of exchange for the maximum number of exchanges possible for the years 1999 and 2000. We then assumed that weather conditions and transit tracks allowed exchanges for all of these entries. For the annual cost of the rule, the number of vessels owned by each small business is multiplied by the number of exchanges performed, and the resulting product is then multiplied by the cost of exchange for the particular vessel type, and added to the maintenance cost of 10 percent of the capital cost of the ballast pump. Of the 10 small businesses that own vessels affected by the rule, we found revenue for nine. For the remaining company where no revenue information was available, we assumed revenue of $1 million for the purposes of the analysis. Table 1 gives the effect of the rule on the average annual revenues for the small business affected. For more detailed information, refer to the Regulatory Evaluation in the docket.

TABLE 1.—EFFECT OF BWM ON AVERAGE ANNUAL REVENUE FOR SMALL BUSINESS ENTITIES OWNING U.S.-FLAGGED VESSELS

Percent of annual revenue that is BWM rule cost	Total small entities per impact category
0–3	8
3–5	2
> 5	0
Total	10

Assistance for Small Entities

Under section 213(a) of the Small Business Regulatory Enforcement Fairness Act of 1996 (Pub. L. 104–121), we want to assist small entities in understanding this rule so that they can better evaluate its effects on them and participate in the rule. If the rule will affect your small business, organization, or governmental jurisdiction and you have questions concerning its provisions or options for compliance, please consult Bivan Patnaik, G–MSO–4, Coast Guard, telephone 202–267–1744, e-mail: *Bpatnaik@comdt.uscg.mil*.

Small businesses may send comments on the actions of Federal employees who enforce, or otherwise determine compliance with, Federal regulations to the Small Business and Agriculture Regulatory Enforcement Ombudsman and the Regional Small Business Regulatory Fairness Boards. The Ombudsman evaluates these actions annually and rates each agency's responsiveness to small business. If you wish to comment on actions by employees of the Coast Guard, call 1–888–REG–FAIR (1–888–734–3247).

Collection of Information

This rule modifies an existing collection of information under the Paperwork Reduction Act of 1995 (44 U.S.C. 3501–3520). We received several comments regarding general collection of information issues. These comments were addressed in the discussion of comments above.

As required by 44 U.S.C. 3507(d), we submitted a copy of the proposed rule to the Office of Management and Budget (OMB) for its review of the collection of information. OMB approved the change to the collection on September 9, 2003: OMB Control Number 1625–0069, expiring on September 30, 2006.

You are not required to respond to a collection of information unless it displays a currently valid OMB control number.

Federalism

A rule has implications for federalism under Executive Order 13132, Federalism, if it has a substantial direct effect on State or local governments and would either preempt State law or impose a substantial direct cost of compliance on them. We received three comments pertaining to Federalism.

Two commenters asked how the Coast Guard is developing partnerships with State agencies to coordinate various BWM policies and research programs for treatment installation. A third commenter asked if States wishing to require stricter standards could issue ''supplements'' that would be enforced only in the issuing States.

As stated in the ''Federalism'' section of the proposed rulemaking, Congress clearly intended for a Federal-State cooperative regime and not for Federal preemption of State requirements. Thus, each State is authorized under NISA to develop its own regulations, including its own research programs, if it believes that Federal regulations or programs are not stringent enough.

We have analyzed this rule under Executive Order 13132. NANPCA contains a ''savings provision'' that provides States the authority to ''adopt or enforce control measures for aquatic nuisance species, [and nothing in the Act would] diminish or affect the jurisdiction of any States over species of fish and wildlife.'' 16 U.S.C. 4725. It also requires that ''all actions taken by Federal agencies in implementing the provisions of [the Act] be consistent with all applicable Federal, State and local environmental laws.'' Thus, the congressional mandate is clearly for a Federal-State cooperative regime in combating the introduction of aquatic nuisance species into U.S. waters from ships' ballast tanks. This makes it unlikely that preemption, which would necessitate consultation with the States under Executive Order 13132, would occur.

Unfunded Mandates Reform Act

The Unfunded Mandates Reform Act of 1995 (2 U.S.C. 1531–1538) requires Federal agencies to assess the effects of their discretionary regulatory actions. In particular, the Act addresses actions that may result in the expenditure by a State, local, or tribal government, in the aggregate, or by the private sector of $100,000,000 or more in any one year. Though this rule will not result in such an expenditure, we do discuss the effects of this rule elsewhere in this preamble. We did not receive any comments regarding unfunded mandates.

Taking of Private Property

This rule will not effect a taking of private property or otherwise have taking implications under Executive Order 12630, Governmental Actions and Interference with Constitutionally Protected Property Rights. We did not receive any comments regarding the taking of private property.

Civil Justice Reform

This rule meets applicable standards in sections 3(a) and 3(b)(2) of Executive Order 12988, Civil Justice Reform, to minimize litigation, eliminate ambiguity, and reduce burden. We did not receive any comments regarding civil justice reform.

Protection of Children

We have analyzed this rule under Executive Order 13045, Protection of Children from Environmental Health Risks and Safety Risks. This rule is not an economically significant rule and does not create an environmental risk to health or risk to safety that may disproportionately affect children. We did not receive any comments regarding the protection of children.

Indian Tribal Governments

This rule does not have tribal implications under Executive Order 13175, Consultation and Coordination with Indian Tribal Governments, because it will not have a substantial direct effect on one or more Indian tribes, on the relationship between the Federal Government and Indian tribes, or on the distribution of power and responsibilities between the Federal Government and Indian tribes. We did not receive any comments regarding Indian Tribal governments.

Energy Effects

We have analyzed this rule under Executive Order 13211, Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use. We have determined that it is not a ''significant energy action'' under that order. Although it is a ''significant regulatory action'' under Executive Order 12866, it is not likely to have a significant adverse effect on the supply, distribution, or use of energy. It has not been designated by the Administrator of the Office of Information and Regulatory Affairs as a significant energy action. Therefore, it does not require a Statement of Energy Effects under Executive Order 13211. We did not receive any comments regarding energy effects.

Environment

The Coast Guard considered the environmental impact of this rule and concluded that preparation of a PEA is necessary and is available in the public docket for this rule. The PEA and Finding of No Significant Impact (FONSI) have been completed and are available in the public docket for inspection. We received nine comments regarding the environment.

Two commenters expressed concern regarding limitations on ballasting in areas near coral reefs, dredging operations, tidal flushing, darkness, and sediment, stating that these types of areas are where their barges load and discharge. One of these commenters also added his concern that his company will not be able to comply with the BWM options.

While we appreciate the commenters' concerns and the effects this rule will have on general operations, we believe that the requirements for ballasting and the options for BWM are necessary to protect the environment from the damages caused by NIS. In order to comply with these requirements, the commenters will have to adjust their ballasting operations accordingly.

One commenter stated that the Coast Guard should include an Essential Fish Habitat determination in the PEA, as required by the Magnuson-Stevens Fishery Act.

We agree with the commenter and have included language regarding essential fish habitat in the PEA.

Two commenters requested that we include language in § 151.2035 regarding conducting BWM near pods of whales, convergence zones, and boundaries of major currents in order to protect threatened or endangered species.

We agree and have amended § 151.2035 to reflect these changes.

Under the consultation process of the Endangered Species Act, the Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS) recommended that the Coast Guard work with ballast water reception facilities and any relevant permitting authorities to address any potential effects to listed species or critical habitats and compliance with the Endangered Species Act.

We have consulted extensively with FWS and NMFS in regards to the issue of approval of facilities to receive ballast water. Currently, there are no ballast water reception facilities in the United States approved for the treatment of ballast water to remove NIS. The Coast Guard is not involved in the regulatory or approval process for ballast water reception facilities. Anyone wishing to establish a ballast water reception facility that would discharge to waters of the United States would need to obtain a National Pollutant Discharge Elimination System (NPDES) permit under the Clean Water Act. Forty-five States and the U.S. Virgin Islands have been approved to issue NPDES permits, and would be the relevant permitting authority. In the remainder of the States, territories, and Indian country that have not been approved to issue NPDES permits, the NPDES permitting authority would be EPA. In the case of a ballast water reception facility that discharges into a local sewage collection system rather than directly to waters of the United States, the discharge would need to comply with local pretreatment requirements and national prohibited discharge standards under section 307 of the Clean Water Act. Non-storm water discharges into a municipal separate storm sewer system are prohibited. Because of these issues, we cannot state with certainty that allowing vessels to discharge their ballast water into a reception facility would be as effective as ballast water exchange in preventing and controlling infestations of NIS as per NISA. As a result, we are eliminating this option from § 151.2035.

The only additional comment regarding reception facilities was a request for Coast Guard approval of such entities, an act that we are not legally authorized to perform. As stated previously, there are no ballast water reception facilities in the United States approved for the treatment of ballast water to remove NIS, nor do we believe there are any applications for approval for such facilities on file. Additionally, all vessels equipped with ballast water tanks would need to be retrofitted with ballast water shore connections in order to utilize a shore-side reception facility. As stated in the Regulatory Evaluation, we do not expect any vessels to utilize the option of discharging into a shore-side facility. Accordingly, we do not believe that eliminating this option from § 151.2035 will have any immediate effect on regulated industry.

The Coast Guard will continue to work with other Federal agencies, such as FWS and NMFS, to examine and resolve issues surrounding ballast water treatment facilities.

Three commenters encouraged the Coast Guard to pursue environmentally sound alternatives to ballast water exchange.

We agree with the commenters. As required by NISA, we are working to facilitate development of alternatives to ballast water exchange that are environmentally sound. To do this, we encourage industry and others to participate in the STEP announced in the **Federal Register** on January 7, 2004 (69 FR 1082, NVIC 01–04).

In considering the environmental impact of this rule, as stated earlier in this section, we believe the PEA is necessary because this rule requires vessels with ballast tanks entering U.S. ports around the country, subject to conditions discussed above, to have completed one of the mandatory BWM practices. Although the national mandatory BWM program provides vessels with ballast tanks the option of using one of three BWM practices, ballast water exchange is likely to be the most used practice for reasons discussed earlier. However, this PEA is necessary to ensure the potential environmental effects of the three BWM practices are considered.

The Coast Guard has considered the implications of the Coastal Zone Management Act (16 U.S.C. 1451, *et seq.*) with regard to this rule. Under this Act, the Coast Guard must determine whether the activities proposed by it are consistent with activities covered by Federally approved coastal zone management plans for each State, which may be affected by this federal action. A listing of 29 States and Territories with federally approved coastal zone management plans can be found in Appendix E of the PEA for this rule.

The Coast Guard has determined that the mandatory BWM program will have no effect on the coastal zones of the listed States and Territories. In addition, we found the regulations in the final rule were consistent, to the maximum extent practicable, with the enforceable policies of the Federally-approved coastal zone management plans and submitted a consistency determination to that effect. The State Administrators for each of the listed States and Territories with coastal zone management plans responded, concurring with the Coast Guard consistency determination that implementing a mandatory BWM program would be consistent with their respective coastal zone management plans.

The Coast Guard provided the U.S. Fish and Wildlife Service and the National Marine Fisheries Service with a copy of the final rule and its environmental assessment of the rule. This information initiated an informal Section 7 Consultation per the Endangered Species Act (16 U.S.C. 1531, *et seq.*), which resulted in both agencies concurring with the Coast Guard's determination that this rule is not likely to adversely affect listed or proposed species or their critical habitats.

List of Subjects in 33 CFR Part 151

Administrative practice and procedure, Oil pollution, Penalties, Reporting and recordkeeping requirements, Water pollution control.

■ For the reasons discussed in the preamble, the Coast Guard amends 33 CFR part 151 as follows:

PART 151—VESSELS CARRYING OIL, NOXIOUS LIQUID SUBSTANCES, GARBAGE, MUNICIPAL OR COMMERCIAL WASTE, AND BALLAST WATER

Subpart D—Ballast Water Management for Control of Nonindigenous Species in Waters of the United States

■ 1. The authority citation for subpart D is revised to read as follows:

Authority: 16 U.S.C. 4711; Department of Homeland Security Delegation No. 0170.1.

■ 2. Revise § 151.2015 to read as follows:

§ 151.2015 Is a vessel in innocent passage exempt from the mandatory requirements?

A foreign vessel merely traversing the territorial sea of the U.S. (i.e., not entering or departing a U.S. port, or not navigating the internal waters of the U.S.) is exempt from the requirements of this subpart.

■ 3. In § 151.2025—

■ a. Add in alphabetical order the definition of ''Ballast tank'' as set out below;

■ b. Under the definition for ''Exchange,'' redesignate paragraph (a) to (1); and

■ c. Revise the definition of ''Waters of the United States'' as set out below:

§ 151.2025 What definitions apply to this subpart?

* * * * *

Ballast tank means any tank or hold on a vessel used for carrying ballast water, whether or not the tank or hold was designed for that purpose.

* * * * *

Waters of the United States means waters subject to the jurisdiction of the United States as defined in 33 CFR § 2.38, including the navigable waters of the United States. For this regulation, the navigable waters include the territorial sea as extended to 12 nautical miles from the baseline, pursuant to Presidential Proclamation No. 5928 of December 27, 1988.

■ 4. In § 151.2035—

■ a. Revise the section heading to read as set out below;

■ b. Revise the introductory text for paragraph (a) to read as set out below;

■ c. Add paragraph (a)(2)(vii) to read as set out below; and

■ d. Revise paragraphs (a)(7) and (b) to read as set out below:

§ 151.2035 What are the required ballast water management practices for my vessel?

(a) Masters, owners, operators, or persons-in-charge of all vessels equipped with ballast water tanks that operate in the waters of the U.S. must:

* * * * *

(2)(vii) Areas with pods of whales, convergence zones, and boundaries of major currents.

* * * * *

(7) Maintain a ballast water management plan that has been developed specifically for the vessel that will allow those responsible for the plan's implementation to understand and follow the vessel's ballast water management strategy.

* * * * *

(b) In addition to the provisions of paragraph (a) of this section, if the vessel carries ballast water that was taken on in areas less than 200 nautical miles from any shore into the waters of the U.S. after operating beyond the Exclusive Economic Zone, you (the master, operator, or person-in-charge of a vessel) must employ at least one of the following ballast water management practices:

(1) Perform complete ballast water exchange in an area no less than 200 nautical miles from any shore prior to discharging ballast water in U.S. waters;

(2) Retain ballast water onboard the vessel;

(3) Prior to the vessel entering U.S. waters, use an alternative environmentally sound method of ballast water management that has been approved by the Coast Guard;

■ 5. Add § 151.2036 to read as follows:

§ 151.2036 If my voyage does not take me into waters 200 nautical miles or greater from any shore, must I divert to conduct a ballast water exchange?

A vessel will not be required to deviate from its voyage, or delay the voyage, in order to conduct a ballast water exchange.

■ 6. Add § 151.2037 to read as follows:

§ 151.2037 If my vessel cannot conduct ballast water management practices because of its voyage and/or safety concerns, will I be prohibited from discharging ballast water?

(a) A vessel that cannot practicably meet the requirements of § 151.2035(b)(1) because its voyage does not take it into waters 200 nautical miles or greater from any shore for a sufficient length of time and elects to retain ballast water on board, or because of the safety concerns contained in § 151.2030, will not be prohibited from the discharge of ballast water in areas other than the Great Lakes and the Hudson River. However, the vessel must discharge only that amount of ballast water operationally necessary to ensure the safety of the vessels for cargo operations and make ballast water records available to the local Captain of the Port upon request.

(b) A vessel that cannot practicably meet the requirements of § 151.2035(b)(3) because its alternative environmentally sound ballast water management method is inoperable must employ one of the other ballast water management practices stated in § 151.2035(b). If the vessel cannot employ other ballast water management practices due to voyage or safety concerns, the vessel will not be prohibited from the discharge of ballast water in areas other than the Great Lakes and the Hudson River. However, the vessel must discharge only that amount of ballast water operationally necessary to ensure the safety of the vessels for cargo operations and make ballast water records available to the local Captain of the Port upon request.

Dated: July 21, 2004.

Thomas H. Collins,

Admiral, U.S. Coast Guard, Commandant.

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Transport Canada Marine Safety / Transports Canada Sécurité maritime

Tp13617E

GUIDELINES FOR THE CONTROL OF BALLAST WATER DISCHARGE FROM SHIPS IN WATERS UNDER CANADIAN JURISDICTION

GUIDELINES FOR THE CONTROL OF BALLAST WATER DISCHARGE FROM SHIPS IN WATERS UNDER CANADIAN JURISDICTION

1.0 Introduction

1.1 The purpose of these guidelines is the protection of waters under Canadian jurisdiction from non-indigenous aquatic organisms and pathogens that can be harmful to existing ecosystems. When a new organism is introduced to an ecosystem, negative and irreversible changes may result including a change in biodiversity. Ballast water has been associated with the unintentional introduction of a number of organisms in Canadian waters and several have been extremely harmful to both the ecosystem and the economic well-being of the nation. These guidelines are intended to minimize the probability of future introductions of harmful aquatic organisms and pathogens from ships' ballast water while protecting the safety of ships.

1.2 Various methods have been proposed for protecting waters under Canadian jurisdiction from harmful aquatic organisms and pathogens that may exist in ballast water. The methods employed must meet the following criteria:

> 1.2.1 Safety of the ship and its crew must not be compromised.
>
> 1.2.2 Techniques utilized shall be effective at minimizing the potential of introduction of harmful aquatic organisms and pathogens from discharged water.

1.3 These guidelines have been developed by Transport Canada and Fisheries and Oceans Canada under the auspices of the Canadian Marine Advisory Council and as such reflect wide consultation with groups such as shipowners, environmental organizations, government departments and the United States Coast Guard.

1.4 In developing these guidelines, consideration and recognition has also been given to the protection of neighboring ecosystems.

1.5 Comments on the guidelines should be addressed to the Ballast Water Working Group of the Canadian Marine Advisory Council at

Tower C, Place de Ville
11th Floor
330 Sparks Street
Ottawa, Ont., Canada
K1A 0N8

c/o Mr. Tom Morris E-mail: morrist@tc.gc.ca
Tel: 613-991-3170 Fax: 613-993-8196

1.6 These guidelines should not be seen as adding to or detracting from existing statutory or regulatory requirements which will prevail in the case of conflict with these guidelines. Statutory provisions dealing with ship-source pollution are included in the *Canada Shipping Act*, the *Arctic Waters Pollution Prevention Act* and the *Fisheries Act.*

2.0 Short Title

2.1 Theses guidelines may be cited by the short title "The Canadian Ballast Water Management Guidelines".

3.0 Definitions

3.1 For the purposes of these Guidelines:

"exclusive economic zone" consists of an area of the sea beyond and adjacent to the territorial sea of Canada that has as its inner limit the outer limit of the territorial sea of Canada and as its outer limit the line every point of which is at a distance of 200 nautical miles from the nearest point of the baselines of the territorial sea of Canada or as specified in the *Oceans Act*,

"foreign voyage" means a voyage extending beyond the area of a home-trade voyage and not being an inland or minor waters voyage,

"harmful aquatic organisms or pathogens" means non-indigenous aquatic organisms or pathogens which, if introduced into a particular sea area including estuaries or fresh water courses, may create hazards to human health, harm living resources or aquatic life, damage amenities, impair biological diversity or interfere with other legitimate uses of such areas,

"home-trade voyage" means a voyage, not being an inland or minor waters voyage, between places within the area following, namely, Canada, the United States other than Hawaii, St. Pierre and Miquelon, the West Indies, Mexico, Central America and the northeast coast of South America, in the course of which a ship does not go south of the sixth parallel of north latitude,

"home trade voyage, class I" has the same meaning as defined in the *Home-Trade, Inland and Minor Waters Voyages Regulations*, that is a home-trade voyage in the course of which a steamship goes anywhere within the limits of a home-trade voyage as defined in the Canada Shipping Act,

"waters under Canadian jurisdiction" means all internal waters of Canada, the territorial sea of Canada and waters in the exclusive economic zone of Canada, including the shipping safety control zones prescribed pursuant to the *Arctic Waters Pollution Prevention Act*.

4.0 Application

4.1 The Canadian Ballast Water Management Guidelines apply to all vessels entering Canada's exclusive economic zone from seaward.

4.2 The effective date for implementation of the guidelines is September 1, 2000.

4.3 These guidelines rescind and supercede the "Voluntary Guidelines for the Control of Ballast Water Discharges from Ships Proceeding to the St. Lawrence River and Great Lakes".

5.0 Consistency with International Guidelines and Other Requirements

5.1 These guidelines are intended to implement the International Maritime Organization's resolution A.868(20), "Guidelines for the Control and Management of Ships' Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens", in waters under Canadian jurisdiction.

5.2 Vessels transiting waters under Canadian jurisdiction bound for Great Lakes ports in compliance with the mandatory ballast water regime of the United States fulfill the requirements of these guidelines.

5.3 Vessels transiting waters under Canadian jurisdiction bound for non-Canadian ports and subject to other national ballast water regimes should complete any ballast water exchange outside waters under Canadian jurisdiction or, in exceptional circumstances, undertake such procedures in the designated alternative exchange zones. Vessels are reminded of the need to contact the appropriate authorities to ensure conformity with the laws of the country of destination.

6.0 **Ballast Water Management Plan**

6.1 As noted in section 7.1 of IMO resolution A.868(20), every ship that carries ballast water should be provided with a ballast water management plan. The intent of such a plan is to provide safe and effective procedures for ballast water management.

6.2 The ballast water management plan should be specific to each ship and should be reviewed on the basis IMO Resolution A.868(20) by the flag administration or a recognized organization.

6.3 For flow-through systems, the tank boundary structure for a tank head equivalent to the full distance to the top of the overflow is to be verified.

6.4 For sequential systems, the sequences indicated in the ship's ballast water management plan are to be approved for strength, stability, minimum draught forward and propeller immersion criteria. Sloshing, slamming and ballast inertia are to be dealt with as necessary. Where the criteria are not met, an operational envelope indicating the permissible significant wave heights for various speeds and headings is required to be developed as part of the ballast water management plan.

6.5 The ballast water management plan shall be included in the ship's operational documentation.

6.6 The Model Ballast Water Management Plan developed by the International Chamber of Shipping (ICS) and the International Association of Independent Tanker Owners (INTERTANKO) may be considered an appropriate reference document when developing the plan.

6.7 Canadian ships that carry ballast water and are making home trade voyage, class I or foreign voyages, should forward a copy of their ballast water management plans to the Regional Board of Steamship Inspection.

6.8 It should be noted that the stability of the ship, and any other safety considerations, remain the responsibility of the ship's master. Nothing in these Guidelines should be construed as an infringement upon that responsibility. In cases where ships are not provided with a Ballast Water Management Plan, masters should pay particular attention to the guidance on safety provided in Appendix 2 of IMO resolution A.868(20).

7.0 **Reporting Requirements**

7.1 With the exception of vessels not destined for a Canadian port, the Master of the vessel shall provide a fully completed ballast water report form as described in Annex 1 by facsimile transmission, or by other means as approved by the appropriate marine communications and traffic services officer.

7.1.1 The Master of the vessel shall provide the appropriate Marine Communication and Traffic Services Centre with the information as requested prior to entry into waters under Canadian jurisdiction.

7.2 Vessels subject to these guidelines that have not submitted a fully completed form in accordance with section 7.1 will be requested to provide the appropriate Marine Communication and Traffic Services Centre with the following information as part of the MCTS interrogative:

(i) Whether a ballast water reporting form signed by the Master has been provided by facsimile to the appropriate agency (i.e. Transport Canada Marine Safety, port authorities or the U.S. Coast Guard) or has been submitted by electronic or other acceptable means.
(ii) Whether ballast water is being carried.

(iii) If the answer to (ii) is affirmative:
(iv) Whether the vessel has a Ballast Water Management Plan appropriate to that ship.
(v) Whether the Ballast Water Management Plan has been reviewed by a classification society or flag administration.
(vi) Whether ballast water management procedures have been performed prior to entering Canada's exclusive economic zone
(vii) If the answer to (vi) is negative – 1) What is the reason for non performance

2) What procedures, consistent with the appropriate Regional Ballast Water Annex are proposed to protect Canada's waters prior to discharge of ballast.

7.3 In order to monitor information provided in ballast water report forms under this section, vessels may be boarded and samples collected. Delays to the ship shall be minimized when taking such samples and the results of their analysis shall be made available to the ships operator on request.

7.4 Under section 562.19 of the *Canada Shipping Act* it is an offence to refuse to provide information, or to knowingly provide false information to a marine communication and traffic services officer, where such information is requested for the promotion of environmental protection.

8.0 **Discharge of Ballast Water**

8.1 Subject to the appropriate regional ballast water annex as outlined in section 12, ballast water taken on in areas outside waters under Canadian jurisdiction should not be discharged in waters under Canadian jurisdiction, unless one of the ballast water management options specified in section 9 has been successfully performed.

8.2 In exceptional circumstances where the procedures in 8.1 can not be successfully performed, conditions of discharge may be specified by the appropriate regional authority as noted in Annexes II to V.

9.0 **Ballast Water Management Options**

9.1 Ballast Exchange

9.1.1 Vessels utilizing ballast exchange should conduct ballast exchange in locations where water depths are not less than 2000 metres, unless otherwise provided in the appropriate Regional Annex.

9.1.2 Alternative Exchange Zones – In exceptional circumstances, where it may not be possible to exchange ballast water due to weather sea or any other conditions the master feels may endanger human life or the safety of the vessel, alternative exchange zones may be utilized on notification of the appropriate marine communications and traffic services officer, as noted in section 7.2(vii). The use of alternative exchange zones may also be appropriate for vessels that are not able to comply with section 9.1.1 because they do not voyage into mid-ocean where water depths are greater than 2000 metres. Masters are advised to consult the appropriate Regional Ballast Water Management Annex.

9.1.3 Sequential Exchange - All of the ballast water should be discharged until suction is lost, and stripping pumps or eductors should be used if possible. Operations shall be logged.

9.1.4 Flow Through Exchange - If flow through methods are employed at least three times the tank volume should be pumped through the tank. Calculations indicating the amount of water to be utilized and pumping rates required to achieve this shall be recorded.

9.2 Non Release of Ballast Water

9.2.1 Ballast water may be retained on board.

9.3 Discharge to reception facilities

9.3.1 Vessels wishing to utilize this option should confirm procedures and availability of this service.

9.4 Alternative Methods

9.4.1 Environmentally sound methods of ballast water treatment that are acceptable to Transport Canada Marine Safety may be utilized. Any alternative method must be at least as effective in removing or killing harmful aquatic organisms and pathogens as the methods listed above.

10.0 **Research**

10.1 In order to further research into the effectiveness of ballast water management, vessels may be boarded and samples of ballast water may be collected for scientific analysis.

11.0 Ballast Tank Sediment Disposal

11.1 Disposal of sediments as a result of routine cleaning of ballast tanks should be carried out in mid ocean outside Canada's exclusive economic zone in accordance with the ship's ballast water management plan.

11.2 In waters under Canadian jurisdiction, sediments from the ballast tanks of ships trading on foreign voyages should be disposed of in land dumpsites approved for that purpose in accordance with the appropriate legislation or at sea.

11.3 Records shall be maintained of sediment removal in accordance with sections 11.1 and 11.2.

12.0 Regional Implementation

12.1 Recognizing that ecosystems are different within Canada, regional implementation of these guidelines is appropriate to account for differences in trade, ship type, geography, specific exotic species introduction risk, etc. Masters should be governed by the specific regional ballast water management procedures required for their vessel and voyage as outlined in annexes II, III, IV and V.

BALLAST WATER REPORTING FORM

1. VESSEL INFORMATION / 2. BALLAST WATER

Vessel Name:	*Type:*	*IMO Number:*		*Specify Units: m³, MT, LT, ST*
Owner:	*GT:*	*Call Sign:*		*Total Ballast Water on Board:*
Flag:	*Arrival Date*	*Agent:*		
Last Port and Country:			*Arrival Port:*	*Total Ballast Water Capacity:*
Next Port and Country:				

3. BALLAST WATER TANKS

BALLAST WATER MANAGEMENT PLAN ON BOARD? YES ____ NO ___ HAS THIS BEEN IMPLEMENTED? YES____NO___

TOTAL NO. OF TANKS ON BOARD ______________________

NO. OF TANKS IN BALLAST _________________ IF NONE IN BALLAST GO TO NO. 5.

NO. OF TANKS EXCHANGED __________________________

NO. OF TANKS NOT EXCHANGED ____________

4. BALLAST WATER HISTORY: RECORD ALL TANKS THAT WILL BE DEBALLASTED IN PORT STATE OF ARRIVAL; IF NONE GO TO NO. 5

Tanks/Holds (List multiple sources/tank separately)	**BW SOURCE**				**BW EXCHANGE** circle one: Empty/Refill or Flow Through					**BW DISCHARGE**			
	DATE DD/MM/YY	*PORT or LAT. LONG.*	*VOLUME (units)*	*TEMP (units)*	*DATE DD/MM/YY*	*ENDPOINT LAT. LONG.*	*VOLUME (units)*	*% Exch.*	*SEA Hgt. (m)*	*DATE DD/MM/YY*	*PORT or LAT. LONG.*	*VOLUME (units)*	*SALINITY (units)*

BALLAST WATER TANK CODES: FOREPEAK = FP, AFTERPEAK = AP, DOUBLE BOTTOM = DB, WING TANK = WT, TOPSIDE = TS, CARGO HOLD = CH, OTHER = O

IF EXCHANGES WERE NOT CONDUCTED, STATE OTHER CONTROL ACTION(S) TAKEN: ____

IF NONE, STATE REASON WHY NOT: ____

5. IMO BALLAST WATER GUIDELINES ON BOARD (RES. A 868(20))? YES ___________ NO _______

6. CANADIAN GUIDELINES FOR THE CONTROL OF BALLAST WATER DISCHARGE FROM SHIPS IN WATERS UNDER CANADIAN JURISDICTION ON BOARD? YES ____ NO

RESPONSIBLE OFFICER'S NAME AND TITLE (PRINTED) AND SIGNATURE ____

ANNEX I

Annex II

Ballast Water Management Procedures for Vessels Proceeding to the West Coast of Canada

1.0 Ballast Water Reporting Forms shall be sent by facsimile to Western Canada Vessel Traffic Services

Facsimile	(604) 666-8453
Phone	(604) 666-6011

2.0 Ports of Vancouver, Nanaimo, and Fraser River

2.1 In addition, vessels entering the Ports of Vancouver, Nanaimo and Fraser River shall be subject to the Harbour Master Department Standing Operating Procedures.

2.2 Compliance with ballast management procedures as set out in section 9 are mandatory.

2.3 Procedures

2.3.1 Harbour Master's representatives when boarding vessel to conduct ballast checks will require to see one of the following:

1) Log book entry (in English)
2) Abstract of log book entry
3) Company or other administration form
4) Ballast Water Reporting form as per Appendix 1 giving details of the ballast water management procedure carried out. The details must include the following information:

- position of ballast water exchange - if utilized - giving latitude and longitude
- place where ballast water originally taken on board
- amount of ballast water
- ballast tanks which have had ballast management performed
- details if ballast water management not performed (see note).

Note – It will be a defense against not performing a ballast exchange (if that is the ballast management procedure utilized) at sea for the following reasons

1) Stress or weather
2) Stability or hull stress concerns – **safety is paramount and the Master shall only carry out the procedure if it is safe to proceed**.

A copy of the above may be faxed to the applicable Harbour Master's Office

Vancouver	(604) 665-9099
Fraser River	(604) 524-1127
Nanaimo	(250) 753-4899

2.3.2 In the event that the vessel is unable to supply the above information in the prescribed manner, then no ballast water will be allowed to be discharged until the following procedures have been undertaken:

1) Samples of ballast water will be drawn and analyzed by a Harbour Master representative.

2) Ballast water found not meeting test standards, will require the vessel depart the port and exchange ballast water in the outgoing current of the north side of Juan de Fuca Strait, west of Longitude 123 degrees 55 minutes west in at least 100 metres of water.

2.3.3 All charges for the movement and delay to the vessel will be for the vessel's account.

2.3.4 Vessels arriving from Ports in British Columbia, Alaska or the West Coast of the United States (North of Cape Mendocino) wishing to discharge ballast water are exempted from these provisions if the ballast water to be discharged originated from these waters. The Habour Master's representative conducting the ballast check will require to see a log book entry showing where the ballast water originated.

2.3.5 These Procedures will not be applied to vessels wishing to discharge less than 1000 metric tonnes of ballast water. However a Port Representative must be in attendance prior to discharge.

3.0 Alternative Exchange Zone

3.1 In exceptional circumstances as noted in section 9.1.2 of these Guidelines, ballast water exchange may be made in accordance with section 2.3.2(2) of this Annex.

Annex III

Ballast Water Management Procedure for Vessels Proceeding to the Great Lakes or St. Lawrence River West of 63 degrees West Longitude

1.0 Ballast Water Reporting Forms shall be send by facsimile to Eastern Canada Vessel Traffic Services (ECAREG)

Facsimile	(902) 426-4483
Phone	(902) 426-4956
Telex	019 22510

2.0 Vessels are asked to carry out ballast water management procedures as set out in section 9 of these Guidelines.

3.0 Alternative Exchange Zone

3.1 In exceptional circumstances as noted in section 9.1.2 of these Guidelines, ballast water exchange may be made in the internal waters of Canada within the Laurentian Channel in depths exceeding 300 metres. Such internal waters exchanges shall be restricted to the area southeast of 63 degrees west longitude.

3.2 In addition to the requirements above - for those ships that have not left the North American Continental shelf on their inbound voyage, if the ballast management procedure utilized is exchange, such exchange may be made in the internal waters of Canada, within the Laurentian Channel in water depths exceeding 300 metres. As above, such internal waters exchanges shall be restricted to the area southeast of 63 degrees west longitude.

4.0 A record of the salinity of the ballast water to be discharged into the Great Lakes / St. Lawrence River west of 63 degrees West longitude shall be entered in the ships log book.

5.0 Ships entering the Great Lakes / St. Lawrence Seaway system should be aware of the U.S. mandatory ballast water regime and the likelihood of joint boarding at Montreal by representatives of the United States Coast Guard, Transport Canada and the St. Lawrence Seaway.

Annex IV

Ballast Water Procedures for Vessels Proceeding to Ports in Eastern Canada North of 60 degrees North Latitude

1.0 Ballast Water Reporting Forms shall be sent by facsimile to Northern Canada Vessel Traffic Services (NORDREG)

Facsimile	(867) 979-4236
Phone	(867) 979-5724

2.0 Alternative Exchange Zones

2.1 In exceptional circumstances as noted in section 9.1.2 of these Guidelines, ballast water exchange may be made:

1) for vessels proceeding to Hudson Bay ports - in Hudson Strait in depths exceeding 300 metres restricted to the areas southeast of 70 degrees west longitude.

2) for vessels proceeding to Higher Arctic ports – in Lancaster Sound in depths exceeding 300 metres restricted to the area southeast of 80 degrees west longitude.

Annex V

Ballast Water Procedures for Vessels Proceeding to Ports on the East Coast of Canada

1.0 Reporting

1.1 Reporting requirements under section 7 shall be fulfilled in accordance with the implementation of these guidelines.

1.2 Ballast Water Reporting Forms shall be sent by facsimile to Transport Canada Marine Safety

Facsimile	(902) 426-6657
Phone	(902) 426-7725
E-mail	balabam@tc.gc.ca

1.3 Ballast water exchange and/ or ballast water management information provided will be verified on board the vessels, on a random basis.

2.0 Alternative Ballast Water Exchange Zones (ABWEZ)

2.1 The delineation of suitable alternative ballast water exchange zones and the determination of possible exemptions is subject to scientific studies and consultation with the appropriate scientific authorities. Locations for ABWEZ are being investigated and may be included in the Annex V at a future date. *In the meantime vessels are encouraged to comply with these guidelines as far as it is safe and practicable.*

3.0 Ballast water samples collection

3.1 The master of any vessel is asked to give a researcher collecting ballast water samples all reasonable assistance to enable the sampler to collect relevant ballast water samples and gather information in connection with the ballast water management program. *Information obtained during this process will be used in order to provide the scientific basis for the future development and implementation of Annex V.*

AMENDMENT NO.	***EFFECTIVE DATE***	***SECTION/S***	***REMARKS***	***ENTERED BY***
1	March 9, 2001	1.2 and 1.3 of Annex V	Revised contact for submitting forms	
2	June 8, 2001	4.1 and 9.1.2	Application section amended to make clearer. Correction made to 9.1.2	

Appendix IV

National Ballast Water Management Regulations Under the Current CSA

Introduction

Introduction of non-indigenous aquatic organisms and pathogens can be harmful to existing ecosystems; an introduction of either has the potential to effect both negative and irreversible changes in biodiversity. Ballast water has been associated with the unintentional introductions of a number of organisms in Canadian waters and several have been extremely harmful to both the ecosystem and the economic well being of the nation. As such, it is incumbent upon the Canadian Government to set standards that minimize the probability of future introductions from ship's ballast water, while simultaneously protecting the safety of the ship and crew.

Background

- Control of ballast water in Canada began with the development of the "Voluntary Guidelines for the Control of Ballast Water Discharges from Ships Proceeding to the St. Lawrence River and the Great Lakes"(TP13617). The scope of these guidelines was expanded in 2000 to include all waters under Canadian jurisdiction. The guidelines request that any ballast water being carried onboard ships entering Canada from outside our Exclusive Economic Zone be exchanged in mid-ocean.

- In 1998, an amendment was made to the *Canada Shipping Act* allowing Canada to make regulations to control and manage ballast water.

- Consultations were held during the fall of 2003 with the intent of making TP 13617 mandatory in the waters of the Great Lakes and St. Lawrence River.

- As a result of the feedback received at the fall 2003 regional and national CMAC consultations held across Canada, the Canadian government is currently developing national "Ballast Water Management Regulations". The scope of this regulation is much broader than originally intended for the Great Lakes and St. Lawrence River and is now proposed to include all waters under Canadian jurisdiction, from coast to coast to coast, as currently covered in TP 13617. This regulation will be drafted under the current *Canada Shipping Act,* with intended coming into force is 2004.

- The regulations under the CSA 2001 will closely follow the regulations developed by the International Maritime Organization (IMO) by implementing international standards for the control of ballast water that will eventually replace the current provisions for exchange at sea. These regulations will be implemented under Phase I of the regulatory reform and will be coming into force in 2006.

Application

These regulations are intended to apply to all vessels equipped with ballast water tanks or system entering Canadian waters from outside Canada's Exclusive Economic Zone (EEZ) bound for Canadian ports, as well as all vessels carrying ballast water transiting to and from Canadian ports.

These regulations shall not apply to vessels transiting between two ports of the Great Lakes Basin or a port of the Great Lakes Basin and a Canadian port east of St-Lambert lock providing that the entire ballast on board originated from the Great Lakes Basin or in Canadian waters.

The management requirements of these regulations shall not apply to:

a. the uptake or discharge of Ballast Water necessary for the purpose of ensuring the safety of a ship in emergency situations or saving life at sea; or
b. the accidental discharge of Ballast Water resulting from damage to a ship or its equipment provided that all reasonable precautions have been taken before and after the occurrence of the damage or discovery of the damage or discharge for the purpose of preventing or minimizing the discharge; and except if the owner, company or officer in charge willfully or recklessly caused damage; or
c. the uptake and discharge of Ballast Water when being used for the purpose of avoiding or minimizing pollution incidents from the ship; or
d. the discharge of Ballast Water from a ship at the same location where the whole of that Ballast Water originated and provided that no mixing with Ballast Water from other areas has occurred. If mixing has occurred, the Ballast Water taken from other areas is subject to Ballast Water Management in accordance with this regulation.

The safety and stability of the ship shall remain the responsibility of the ship's Master.

Regional Implementation

Regional implementation of these regulations is necessary to account for differences in trade, ship type, geography, specific exotic species introduction risk, etc., Masters shall be governed by the specific regional ballast water management procedures required for their vessel and voyage as outlined in annexes II, III, IV and V of the Standard for the Control of Ballast Water Discharge.

Appendix V

National Ballast Water Management Regulations Under NISA

Introduction

- The introduction of aquatic nuisance species (ANS) by ballast water is increasingly viewed as a growing global environmental problem. Introduced into habitats where they are not native, ANS can degrade marine and estuarine ecosystems; wrecking havoc with coastal infrastructures, resulting in billions of dollars in damages, as well as billions of dollars spent in preventing and controlling ANS. ANS can also have adverse effects on human health and lifestyles. It is believed that ANS is the second most leading threat to biodiversity behind habitat loss (Ecological Society of America, 2001).

- Ballast water has long been known to be a major pathway of ANS from one area to another. Ballast water is water carried by vessels to ensure stability, list, trim and structural integrity, and is essential to the safe and efficient operation of cargo vessels. Modern cargo vessels contain large tanks, capable of holding millions of gallons of water within the hull, located fore and aft as well as along each side. Water can be exchanged among these tanks so that the vessel is optimally situated in the water. How the vessel is trimmed affects the speed (economy) at which the vessel can travel given the height of waves.

- The economy of the U.S. is dependent on ocean transport, and the number and frequency of ships that enter U.S. waters from foreign locations is quite large; ranging from 50,000 – 70,000 arrivals per year of vessels over 300 gross tons (Ruiz, G.M. et al., 2001). The U.S. Coast Guard's Shipping Study (Carlton, J. T. et al., 1995) determined that the aggregate effect of these shipping practices was the discharge of over 21 billion cubic meters of foreign ballast water (and associated organisms) into the U.S. each year. For perspective, this is the equivalent of 2.4 million gallons per hour. How do these volumes and rates of discharged ballast water influence the delivery of foreign organisms? Further studies have estimated that, globally, there are between 1,000 and 3,000 species of organisms in transit with ballast water at any one time (Carlton, J. T. and J. B. Geller, 1993), and documented (Lavoie, D. M. et al, 1999) that hundreds of millions of foreign organisms can be delivered into U.S. waters with the ballast water of a single discharging vessel.

Background

- Following the invasion of the Great Lakes by zebra mussels in the 1980s, Congress passed the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA), and reauthorized, and amended it by passing the National Invasive Species Act of 1996 (NISA). These acts directed the U.S. Coast Guard to issue regulations and guidelines for ballast water management to prevent and control the spread of ANS to U.S. waters via ballast water discharges.

- Responding to NANPCA's directive, the U.S. Coast Guard developed mandatory ballast water management provisions for the Great Lakes in 1993, and later extended the provisions to include the Hudson River north of the George Washington Bridge in 1994.

- In 1999, the U.S. Coast Guard developed voluntary ballast water management guidelines for vessels entering all other U.S. waters, and developed regulations mandating ballast water management reporting and recordkeeping requirements, without penalty provisions. It was Congress' intent to exclude penalty provisions from the mandatory ballast water management reporting and recordkeeping requirements until the voluntary ballast water management program was evaluated.

- NISA required the U.S. Coast Guard to submit a Report to Congress evaluating the effectiveness of the voluntary ballast water management program after it have been in place for two years. Congress anticipated that in this report, the U.S. Coast Guard might determine that either compliance with the voluntary guidelines was inadequate, or the rate of reporting would be too low to allow for a valid assessment of the compliance. In either case, Congress stipulated the development of additional regulations to make the voluntary guidelines a mandatory national ballast water management program, and providing penalties for violations of these regulations. The report, which was submitted to Congress on June 3, 2002, concluded that compliance with the reporting requirements was insufficient to allow for an accurate assessment of the voluntary ballast water management guidelines.

- On June 14, 2004, the Coast Guard established penalty provisions of up to $27,500 for vessels equipped with ballast water tanks who are bound for ports or places within the United States that fail to submit a ballast water management (BWM) reporting form. Penalty provisions are also established for vessels bound for the Great Lakes or portions of the Hudson River that violate the mandatory ballast water management requirements and these regulations widen the reporting and recordkeeping requirements of vessels subject to the regulations. A person who knowingly violates either provision will be guilty of a class C felony.

- On July 28, 2004, the Coast Guard, under the authority of the Nonindigenous Aquatic Nuisance Prevention and Control Act and the National Invasive Species Act, established mandatory ballast water management (BWM) requirements for vessels equipped with ballast water tanks that are bound for ports or places within the United States. Vessels that operate outside the U.S. Exclusive Economic Zone, must conduct one of the following ballast water management practices: conduct mid-ocean exchange, retain ballast water onboard, or use a Coast Guard approved alternative management method to mid-ocean exchange. Also, vessels subject to this rule are required to develop and maintain a BWM plan. The plan shall be specific to each vessel and shall fulfill two purposes: 1) Show that there is a BWM strategy for the vessel; and 2) allow any master, or other ship's officer as appropriate, serving on that vessel to understand and follow the BWM strategy for the vessel. The International Maritime Organization has issued guidelines on the content of BWM plans in IMO

Resolution A.868(20) Annex 1, Chapter 7. Any plan meeting these IMO guidelines will meet our regulatory requirements. Finally, vessels that operate within U.S. waters must conduct ballast water management practices to minimize the movement of nonindigenous species. These practices include: avoid the discharge or uptake of ballast water in certain areas; clean ballast tanks regularly; dispose of sediments; rinse anchors and anchor chains; and remove fouling organisms from hull, piping, and tanks on a regular basis and dispose of any removed substances.

Application

These regulations are intended to apply to all vessels equipped with ballast water tanks or system entering U.S. waters and/or after operating outside the U.S. Exclusive Economic Zone (EEZ) bound for U.S. ports or places.

The reporting and recordkeeping requirements of these regulations shall not apply to:
a. A crude oil tanker engaged in coastwise trade.
b. A Department of Defense or Coast Guard vessel subject to the Uniform National Discharge Standards under the Clean Water Act.
c. A vessel operating within the same Captain of the Port Zone.

The safety and stability of the ship shall remain the responsibility of the ship's Master.

Regional Implementation

The Great Lakes Ballast Water Management Program remains unchanged and is as follows: vessels must employ one of the following ballast water management practices:

- Conduct ballast water exchange beyond the Exclusive Economic Zone (EEZ), 200 nautical miles from any shore, and at a depth of 2000 meters, prior to entering the Great Lakes;
- Retain the ballast on board your vessel; or
- Use an alternative environmentally sound method of ballast water management that has been approved by the U.S. Coast Guard.

Literature Cited

1. Ecological Society of America Fact Sheet, http://esa.scsc.edu/invas3.htm, printed 8/26/2003.

2. Ruiz, G. M. et al., 2001. Status and Trends of Ballast Water Management in the United States. First Biennial Report of the National Ballast Information Clearinghouse. Submitted to U.S. Coast Guard, November 16, 2001.

3. Carlton, J. T. et al., 1995. Shipping Study: 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. U.S. Coast Guard Report No. CG-D-11-95.

4. Carlton, J. T. and J. B. Geller, 1993. Ecological Roulette: The Global Transport of Nonindigenous Marine Organisms. Science 261: 78-82.

5. Carlton J.T. 2001. Introduced Species in U.S. Coastal Water: Environmental Impacts and Management Priorities. Prepared by Williams College and Mystic Seaport for the Pew Oceans Commission. Pew Oceans Commission, Arlington, VA (pp. 1-22).

6. Lavoie, D. M. et al, 1999. The Potential for Intracoastal Transfer of Nonindigenous Species in the Ballast Water of Ships. Estuary, Coastal & Shelf Science. 48: 551-564.

7. Nonindigenous Aquatic Nuisance Prevention and Control Act, U.S. Public Law 101-636, November 29, 1990.

8. National Invasive Species Act, U.S. Public Law 104-332, October 26, 1996.

Appendix VI

An Assessment of the Risk of Ballast Water-Mediated Introduction of Non-indigenous Phytoplankton and Zooplankton into Atlantic Canadian Waters

Final Report

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March 31, 2002

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Executive Summary

To assess the risk of ballast water-mediated introduction of non-indigenous phytoplankton and zooplankton taxa, samples of ballast water were obtained from 98 ships arriving at 15 ports in the four Atlantic provinces. The ships were selected on the basis of their port of origin to comprise a representative cross-section of the foreign vessel traffic. Samples were obtained from a total of 29 Tankers, 21 Bulk carriers, 17 Container carriers and 31 General Cargo ships. An analysis of ballast water records indicated that the Tankers and Bulk carriers consistently discharged from 85 to 100% of their ballast water load (750 to 46,407 m^3), whereas the Container and General Cargo ships occasionally discharged 10 to 30% of their ballast water (150 to 2400 m^3). Of the 50 Bulk carriers and Tankers originating from ports on the east coast of the US, 52% and 70%, respectively, reported conducting a ballast water exchange in coastal or oceanic waters along their route. Approximately 77% of the Container and General Cargo carriers arriving from ports in Europe, the US and the Caribbean also reported undertaking a ballast water exchange in open water.

Examination of ballast water samples (235 for phytoplankton and 59 for zooplankton) from the various ships revealed 424 phytoplankton taxa and 79 zooplankton taxa for a total of 503 taxa. Of the 424 phytoplankton taxa, 105 (25%) were classified as non-indigenous, of which five were known toxic species and another nine were considered potentially toxic/harmful. Among the remaining 319 phytoplankton taxa, including those considered indigenous or of unknown geographic affiliation, 15 were known to be toxic/harmful and another 25 were classified as a potentially toxic/harmful. None of the 79 zooplankton taxa was classified as either non-indigenous or harmful, although many were larval and juvenile stages which could not be fully identified.

The maximum number of phytoplankton taxa observed in a single sample was 68 and the highest concentration was 228,000 cells/liter. Overall, the ballast water of Bulk carriers and Tankers originating from ports on the US east coast (FAO regions A and G) had the highest number of taxa as well as the highest cell concentrations, probably because the water was less than 5 d old. Many of the ballast water samples from the Container and General Cargo carriers originated from various parts of the Northeast Atlantic, the Pacific and the Mediterranean (FAO regions B,D and C); these samples typically had fewer taxa and lower cell concentrations due in part to their greater age. Overall, samples of ballast water originating from port areas had higher cell concentrations but fewer taxa than those originating from coastal or oceanic regions. The incidence of non-indigenous taxa, as well as toxic/harmful taxa of indigenous or unknown geographic affiliation was higher in exchanged water than in non-exchanged water; further research on the seasonal risks associated with ballast water exchange is required to verify this finding.

This study has demonstrated the enormous potential of ballast-carrying vessels to transport high numbers of phytoplankton and zooplankton taxa. In the case of the phytoplankton, a significant proportion of these taxa (25%) were non-indigenous, while the lack of information on the zooplankton taxa may have underestimated the risks posed by these organisms. Those regions of Atlantic Canada that are receiving Bulk carrier and Tanker traffic may be at greater risk given the large volumes of ballast water being discharged. In particular, the Bras d'Or Lakes area with its estuarine conditions may provide suitable habitat for brackish-water taxa from US ports. Given the scope of ballast water issues, it may be advisable to focus on developing strategies to minimize the impact of regular ballast-water discharges in ecologically-sensitive areas.

1 Introduction

The unregulated movement and discharge of ballast water by commercial shipping traffic has been repeatedly implicated in the global dispersion of exotic marine and freshwater species (Medcof 1975, Carlton 1985, Williams et al. 1988, Carlton and Geller 1993, Hallegraeff 1995, Gauthier and Steel 1996). Numerous cases have been documented where the rapid proliferation of invasive macrofaunal species has had serious ecological and economic ramifications; some of the worst examples include the introduction of the European zebra mussel *(Dreissena polymorpha*) into the Great Lakes (Nalepa and Schlosser 1993), the Asian clam (*Potamocorbula amurensis*) into San Francisco Bay (Carlton et al. 1990, Nichols et al. 1990), and the Atlantic comb jelly (*Mnemiopsis leidyi*) into the Black Sea (Vinogradov et al. 1989).

The concept of ballast water as a vector for the introduction of non-indigenous planktonic organisms was first proposed to account for the appearance of the tropical phytoplankton *Odontella sinensis* in the North Sea in the early 1900's (Ostenfeld 1908, Boalch 1987). The potentially serious consequences of such introductions were highlighted by the subsequent discovery of another tropical phytoplankton *Coscinodiscus wailesii*; this nuisance species produces a copious slime which can clog or break fishing trawl nets (Boalch 1977b, Mahoney and Steimle 1980, Rince and Paulmier 1986, Rick and Durselen 1995). Growing awareness of the risks of ballast water transport was heightened by the discovery of toxic phytoplankton species in Australian waters (Hallegraeff et al. 1988). Paralytic Shellfish Poisoning (PSP) was unknown in Australia until the 1980's when the first outbreaks of toxic species appeared in the ports of Hobart (*Gymnodinium catenatum*), Melbourne (*Alexandrium catenella*) and Adelaide (*Alexandrium minutum*). Viable cysts of *G. catenatum* and *A. catenella* were subsequently found in the ballast water sediments of ships originating from Japan and Korea (Hallegraeff and Bolch 1992), and the source of *A. minutum* was eventually traced to shipping traffic from the Mediterranean (Scholin and Anderson 1991). The proliferation of these toxic species had major economic consequences for the Australian aquaculture industry; specifically, widespread blooms necessitated the prolonged closures of shellfish farms in several areas (Hallegraeff and Sumner 1986, Hallegraeff et al. 1995). Concern over the Australian experience prompted several countries to develop research programs focusing on the potential for ballast water-mediated introductions of toxic or harmful phytoplankton (Kelly 1993, Carleton and Geller 1993, MacLeod 1995, Gollasch 1995, Chu et al. 1997, Zhang and Dickman 1999).

Effort has also been directed towards documenting the transport and impact of non-indigenous zooplankton species, particularly predatory forms which may disrupt the local ecology and fisheries (Locke et al. 1993). For example, it has now been recognized that at least six species of Asian copepods have been introduced to the west coast of North America (Avent et al. 2000); the increasing dominance of *Pseudodiaptomus inopinus* in several estuaries will likely alter food web dynamics with unknown ecological consequences. One of the most prominent examples of the potential damage associated with the introduction of a marine zooplankton species is the destruction of the Black Sea anchovy fishery by the American comb jelly (*Mnemiopsis leidyi*) at an estimated loss of US$250 million (GESAMP 1997). This introduced species outcompeted the local fish species for the zooplankton food resources while directly preying on the fish eggs and larval stages, resulting in the demise of the anchovy population. It has also been recognized that many potentially-invasive benthic invertebrates have a planktonic larval stage which may be taken up and transported in ballast waters. For example, the Japanese shore crab *Hemigrapsus sanguineus* was recently introduced to northeastern US where it is now providing serious competition for the previously introduced green crab *Carcinus maenas*.

Growing concern over the potential impacts of non-indigenous species invasions prompted the development of guidelines to govern the management of ballast water. In 1991, the International Marine Organization (IMO) Environmental Protection Committee adopted a resolution specifiying "Guidelines for the Control and Management of Ship's Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens". These included specific recommendations for ballast water management such as avoiding taking on ballast in shallow water, exchanging ballast in deep water while en route, and disposing of ballast tank sediments away from sensitive areas. Although the practice of mid-ocean exchange is now widely promoted, it is acknowledged to be less than 100% effective at eliminating taxa taken up in inshore areas (e.g. Locke et al. 1993, Dickman and Zhang 1999). Currently, the major drive is to develop ballast water treatment methods which would eradicate all biota using some combination of physical, chemical and/or mechanical means (Bolch and Hallegraeff 1993, Rigby and Hallegraeff 1994, Jelmert 1999, Rigby et al. 1999).

In Canada, the ecological and economic havoc surrounding the “zebra mussel crisis” in the Great Lakes (Hebert et al. 1991, Griffiths et al. 1991), prompted the Canadian government to take measures to reduce the risk of further introductions. Specifically, they developed “Guidelines for the Control of Ballast Water Discharge from Ships in Waters under Canadian Jurisdiction”. Under these guidelines, it is highly recommended that ships originating from foreign ports undertake a ballast water exchange, preferably in waters >200 nm offshore and >2000 m deep, before entering Canadian waters. As of September 2001, all ships arriving at ports in Eastern Canada were instructed to report ballast water information to Transport Canada, Marine Safety (Annex V: Ballast Water Procedures for Vessels Proceeding to Ports on the East Coast of Canada). At present, Canada has no official regulations for ballast water management, but countries such as the US and Australia have implemented such regulations and it is anticipated that many countries will follow suit.

Until recently, Canadian research on the risk of ballast water-mediated introduction of phytoplankton and zooplankton species was confined to the Gulf of St. Lawrence area. A survey of ballast water samples from ships entering the St. Lawrence (Rao et al. 1994) revealed 13 non-indigenous taxa and 21 indigenous but potentially toxic/harmful taxa. None of the non-indigenous taxa was reputed to pose any risk to the aquaculture or fishing industry. In a subsequent study, Harvey et al. (1999) found that 60% of the phytoplankton taxa and 57% of the zooplankton taxa observed in the ballast waters of foreign ships entering the Estuary and Gulf of St. Lawrence were non-indigenous. Of the 19 toxic/harmful taxa, however, only one very rare species (*Coscinodiscus wailesii*) was not endemic to Canadian waters.

To extend this knowledge base to other areas of Atlantic Canada, Transport Canada funded a study in July 2000 to obtain information on the diversity and abundance of phytoplankton and zooplankton taxa in the ballast water of 34 ships arriving at three ports in Nova Scotia (Carver and Mallet 2000). These samples revealed 226 phytoplankton taxa of which 6% were non-indigenous and 44 zooplankton taxa of which 2% were classified as non-indigenous. A second more comprehensive study was initiated in September 2001 to conduct a similar survey of the ballast water of 98 ships docking at various ports in the four Atlantic provinces. The following report documents the results of this study, including an assessment of the risk of introducing non-indigenous and toxic/harmful taxa, and an evaluation of the effectiveness of current ballast water management practices.

2 Materials and methods

2.1 Location of the ports

Ballast water samples were obtained from 98 ships at fifteen ports in the four Atlantic provinces; six ports in Newfoundland (NFLD), five ports in Nova Scotia (NS), two ports in New Brunswick (NB) and two ports in Prince Edward Island (PEI) (Figure 1). The original plan was to sample 42 ships at five NFLD ports, 38 ships at three NS ports, 15 ships at two NB ports, and 3 ships at two PEI ports. However, the Newfoundland ship traffic in the fall 2001 was lower than expected which led to a reallocation of the sampling effort. In Nova Scotia, two new ports were added, Pugwash and Little Narrows, and a total of 48 ships were sampled, whereas in Newfoundland, one port was added, Corner Brook, and the number of ships sampled was reduced to 32. Sampling was conducted over a 5-mo period from September 24 2001 to February 28 2002; the number of ships sampled at each port in each province over time is shown in Table 1.

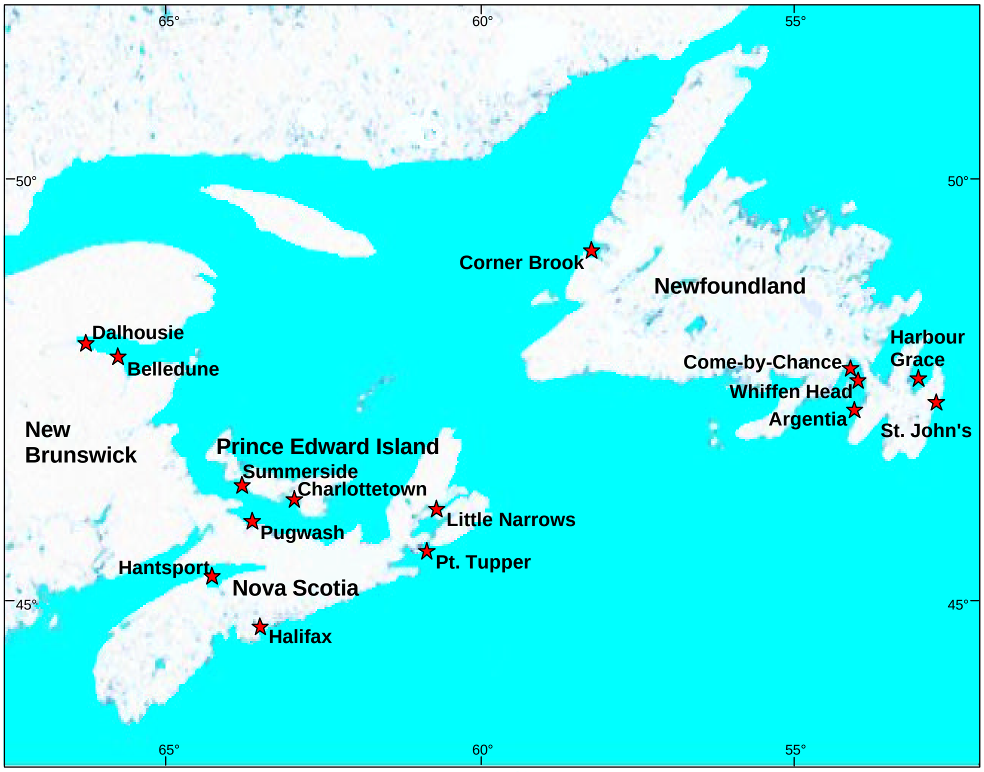

Figure 1. Map of the Atlantic region indicating the various ports where the 98 ships were sampled.

2.2 Selection of ships

Information on ships arriving with ballast water in Atlantic Canada was faxed to Mallet Research Services (MRS) from the Halifax and St. John's Offices of ECAREG-VTS (Eastern Canadian Region-Vessel Traffic Service). This information included the “Active-all” list which indicated the last reported position and estimated arrival time of all ships entering the Atlantic Region, as well as individual vessel status sheets for those ships which reported carrying ballast water. Official Ballast Water Report forms were also forwarded to MRS from Transport Canada, Marine Safety in Dartmouth, NS. Ships were selected according to their port of origin, port of arrival and their ballast water status.

2.3 Pre-boarding

After identifying an appropriate vessel for sampling, the shipping agent for the company was contacted to set up a boarding time. A brief information sheet outlining our intentions/requirements (Appendix 1) was provided to the agent who either faxed this information directly to the ship or personally relayed the appropriate details to the Captain and/or Chief Officer. The purpose of this sheet was to (1) state the purpose of the study and specify that the work was officially sponsored by the Department of Transport; (2) outline the general background information required; specifically, a ballast water report or a detailed record of the ballast water history; and (3) clarify that samples would be taken from only three tanks, either through the sounding pipes or from the ballast water pump system. This forewarning approach proved to be quite effective and the level of cooperation was excellent.

Table 1. Number of ships sampled per week at each port. The total by province, by port, and by month is shown. CBC is Come-by-Chance, SUM is Summerside, and CHN is Charlottetown.

		2001															2002			
Description		10 Sep-16 Sep	17 Sep-23 Sep	24 Sep-30 Sep	01 Oct- 07 Oct	08 Oct- 14 Oct	15 Oct- 21 Oct	22 Oct- 28 Oct	29 Oct- 04 Nov	05 Nov-11-Nov	12 Nov- 18 Nov	19 Nov- 25 Nov	26 Nov- 2 Dec	3 Dec - 8 Dec	10 Dec - 16 Dec	17Dec - 23 Dec	24 Dec- 30Dec	01Jan-31Jan	01Feb-17Feb	18Feb-28Feb	
Newfoundland				**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**32**
	CBC			2	1	1	1		1		1	1	1	1	1	1	2				**14**
	WhiffenHead							1	1		1		1		1	1	1				**7**
	Argentia			1		1		1			1	1									**5**
	Hbr. Grace						1														**1**
	St. John's						1	1						1							**3**
	Cornerbrook												1	1							**2**
Nova Scotia																					**48**
	Halifax			5	1	8	3	3	5	1					1			1		1	**29**
	Hantsport				1	1				1			1					1		1	**6**
	Pt. Tupper				2					1	1	1		1					1	1	**8**
	Lit Narrows								1	1		1		1							**4**
	Pugwash										1										**1**
New Brunswick																					**15**
	Belledune				3		1	2			2		1		1						**10**
	Dalhousie				1		2				1		1								**5**
PEI																					
	CHN, SUM										2					1					**3**
Subtotal				**8**	**9**	**11**	**9**	**8**	**8**	**4**	**10**	**4**	**6**	**5**	**4**	**3**	**3**	**2**	**1**	**3**	**98**
Monthly Total		8			37				32					15				2	4		

2.4 Establishing ballast water history

Upon boarding, the ballast water history was reviewed with the Chief Officer to determine the volume and the source of the ballast water in each tank. In the case of the Bulk carriers and Tankers, all the tanks were typically full and the water originated from a single port or from some offshore region where the water had been exchanged. In the case of the General Cargo ships and Container carriers where variable amounts and types of ballast water were present, a range of tanks were selected based on availability (tank fullness), origin (foreign ports over open ocean) and age (younger water tended to contain more live taxa).

2.5 Sampling procedure

After identifying the three tanks to be sampled, the Chief Officer designated a crew member to escort us either to the appropriate sounding pipes or the ballast pump in the engine room. Whenever possible, the preferred sampling method was to obtain water through the sounding pipes due to the risk of cross-contamination between ballast pump samples. The Bulk carriers and Tankers generally had full ballast tanks which could be readily accessed from the sounding pipes on the main deck. Most General Cargo ships could also be sampled from the sounding pipes, although in some instances, the ballast water pump had to be used because the water level in the tanks was below that accessible with our sampling system. Overall, the Container ships offered the greatest sampling challenge: (1) the water in the double-bottom tanks was too deep to raise to deck level; (2) the sounding pipes were frequently not accessible due to cargo obstruction; (3) no sounding pipes existed; and/or (4) the Chief Officer did not want to use the ballast water pump. A list of the sampling equipment used in this study can be found in Appendix 2.

2.5.1 Sounding pipes

Sampling from the sounding pipes was generally straightforward given a sufficient height of water in the tank. The procedure involved lowering a weighted 3/8" tube into the sounding pipe until the weight touched bottom (Figure 2). The sampling tube was connected to a Husky Diaphragm pump driven by compressed air from a scuba tank. The pump was capable of lifting water from 7.5 m below the top of the pipe at a rate of approximately 2.5 liters/min. The first 5 to 6 liters were pumped into a waste bucket in order to flush out any rusty or dirty water originating inside the sounding pipe as opposed to the open tank. Once the water clarified, the outflow was directed through a 20-um mesh screen into a series of buckets, two 20-liter and one 10-liter for a total of 50 liters (Figure 3). After concentrating all the organisms greater than 20 um on the screen, a wash bottle containing a subsample of the 20-um filtered seawater was used to rinse the screen and transfer the organisms to a 500-ml bottle. The temperature of the remaining 50 liters of filtered water was recorded and a sample was taken for salinity measurement. The filtered water was then returned to the ballast tank via a large funnel inserted into the sounding pipe.

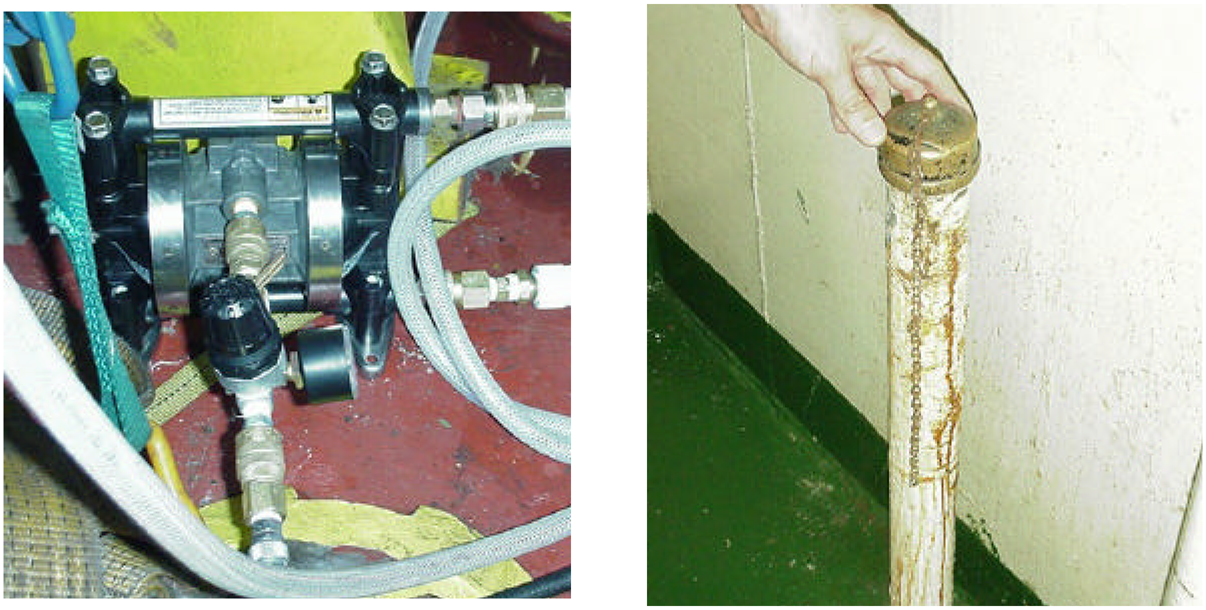

Figure 2. The lightweight air-pump (left) used to obtain samples of ballast water through the sounding pipes (right). The air-pump was connected to a scuba diving tank by means of quick disconnect fittings.

2.5.2 Ballast pump

Sampling from the ballast pump was relatively convenient in that there was no need to move equipment from one part of the ship to another. However, this procedure required that the Chief Officer or the Chief Engineer direct water from the selected tanks through the ballast pump system into an alternate tank. Samples were obtained by dismantling the line to the pressure gauge on the discharge side of the pump, and fitting a plastic tube either over the copper tubing or the valve opening (Figure 3). When the valve at the base of the pressure line was opened, water was directed through the tube onto the collecting screen and into the buckets. Although we waited 1 to 2 min with the pump running between one sample and the next, it was impossible to determine whether the water from the previous sample had been fully flushed out of the pipe. The filtered water could not be returned to the tank but had to be discarded on the floor of the engine room where it drained into the bilge. Some ballast pumps had been fitted with a 1/2" valve on the discharge side of the ballast pump which greatly facilitated the collection of the water samples.

Figure 3. Example of a ballast water pump in the engine room where the ballast water samples were collected. Note the 20-um mesh screen used to collect the phytoplankton and zooplankton specimens.

2.5.3 Safety precautions

An array of personal safety equipment was specified including steel-toed boots, hard hats, safety vests and at the Gypsum terminals, safety glasses (Appendix 2). Ear protectors were also found to be essential when collecting samples from the ballast water pump in the engine room. Surgical gloves were used in the handling of the ballast water samples. For safety reasons, no fixative was taken on board; samples were fixed with 2% formaldehyde:acetic acid (50:50) immediately upon disembarking from the ship.

2.6 Sample processing

2.6.1 Phytoplankton identification

A total of 235 samples were processed for microscopy using the Filter-Freeze-Transfer technique (Hewes and Holm-Hansen 1983); the proportion of the sample examined varied from 1 to 10% of the total sample volume, depending on the concentration of organisms. All individuals, including microzooplankton taxa other than copepods, were counted and identified to species, when possible. Because the objective was to evaluate the risk of introduction, an effort was made to distinguish live from dead cells, based on appearance. Given the subjectivity of this approach, any cells that looked even slightly alive were assigned to the Live category. Unidentified taxa were photographed for distribution to other plankton taxonomists.

2.6.2 Zooplankton identification

A subset of 59 samples (29 from NS, 19 from NFLD, 9 from NB and 2 from PEI) was selected for zooplankton assessment and provided to Sprytech Biological Services Ltd. Preference was given to samples originating from more distant regions (e.g. Europe), as well as those which appeared to contain high concentrations of zooplankton. Samples were analysed by taking sufficient aliquots from a known volume to count a minimum of 200 organisms (excluding damaged individuals); in some cases this required counting the whole sample. Identification and enumeration were carried out using a stereo microscope.

3 Results

3.1 Ship Profile

3.1.1 Port of origin

Given the limited data on the expected distribution by port of origin of ships arriving at each of the provinces in Atlantic Canada, we attempted to sample a range of ships which approximately matched the overall Country of Origin profile for the Year 2000 (Balaban 2001). Table 2 illustrates the projected number of ships from the various countries to be sampled in 2001 as well as the actual number of ships sampled. Only the distribution by province is indicated; for specific ports within each province, see Appendix 3. The greatest variation in terms of ports of origin was observed in Nova Scotia, primarily because of the Container traffic in the port of Halifax. Note that no ships were sampled from Norway, Venezuela, Russia/Far East or any Mediterranean countries other than Spain or Malta, either because of their rarity or their lack of ballast water.

A total of 98 ships were sampled including 32 in NFLD, 48 in NS, 15 in NB and 3 in PEI. These ships originated from ports in six FAO or Food and Agricultural Organization Maritime Regions: A - Northwest Atlantic, B - Northeast Atlantic, C - Mediterranean and Black Sea, F- Eastern Central Atlantic, G - Western Central Atlantic, and H - Indian Ocean (Figure 4). Note that over 90% of the ships originated from three FAO regions: A (53%), B (20%), and G (17%).

Table 2. Sampling objectives based on Country of Origin data for ships arriving in Atlantic Canada in the Year 2000 (Balaban 2001). Projected data were calculated based on a total of 98 ships to be sampled.

FAO Region	Country of Origin	Data from Year 2000	Target for 2001	Sampled in 2001	Ships in NF	Ships in NS	Ships in NB	Ships in PEI
A/G	USA	62.00	61	62	26	24	11	1
B	UK	5.33	5	6		5	1	
	Netherlands	3.67	4	3	1	2		
	Iceland	2.25	2	3	3			
	Norway	2.22	2	0				
	N. Europe / Scan	1.69	2	2	1			1
	France	1.16	1	3		3		
	W. Europe	1.13	1	1			1	
	Belgium	1.00	1	1		1		
	Germany	0.83	1	1		1		
	Subtotal	19.28	19	20	5	12	2	1
C	Spain	4.85	5	5		5		
	Malta	1.59	1	1		1		
	Mediterranean	0.93	1	1				
	Subtotal	7.37	7	7	0	6	0	1
G	Caribbean Islands	2.49	2	1	1			
	Central / S. America	2.45	2	3		2	1	
	Cuba	1.83	2	3		3		
	Venezuela	1.71	2	0				
	Subtotal	8.48	8	7	1	5	1	0
H	Persian Gulf	0.69	1	1		1		
D	Russia / Far East	1.55	1	0				
F	Africa	0.63	1	1			1	
	Total	100.00	98	98	32	48	15	3

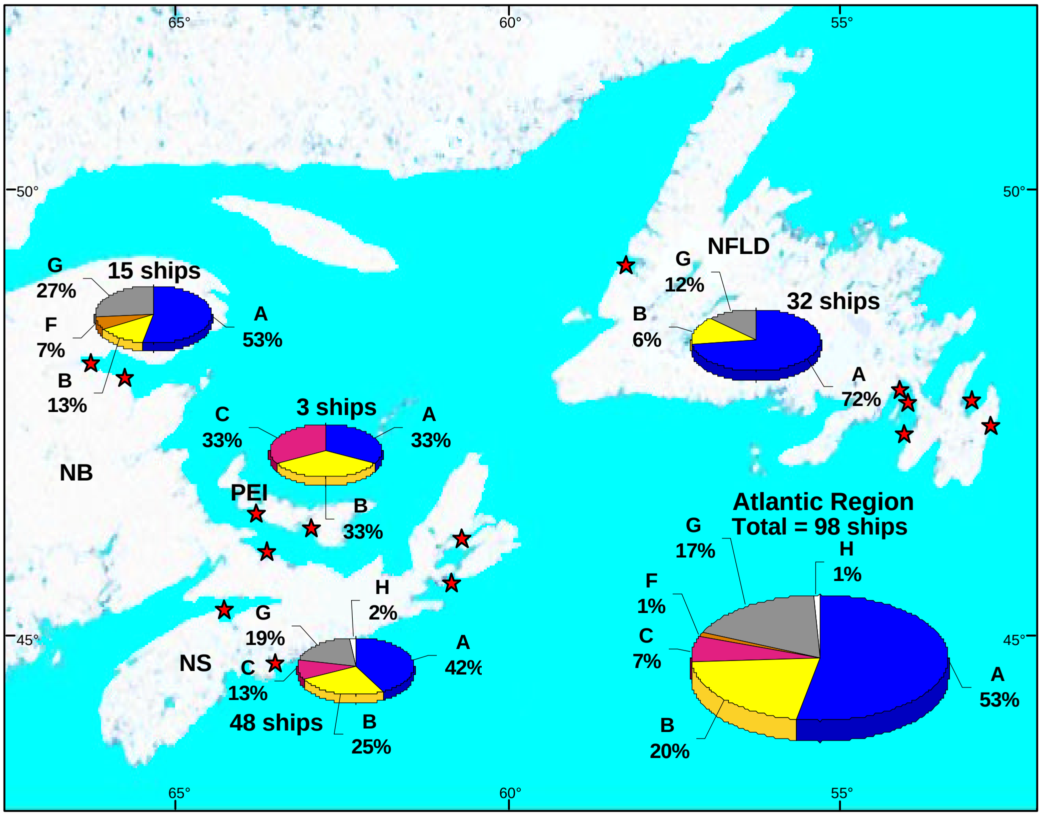

Figure 4. Map indicating the ports of origin of the ships sampled in each province in terms of FAO region. The large pie is an overall summary for the Atlantic region.

3.1.2 Types of ships

The ships were assigned to four categories based on cargo type and tonnage (Appendix 3): 17 Container carriers (Cont); 31 General Cargo carriers (GenC); 21 Bulk carriers (Bulk); and 29 Tankers (Tank). In terms of Gross Registered Tonnage (GRT), the Container ships ranged from 35,994 to 58,358 mt, the General Cargo carriers from 2,301 to 30,150 mt, the Bulk carriers from 5,456 to 41,173 mt, and the Tankers from 2,621 to 81,093 mt. Ships that typically carry large amounts of ballast water (i.e. Bulk carriers and Tankers) accounted for 51% of the ships sampled whereas the Container and General Cargo carriers accounted for 49% (Figure 5). Most of the Tankers were sampled in NFLD (Come-by-Chance and Whiffen Head), whereas all the Container ships were sampled in the port of Halifax. Chemical Tankers were only sampled in Belledune, NB whereas General Cargo ships were sampled at ports in all four provinces.

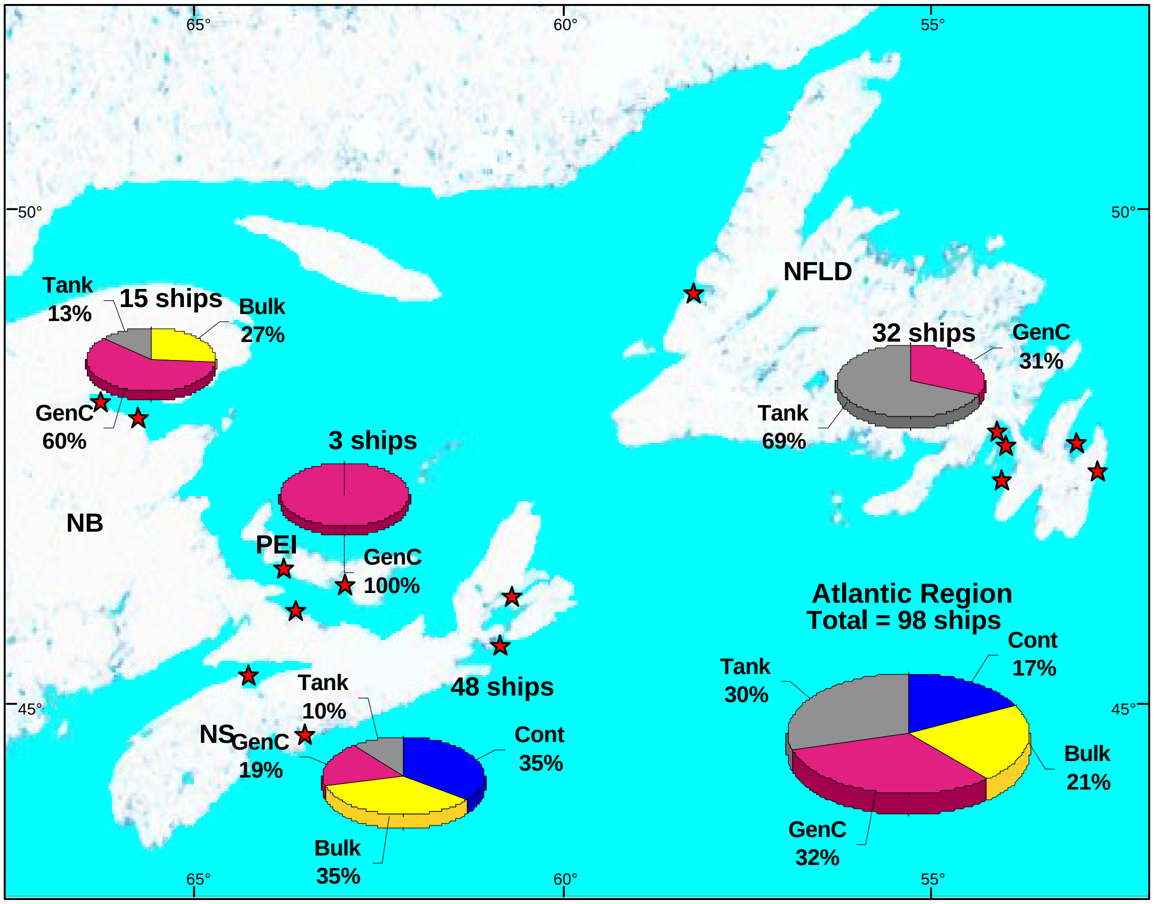

Figure 5. Map indicating the types of ships sampled in each province and over the whole Atlantic region.

3.1.3 Ballast water management

Seventeen of the 98 ships (17.3%) had no approved ballast water management plan or official ballast water forms, but there were typically sufficient records available to decipher their ballast water history (Table 3, Appendix 3). The remaining 81 ships submitted a mixture of Canadian, US, IMO, or "Other" forms which generally provided adequate information as to the source, age, and volume of the ballast water in each tank. In cases where ships were not using one of the standard ballast water forms, a copy of the Canadian Ballast Water Guidelines, a Canadian Ballast Water form as well as an explanation of the requirements were offered to the Chief Officer.

Table 3. Types of ballast water report forms encountered during this study.

BW Report Form	Number of ships	% of total
Canadian	24	24.5
US	26	26.5
IMO	20	20.4
Other	11	11.2
No form	17	17.3
Total	98	

In general, the Bulk carriers were less likely to report having undertaken a ballast water exchange than were the other three ship types (Table 4). Reasons for not undertaking an exchange included poor weather conditions, lack of awareness of the Guidelines, and not passing through oceanic waters (>2000 m deep, 200 nm offshore) during a coastal voyage.

Table 4. Proportion (%) of each ship type which reported undertaking an exchange en route.

	Ship Types				
Status of Exchange	Bulk	Cont	GenC	Tank	Mean
Yes	52.4	76.5	77.6	69.0	69.4
No	47.6	23.5	22.6	31.0	30.6

3.1.4 Ballast water discharge

Of the 98 ships sampled, 67 reported an intention to discharge all or some of their ballast water and of these, 22 or approximately 1/3 had not exchanged their ballast water en route (Table 5). Interestingly, 23 of the 31 ships that did not plan to discharge any ballast water had still undertaken an exchange.

Table 5. Number of ships that conducted a ballast water exchange en route and/or discharged ballast water.

Status of Exchange	BW Discharged	No BW Discharged	Total
Yes	45	23	68
No	22	8	30
Total	67	31	98

On average, Tankers entering the Atlantic region had 24,000 m^3 of ballast water on board, the Container ships and the Bulk carriers had 8,000 m^3, and the General Cargo carriers approximately 2,000 m^3 (Appendix 3). In terms of discharge, all 29 Tankers and 21 Bulk carriers reported an intention to discharge 100% of their load at the port (Figure 6). Of the 31 General

Cargo carriers, ten discharged their full ballast load, whereas seven of the 17 Container vessels discharged a maximum of 20% of their load.

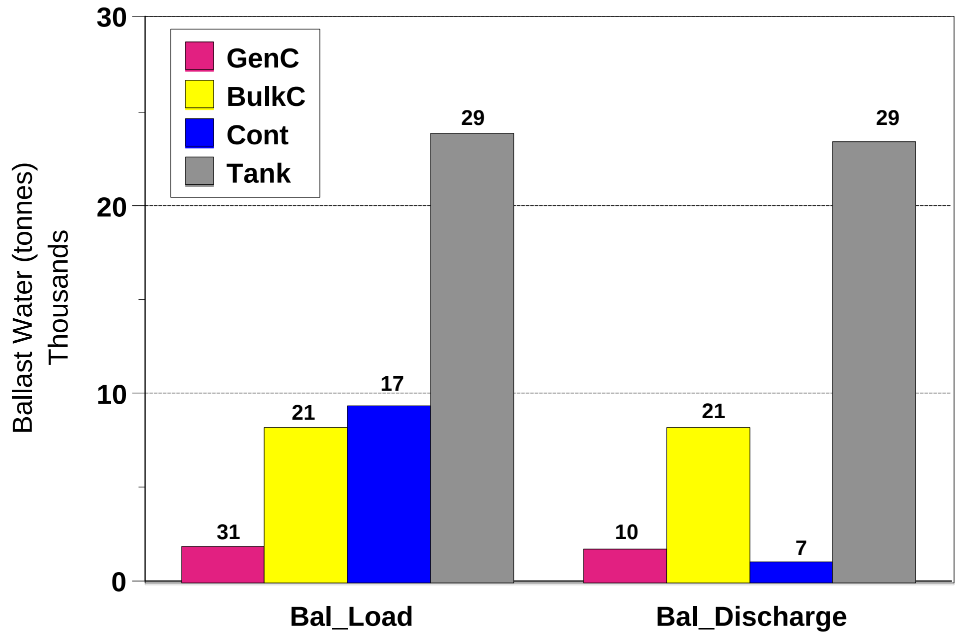

Figure 6. Variation in ballast water discharge patterns among ship types - average ballast water on board and average volume of ballast water discharged by each ship type. The number of ships in each category is indicated on the top of the bar.

The ships discharging the greatest volumes of water were the Oil Tankers docking at Come-by Chance and Whiffen Head in NFLD (max 46,407 m^3) and Point Tupper in NS (max 40,950 m^3). The Bulk Gypsum carriers docking in the four ports of Halifax, Hantsport, Point Tupper, and Little Narrows in NS discharged ballast water loads as high as 28,763 m^3. At Hantsport where the tidal regime imposes a docking period of approximately 3 h, this ballast water discharge is often initiated in the lower reaches of the Bay of Fundy. The Chemical Tankers and Bulk Ore carriers docking in Belledune, NB discharged a maximum of 12,400 m^3. By comparison, the Container ships and General Cargo carriers discharged relatively small volumes of ballast water between 150 and 2400 m^3.

The origin and type of ballast water discharged in each province varied depending on the whether the ships had undertaken an open water exchange (Figure 7). All ships that discharged ballast water in NFLD originated from FAO region A and approximately 50% of these had conducted an exchange in either coastal or oceanic waters. In NB, the water sources were more varied but FAO region A predominated and the bulk of the ships discharged ocean water. In NS, the dominant water source was FAO region A, but in this instance, the proportion of ships which had not conducted an exchange was relatively high. In PEI, no ballast water was discharged.

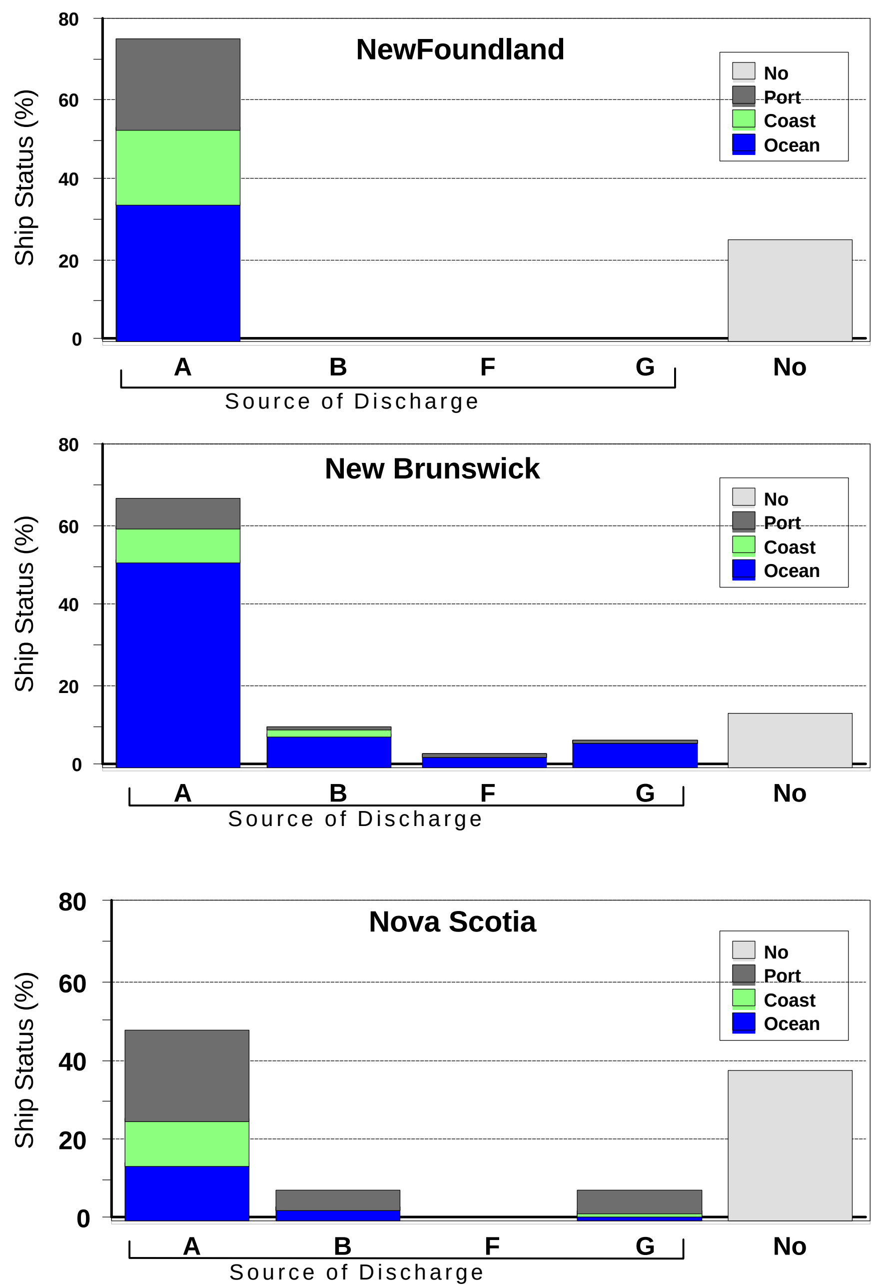

Figure 7. Proportion of ships in each province discharging ballast water originating from the various FAO regions. The proportion of the ships which did not discharge ballast water in each province is also indicated.

3.2 Ballast Water Samples

3.2.1 Distribution by origin

A total of 270 samples (approximately three per ship) were obtained from the 98 ships between September 10 2001 and February 28 2002. The details of the sampling schedule, the tanks sampled, the geographical origin of the samples, the sampling method used and the volume sampled are indicated in Appendix 4. A map describing the geographical origin of the samples (Figure 8) indicates the range of source regions, as well as the high incidence of samples from the eastern US and the mid-Atlantic.

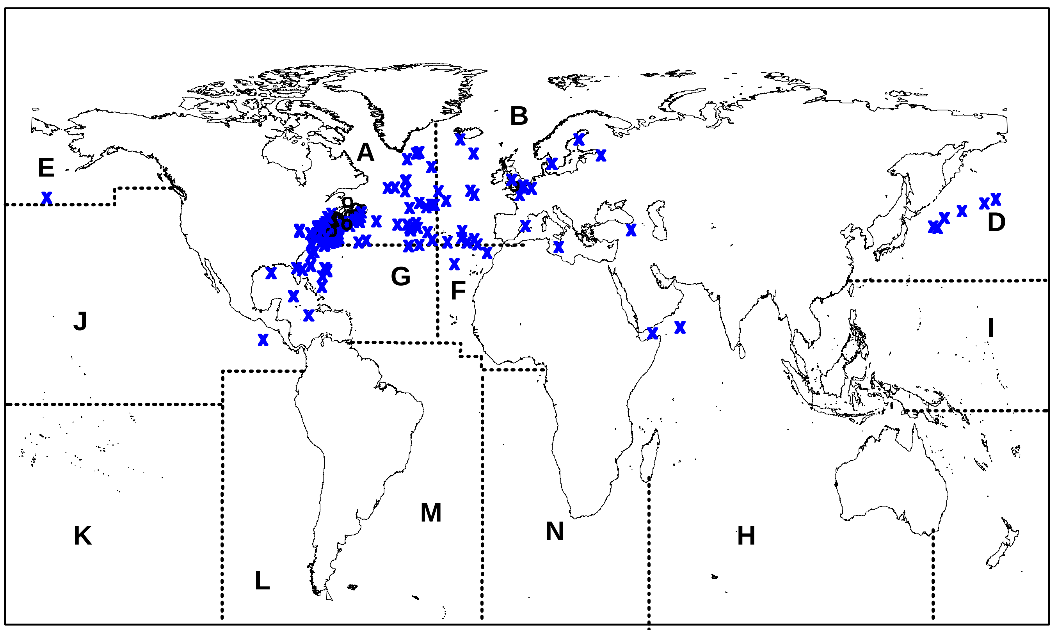

Figure 8. World map indicating the origin of the ballast water samples in terms of FAO region.

The relative distribution of samples from the various regions by water type is indicated displayed for each province (Figure 9) and the Atlantic region overall (Figure 10). In general, the predominance of samples from region A is consistent with the discharge patterns. Overall, 70.7% of the ballast water samples originated from region A, 13.3% from region B, and 10% from region

G. In terms of water type, approximately 42% of these samples originated from port waters, 16% had been exchanged in coastal waters and 42% had been exchanged in oceanic waters.

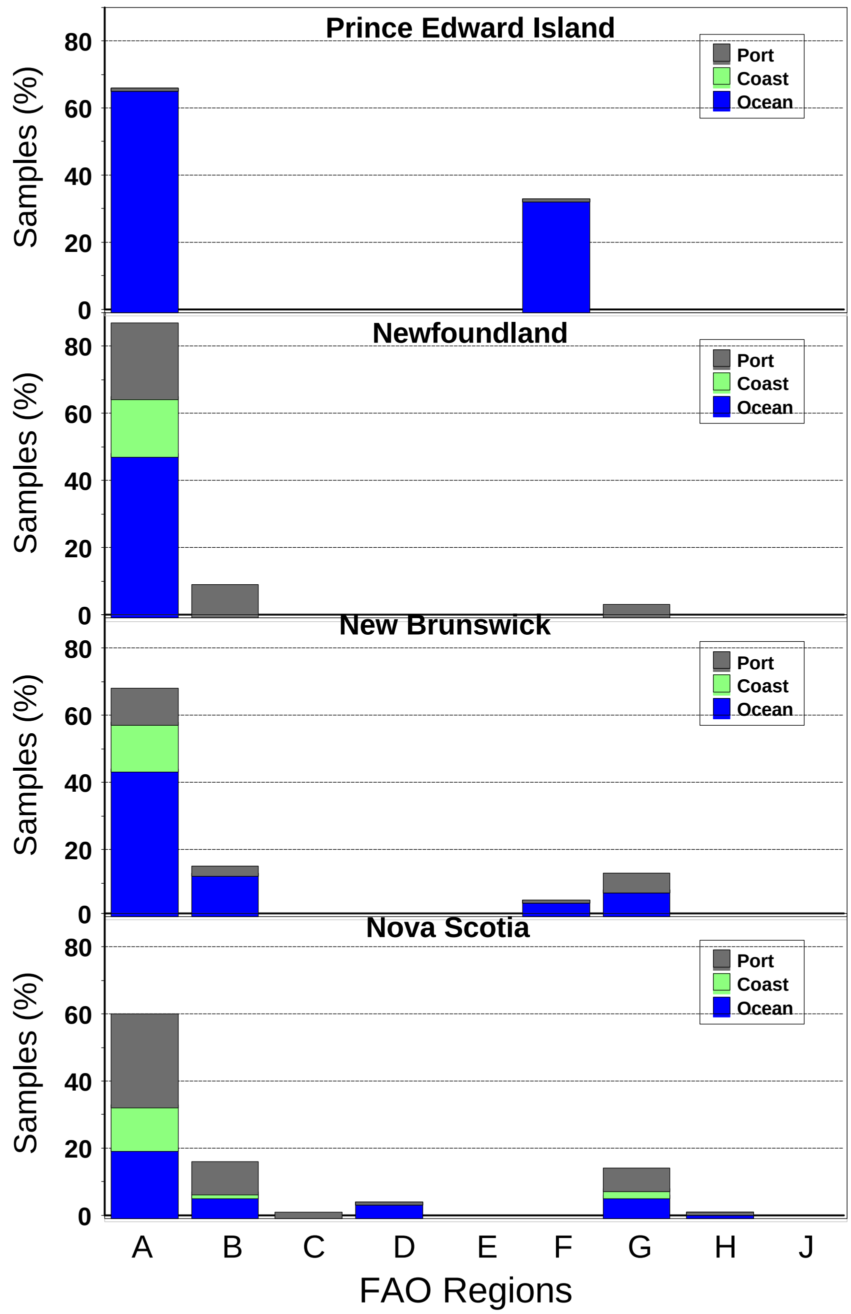

Figure 9. Bar graph summarizing the origin of the ballast water samples (FAO region) by water type in each province. Note that the distribution of the samples by origin for the four provinces was similar with the exception of PEI for which there were only six samples.

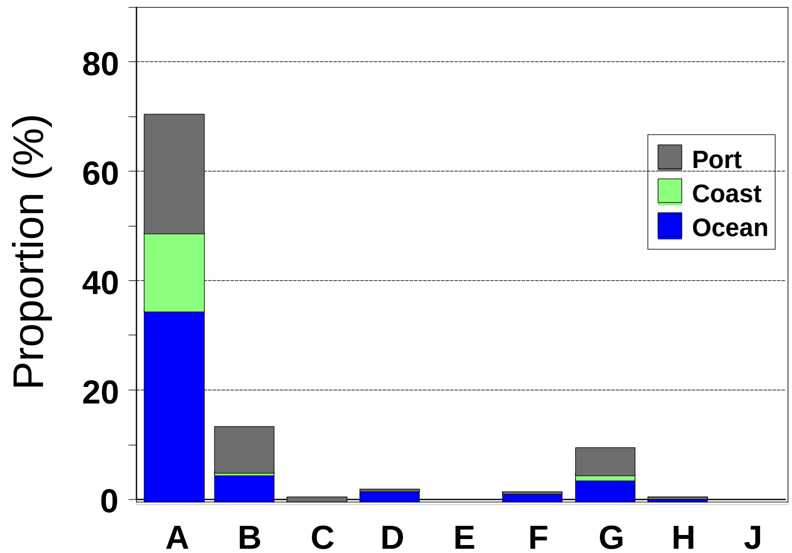

Figure 10. Bar graph summarizing the origin of the ballast water samples (FAO region) by water type over all provinces. Coastal water was defined as >1 km offshore but less than 2000 m deep as opposed to oceanic water which was >2000 m deep.

3.2.2 Age characteristics

The age of the ballast water samples varied from 1 to 289 d old (Appendix 3, Table 6). Tankers and Bulk carriers tended to have ballast water with similar age characteristics (<5-d-old) and ballast water exchange had little impact on the mean age of the samples given that the trips were generally of short duration. The mean age of exchanged water on board Container ships was 22 d compared to 83 d for non-exchanged water. Samples of exchanged ballast water from General Cargo ships were 8.4 d old compared to 12.9 d old for non-exchanged water.

Table 6. Age of the ballast water by ship type and status of exchange.

		Age (days)		
Ship Type	Status of Exchange	Mean	Minimum	Maximum
Tank	Yes	2.9	1	18
	No	4.3	1	7
Bulk	Yes	3.7	1	25
	No	4.0	1	6
GenC	Yes	8.4	1	39
	No	12.9	4	56
Cont	Yes	22.3	2	169
	No	83.0	7	289

3.2.3 Salinity characteristics

The salinity of samples obtained from ballast water tanks exchanged in oceanic areas were typically greater than 30°/oo. Samples from tanks exchanged in coastal areas had salinities exceeding 25°/oo whereas samples of water taken up in various ports had highly variable salinities. Statements regarding the effectiveness of ballast water exchange can be verified to some degree by comparing the observed and the expected salinity in a tank (Table 7). For example, 5.2% of the ballast water samples originating from tanks which had supposedly undergone an oceanic exchange had salinities less than 25°/oo (14 samples from 6 ships). Another 2.6% of the samples were also from tanks which had supposedly been exchanged in oceanic areas but the salinities were between 25°/oo and 30°/oo which suggest that the exchange was less effective than expected. Similarly, another 1.5% of the tanks were exchanged in coastal water and yet the observed salinity was less than 25°/oo. These discrepancies suggest that there may be problems with the exchange process or inaccuracies in the ballast water reporting. It should be noted that salinity discrepancies only detect problems in cases where ships have originated from low salinity ports.

Table 7. Classification of the ballast water samples (%) in terms of the observed salinity, whether the ballast water had been exchanged, and the origin in terms of water type. Highlighted is the proportion of ships where the measured salinity did not agree with the reported source.

Exchanged	Source	<25°/oo	25-30°/oo	>30°/oo
No	Port	13.3	10.4	11.1
Yes	Coastal <2000 m	1.5	4.1	10.4
Yes	Oceanic >2000 m	5.2	2.6	41.5

3.3 Phytoplankton Taxa

3.3.1 Incidence and abundance

Microscopic assessment of the 235 phytoplankton samples yielded a total of 424 taxa of which 349 belonged to the phytoplankton and 75 belonged to various microzooplankton groups (excluding larger forms such as copepods). A full list indicating the frequency of occurrence and the mean and maximum cell concentration of each taxa is included in Appendices 5 and 6.

Among the 349 phytoplankton taxa were 213 Diatoms, 96 Dinoflagellates, 13 Chlorophytes, six Prasinophytes, five Cyanophytes, three Dictyochophytes, two Chrysophytes, one Euglenophyte, one Prymnesiophyte and 9 unidentified cysts which were presumed to be phytoplanktonic. Of these taxa, 47 are typically found in fresh or brackish-water environments including all the Chlorophytes, Cyanophytes, Chrysophytes, Euglenophytes and 26 of the Diatoms. Among the 75 microzooplankton taxa were 59 Tintinnids, five brackish-water Rotiferans, two Protozoans, one Nematode, one Echinoderm larva, one Ostracod, one Radiolarian, one Foraminiferan, and four unidentified taxa.

In terms of incidence, the five dominant phytoplankton taxa were the diatom *Skeletonema costatum* (141samples), the dinoflagellate *Ceratium fusus* (119), the diatom *Ditylum brightwelli* (112), the dinoflagellate *Prorocentrum gracile* (100), and the dictyochophyte *Dictyocha speculum* (93). In terms of relative incidence, two taxa were found in greater than 50% of the samples, 20 taxa in 25 to 50% of the samples, 116 taxa in 5 to 25% of the samples, and 286 taxa occurred in fewer than 5% of the samples.

In terms of mean cell concentration, the five dominant taxa were the three diatoms *Skeletonema costatum* (3246 cells/liter), *Dactyliosolen fragilissimus* (1098 cells/liter), and *Actinocyclus tenuissimus* (681 cells/liter), and the two dinoflagellates *Prorocentrum gracile* (684 cells/l) and *Prorocentrum micans* (571 cells/liter). In terms of relative abundance, two taxa occurred at concentrations greater than 1000 cells/liter, 33 taxa at 100 to 1000 cells/liter, 115 taxa at 10 to 100 cells/liter, 241 taxa at 1 to 10 cells/liter, and 33 taxa at less than 1 cell/liter.

Among the 75 microzooplankton taxa (Appendix 6), the five dominant forms were the tintinnids *Tintinnus lusus-undae* (49 samples), *Tintinnopsis brevicollis* (27), and *Helicostemella kilensis* (26), the brackish-water rotifer *Keratella cochlearis* (31) and an unidentified nematode (39). In terms of abundance, the five dominant microzooplankton taxa were the three tintinnids *Tintinnopsis rapa* (112 ind/liter), *Tintinnopsis tubulosoides* (37 ind/liter), and *Tintinnopsis sufflata* (31 ind/liter), the brackish-water rotifer *Keratella cochlearis* (26 ind/liter) and an unidentified ostracod (63 ind/liter).

3.3.2 Variations in phytoplankton diversity and abundance

Overall, the maximum number of taxa observed in a single sample was 68 and the maximum abundance was 218,363 cells/liter (Appendix 8). In terms of diversity, eight samples had in excess of 50 taxa, 93 samples had 25 to 50 taxa, 86 samples had 10 to 25 taxa, and 44 samples had 2 to 10 taxa. In terms of overall abundance, one sample had a concentration over 100,000 cells/liter; 16 samples had between 10,000 and 100,000 cells/liter, 65 samples had between 1000 and 10,000 cells/liter, 87 samples had between 100 and 1000 cells/liter, 48 samples had between 10 and 100 cells/liter, and 18 samples had from 1 to 10 cells/liter.

Variation due to sampling volume

On two occasions trials were undertaken to evaluate the sampling strategy, specifically the effect of sample volume on the results (Table 8). Two replicate samples of 50 liters were taken from the same ballast tank (Tank 1A and 1B) and the data were compared with another 50-liter sample from a separate tank (Tank 2A) containing water from the same source (Jacksonville, FL). The various replicates were also pooled (100 liters or 150 liters) to determine the effect of increasing the sample volume. The data appeared to suggest that whereas the three 50-liter samples gave similar results, augmenting the sample volume could have a substantial positive impact on the number of taxa detected. These results reflect the high frequency of rare taxa in the samples; as the sample volume increases more of these taxa are detected, but they occur in such low concentrations that they have little impact on the overall abundance. This dataset is based on only two ships, but it may be important to confirm these relationships for future monitoring studies.

Table 8. Relationship between sample volume and the diversity (number of taxa) and abundance (cells/liter) of phytoplankton taxa in samples of water from the same source. Tank 1A and Tank 1B are 50-liter samples from the same ballast tanks; Tank 2A is a 50-liter sample from a separate ballast tank. The effect of pooling the data from samples either within a ballast tank, between ballast tanks, or over all samples is indicated.

Ship Name	Sampling date	Sample	Diversity	Abundance
AV Kastner	09-Nov-2001	50 liters (Tank 1A)	29	4192
		50 liters (Tank 1B)	29	7121
		50 liters (Tank 2A)	28	3352
		100 liters (1A+1B)	44	4608
		100 liters (1A+2A)	43	3772
		150 liters (1A+1B+2A)	56	2093
AV Kastner	22-Nov-2001	50 liters (Tank 1A)	52	799
		50 liters (Tank 1B)	45	1019
		50 liters (Tank 2A)	44	695
		100 liters (1A+1B)	72	709
		100 liters (1A+2A)	69	747
		150 liters (1A+1B+2A)	86	352

Variation due to ship type

Among the various ship types, the Tankers had the highest number of taxa at 33.0 followed by the Bulk carriers at 22.5, the General Cargo carriers at 19.7 and the Container ships at 17.8 (Figure 11). The Tankers also had the highest cell concentration with a mean of 7183 cells/liter, followed by the Container carriers at 3284 cells/liter and the Bulk carriers at 2710 cells/liter.

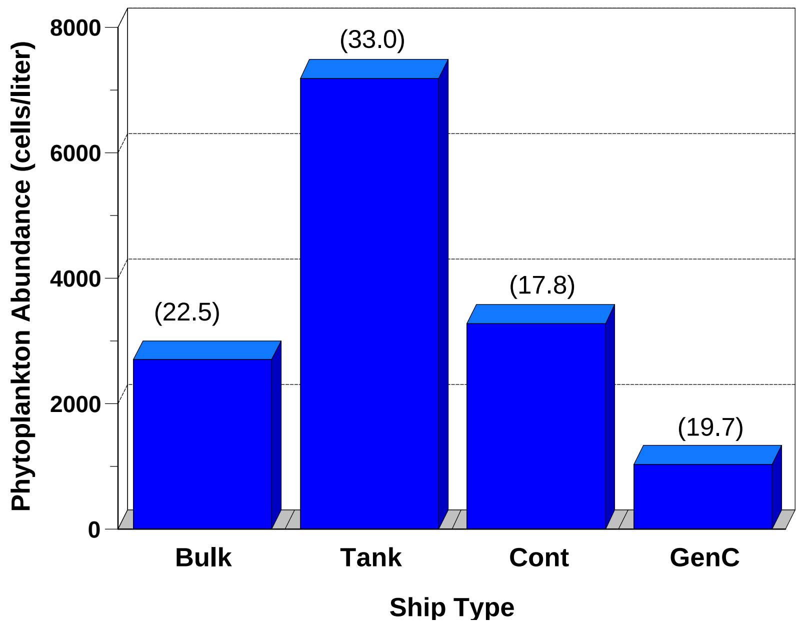

Figure 11. Abundance of phytoplankton taxa in the ballast water samples from each ship type. The mean number of taxa for each ship type is indicated above each bar.

Variation due to origin

The origin of the water samples had a significant effect on the number of phytoplankton taxa and the cell concentration (Figure 12). Water samples originating from FAO region A (Northwest Atlantic) had a mean of 25.9 taxa followed by FAO region B (Northeast Atlantic) with 23.4 taxa and region G (Western Central Atlantic) at 19.4 taxa. Although the highest value was 27.0 taxa for region E (Northeast Pacific), this region was represented by a single sample. Region D (Northwest Pacific) also had a relatively high number of taxa (19.1) considering the age of the samples (>40 d old on average). This result may also be an artefact of sampling from the ballast water pump system on the Container ships. In terms of cell concentration, water samples originating from region B had the highest mean value at 4920 cells/liter (99% live) followed by region A at 4025 cells/liter (99% live), and region H at 3365 cells/liter (1%live). Note that this comparison may be compromised by the wide variation in the number of samples originating from each region; only regions A, B, D, and G had greater than 5 samples.

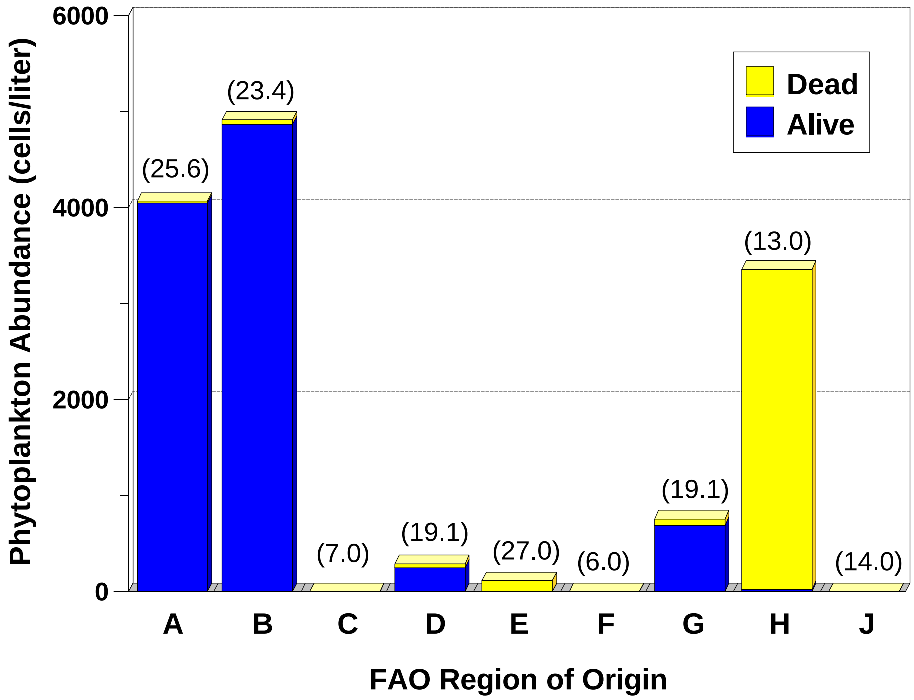

Figure 12. Mean concentration of phytoplankton cells in the ballast water samples from the various FAO regions. The mean number of taxa (dead and alive) is indicated above each bar.

Variation due to water type

To determine whether there were differences in the number of phytoplankton taxa and cell abundance originating from different water types, the samples were classified as port (non-exchanged), coastal (exchanged) or oceanic (exchanged) (Figure 13). Coastal water was found to contain the greatest number of taxa (29.6), followed by oceanic water (23.7) and port water (21.9). In terms of cell abundance, however, port water had the highest mean abundance (5000 cells/l) compared to coastal water (4000 cells/liter) and oceanic water (2000 cells/liter). There was no significant variation in the proportion of live cells from the three water types.

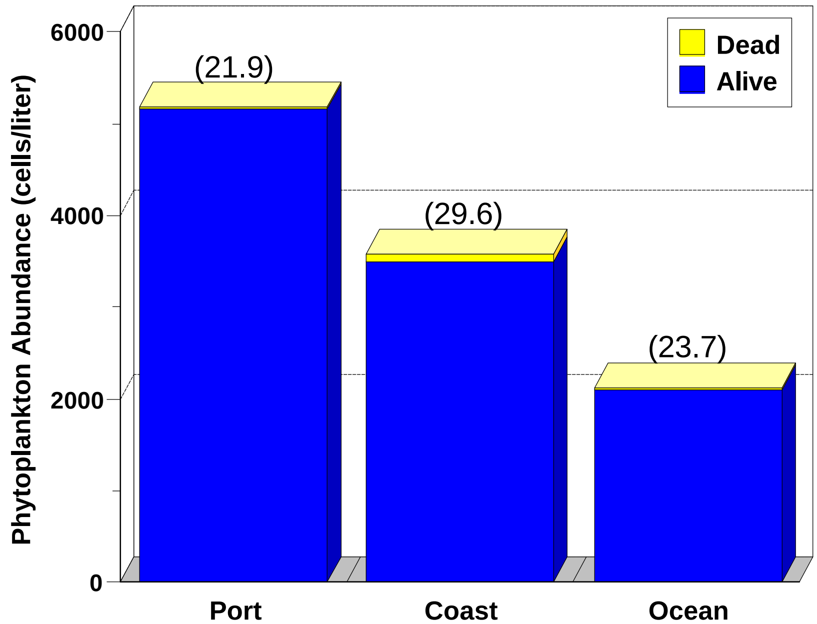

Figure 13. Mean abundance of phytoplankton cells in the ballast water samples from the various water types. The mean number of taxa (dead and alive) is indicated above each bar.

Variation due to age

The mean age of the water arriving in the Bulk carriers and Tankers was less than 4.3 d (Table 6). Water arriving in the General Cargo carriers was on average 10 d old whereas water arriving in Container carriers had a mean age of 34 d. Overall, 182 of the 235 samples were from ballast water less than 1 wk old and 202 were less than 2 wk old. Phytoplankton abundance and the number of taxa declined with age; typically, very few live cells (Figure 14) or taxa (Figure 15) were observed in samples older than 6 wk. It should be noted that there was a wide variation in the abundance of live cells in the samples less than 2-wk old.

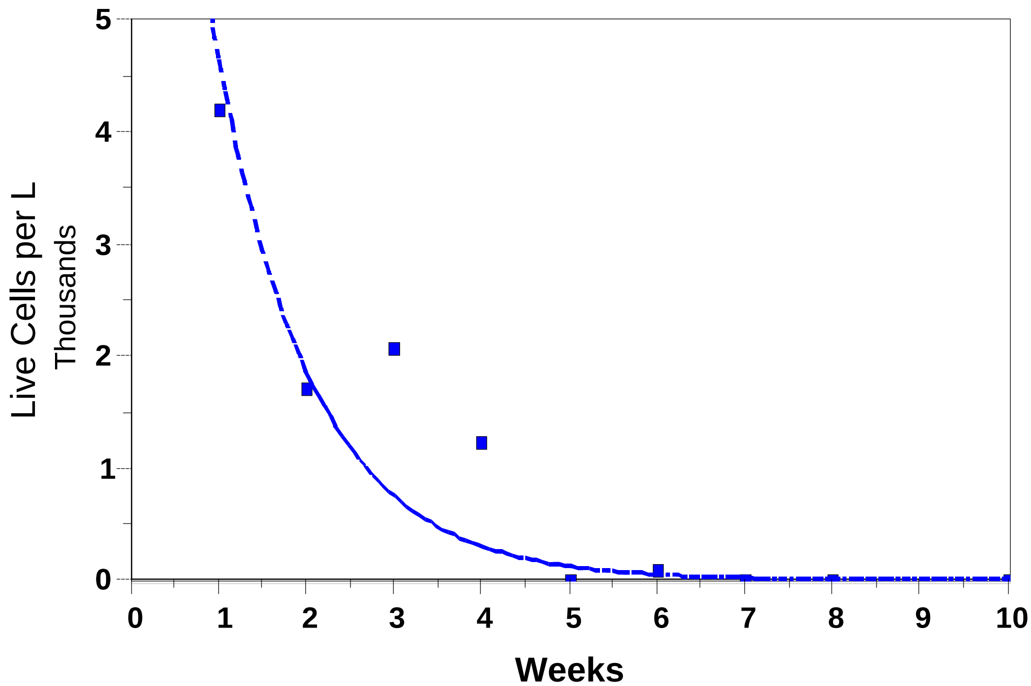

Figure 14. Concentration of live phytoplankton taxa vs age (weeks) in ballast water samples.

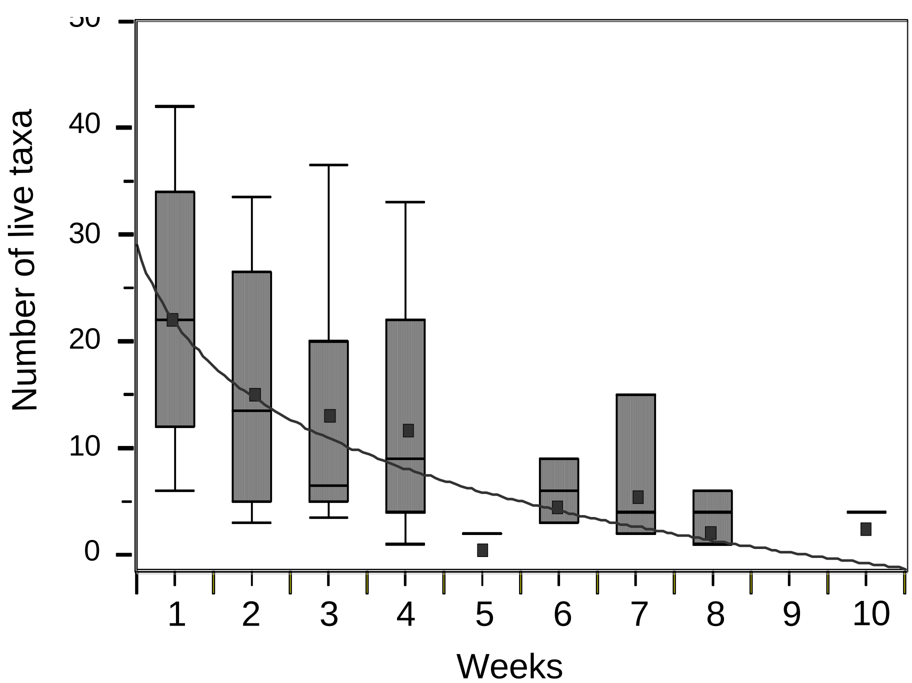

Figure 15. Number of live phytoplankton taxa vs age (weeks) in ballast water samples.

3.3.3 Non-indigenous and toxic/harmful taxa

Non-indigenous taxa

Of the 424 phytoplankton taxa observed, 105 (25%) were classified as non-indigenous, 187 (44%) were classified as indigenous, and 132 (31%) were considered of unknown geographic affiliation. Among others this last category included: (a) nine unidentified cyst forms; (b) 43 tintinnid taxa; (c) four unidentified microzooplankton taxa; and (d) 47 brackish-water taxa which are likely native to North America but are not normally observed in marine waters. Some of these unaffiliated taxa were very likely non-indigenous but there was insufficient local information to determine their status.

Of the 105 non-indigenous taxa, many are reported to occur in warm temperate to tropical waters (Table 9). Five were known toxic/harmful species which pose a threat to other organisms, and nine were declared a potential risk because they belonged to genera which include harmful/toxic species (see Table 10). The remaining 91 taxa pose an unknown risk with respect to possible ecological disruption, e.g. competition with native species.

In terms of frequency of occurrence, the five most common non-indigenous taxa were the diatoms *Bacteriastrum delicatulum* (43 samples), *Pleurosigma normanii* (41), and *Odontella sinensis (33),* followed by the dinoflagellate *Ceratium minutum (33)*, and the diatom *Chaetoceros peruvianus* (28). Of the 100 remaining non-indigenous taxa, 77 occurred in fewer than 10 samples. Mean cell concentrations were relatively low; the highest values were recorded for the diatoms *Chaetoceros tortissimus* (416 cells/liter), *Pseudo-nitzschia lineola* (415 cells/liter), *Thalassiosira oestrupii venrickae* (175 cells/liter), *Pseudoleyanella lunata* (89 cells/liter) and *Roperia tesselata* (63 cells/liter).

Table 9. List of non-indigenous taxa, their frequency of occurrence, mean and maximum cell concentration and geographic affiliation. "?" represents unknown geographic affiliation.

Status Class Taxa	Freq	Mean Conc cells/liter	Max Conc cells/liter	Geographic affiliation
Known to be Toxic				
Diatom				
Pseudo-nitzschia australis?	2	6.9	6.9	Temperate to warm water (Pacific?)
Dinoflagellate				
Dinophysis acuta	8	3.2	6.5	Cold temperate waters, oceanic/coastal
Dinophysis caudata	10	2.8	8.0	Warm temperate waters, estuarine/coastal
Dinophysis fortii	4	9.8	32.5	Cold temperate to tropical waters
Dinophysis mitra	1	1.6	1.6	Warm temperate to tropical waters
Potentially Toxic/Harmful				
Diatom				
Pseudo-nitzschia lineola?	7	415.3	1837.5	Cold temperate to tropical waters

Pseudo-nitzschia subpacifica	24	53.4	386.8	Temperate to warm temperate waters
Dictyochophyte				
Dictyocha octonaria	6	1.7	3.1	Oceanic, Atlantic, Pacific
Dinoflagellate				
Dinophysis dens	7	4.7	19.5	Cold temperate to tropical waters
Dinophysis pulchella	3	1.1	1.3	?
Dinophysis sp	12	36.0	189.8	Temperate waters?
Gonyaulax birostris	1	0.4	0.4	Warm temperate to tropical waters
Gonyaulax turbynaii	1	1.6	1.6	Temperate waters (region B?)
Prorocentrum scutellum	1	7.0	7.0	Arctic to tropical waters
Unknown Risk				
Diatom				
Achnanthes brevipes	5	6.1	20.4	Temperate waters (region B?)
Actinoptychus splendens	3	0.8	1.4	Region B
Amphora robusta	1	0.9	0.9	?
Asterionellopsis kariana	1	5.8	5.8	Cold to temperate waters
Asteromphalus flabellatus	1	0.9	0.9	?
Bacteriastrum delicatulum	43	13.8	168.0	Temperate waters (regions B and C)
Bacteriastrum elongatum	5	10.5	42.7	Warm temperate to tropical waters, oceanic
Bacteriastrum furcatum	3	3.1	4.3	Warm to temperate waters
Bacteriastrum hyalinum	19	15.5	156.4	Temperate waters (regions B and C)
Bellerochea horologicalis	27	27.0	97.5	Gulf of Mexico
Biddulphia obtusa	13	5.5	14.0	?
Biddulphia pulchella	1	0.6	0.6	?
Biddulphia reticulum	1	3.5	3.5	Region B
Biddulphia rhombus	5	2.2	3.8	?
Campylosira cymbelliformis	6	53.0	136.5	?
Cerataulus turgida	2	11.9	16.3	Region B, coastal
Chaetoceros decipiens singularis	2	45.8	63.0	?
Chaetoceros densum	3	61.3	127.1	Temperate waters
Chaetoceros diversus	8	11.7	32.5	Warm waters (region B, coastal)
Chaetoceros laevis	6	6.3	15.3	Warm waters
Chaetoceros messanensis	6	6.4	14.6	Warm waters (region B, oceanic)
Chaetoceros peruvianus	28	5.4	22.8	Warm to temperate waters (region B)
Chaetoceros rostratus	3	15.4	27.2	Warm waters
Chaetoceros sp	4	39.6	84.5	Warm waters, estuarine?
Chaetoceros tortissimus	1	416.0	416.0	Temperate waters
Climacodinium frauenfeldianum	5	9.8	27.8	Warm temperate (coastal)
Cymatosira lorenziana	11	21.6	86.3	Warm to temperate waters, coastal
Dactyliosolen phuketensis	2	6.5	11.3	Warm to temperate waters, North Sea
Detonula pumila	2	6.8	9.9	Warm waters
Ditylum sol	1	15.4	15.4	Warm waters
Eucampia cornuta	1	0.8	0.8	Temperate to warm waters
Eupodiscus radiatus	4	5.5	16.1	Atlantic waters
Fragilariopsis doliolus	1	6.9	6.9	Warm temperate to tropical waters
Guinardia striata	17	47.7	435.2	Cold temperate to tropical waters
Gyrosigma prolongatum	4	11.5	25.6	?
Hemiaulus hauckii	7	1.5	3.1	Temperate to warm waters
Hemiaulus membranaceus	15	4.3	9.2	Warm waters
Hemiaulus sinensis	6	8.1	13.0	Temperate to warm waters
Lioloma delicatulum	1	3.8	3.8	Warm to temperate waters, Gulf of Mexico
Lioloma pacificum	8	6.4	18.9	Temperate to warm waters (region C)
Lithodesmium undulatum	17	4.8	32.0	Temperate to warm waters (region B)
Manguinea fusiformis?	4	2.2	4.5	?

Manguinea rigida?	2	9.3	16.8	?
Membraneis challengeri	4	11.8	17.4	?
Meuniera membranacea	4	5.6	7.1	Temperate waters
Odontella longicruris	13	3.6	7.5	Temperate to warm waters
Odontella mobiliensis	27	4.4	15.0	Cosmopolitan
Odontella sinensis	33	7.1	48.0	Cosmopolitan
Pinnularia stauntonii	17	5.7	27.0	?
Plagiotropis lepidoptera	14	5.0	18.0	?
Planktoniella sol	3	2.9	7.0	Temperate to warm waters (region B)
Pleurosigma elongatum	13	5.6	21.0	?
Pleurosigma normanii	41	8.3	45.0	Cosmopolitan
Podosira stelliger	3	3.6	7.3	?
Proboscia eumorpha	3	4.1	7.5	Subarctic waters
Pseudoleyanella lunata	3	89.5	240.0	?
Pseudosolenia calcar avis	5	4.6	6.8	Warm waters (region B)
Rhizosolenia styliformis	9	14.1	97.9	Northern part of North Atlantic (region B)
Roperia tesselata	3	63.1	101.5	Warm waters (region B)
Stephanopyxis nipponica	6	28.9	99.0	Temperate to northern cold water region
Stephanopyxis palmeriana	3	1.8	3.3	Temperate to warm waters (region B)
Stephanopyxis turris	16	6.4	22.5	Temperate to warm waters
Thalassionema bacillare	3	8.9	22.3	Warm waters
Thalassiosira oestrupii venrickae	14	174.8	630.5	Arctic to temperate waters
Thalassiosira punctigera	9	38.8	105.0	Temperate to warm waters (region B)
Triceratium spinosum	2	0.7	1.0	?
Dinoflagellate				
Amphisolenia bidentata	1	0.7	0.7	Warm temperate to tropical, oceanic
Ceratium arietinum	4	3.4	6.3	Warm temperate to tropical waters
Ceratium azoricum	3	2.2	3.8	Temperate waters
Ceratium candelabrum	1	0.4	0.4	Warm temperate to tropical waters, oceanic
Ceratium extensum	1	1.0	1.0	?
Ceratium furca	24	14.1	82.7	Cold temperate to tropical waters, coastal
Ceratium gibberum	1	0.4	0.4	Warm temperate to tropical waters
Ceratium inflatum	23	4.1	12.8	Warm temperate to tropical waters, oceanic
Ceratium longirostrum	1	1.7	1.7	Warm waters (regions B and C)
Ceratium massiliense	1	0.3	0.3	Warm temperate to tropical waters (reg B)
Ceratium minutum	33	22.6	214.5	?
Ceratium pentagonum	10	3.9	12.0	Warm temperate to tropical waters (reg B)
Ceratium platycorne	1	0.4	0.4	Warm waters (region B)
Ceratium setaceum	11	3.1	8.3	?
Ceratium teres	13	4.2	8.3	Warm temperate to tropical waters, oceanic
Corythodinium tesselatum	3	4.6	10.0	Warm temperate to tropical waters, oceanic
Goniodoma polyedricum	2	1.0	1.6	Subtropical to tropical waters, oceanic
Gonyaulax polygramma	6	10.4	32.8	Cold temperate to tropical waters
Gonyaulax scrippsae	1	1.7	1.7	Cosmopolitan, coastal
Ornithocercus heteroporus	2	0.8	1.1	Warm temperate to tropical waters, oceanic
Oxytoxum milneri	1	1.2	1.2	?
Oxytoxum scolopax	12	2.3	6.4	Warm temperate to tropical waters
Podolampas palmipes	9	3.4	6.5	Warm temperate to tropical waters, oceanic
Protoperidinium diabolum	3	4.8	9.5	?
Roscoffia capitata	2	0.8	0.9	Temperate waters, usually benthic

Toxic/Harmful taxa

Of the 424 taxa observed, 20 (5%) were classified as toxic or harmful (Table 10). The toxic species included 6 diatoms and 11 dinoflagellates which are known to be produce toxins which can accumulate in shellfish and cause gastrointestinal and/or neurological illnesses in consumers. The three harmful taxa included two diatoms and one dictyochophyte which have been associated with fish-kills. Of these 20 toxic/harmful taxa, five were non-indigenous and 15 were indigenous to Eastern Canadian waters. All five non-indigenous taxa were relatively rare; none occurred in more than ten samples and cell abundance was <10 cells/liter. Among the 15 indigenous taxa the dominant forms were the diatoms *Pseudo-nitzschia multiseries* (70 samples) and *Pseudo-nitzschia fraudulenta* (56), and the dinoflagellates *Dinophysis norvegica* (38) and *Dinophysis rotundata* (37). The highest mean cell concentrations were observed for *Pseudo-nitzschia multiseries* (397 cells/liter), *Pseudo-nitzschia delicatissima* (213 cells/liter), and *Dinophysis norvegica* (138 cells/liter). It should be noted that cells identified as *P-n. multiseries* could equally well have belonged to the non-toxic species *Pseudo-nitzschia pungens* but Scanning Electron Microscopy would have been required to distinguish the two forms.

Another 33 of the 424 taxa (8%) were assigned to the possible concern category; this group included 15 marine taxa belonging to genera with known toxic species (e.g. *Dinophysis* or *Alexandrium*), five brackish-water Cyanophyte taxa, four unidentified microzooplankton taxa and nine unidentified cysts. The Cyanophytes were included because certain members of this genus are associated with toxic blooms in brackish waters. Among these 33 taxa of potential concern, eight were non-indigenous, four were indigenous (see Table 9), and 21 were considered of unknown affiliation. In terms of frequency, only five of the identified taxa occurred in more than ten samples: *Dictyocha fibula* (59 samples), *Prorocentrum compressum* (45), *Pseudo-nitzschia subpacifica* (24), *Dinophysis punctata* (13), and *Dinophysis sp* (12). The highest cell concentrations were observed for *Pseudo-nitzschia lineola* (415 cells/liter), *Oscillatoria sp* (148 cells/liter), *Alexandrium* sp2 (103 cells/liter) and *Pseudo-nitzschia subpacifica* (53 cells/liter).

Table 10. List of phytoplankton taxa classified as toxic, harmful, or of possible concern. DSP = Diarrhetic Shellfish Poisoning, ASP= Amnesic Shellfish Poisoning, and PSP = Paralytic Shellfish Poisoning. Yes = indigenous, No = non-indigenous, and ? = unknown geographic affiliation.

Status / Class / Taxa	Indigenous	Freq	Mean Conc cells/liter	Max Conc cells/liter	Problem
Known to be Toxic					
Diatom					
Pseudo-nitzschia australis?	No	2	6.9	6.9	ASP
Pseudo-nitzschia delicatissima	Yes	27	212.6	1770.3	ASP
Pseudo-nitzschia fraudulenta	Yes	56	87.1	967.1	ASP
Pseudo-nitzschia multiseries?	Yes	70	396.5	13636.0	ASP
Pseudo-nitzschia pseudodelicatissima	Yes	3	36.5	95.5	ASP
Pseudo-nitzschia seriata	Yes	1	3.0	3.0	ASP
Dinoflagellate					
Dinophysis acuminata	Yes	23	26.5	156.8	DSP
Dinophysis acuta	No	8	3.2	6.5	DSP
Dinophysis caudata	No	10	2.8	8.0	DSP
Dinophysis fortii	No	4	9.8	32.5	DSP
Dinophysis mitra	No	1	1.6	1.6	DSP
Dinophysis norvegica	Yes	38	137.6	3291.8	DSP
Dinophysis rotundata	Yes	37	5.4	28.9	DSP
Dinophysis tripos	Yes	7	5.2	13.0	DSP
Prorocentrum minimum	Yes	2	1.2	1.4	Fish and shellfish-kills
Protoceratium reticulatum	Yes	1	0.8	0.8	Yessotoxins
Protoperidinium crassipes	?	5	4.1	7.3	Azaspiracid toxins
Known to be harmful					
Diatom					
Chaetoceros concavicornis	Yes	26	26.9	81.2	Fish-kills
Chaetoceros convolutus	Yes	6	8.5	27.2	Fish-kills
Dictyochophyte					
Dictyocha speculum	Yes	93	16.9	220.0	Fish-kills
Possible Concern					
Cyanophyte					
Anabaena sp	?	2	2.2	3.8	Cyanotoxins?
Chroococcus sp	?	10	11.4	27.6	Cyanotoxins?
Merismopedia punctata	Yes	1	3.5	3.5	Cyanotoxins?
Merismopedia sp	?	8	10.1	31.5	Cyanotoxins?
Oscillatoria sp	?	5	148.6	540.0	Cyanotoxins?
Diatom					
Pseudo-nitzschia lineola?	No	7	415.3	1837.5	ASP?
Pseudo-nitzschia subpacifica	No	24	53.4	386.8	ASP?
Dictyochophyte					
Dictyocha fibula	Yes	59	6.9	45.0	Fish-kills?
Dictyocha octonaria	No	6	1.7	3.1	Fish-kills?
Dinoflagellate					
Alexandrium sp1	?	1	53.6	53.6	PSP?
Alexandrium sp2	?	2	103.2	195.0	PSP?
Dinophysis dens	No	7	4.7	19.5	DSP?
Dinophysis pulchella	No	3	1.1	1.3	DSP?
Dinophysis punctata	Yes	13	3.0	12.2	DSP?
Dinophysis sp	No	12	36.0	189.8	DSP?

Gonyaulax birostris	No	1	0.4	0.4	PSP?
Gonyaulax turbynaii	No	1	1.6	1.6	PSP?
Prorocentrum compressum	Yes	45	6.0	41.3	DSP?
Prorocentrum scutellum	No	1	7.0	7.0	DSP?
Protoperidinium curtipes	?	12	9.2	49.5	Azaspiracid toxins?
Microzooplankton					
Unidentified sp (4)	?	.	.	.	?
Phytoplankton?					
Unidentified cysts (9)	?	.	.	.	?

Variation due to region of origin

To evaluate the risk of introducing non-indigenous or toxic/harmful taxa from the various FAO regions, the 424 taxa were sorted into several classes according to their characteristics (e.g. indigenous-toxic/harmful or non-indigenous-possible concern, etc.) (Figure 16). To reduce the level of complexity, any taxa which were indigenous or of unknown geographic affiliation but not considered potentially toxic/harmful were excluded. This comprised 169 indigenous taxa and 110 taxa whose origin was unclear for a total of 279 (66%). The remaining taxa were subdivided into four categories. The first category included the 18 indigenous taxa which were considered either toxic/harmful or a possible concern (Ind-Risk). The second category included the 14 non-indigenous taxa considered toxic/harmful or a possible concern (Non-Ind-Risk). The third category comprised the 21 taxa of unknown geographic affiliation which were considered toxic/harmful or a possible concern (Unknown-Risk). The fourth category included the 91 non-indigenous taxa not considered a toxic/harmful risk (Non-Ind). Note that because the number of samples from each FAO region varied, the graph serves only to illustrate the relative proportion of each category within a region rather than among regions.

Taxa belonging to all four categories of concern (Ind-Risk, NIND-Risk, Unknown-Risk, NIND -No Risk) were observed in ballast water originating from all nine FAO regions. In terms of the risk of ballast water-mediated introduction, the most critical of these regions were A (Northwest Atlantic), B (Northeast Atlantic) and G (Western Central Atlantic).

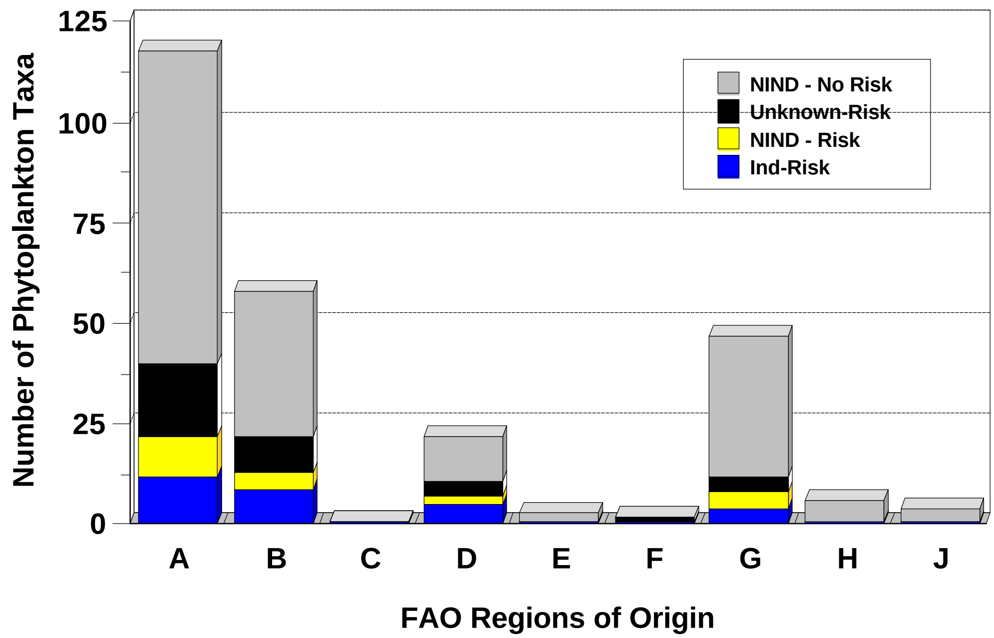

Figure 16. Number of non-indigenous and toxic/harmful phytoplankton taxa originating from the nine FAO regions. **Ind-Risk** refers to all indigenous taxa which are considered toxic/harmful or a possible concern, **NIND-Risk** includes all non-indigenous taxa which are considered toxic/harmful or a possible concern, **Unknown-Risk** includes all taxa of unknown geographic affiliation which were classified as toxic/harmful or a possible concern, and **NIND-No Risk** includes all non-indigenous taxa which were not considered toxic/harmful or a possible concern.

To better assess the risk of finding a non-indigenous or toxic/harmful taxa in a sample from a given region, we summed the number of occurrences of taxa from each group in a given region (e.g. occurrence of non-indigenous taxa in samples from region A) and divided by the number of samples from that region (Figure 17). Only regions with more than five samples were included (A, B, D, and G). This comparison suggested that ballast water from all four regions had similar overall levels of non-indigenous and/or toxic/harmful taxa (approximately 5-6 taxa/sample). However, the relative occurrence of taxa belonging to each of the four categories of concern varied among regions. For example, the mean number of NIND-Risk taxa was highest in samples originating from region D (0.83 taxa/sample), followed by regions B (0.34 taxa/sample), A (0.25 taxa/sample) and G (0.22 taxa/sample). In contrast, the mean estimate for NIND-No Risk taxa was highest in samples from region G (3.9 taxa/sample) followed by regions A (3.1 taxa/sample), B (2.4 taxa/sample) and D (2.3 taxa/sample).

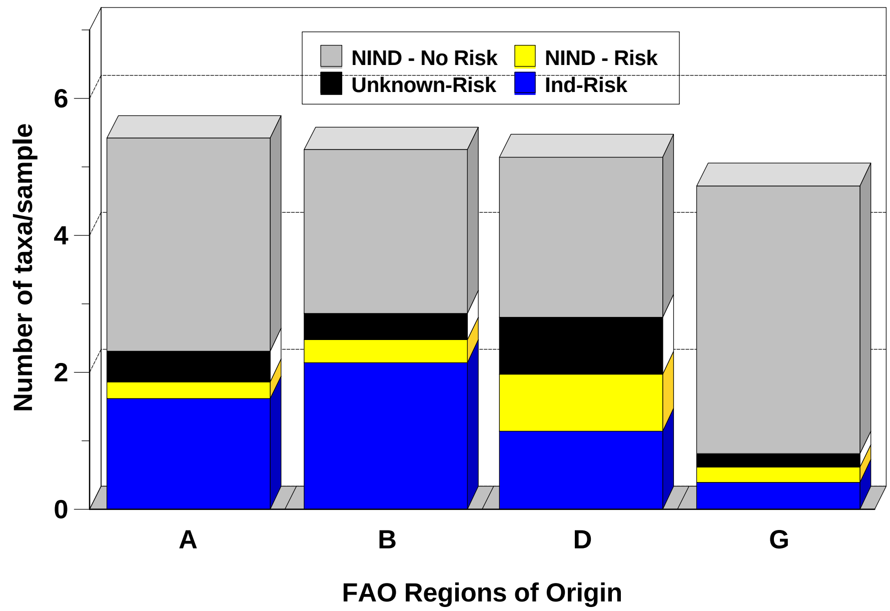

Figure 17. Number of non-indigenous and/or toxic/harmful taxa per sample for four of the nine FAO regions. See Figure 16 for descriptions of the categories.

Variation due to water type

The most widely accepted strategy for reducing the risk of non-indigenous species introductions is to conduct an exchange en route to the next port. The rationale for this action is that the number and abundance of potentially non-indigenous taxa will be lower in the ocean water than in the port water. To determine whether the source of the water (port, coastal, oceanic) had an impact on the occurrence of taxa from each of the four categories of concern, we undertook a comparison similar to that described above (Figure 18). These results suggested that the average number of non-indigenous or toxic/harmful taxa was higher in ballast water which had been exchanged in oceanic waters (5.9 taxa/sample) than in ballast water which had not been exchanged (4.3 taxa/sample). The probability of finding taxa belonging to the three risk categories was similar for coastal and oceanic water (2.3 taxa/sample), but slightly higher than that estimated for water of port origin (2.0 taxa/sample).

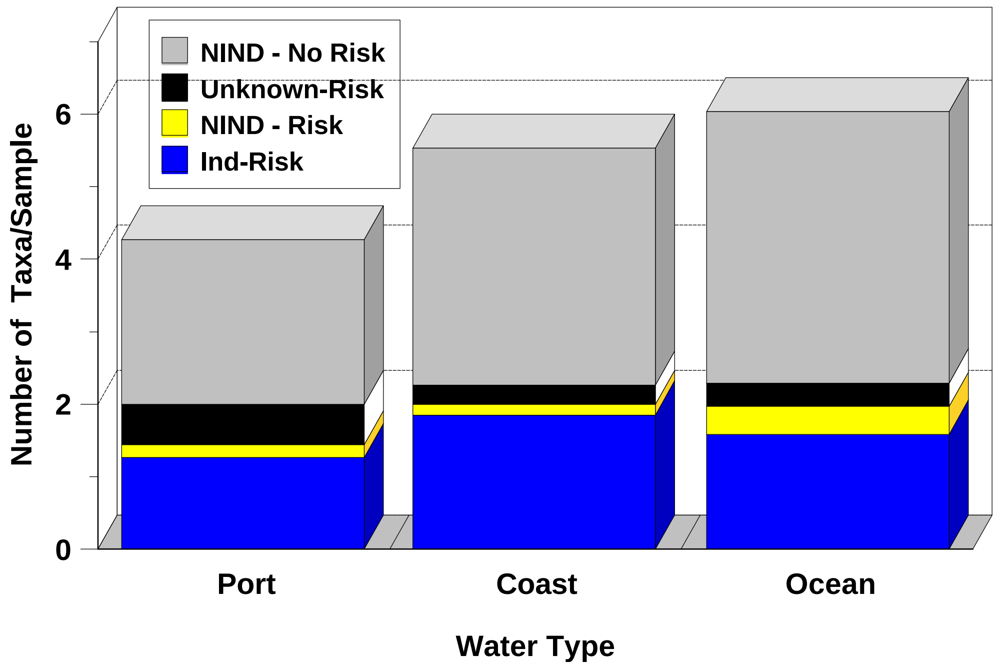

Figure 18. Number of non-indigenous and/or toxic/harmful taxa in samples originating from the three water types: port (non-exchanged), coastal and oceanic (exchanged). See Figure 16 for legend details.

Effect of exchanging ballast water

In the array of ships surveyed, there were four cases where samples of exchanged and non-exchanged water were available from the same ship. A comparison of the number of taxa and cell abundance was therefore conducted to evaluate the impact of the exchange process on the phytoplankton community (Table 11). Contrary to expectations, these results also suggested that undertaking an exchange may increase the risk of introducing non-indigenous taxa. Specifically, in three of the four cases the number of taxa, the cell concentration and the number of non-indigenous taxa was higher in the tanks that had been exchanged in oceanic waters.

Table 11. Subset of four ships carrying both exchanged and non-exchanged ballast water. NIND is the number of non-indigenous taxa and origin of BW indicates the port and the general location where the ballast water was exchanged.

Ship	BW Exchange	Number of Taxa	Conc cells/liter	Sal °/oo	NIND Taxa	Origin of BW
Melfi Atlantic	No	8	208	35.1	3	Cuba (region G)
(GenC)	Yes	8	116	36.1	4	WC Atlantic (region G)
Sophia Britannia	No	3	20	37.1	0	Malta (region C)
(Cont)	Yes	15	97	36.5	8	NE Atlantic (region B)
Valga	No	3	12	1.0	0	Camden NJ (region A)
(GenC)	Yes	13	47	34.2	2	NW Atlantic (region A)
Wilana	No	15	124	2.0	0	Philadelphia (region A)
(Tanker)	Yes	37	162	31.2	3	NW Atlantic (region A)

Within region variability

Given the apparent risks associated with ballast water exchange, we decided to evaluate whether the tentative ballast water exchange zone along the NS continental shelf offered a possible solution, i.e. a relatively lower risk of taking up non-indigenous or toxic/harmful taxa than other coastal/oceanic areas. We therefore compared the incidence of taxa belonging to the four risk categories in water samples originating from region G (port, coastal and oceanic), and region A - northeast US (port, coastal and oceanic) with samples of ballast water which had been exchanged in the vicinity of the tentative NS exchange zone (coastal and oceanic) (Figure 19).

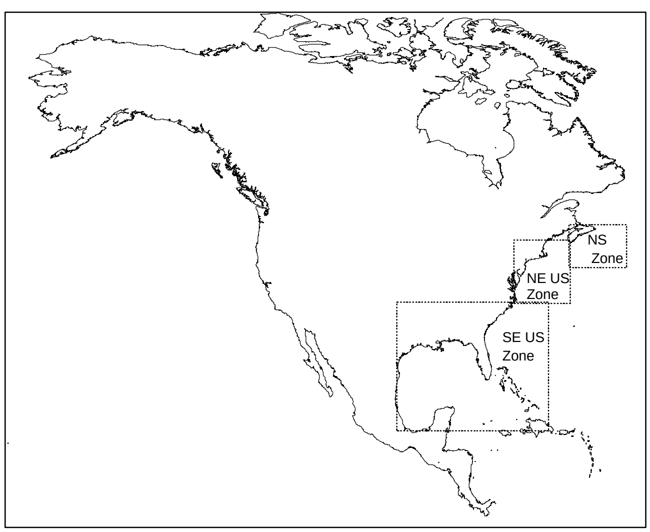

Figure 19. Map of North America showing the three general areas where samples of exchanged ballast water were available. NE-US is northeast US; SE US is southeast US.

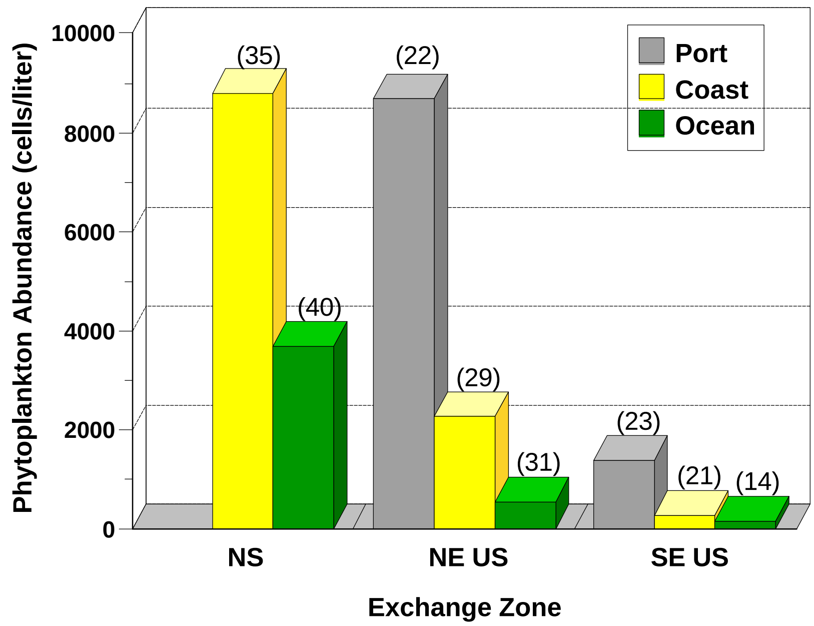

Figure 20. Abundance of phytoplankton in ballast water samples from port, coastal and oceanic water within the three areas of interest: NS, Northeast US and southeast US. The number of taxa recorded is shown in brackets above each bar.

During the period of this study, the diversity and abundance of phytoplankton taxa were generally higher in the coastal and oceanic areas off Nova Scotia than in the other two zones (Figure 20). Within a zone, phytoplankton abundance was lowest in oceanic waters and highest in port waters. Only in the southeast US, however, was there a decline in the number of phytoplankton taxa with distance from land. In effect, a ship which left a port in the southern region and exchanged its ballast water off Nova Scotia would increase rather than decrease the diversity and abundance of phytoplankton taxa.

A comparison of the number of non-indigenous taxa per sample indicated that levels were higher in water originating from the oceanic area off NS than in any of the water types from the US (exchanged and non-exchanged water) (Figure 21). Similarly, samples from the NS area had the highest incidence of toxic/harmfu taxa. With the exception of the US southern zones where there was a decline in the incidence of non-indigenous taxa in offshore waters, there seemed to be an increasing risk associated with exchanging port water for coastal or oceanic water.

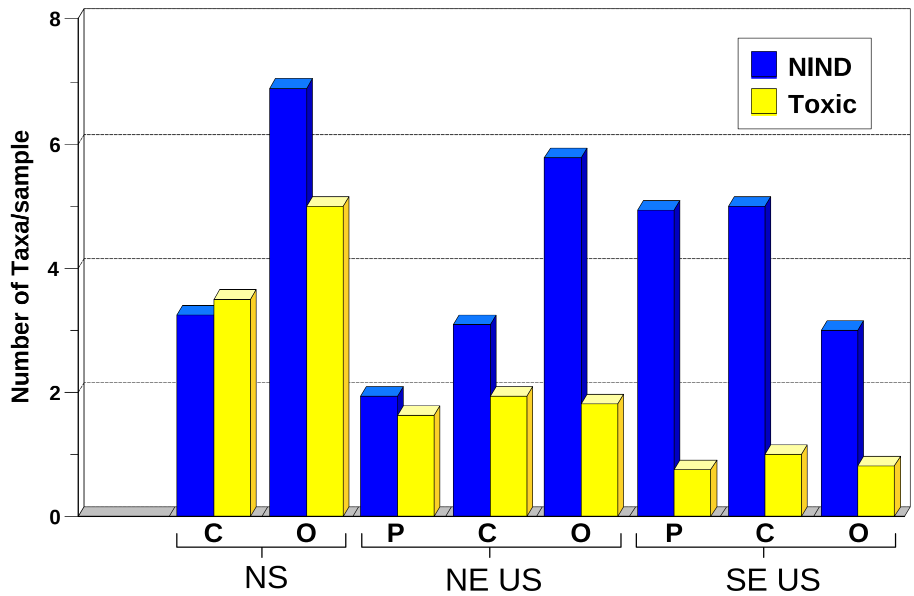

Figure 21. Mean number of non-indigenous (NIND) and toxic/harmful (Toxic) phytoplankton taxa occurring in samples originating from Port (P), Coastal (C) and Oceanic (O) water in the three zones.

3.4 Zooplankton Taxa

All 79 zooplankton taxa observed in the 59 samples were microzooplanktonic (<1 mm in size); for a complete list of the zooplankton taxa and their geographic affiliation see Appendix 7. The zooplankton samples were dominated by small species of copepods, notably, juvenile harpacticoids and cyclopoids. These groups are considered to be cosmopolitan in distribution and occur commonly. Calanoid copepods were also identified in many samples, but none were considered to be invasive. Organisms to take note of included the bivalve, polychaete, and barnacle nauplii/larvae. Identification of bivalve larvae is difficult as not much literature is available. Polychaete and barnacle larvae also are not generally identified to species and although the organisms seen in these samples appear to be similar to those found in northern Atlantic waters, this may not be the case. A total of 79 taxa were identified: Copepoda (55 taxa) including cyclopoid and harpacticoid types, Cladocera (7), Cirripedia (2), Crustacea (1), Amphipoda (1), Cumacea (1), Isopoda (1), Decapoda (1), Mysidacea (1), Ostracoda (1), Ctenostomata (1), Echinodermata (2), Ctenophora (1), Bivalvia (1), Gastropoda (2), and Polychaete larvae (1). In general, the majority of the taxa recorded were larval or juvenile forms.

3.4.1 Incidence and abundance

In terms of incidence, the five dominant taxa were unidentified copepod nauplii (55 samples), the cyclopoid copepod *Oithona similis* (42), unidentified calanoid copepod juveniles (40), the harpacticoid copepod *Microsetella norvegica* (29) and the calanoid copepod *Acartia clausi* (26). Four taxa occurred in greater than 50% of the samples, 6 taxa occurred in 25% to 50% of the samples, 25 taxa in 5% to 25% of the samples, and 44 taxa occurred in less than 5% of the samples.

In terms of abundance, the five dominant taxa were unidentified copepods (20 ind/liter), the cladoceran *Bosmina longirostris* (14 ind/liter), the harpacticoid copepod *Clytemnestra scutellata* (11.4 ind/liter), the calanoid copepod *Acartia tonsa* (8 ind/liter), and the harpacticoid copepod *Euterpina acutifrons* (7 ind/liter). Three taxa occurred at a concentration between 10 and 20 ind/liter, 24 taxa occurred at a concentration between 1 and 10 ind/liter, 52 taxa occurred at concentrations less than 1 ind/liter. It should be noted that the 59 samples selected for zooplankton identification were not chosen at random. Because the objective was to assess the risk of introducing non-indigenous taxa, priority was given to samples from ships originating from more distant regions as well as those which appeared to contain zooplankton. Hence, these samples should tend to reflect the higher limit in abundance and incidence of zooplankton taxa.

3.4.2 Geographic affiliation

None of the 79 taxa was considered non-indigenous to Atlantic Canadian waters; most of the taxa are considered cosmopolitan, especially the copepods. Five taxa were classified as freshwater and another six taxa could not be fully identified; these may have been non-indigenous, but were more likely larval/juvenile stages of endemic species which are difficult to identify.

3.4.3 Variations in zooplankton diversity and abundance

Of the 59 samples analyzed for zooplankton, 24% had 11 to 17 taxa, 56% had 6 to 10 taxa and 20% had five or fewer taxa (Appendix 7). Overall the maximum concentration was 732 ind/liter; 14% of the samples exceeded 50 ind/liter, another 31% had 10 to 50 ind/liter, and the remaining 55% had fewer than 10 ind/liter.

Of the 59 samples, 10 originated from Bulk carriers, 15 from Container carriers, 18 from General Cargo carriers and 16 from Tankers. Among the various ship types, the Tankers had the highest number of zooplankton taxa at a concentration of 9.6 ind/liter followed by the Bulk carriers and the Container carriers (Figure 22). In terms of concentration, the Tankers had the highest mean value (75 ind/liter), followed by the Bulk carriers (55 ind/liter), and the two other ship types (<20 ind/liter). This pattern is consistent with the assumption that greater numbers of taxa will likely occur in younger water.

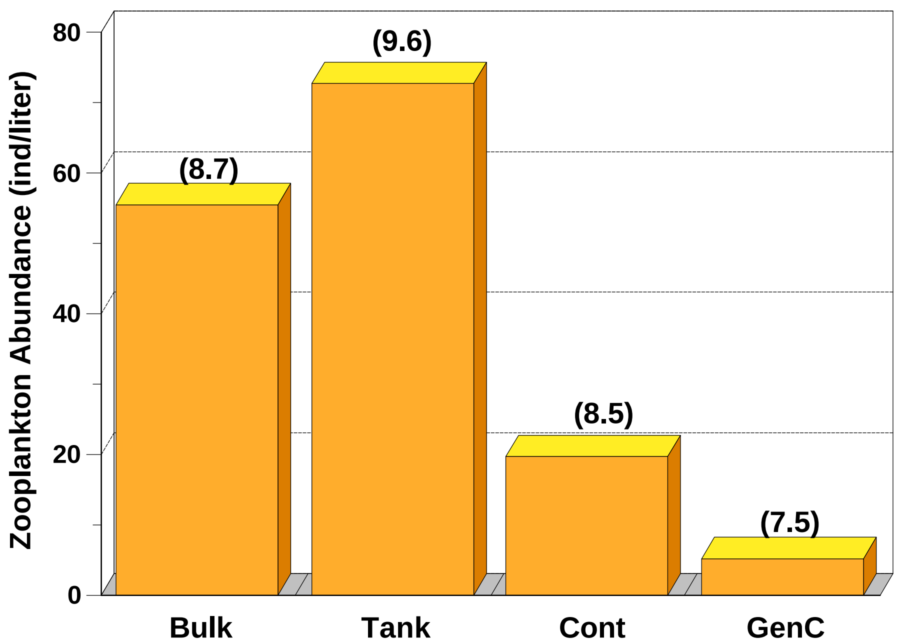

Figure 22. Abundance of zooplankton taxa in the ballast water samples from the four ship types. The mean number of zooplankton taxa is indicated above each bar.

The number of zooplankton taxa and overall abundance also varied depending on the origin of the water samples (Figure 23). Note that the majority of samples originated from FAO region A (34) followed by region B (15), region G (6), region D (2), and regions C (1) and H (1) . Zooplankton abundance was highest in water originating from region A, followed by region B and region G. The highest number of taxa was observed in samples from region B (9.9), followed by region C (9.0) and region A (8.4).

The abundance and number of zooplankton taxa was similar in samples from oceanic and port water (Figure 24); approximately 40 ind/liter and from 7.6 to 9.4 taxa per sample. The coast samples had the lowest abundance at 15 ind/liter and 8.3 taxa per sample. In one case where a ship had undertaken a partial exchange, zooplankton abundance increased from 147 ind/liter in the original port water to 732 ind/liter in the ocean-exchanged water.

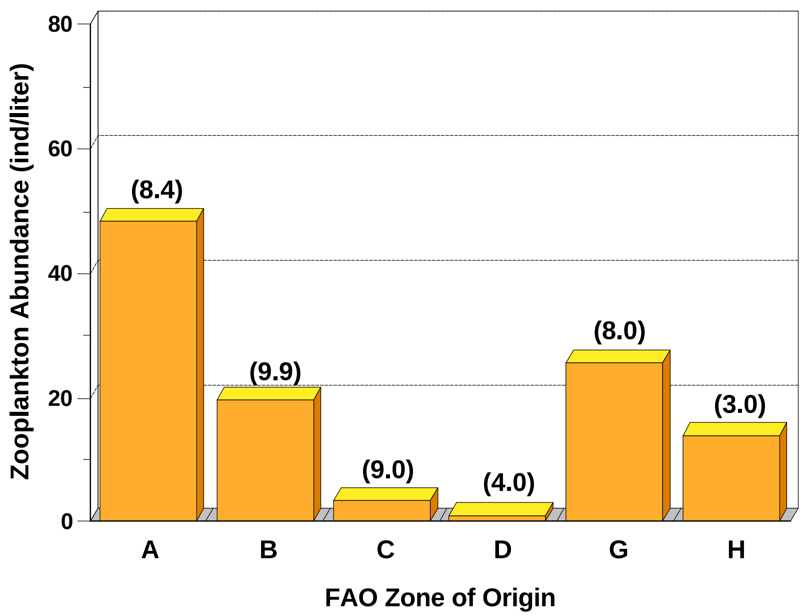

Figure 23. Abundance of zooplanktonic organisms (ind/liter) in ballast water samples originating from six FAO regions. The mean number of zooplankton taxa is indicated above each bar.

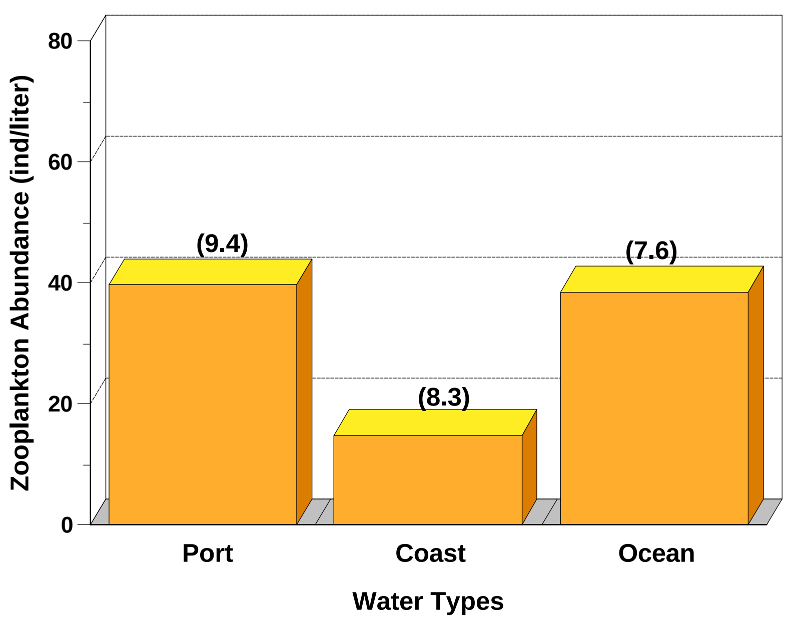

Figure 24. Mean concentration of zooplanktonic organisms (ind/liter) in ballast water samples from the three water types. The mean number of zooplankton taxa is indicated above each bar.

4 Discussion

The 2001-2002 ballast water survey revealed the presence of 503 taxa including 424 phytoplankton and 79 zooplankton in samples obtained from 98 ships docking at 15 ports in Atlantic Canada. Of the 424 phytoplankton taxa, 66% occurred in less than 5% of the samples and many of these rare forms were non-indigenous to Atlantic Canadian waters. The results suggested that there is a significant risk of ballast water-mediated introduction of non-indigenous as well as toxic/harmful taxa. Contrary to previous studies, it was found that conducting a ballast water exchange in certain regions could potentially increase, as oppose to decrease the risk of introduction. The following discussion reviews the key findings and assesses the potential risks associated with undertaking ballast water exchange in certain regions.

4.1 Risks related to ship traffic

In 2000, 5,504 vessels originating from foreign ports entered Eastern Canadian waters and of these, 3386 visited ports in the Atlantic region. From June to December 2001, approximately 5,500,000 tonnes of ballast water were discharged in the Atlantic region (Mike Balaban, 2001, pers. comm., Transport Canada Marine Safety). The volume and characteristics of the ballast water discharged into the various ports depended primarily on the ship types, their port of origin and their ballast water management practices. Bulk carriers and Tankers originated almost exclusively from US ports (regions A/G) and consistently discharged large volumes of <5-d-old water with a high proportion of live taxa. In contrast, approximately 1/3 of the General Cargo and Container carriers discharged small volumes (<2000 m^3) of older water with fewer live taxa, originating from multiple FAO regions. Overall, 52% of the Bulk carriers reported exchanging their ballast water en route compared to approximately 70% for the other three ship types.

Table 12. Discharge volumes (June to December 2001) for some of the ports where ships were sampled in the 2001 survey.

Province	Port	Volume discharged (m^3)	Types of ships
NFLD	Come-by-Chance	364,025	Tank
	Whiffen Head	466,983	Tank
	Corner Brook	18,600	GenC
NS	Pt Tupper	1,652,030	Tank, Bulk
	Halifax/Dartmouth	587,058	Bulk, Cont, GenC
	Hantsport	261,224	Bulk
	Little Narrows	198,055	Bulk
	Pugwash	7,455	Bulk
NB	Belledune	61,102	Tank, Bulk, GenC
	Dalhousie	23,388	GenC
PEI	Summerside	415	GenC

In Newfoundland, the majority of the water discharged was from Tankers docking at the Come-By-Chance and Whiffen Head ports of Placentia Bay (Table 12). In the case of the ships sampled in this study, this water originated exclusively from region A (US northeast coast) and had frequently been exchanged en route. It should be noted that Tankers had the highest number of phytoplankton and zooplankton taxa and the highest cell densities of all the ship types. General Cargo carriers were the primary traffic at other Newfoundland ports, and although these were often carrying water from Europe (e.g. Iceland), this water was typically older, had fewer taxa and was not discharged.

In the case of Nova Scotia, the Pt Tupper area received the greatest volume of water; if one includes the volumes discharged at other terminals in the same bay (i.e. Aulds Cove, Cape Porcupine), the overall total was 1.9 million m^3. Both the Tankers and Bulk carriers docking at Pt Tupper originated from the US (regions A/G), and discharged <5-d-old water with a high proportion of live taxa. Halifax had the most varied traffic including Bulk carriers from the US, and General Cargo ships and Container ships from multiple FAO regions. With the exception of the Bulk carriers, however, the volumes of water discharged were typically low, and the number of taxa were also low. Even with its high traffic volume, the Halifax port accounted for only 10% of the total ballast water discharged in Atlantic Canada. The traffic at the other three ports surveyed in NS consisted exclusively of Bulk carriers discharging water from the US (Regions A/G). Of these ports, Little Narrows in Cape Breton may be the most sensitive to possible invasion by non-indigenous brackish-water species.

In New Brunswick, Belledune was the primary port in terms of level of activity and volume of water discharged. Belledune had a mixed traffic of Bulk carriers, Chemical Tankers and General Cargo vessels and the water discharged originated from multiple FAO regions (A/B/F/G). The General Cargo vessels which visited Dalhousie typically discharged ballast water, but the volume and the number of taxa was relatively low because of the greater age of the water.

In the case of PEI, the level of sampling was insufficient to make any general statements. It should be noted, however, that while none of the three General Cargo vessels sampled discharged any water, two had originated from the Baltic Sea and the Black Sea both of which are brackish environments possibly similar to the Charlottetown estuary.

4.2 Risk of introducing non-indigenous taxa

Examination of the ballast water samples revealed that 25% of the phytoplankton taxa were non-indigenous, compared to 6% observed in the 2000 ballast water survey which was conducted during the summer months. Another 31% of the phytoplankton taxa could not be assigned to any specific geographic region, but likely included several non-indigenous forms. Relatively little information is available on the geographic distribution of many planktonic species. In the case of tintinnids which comprised a large proportion of the microzooplankton, it has been suggested that delineating native distributions may no longer be possible because they have been so widely dispersed by ballast water transport (Pierce et al. 1997).

Another group of taxa included in the unknown affiliation category were nine types of cysts; often these can only be identified by hatching them under laboratory conditions. Cysts were observed in samples from all four ship types, although qualitative observations suggested that the Bulk carriers tended to have the highest sediment load in their tanks, probably from taking on ballast in shallow water. These cysts are often extremely resistant and if discharged may represent another important vector for introducing non-indigenous taxa to new environments (Hallegraeff and Bolch 1992).

Non-indigenous taxa were observed in ballast water samples originating from seven of the nine FAO regions (excluding C and F). A comparison among the four major regions (A,B,D,G) indicated that the average number of non-indigenous taxa was highest in ballast water originating from region G (W Central Atlantic), followed by regions A (NW Atlantic), D (NW Pacific) and B (NE Atlantic). The relatively high risk recorded for region G (4.1 non-indigenous taxa per sample) was likely due to the presence of warm temperate and tropical taxa originating from the southern US, Gulf of Mexico and the Caribbean. Several of these reputedly warm water taxa were observed in samples from the previous ballast water study (2000), e.g. *Bacteriastrum furcatum*, *Bellerochea horologicalis* and *Oxytoxum scolopax*. Harvey et al. (1999) also listed many of these warm water taxa in their ballast water survey of ships entering the St. Lawrence Estuary. It is conceivable that many non-indigenous warm-water species are regularly discharged into Canadian waters, but do not survive the transition to our colder temperate zone. At the same time, it should be noted that certain warmer water areas such as the Bras D'Or Lakes or the Gulf of St. Lawrence may provide suitable conditions.

The average number of non-indigenous taxa in ballast water from region A was relatively high (3.4 taxa/sample), given that Atlantic Canada is located within region A. This indicates that there is likely a high within-region variability in the phytoplankton community. Given that region A is the major source of the water discharged in Atlantic Canada, there would appear to be a significant risk of introducing non-indigenous taxa.

The average number of non-indigenous taxa in ballast water from region D was slightly lower (3.2 taxa/sample). All six samples from Region D were taken from Container ships in the port of Halifax and none of this water was supposed to have been discharged. One mitigating factor is that the proportion of live cells in these samples was relatively low. This case illustrates the importance of encouraging Container ships to undertake mid-ocean exchange and/or to be selective in choosing which tanks to discharge.

The average number of non-indigenous taxa in ballast water from region B (2.7 taxa/sample) was lower than region G, but is possibly of greater concern because of the similarity in our ecological conditions. In other words, a species which originates in northern European waters is perhaps more likely to survive in Atlantic Canada than a species from Florida. The only ships carrying water from region B were General Cargo carriers and Container ships; the only ports where water from region B was discharged were Halifax, NS, and the two NB ports, Dalhousie and Belledune.

None of the zooplankton taxa were identified as being non-indigenous, but a large proportion were larval or juvenile forms which could not be fully identified. Harvey et al. (1999) classified many of these forms as non-indigenous, which may account for the relatively high estimate of 57% non-indigenous zooplankton.

4.3 Risk of introducing toxic/harmful taxa

Of the 20 taxa classified as toxic/harmful, 17 were known toxic species and the other three were classified as harmful. Six of the toxic species belonged to the genus *Pseudo-nitzschia* which produces domoic acid, the toxin which causes Amnesic Shellfish Poisoning (ASP) in shellfish consumers. Similarly, another eight taxa were members of the genus *Dinophysis* which produce toxins which cause Diarrhetic Shellfish Poisoning (DSP) in shellfish consumers. Two of these species, *Dinophysis fortii* and *Dinophysis acuta* are responsible for serious cases of human illness in Europe and Japan (Yasumoto et al.1980, Edler and Hageltorn 1989, Lee et al. 1989). In contrast to the previous 2000 study where none of the toxic/harmful taxa was non-indigenous, five of these toxic species are not reported in Atlantic Canadian waters. The three taxa classified as harmful do not produce toxins but can form intense blooms which may be associated with fish- or shellfish-kills (Shumway 1990). All three taxa are indigenous to Atlantic Canada, but only *Dictyocha speculum* has been directly implicated in fish-kills in NS. Blooms of the two *Chaetoceros* species are known to cause physical damage to the gill tissue of cultured fish on the west coast of Canada.

In addition to the known toxic/harmful species there were 33 taxa which were listed as a possible concern. This category comprised 15 taxa belonging to toxic/harmful marine genera, of which nine were non-indigenous, as well as five brackish-water Cyanophytes, nine cyst forms and four unidentified microzooplankton taxa. Certain cyanophyte species are known to produce hepatotoxic and neurotoxic chemicals, although they typically do not bloom in marine waters (Hawser et al. 1991, Edler 1985). The nine cyst forms were likely true dinoflagellate cysts and/or temporary cysts; several toxic dinoflagellate species are known to produce cysts which can survive for long periods in ballast water (Hallegraeff and Bolch 1992).

The inclusion of indigenous toxic/harmful taxa as a possible risk to Atlantic Canadian waters is based on the observation that many of these taxa do not occur in every region within Atlantic Canada. There is always the possibility that the discharge of large volumes of water containing an undesirable form may trigger a bloom in an area where it would not otherwise have occurred. For example, the toxic diatom species *Pseudo-nitzschia seriata* is typically associated with influxes of cold offshore water during the spring. Exchanging ballast in an offshore oceanic area where this species may be more common, and then de-ballasting inshore could potentially increase the local concentration of an otherwise rare species. This scenario would be consistent with the study of Gosselin et al. (1995) who concluded that the discharge of toxic phytoplankton species into the Magdalen Island lagoons could significantly increase local levels.

Another concern is the introduction of a different, but potentially more toxic clone of an already indigenous species. For example, in NS, blooms of *Dinophysis norvegica*, a reputed DSP-toxin producer, have never been associated with the accumulation of toxin in shellfish whereas in Europe this species has been implicated in several DSP outbreaks. It has been suggested that the Canadian clone or variant of this species is non-toxic; if so, any importation of a potentially toxic variant from Europe could pose a threat to the shellfish industry.

Toxic/harmful taxa as well as taxa considered a possible concern were observed in ballast water samples originating from all nine FAO regions. A comparison among the four major regions (A,B,D,G) indicated that the average number of toxic/harmful taxa was highest in ballast water originating from region B (NE Atlantic- 2.9 taxa/sample), followed by region D (NW Pacific - 2.8 taxa/sample), region A (NW Atlantic - 2.3 taxa/sample) and region G (NW Atlantic - 0.8 taxa/sample). Despite the slightly lower incidence of toxic/harmful taxa in ballast water from region A, the relatively high volumes of water discharged translate into a significant risk of introduction.

4.4 Effectiveness of ballast water exchange

The rationale for mid-ocean exchange is based on several assumptions: (1) potentially invasive inshore taxa taken up in port water will be replaced by oceanic taxa which are less likely to survive when discharged into the waters of a new port; (2) depending on the conditions at the port of origin, the change in the temperature and salinity within the tank should have a negative impact on any inshore taxa which have not been flushed out during the exchange; and (3) the community of species taken up in mid-ocean will be less diverse and of lower abundance than the original inshore community, and will contain fewer toxic/harmful taxa.

Contrary to these assumptions, a comparison of four cases of exchanged vs. non-exchanged water within the same ship, indicated a general increase in the total number of taxa as well as the number of non-indigenous taxa following exchange. A second more extensive comparison indicated that the mean incidence of non-indigenous as well as toxic/harmful taxa was higher in ballast water exchanged in oceanic areas (5.9 taxa/sample) or coastal areas (5.5 taxa/sample) than in non-exchanged water of port origin (4.3 taxa/sample). These results would appear to contradict the basic rationale for conducting ballast water exchange, i.e. to reduce the probability of introducing non-indigenous and/or toxic/harmful taxa. It should be noted that if the reporting of ballast water exchange activities was inaccurate, i.e the water had not been exchanged in the open water position indicated and was actually from a port, this would confound the results. Likewise, if the exchange process was ineffective, taxa originating from inshore waters may have been retained in the ballast tanks (Locke et al. 1993, Rigby and Hallegraeff 1994). Neither of these sources of error, however, can account for the results of the within-ship comparison.

It is widely accepted that mid-ocean exchange can reduce the abundance of freshwater zooplankton in ballast water (Locke et al. 1993, Harvey et al. 1999). Trials conducted in the Pacific Ocean also suggested that mid-water exchange was effective in reducing the risk of introducing toxic phytoplankton species to ports in Australia (Rigby et al. 1993). Zhang and Dickman (1999) reported that mid-ocean exchange en route from Oakland, California to Hong Kong reduced the number of toxic phytoplankton taxa from 15 to 8 and reduced their abundance by 87%. In contrast, MacDonald and Davis (1998) found that the diversity and abundance of diatoms and dinoflagellates increased following ballast water exchange in ships travelling between Europe and ports in northern Scotland. Although they did not specify which of these taxa were non-indigenous, they did conclude that mid-water exchange in regional seas is less efficient than in oceanic waters and may increase the probability of dispersing harmful phytoplankton species within regions.

One factor which may contribute to the relatively high incidence of non-indigenous warm-water taxa in the present study is that exchanges were frequently being carried out in areas adjacent to the Gulf Stream. In the case of NS the higher water temperatures in late summer may enhance the probability of Gulf Stream taxa intruding into the shelf/slope area. The likelihood of these warm-water taxa surviving to colonise inshore waters is unknown, but in the case of the North Sea, it has been suggested that global warming has allowed the recent invasion of several new phytoplankton species which had previously been excluded by low winter temperatures (Reise et al.1999).

Despite the risks associated with the possible introduction of toxic/harmful phytoplankton taxa via exchanged ballast water, we would argue that the underlying rationale is still valid because the majority of invasive species are benthic or inshore forms (Gollasch 1995, Cohen and Carlton 1998). A survey of 80 exotic taxa in the North Sea (Reise et al. 1999) revealed that 59% were invertebrates, primarily molluscs, polychaetes and hydroids, and another 25% were macroalgae. Phytoplankton, including toxic/harmful species, accounted for 11% and parasitic protozoans for another 4%. The authors acknowledged that sources other than ballast water discharge, e.g aquaculture activity and hull fouling, may have contributed to these introductions.

A number of potentially invasive estuarine or benthic taxa have also been identified in US inshore waters (P. Fofonoff, Smithsonian Marine Environmental Research Center). One species is the aggressive Asian Shore Crab *Hemigrapsus sanguineus* which was introduced to the northeast US coast where it now competes with native crab species for food resources. Another predator, the Veined Rapa Whelk *Rapana venosa* originated in the Pacific, spread to the Mediterranean and thence to the US east coast. This species preys on clams, mussels and oysters and has the potential to disrupt the shellfish industry, similar to the Green Crab (*Carcinus maenas*) which is currently spreading through Atlantic Canada. Likewise, the red alga *Grateloupia doryphora*, supposedly an aggressive competitor, was introduced from the Pacific to European waters and has since been identified in Rhode Island.

Another important reason for avoiding the discharge of water directly from US ports is to reduce the probability of transferring shellfish disease organisms. Two examples are the protozoan parasites *Haplosporidium nelsoni* and *Perkinsus marinus* which have severely impacted Eastern Oyster (*Crassostrea virginica*) populations in the eastern US. Another parasite, *Bonamia ostreae*, which was responsible for decimating the European oyster (*Ostrea edulis*) industry in France, has now been identified in Maine estuaries and poses a threat to European oyser culture in NS. The inadvertent introduction of any of these disease species would potentially have a greater negative impact on the oyster industry in Atlantic Canada than the importation of a toxic/harmful phytoplankton species.

Many toxic/harmful phytoplankton taxa are also found primarily in inshore waters; none of these were observed in the present study with the exception of the rare taxa *Dinophysis caudata.* Two prominent examples would be the estuarine species *Pfiesteria piscicida* and the recently identified *Pfiesteria shumwayae*, which have been linked to massive fish kills and human illness in Maryland, Virginia, and North Carolina (Burkholder et al. 1995, Glasgow et al. 2001). Concern over the possible spread of these species has prompted many ports on the US East coast to deny entry to ships carrying ballast water from the Baltimore area; yet, ballast water from Baltimore is frequently discharged in several Atlantic Canadian ports. Preventing the dispersion of *Pfiesteria* spp. should be considered a high priority issue for both the US and Canada.

4.5 Alternative ballast water exchange zone

The rationale for a ballast water exchange zone is that it provides an area where ships can safely discharge ballast water with minimal risk of non-indigenous taxa either surviving and/or being carried into inshore regions. In general, the greater the distance from land, the lower the probability that benthic invertebrates or disease organisms associated with coastal species would impact local communities. The results of the present study, however, suggest that the incidence of non-indigenous and toxic/harmful phytoplankton taxa in the slope water region off the NS coast may be higher than in more southerly offshore regions. This evidence suggests that it would be unwise to encourage ships to undertake ballast water exchange in this highly productive zone during the fall period. More research is required to assess the seasonal variability in the risks associated with this possible exchange zone.

4.6 Ballast water treatment

The findings of this study highlight the pressing need to develop practical ballast water treatment measures which would eliminate all live biota. Considerable effort is currently being directed towards evaluating a wide range of techniques, some of which are designed to be installed on board where they could be used to treat water at the time of uptake, and others which focus on treating ballast water at the point of discharge. These various technologies can be divided into three main categories: chemical, mechanical, and physical.

Chemical technologies include biocides which degrade rapidly such that the water does not require further treatment prior to release. Various compounds such as hydrogen peroxide and peroxy acetic acid (Peraclean) have been evaluated in laboratory trials, but are probably too expensive for large-scale applications (Ichikawa et al. 1992, Bolch and Hallegraeff, 1993, Montani et al. 1995). One natural compound, Seakleen is viewed as potentially more environmentally friendly as well as more economical than other biocides for ballast water treatment and would retail at less than $0.20 per metric tonne of ballast water treated. Another chemical strategy is deoxygenation; this approach assumes that most organisms will be unable to survive in ballast water tanks stripped of oxygen. Two methods to remove oxygen are to pass the seawater through a vaccum chamber or bubble with liquid nitrogen. Proponents of the nitrogen method claim that there may be an added benefit of reduced corrosion in the ballast tanks. Drawbacks include the ability of cysts and spore stages to survive anoxic conditions and the production of hydrogen sulphide which may restrict the discharge of this water. Other chemical strategies include treating ballast water with chlorine, sodium hypochlorite or ozone. The first two methods would require that the water be neutralized prior to discharge, whereas ozone is a relatively expensive technology unsuitable for large volume applications.

Mechanical technologies are designed to remove organisms from the ballast water prior to discharge. A number of systems are currently being evaluated including self-cleaning strainers which can effectively remove particles down to a size of 20 um. Other techniques include sand filtration, membrane filtration and screen filters. Cangelosi et al. (in progress) found that filtration at 25 and 50 um yielded similar results: 96% removal of zooplankton, 70-80% removal of microzooplankton (rotifers) and phytoplankton, but no reduction in total bacteria. Trials with cyclonic separation systems have indicated a very efficiency in eliminating large particles (>50 um), but limited effectiveness in removing particles that have the same specific gravity as seawater. One advantage of this approach is that the physical forces involved in the separation process will damage or kill many organisms.

Research is also being conducted on the feasibility of using physical technologies such as UV treatment originally developed to sterilize domestic water supplies of bacteria and viruses. Sutherland and Levings (2001) found that UV treatment apparently inhibited phytoplankton reproductive activity. There are no toxic residues, but the seawater must be relatively clear of particles and will therefore require some form of pre-treatment such as filtration. Also, spores and cysts are not affected to any great extent by UV radiation. Another form of physical sterilization is heat treatment where the waste heat from the main engine is used to raise the temperature of the ballast water to 35-45^{0}C. Field trials (Rigby et al. 1999) indicated that 30 h were required to raise the temperature in the ballast tanks to this critical level, but none of the zooplankton and few of the phytoplankton survived the treatment. Some of the limitations of this approach are that certain microbes and spores can resist temperatures up to 60^{0}C, and there may insufficient time to heat large volumes of water on short duration voyages. To address these issues, high intensity heat treatment has also been suggested; specifically ballast water is circulated through the main engine heat exchanger where it attains 50-60^{0}C for 60 s. This approach was apparently sufficient to kill 80-90% of *Gymnodinium catenatum* cysts.

Given the various limitations of the individual treatment technologies, many researchers are investigating combinations of treatments. Most of these involve some form of mechanical treatment (filtration or cyclonic separation) to remove larger particles followed by treatment with UV, heat or a biocide to kill any remaining organisms. For example, Jelmert (1999) reported that a combination of cyclonic treatment and UV reduced the level of phytoplankton, bacteria and *Artemia* nauplii by >90%. Ultimately, the objective is to develop a system which (a) effectively removes all organisms of concern, (b) can be operated at a reasonable cost, (c) does not negatively impact the environment, (d) can cope with large quantities of water, and (e) poses no health or safety risk to the crew. Although considerable effort is being directed towards developing these systems, it will likely be several years before an effective strategy has been developed, approved and accepted for operational use.

5 Recommendations

5.1 Risk management

a. *Continue to support the principle of ballast water exchange but delay the decision to establish an Alternative Ballast Water Exchange Zone off Nova Scotia until more data are available.*

This study suggests that undertaking a ballast water exchange off the coast of Nova Scotia or the northeast US can augment, rather than diminish the number of non-indigenous and toxic/harmful phytoplankton taxa. In contrast, ocean exchange in the southeastern US region tended to produce the expected results; ie, a reduction in the number of taxa and abundance relative to port levels. It is important to note that the present study did not account for the possible risks associated with disease organisms, and may have underestimated the abundance of invertebrate larvae belonging to potentially-invasive benthic species. In addition, most of the samples were taken during the months of October-November 2001 and the results may not be relevant to other seasons. For these reasons, we would argue that ocean exchange is still a necessary precaution, but that it may be premature to establish an alternative ballast water exchange zone off the coast of NS.

b. *Discourage discharge of ballast water from brackish-water ports in the US into the Bras D'Or lakes (Little Narrows)*

The Bras d'Or Lakes is an area with limited tidal exchange and brackish-water conditions which may be particularly vulnerable to the invasion of non-indigenous taxa from other brackish-water ports. During the course of this study, several Bulk carriers originating from estuarine areas such as Jacksonville, Florida discharged their full ballast load of non-exchanged water at the Little Narrows Gypsum Terminal in Cape Breton. Given the high temperatures encountered in this area during the summer, the practice of discharging non-indigenous warm-water taxa should be discouraged.

c. *Develop educational materials to promote mid-ocean exchange and improve ballast water management practices, particularly for ships carrying water from Europe, Asia or the west coast of North America*

Container ships and General Cargo carriers typically discharge small volumes of ballast water, but frequently carry water originating from other continents. Given that they often travel through areas >1000 nautical miles offshore, they should be encouraged to undertake an exchange whenever safety restrictions permit. Container ships which often carry ballast water of various ages should be requested to preferably discharge water older than some specified age, perhaps 40 d. Several studies including this one, have indicated that species diversity and abundance declines with the age of the ballast water (Chu et al 1997; Gollash et al. 1995; Dickman and Zhang 1999). Another strategy is to discharge ballast water which originated from the receiving port; for example, the Container ships which follow regular routes were sometimes carrying Halifax water from a previous visit. Implementing this strategy would, however, necessitate more internal transfers of water within the ballast tank system, i.e., dumping the low risk water and then redistributing the ballast.

d. *Support efforts to develop ballast water treatment methods*

Given the risks that may be associated with ballast water exchange in certain regions or seasons, the development of ballast water treatment methods should be given high priority.

5.2 Future research

a. *Expand the scope of sampling and develop sampling techniques to better assess the risks associated with other types of organisms including cysts, bacteria, parasitic protozoans, and benthic invertebrates*

Although the present study documented the levels of phytoplankton and zooplankton in the ballast water of ships entering Atlantic Canada, information on other taxonomic groups would assist in defining the best strategy for this region. An important ballast water component which was not sampled was the sediment in the bottom of the tanks. Many toxic dinoflagellate species are known to form cysts which may persist in ballast water sediments for long periods (Hallegraeff and Bolch 1992). Obtaining sediment samples may prove to be a challenge, but with some ingenuity an appropriate technique may be devised for sampling through sounding pipes. The risk of introducing pathogenic bacteria and other disease-causing organisms in ballast water also needs to be assessed. For example, it has been suggested that ballast water discharge is responsible for the global dissemination of the cholera-causing bacteria *Vibrio cholerae* (McCarthy and Khambaty 1994). A recent survey of ballast water in France indicated the presence of viable *Vibrio* and *Clostridium* species, two pathogens which can cause gastrointestinal illness (Masson et al. 2000). A similar issue, with significant implications for Canadian fisheries is the introduction of shellfish or finfish diseases. The incidence of such diseases along the US coast has increased dramatically over the last decade; the introduction of one of these pathogenic species could have important ecological and economic ramifications. It should be noted that an investigation of the bacterial component in ballast water would likely require a research commitment from the Department of the Environment, while an assessment of the risks of introducing shellfish and finfish disease organisms would involve experts from the Fish Health Unit of Fisheries and Oceans. Identification of phytoplankton cysts may require the incubation of sediments under different conditions as well as the involvement of taxonomic experts. This work would involve the development of risk profiles for various ports of origin, particularly those in the US which contribute the major proportion of the ballast water discharged in Atlantic Canada. Targeting known risk organisms in ships arriving from specific ports would improve the basis for developing appropriate management strategies.

b. Assess the risks associated with undertaking ballast water exchange in various regions and in different seasons

The observation that ballast water exchange in certain areas increased rather than decreased the number of non-indigenous phytoplankton taxa contradicted several previous studies which had been conducted in more southerly, or warmer water regions (e.g. the tropical Pacific). Rather than comparing the phytoplankton taxa in various ships carrying different types of water, as in the present study, we would focus on within-ship comparisons to obtain a better index of risks associated with exchange. The preferred strategy would be to compare samples of the original port water with samples from tanks which had been exchanged at two or perhaps three different locations along a route. This would require the cooperation of the ships' crew in keeping a detailed ballast water log, but would allow an assessment of the effectiveness of the exchange process as well as an opportunity to document the incidence of non-indigenous taxa in water from different regions. The most appropriate ships to undertake this study would be those Tankers and Bulk carriers which travel back and forth regularly between ports in the US and Atlantic Canada. Possible candidates would include the ships involved in the Gypsum trade in Nova Scotia and the Tankers associated with the oil refinery in Come-by Chance and Whiffen Head in Newfoundland. It is important that this study have a seasonal sampling component in order to obtain a more comprehensive assessment of the risks associated with ballast water exchange.

c. *Conduct surveys of potentially-impacted areas to determine whether non-indigenous taxa are being introduced*

Certain areas of Atlantic Canada are receiving large volumes of ballast water, not all of which has been exchanged and even so may still contain non-indigenous taxa. In terms of discharge volume the ports of greatest risk are likely Come-by-Chance and Whiffen Head in Placentia Bay, NFLD and Pt Tupper, in Chedabucto Bay, NS. Other areas of interest include the drydock zone in Halifax, the docks in Belledune, NB and the Little Narrows Gypsum Terminal in the Bras D'Or Lakes. Because of the unique ecology of the Bras D'Or Lakes system, this might be an appropriate area to conduct a pilot project to determine if the presence of non-indigenous taxa can be detected in the local community. This would involve a survey of the dock pilings, shore areas, entrance to the bay, and benthic habitat for evidence of exotic invertebrate taxa which had succeeded in establishing local populations. Plankton tows would also be carried out in the bay to check for the presence of non-indigenus phytoplankton and zooplankton taxa. Specific samples could be obtained in the vicinity of the wharf prior to the arrival of the ship, during the period when the ship was discharging and 24-h later to determine whether any of the taxa from the ballast tanks could be detected in the surrounding environment. This preliminary study could be carried out over a two week period and would offer some indication as to the whether non-indigenous taxa can make the transition to our Canadian waters.

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7 References

Avent, S.R., S.M. Bollens, J. Cordell and B.W. Frost. 2000. The ecology of two invasive copepods, *Pseudodiatomus inopinus* and *Pseudodiaptomus marinus* to North American Pacific coast estuaries. ASLO Ocean Sciences Meeting, Abstract.

Balaban, M. 2001. Vessel traffic/vessel shipping patterns on the east coast of Canada, 2000 shipping season.

Baldwin, R. 1992. Cargo vessel ballast water as a vector for the spread of toxic phytoplankton species to New Zealand. J. Roy. Soc. N.Z. 22(4): 229-242.

Boalch, G.T. and D.S. Harbour. 1977. Unusual diatom off the coast of south-west England and its effect on fishing. Nature 269:687-688.

Bolch, C.J. And G.M. Hallegraeff. 1993. Chemical and physical treatment options to kill toxic dinoflagellate cysts in ships' ballast water. J. Mar. Env. Eng. 1: 23-29.

Burkholder, J.M., H.B. Glasgow and C.W. Hobbs. 1995. Distribution and environmental conditions for fish kills linked to a toxic ambush-predator dinoflagellate: distribution and environmental conditions. Mar. Ecol. Prog. Ser. 124: 43-61.

Buttermore, R.E., E. Turner and M.G. Merrill. 1994. The introduced Northern Pacific seastar *Asterias amurensis* in Tasmania. Mem. Queensland Mus. 36: 1-25.

C.E.F. Consultants, 1999. Vessel traffic/vessel shipping patterns on the East Coast of Canada.

Carlton, J.T. 1985. Transoceanic dispersal of coastal marine organisms: the biology of ballast water. Oceanogr. Mar. Biol. Ann. Rev. 23: 313-374.

Carlton, J.T. and J.B. Geller. 1993. Ecological roulette: the global transport of non-indigenous marine organisms. Science 261: 78-82.

Carlton, J.T., J.K. Thompson, L.E. Schemel and F.H. Nichols. 1990. Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam *Potamocorbula amurensis*. I. Introduction and dispersal. Mar. Ecol. Prog. Ser. 66: 81-94.

Carver, C.E. and A.L. Mallet. 2001. A preliminary assessment of the risks of ballast water mediated introduction of non-indigenous phytoplankton and zooplankton species into Nova Scotia waters. Report to Transport Canada Marine Safety Section, Halifax, Nova Scotia.

Chu, K.H., P.F. Tam, C.H. Fung and Q.C. Chen. 1997. A biological survey of ballast water in container ships entering Hong Kong. Hydrobiologia 352: 201-206.

Cohen, A.N. And J.T. Carlton. 1998. Accelerating invasion rate in a highly invaded estuary. Science 279: 555-557.

Cosper, E.M., V.M. Bricelj and E.J. Carpenter. 1989. Novel phytoplankton blooms: causes and impacts of recurrent brown tides and other unusual blooms. Lecture notes on caostal and estuarine studies. Springer-Verlag, Berlin. 799 pp.

Dickman, M. And F. Zhang. 1999. Mid-ocean exchange of container vessel ballast water. 2. Effects of vessel type in the transport of diatoms and dinoflagellates from Manzanillo, Mexico to Hong Kong, China. Mar. Ecol. Prog. Ser. 176: 253-262.

Edler, L. And M. Hageltorn. 1989. Identification of the causative organism of a DSP-outbreak on the Swedish west coast. In: Graneli, E., D.M. Anderson, I. Edler and B.G. Sundstrom (eds) Toxic Marine Phytoplankton. Elsevier, NY., pp.

Edler, L., S. Ferno, M.G. Lind, R. Lundberg and P.O. Nilsson. 1985. Mortality of dogs associated with a bloom of the cyanobacterium *Nodularia spumigena* in the Baltic Sea. Ophelia: 24:103-109.

Gauthier, D. And D.A. Steel. 1996. A synopsis of the situation regarding the introduction of nonindigenous species by ship-transported ballast water in Canada and selected countries. Can. Man. Rep. Fish. Aquat. Sci. No. 2380, 57 pp.

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) 1997. Opportunistic settlers and the problem of the ctenophore *Mneimiopsis leidyi* invasion in the Black Sea. Rep. Stud. GESAMP, (58):84 pp.

Glasgow, H.B. J.M. Burkholder, S.L. Morton and J. Springer. 2001. A second species of icthyotoxic Pfiesteria (Dinamoebales, Dinophyceae). Phycologia 40: 234-245.

Gollasch, S., M. Dammer, J. Lenz and H.G. Andres. 1995. Non-indigenous organisms introduced via ships into German waters. ICES Coop. Res. Rep. 224: 50-64.

Gosselin, S., M. Levasseur and D. Gauthier. 1995. Transport and deballasting of toxic dinoflagellate blooms in the Grande Entree lagoon of the Iles-de-la-Madeleine (Gulf of St. Lawrence, Canada). In: Lassus, P., G. Arzul, E.Erard, P. Gentien and C. Marcaillou (eds.) Harmful Marine Algal Blooms, p 591-596.

Hallegraeff, G.M. 1993. Review of harmful algal blooms and their apparent global increase. Phycologia 32: 79-99.

Hallegraeff, G.M. 1995. Transport of toxic dinoflagellate cysts via ship's ballast water: an interim review. ICES CM 1995/O:15.

Hallegraeff, G.M. and C.J. Bolch. 1992. Transport of toxic dinoflagellate cysts via ship's ballast water. Mar. Poll. Bull. 22:27-30.

Hallegraeff, G.M. and C.J. Bolch. 1992. Transport of diatom and dinoflagellate resting spores in ship's ballast water: implication for plankton biogeography and aquaculture. J. Plankton Res. 14: 1067-1084.

Hallegraeff, G.M. and C. Sumner. 1986. Toxic plankton blooms affect shellfish farms. Australian Fisheries 45: 15-18.

Hallegraeff, G.M., M.A. McCausland and R.K. Brown. 1995. Early warning of toxic dinoflagellate blooms of *Gymnodinium catenatum* in southern Tasmanian waters. J. Plankton Res. 17: 1163-1176.

Hallegraeff, G.M., Steffensen, D.A. and R. Wetherbee. 1988. Three estuarine dinoflagellates that can produce paralytic shellfish toxins. J. Plankton Res. 10: 533-541.

Harvey, M., M. Gilbert, D. Gauthier and D.M. Reid. 1999. A preliminary assessment of risks for the ballast water-mediated introduction of non-indigenous organisms in the Estuary and Gulf of St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. #2268, 56 p.

Hawser, S.P. G.A. Codd, D.G. Capone and E.J. Carpenter. 1991. A neurotoxic factor associated with the bloom-forming cyanobacterium *Trichodesmium*. Toxicon 29: 277-278.

Hay, C.H. And D. Tanis 1998. Mid-ocean ballast water exchange: procedures, effectiveness, and verification. Cawthron Report No. 468, 48 pp.

Hecht, T. and K. Heasman. 1999. The culture of *Mytilus galloprovincialis* in South Africa and the carrying capacity of mussel farming in Saldanha Bay. World Aquaculture 30(2): 50-55.

Hewes, C.D. and O. Holm-Hansen. 1983. A method for recovering nanoplankton from filters for identification with the microscope: the filter-transfer-freeze (FTF) technique. Limnol. And Oceanogr. 28(2): 389-394.

Ichikawa, S., Y. Wakao, and Y. Fukayo. 1992. Extermination efficacy of hydrogen peroxide against cysts of red tide and toxic dinoflagellates, and its adaptability to ballast water of cargo ships. Bull. Jap. Soc. Sci. Fish. 58(12): 2229-2233.

Jelmert, A. 1999. Update on hydrocyclone and UV tests. ICES 1999/ACME:2, p.9.

Karayucel, S. 1997. Mussel culture in Scotland. World Aquaculture 28(1): 4-10.

Kelly, J.M. 1993. Ballast water and sediments as mechanisms for unwanted species introductions into Washington state. J. Shellfish Res. 12:405-410.

Lambert, C.C. and G. Lambert. 1998. Non-indigenous ascidians in southern California harbors and marinas. Mar Biol. 130: 675-688.

Lee, J.-S., T. Igarashi, S. Fraga, E. Dahl, P. Hovgaard, T. Yasumoto. 1989. Determination of diarrhetic shellfish toxins in various dinoflagellate species. J. Appl. Phycol. 1:147-151.

Locke, A., D.M. Reid, H.C. Va Leeuwen, W.G. Sprules and J.T. Carlton. 1993. Ballast water exchange as a means of controlling dispersal of freshwater organisms by ships. Can. J. Fish. Aquat. Sci. 50: 2086-2093.

MacDonald, E.M. 1995. Dinoflagellate resting cysts and ballast water discharges in Scottish ports. ICES Coop. Res. Rep. 224:24-35.

MacDonald, E. And R. Davidson 1997. Ballast water transport of harmful phytoplankton to Scottish ports and the effects of mid-water exchange in regional seas. In: Reguera, B., Blanco, J., Fernandez, L. And T. Wyatt (eds.) VIII International Conference on Harmful Algae - Vigo, Spain. UNESCO 1998, pp. 220-223.

Mahoney, J.B. and F.W. Steimle. 1980. Possible association of fishing gear clogging with a diatom bloom in the middle Atlantic Bight. Bull. New Jersey Acad. Sci. 25: 18-21.

Marangoni, C. R.N. Pienaar and S.D. Sym. 2001. Possible introduction of alien phytoplankton via shipping ballast water: A South African perspective. South African J. Botany 67: 465-474.

Masson, D., O. Courtois, N. Masson, S. Guesdon and G. Rocher. 2000. Ballast water research in France: current status. ICES/CM 2000/U12, 7 pp.

McCarthy, S.A. and F.M. Khambaty. 1994. International dissemination of epidemic *Vibrio cholerae* by cargo ship ballast and other nonpotable waters. Appl. Environ. Microbiol. 2597-2601.

Medcof, J.C. 1975. Living marine animals in a ship's ballast water. Proc. Natl. Shellfish. Assoc. 65: 11-12.

Montani, S., S. Meksumpun, and K. Ichimi. 1995. Chemical and physical treatments for destruction of dinoflagellate cysts. J. Mar. Biotechnol. 2: 179-181.

Nalepa, T.F. and D.W. Schloesser. 1993. Zebra Mussels: Biology, Impacts and Control. Lewis Publishers, Boca Raton, Florida: 810 pp.

Nehring, S. 1998. Non-indigenous phytoplankton species in the North Sea: supposed region of origin and possible transport vector.

Nichols, F.H., J.K. Thompson and L.E. Schemel. 1990. Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam *Potomocorbula amurensis*. II. Displacement of a former community. Mar. Ecol. Prog. Ser. 66: 95-101.

Ostenfeld, C.J. 1908. On the immigration of *Biddulphia sinensis* Grev. and its occurrence in the North Sea during 1903-1907. Medelelser fra Kommissionen for Havundersogelser, Serie Plankton 1, no. 6, 44p.

Pierce, R.W., J.T. Carlton,D.A. Carlton, and J.B. Geller. 1997. Ballast water as a vector for tintinnid transport. Mar. Ecol. Prog. Ser. 149: 296-297.

Reise, K., S. Gollasch and W.J. Wolff. 1999. Introduced marine species of the North Sea coasts. Helgol. Meeres. 52: 219-234.

Richardson, K. 1997. Harmful or exceptional phytoplankton blooms in the marine ecosystem. Adv. Mar. Biol. 31: 302-369.

Rick, H.-J. and C.-D. Durselen. 1995. Importance and abundance of the recently established species *Coscinodiscus wailesii* Gran and Angst in the German Bight. Helgolander Meeresunters 49: 355-374.

Rigby, G.R. and G.M. Hallegraeff. 1994. The transfer and control of harmful marine organisms in shipping ballast water: Behaviour of marine plankton and ballast water exchange trials on the MV "Iron Whyalla". J. Mar. Environ. Engineering 1: 91-110.

Rigby, G.R., G.M. Hallegraeff and C. Sutton. 1999. Novel ballast water heating technique offers cost-effective treatment to reduce the risk of global transport of harmful marine organisms. Mar. Ecol. Prog. Ser. 191: 289-293.

Rigby, G.R., I.G. Steverson, C.J. Bolch, and G.M. Hallegraeff. 1993. The transfer and treatment of shipping ballast waters to reduce the dispersal of toxic marine dinoflagellates. In: Smayda, T.J. And Y. Shimizu (eds) Toxic phytoplankton blooms in the sea. Developments in Marine Biology 3. Elsevier Science Publishers B.V. pp. 169-176.

Rince, Y. and G. Paulmier. 1986. Donnees nouvelles sur la distribution de la diatomee marine *Coscinodiscus wailesii* Gran and Angst (Bacillariophyceae). Phycologia 25: 73-79.

Scholin, C.A. and D.M. Anderson. 1991. Population analysis of toxic and non-toxic Alexandrium species using ribosomal RNA signature sequences. Fifth Int. Conf. Tox. Mar. Phyto. Abstracts, p.113.

Shumway, S.E. 1990. A review of the effects of algal blooms on shellfish and aquaculture. J. World Aquaculture Soc. 21: 65-104.

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+16p.

Subba Rao, D.V., W.G. Sprules, A. Locke and J.T. Carlton. 1994. Exotic phytoplankton from ships' ballast waters: Risk of potential spread to mariculture sites on Canada's east coast. Can. Data Rep. Fish. Aquat. Sci. No. 937, 51 p..

Sutherland, T.F., C.D. Levings, C.C. Elliott, W.W. Hesse. 2001. Effect of a ballast water treatment system on survivorship of natural populations of marine plankton. Mar. Ecol. Prog. Ser. 2010: 139-148.

Vinogradov, M.Y., E.A. Shushkina, E.I. Musayeva and P.Y. Sorokin. 1989. A newly acclimated species in the Black Sea: the ctenophore *Mnemiopsis leiydi* (Ctenophora: Lobata). Oceanology 29: 220-224.

Williams, R.J., F.B. Griffiths, E.J. Van der Wal and J. Kelly. 1988. Cargo vessel ballast water as a vector for the transport of non-indigenous marine species. Est. Coast. Shelf Sci. 26: 409-420.

Yasumoto, T., Y. Oshima, W. Sugawara, Y. Fukuyo, H. Oguri, T. Igarashi and N. Fujita. 1980. Identification of *Dinophysis fortii* as the causative organism of diarrhetic shellfish poisoning. Bull. Jap. Soc. Sci. Fish. 46:1405-1411.

Zhang, F. And M. Dickman. 1999. Mid-ocean exchange of container vessel ballast water 1: Seasonal factors affecting the transport of harmful diatoms and dinoflagellates. Mar. Ecol. Prog. Ser. 176: 243-251.

Appendices

Appendix 1*: Ballast Water Information Sheet and Questionnaire*

In order to provide a scientific basis for the development and implementation of the Annex V, "*Ballast Water Procedures for Vessels Proceeding to Ports on the East Coast of Canada"* as part of the "GUIDELINES FOR THE CONTROL OF BALLAST WATER DISCHARGE FROM SHIPS IN WATERS UNDER CANADIAN JURISDICTION", a study consisting of sampling and analysing ballast water originating from ships calling at various ports on the East Coast of Canada has been undertaken at the request of the Marine Safety Branch of Transport Canada. Mallet Research Services is the company contracted to conduct this study on board vessels calling at ports in Nova Scotia, Prince Edward Island, New Brunswick and Newfoundland.

In order to facilitate the collection of samples and minimize any inconvenience to the crew, a description of the information required and the sampling procedure is provided below.

General Information (not necessary if you can provide an official Ballast Water Report form)

Name of ship ________________________________ *IMO number* ________________

Type of ship _________________________________ *Tonnage* ____________________

Last port of call ______________________________ *Departure date* ________________

Next port of call __________________________________

Total number of ballast tanks ___________ *Total volume when full* ________________

Number of tanks in ballast _______________ *Ballast on board* _________________

Volume to be discharged at this port ______________

Sampling Procedure

Depending on the exchange history of the ballast water, we will select **three tanks** for sampling. The recommended sampling volume is **50 liters per tank** - this water is filtered through a mesh to concentrate the organisms - after filtering, the remaining water is then returned to the ballast tank or drained onto the deck/into the bilge if this is impossible. The **two possible methods** for collecting the water samples are:

1) From the ballast water pump system - in this case, we would require the assistance of a crew member who is familiar with the valves on the pumps.
2) From the sounding pipes using an air-driven pump or a hand pump. In order to obtain a sample, the distance from the top of the pipe to the surface of the water in the tank should not exceed 20 feet. This activity requires the assistance of a crew member familiar with the layout of the sounding pipes.

If any information can be prepared in advance, such as a list of the status of the various ballast tanks, this would speed up the sampling process.
Thank you for your cooperation - Claire Carver (Mallet Research Services).

Appendix 2: Sampling equipment list

A. Pumping system

- Husky Diaphragm air pump
- Scuba tank with regulator
- 20 m of 3/8” reinforced PVC tubing weighted on one end
- Check valve between pump and inflow hose
- Tools - adjustable wrench, pliers

B. Filtration system

- 2 20-litre buckets
- 1 10-litre bucket
- 20-um mesh filtering screen
- 10’ diameter funnel
- Wash bottles with filtered water

C. Sampling equipment

- 500-ml sampling bottles
- 200-ml jars for salinity samples
- Thermometer
- 4” funnel for filling bottles
- Cooler
- Fixative - formalin:acetic acid (50:50)

D. Miscellaneous

- Self-adhesive labels
- Waterproof markers, pens
- Clipboard with ship data forms, introductory letters
- Paper towels, rags
- Knife, twine

E. Clothing

- Fluorescent safety vests
- Steel-toed boots
- Safety glasses
- Hard hats
- Ear protectors
- surgical gloves

Appendix 3 - List of ships docking in the Atlantic provinces. Also indicated is whether the vessel was using the official Ballast Water Reporting Form or whether there was any indication of open ocean exchange in the ballast history. The gross registered tonnage (GRT), the number of ballast tanks, total ballast water capacity, load on board, and the intended discharge volume are also indicated.

Ship ID	Arrival Port	Sampling Date	Ship Name	Ship Type	GRT MT	Port of Origin	Country of Origin	FAO	Ballast Report Form	Open Ocean Exchange	Num Ballast Tanks	Ballast Capacity cu m	Load %	Disch %	Source of Ballast Water Discharge
NF-01	CB-Chance	23-Sep-01	Margara	Tank	40705	Riverhead, NY	USA	A	IMO	No	12	29087	70	100	Riverhead, NY, USA
NF-02	CB-Chance	26-Sep-01	Bering Sea	Tank	27256	Houston, TX	USA	G	USA	Yes?	9	21160	87	100	NW Atlantic?
NF-03	Argentia	27-Sep-01	Lagarfoss	GenC	6670	Isafiordur	Iceland	B	Can	No	16	3344	79	0	
NF-04	CB-Chance	06-Oct-01	MT Aquidneck	Tank	23709	Portsmouth, NH	USA	A	IMO	No	6	13194	92	100	New Haven, CT + Providence, RI, USA
NF-05	CB-Chance	08-Oct-01	Isola Gialla	Tank	22680	Jacksonville, FL	USA	G	Other	Yes	13	16400	86	100	NW Atlantic
NF-06	Argentia	11-Oct-01	Skogafoss	GenC	5503	Reykjavik	Iceland	B	Can	No	12	2417	52	0	
NF-07	CB-Chance	16-Oct-01	MT Iliad	Tank	28933	New York, NY	USA	A	No	No	12	17290	86	100	New York, NY, USA
NF-08	Harbour Grace	19-Oct-01	Green Austevoll	GenC	5084	New Bedford, MA	USA	A	USA	Yes	13	1437	88	0	
NF-09	St. John's	21-Oct-01	MV Radeplein	GenC	2615	Norfolk, VG	USA	A	Other	Yes	18	1803	81	0	
NF-10	Whiffen Head	22-Oct-01	Vancouver Spirit	Tank	63709	Portland, ME	USA	A	Can	No	12	45230	92	100	Portland, ME, USA
NF-11	Argentia	24-Oct-01	Lagarfoss	GenC	6670	Reykjavik	Iceland	B	Can	No	16	3344	73	0	
NF-12	St. John's	25-Oct-01	Emma	Tank	2621	Copenhagen	Denmark	B	Can	Yes	4	750	100	100	NW Atlantic
NF-13	CB-Chance	29-Oct-01	Ostankino	Tank	28223	New York, NY	USA	A	IMO	Yes	10	16946	88	97	NW Atlantic
NF-14	Whiffen Head	31-Oct-01	Vancouver Spirit	Tank	63709	Portland, ME	USA	A	Can	No	12	46360	92	100	Portland, ME, USA
NF-15	CB-Chance	12-Nov-01	Nordscot	Tank	23740	Portland, ME	USA	A	IMO	Yes	15	18224	85	100	NW Atlantic
NF-16	Argentia	13-Nov-01	MV Radeplein	GenC	2615	Norfolk, VG	USA	A	No	Yes	18	1803	82	0	
NF-17	Whiffen Head	15-Nov-01	Hamane Spirit	Tank	57463	Portland, ME	USA	A	Other	Yes	13	38587	93	100	NW Atlantic
NF-18	CB-Chance	21-Nov-01	Nordscot	Tank	23740	Boston, MA	USA	A	IMO	Yes	15	18224	81	100	NW Atlantic
NF-19	Argentia	24-Nov-01	Ras Sedr	GenC	4591	Inagua	Bahamas	G	No	No	14	2016	43	0	
NF-20	Corner Brook	26-Nov-01	Joh. Gorthon	GenC	11907	Richmond, VA	USA	A	Can	Yes	16	3268	50	72	NW Atlantic
NF-21	CB-Chance	28-Nov-01	Turmoil	Tank	22847	New York, NY	USA	A	IMO	Yes	10	12714	85	100	NW Atlantic
NF-22	Whiffen Head	28-Nov-01	Singapore Spirit	Tank	52997	Delaware City,	USA	A	Other	Yes	13	39489	97	100	NW Atlantic
NF-23	Corner Brook	04-Dec-01	Ingrid Gorthon	GenC	12750	Rotterdam	Netherlands	B	No	Yes?	17	4445	71	21	NW Atlantic?
NF-24	CB-Chance	07-Dec-01	Nordeuropa	Tank	23740	Boston, MA	USA	A	IMO	Yes	15	18683	88	100	NW Atlantic
NF-25	St. John's	08-Dec-01	Bavaria	GenC	2532	Houston, TX	USA	G	USA	Yes	9	1572	51	0	
NF-26	CB-Chance	16-Dec-01	Nordeuropa	Tank	23740	Bridgeport, CT	USA	A	IMO	Yes	15	18683	88	100	NW Atlantic
NF-27	Whiffen Head	16-Dec-01	Front Sunda	Tank	77931	Philadelphia, PA	USA	A	IMO	Yes	10	46407	100	100	NW Atlantic
NF-28	CB-Chance	18-Dec-01	MT Burgas	Tank	26540	New York, NY	USA	A	Other	Yes	8	26355	90	100	NW Atlantic
NF-29	Whiffen Head	20-Dec-01	Orkney Spirit	Tank	55864	Portland, ME	USA	A	Other	No	16	39367	98	100	Portland, ME, USA
NF-30	Whiffen Head	04-Jan-02	Front Sun	Tank	81093	Philadelphia, PA	USA	A	Other	Yes	14	54187	95	76	NW Atlantic

NF-31	CB-Chance	06-Jan-02	Nordscot	Tank	23740	Boston, MA	USA	A	IMO	Yes	15	18683	86	100	NW Atlantic
NF-32	CB-Chance	21-Jan-02	Ratna Abba	Tank	15813	New York, NY	USA	A	No	No	7	31414	77	100	New York, NY, USA
NB-01	Dalhousie	30-Sep-01	Stig Gorthon	GenC	10165	Vera Cruz	Mexico	G	Can	Yes	17	4451	74	61	NW Atlantic + W Central Atlantic
NB-02	Belledune	01-Oct-01	Okoltchitza	BulkC	16068	Casablanca	Morocco	F	IMO	Yes	27	9612	60	100	NW Atlantic + E Central Atlantic
NB-03	Belledune	05-Oct-01	TK Istanbul	BulkC	5456	Alsen, NY	USA	A	IMO	Yes	7	1200	72	100	NW Atlantic
NB-04	Belledune	06-Oct-01	Marinor	Tank	4950	Southport, NC	USA	G	USA	Yes	14	2663	81	99	NW Atlantic + W Central Atlantic
NB-05	Belledune	15-Oct-01	Marneborg	GenC	6540	Philadelphia, PA	USA	A	No	No	27	4293	88	100	Philadelphia, PA, USA
NB-06	Dalhousie	17-Oct-01	Ada Gorthon	GenC	13525	Philadelphia, PA	USA	A	USA	Yes?	15	3191	68	100	NW Atlantic?
NB-07	Dalhousie	21-Oct-01	Alida Gorthon	GenC	12750	Richmond, VG	USA	A	Can	Yes	17	4554	71	64	NW Atlantic
NB-08	Belledune	22-Oct-01	Valga	GenC	8545	Camden, NJ	USA	A	No	Yes	21	2200	52	35	NW Atlantic
NB-09	Belledune	28-Oct-01	Viljandi	GenC	8545	Baltimore, MD	USA	A	No	No	20	2036	50	0	
NB-10	Dalhousie	14-Nov-01	Ada Gorthon	GenC	13525	Tilbury	UK	B	Can	Yes	15	3191	80	45	NE Atlantic
NB-11	Belledune	16-Nov-01	Bow Flower	Tank	23197	Providence, RI	USA	A	IMO	Yes	12	15348	89	91	NW Atlantic + NE Atlantic
NB-12	Belledune	18-Nov-01	Kapitonas Stulpina	BulkC	9965	Tampa, FL	USA	G	Other	Yes	14	5189	32	100	NW Atlantic
NB-13	Dalhousie	30-Nov-01	Stig Gorthon	GenC	10165	Azores	Portugal	B	Can	Yes	17	4451	85	91	NW Atlantic
NB-14	Belledune	30-Nov-01	Salvador	GenC	15893	Baltimore, MD	USA	A	USA	No	20	4310	89	0	
NB-15	Belledune	11-Dec-01	Tofton	BulkC	12400	Wilmington, NC	USA	G	USA	Yes	24	4713	83	100	NW Atlantic
PE-01	Charlottetown	16-Nov-01	Akademikis Zavarickis	GenC	9552	St. Petersburg	Russia	B	USA	Yes	8	1602	23	0	
PE-02	Summerside	16-Nov-01	Green Malloy	GenC	5084	Philadelphia, PA	USA	A	No	Yes?	13	1437	54	0	
PE-03	Charlottetown	20-Dec-01	Tasman Start	GenC	9632	Ilyichevsk	Ukraine	C	USA	Yes	7	1552	48	0	
NS-01	Halifax	23-Sep-01	Maersk Wind	Ro/Ro	51770	Southampton	UK	B	No	Yes	15	7519	50	0	
NS-02	Halifax	23-Sep-01	Charlotte C	GenC	2999	Antwerp	Belgium	B	No	Yes	18	1660	87	0	
NS-03	Halifax	26-Sep-01	Zim Italia	Cont	37209	Barcelona	Spain	C	Can	Yes	21	13251	47	0	
NS-04	Halifax	26-Sep-01	Stuttgart Express	Cont	53815	Le Havre	France	B	USA	Yes	21	16673	74	0	
NS-05	Halifax	28-Sep-01	Lovisa Gorthon	GenC	10165	Puerto Limon	Costa Rica	G	No	Yes	16	4329	58		
NS-06	Pt Tupper	29-Sep-01	Wilana	Tank	79494	Philadelphia, PA	USA	A	IMO	Yes	18	54172	76	100	Philadelphia, PA, USA
NS-07	Pt Tupper	30-Sep-01	MH Baker	BulkC	23955	Camden, NJ	USA	A	USA	No	14	18429	87	100	Camden, NJ, USA
NS-08	Halifax	03-Oct-01	New York Express	Cont	54437	Le Havre	France	B	Can	Yes	20	18800	66	0	
NS-09	Hantsport	04-Oct-01	Gypsum Baron	BulkC	12272	Baltimore, MD	USA	A	Can	No	20	7155	87	100	Baltimore, MD, USA
NS-10	Halifax	08-Oct-01	Cosco Norfolk	Cont	35994	New York, NY	USA	A	Can	Yes	22	12843	36	17	NW Atlantic
NS-11	Halifax	08-Oct-01	Georgia S	BulkC	20053	Wilmington, DE	USA	A	IMO	Yes?	15	15411	71	100	NW Atlantic?
NS-12	Halifax	09-Oct-01	Shanghai Express	Cont	53523	Le Havre	France	B	USA	Yes	22	17585	67	0	
NS-13	Halifax	10-Oct-01	Zim Korea	Cont	37209	Barcelona	Spain	C	No	Yes	21	13251	55	0	
NS-14	Halifax	10-Oct-01	BBC Chile	GenC	6204	Houston, TX	USA	G	IMO	Yes	14	2592	32	0	
NS-15	Halifax	11-Oct-01	Mariel	GenC	6395	Moa	Cuba	G	Can	Yes	24	2400	89	0	
NS-16	Hantsport	11-Oct-01	Gypsum King	BulkC	12272	Norfolk, VG	USA	A	Can	Yes	26	8099	76	100	NW Atlantic

NS-17	Halifax	13-Oct-01	Blue Sky	GenC	5086	Cuxhaven	Germany	B	No	Yes	18	1530	95	0	
NS-18	Halifax	13-Oct-01	Maren Maersk	Cont	52191	Rotterdam	Netherlands	B	Can	Yes	44	22178	38	18	NW Atlantic + NE Atlantic
NS-19	Halifax	13-Oct-01	Gerd Maersk	Cont	50698	Algeciras	Spain	C	IMO	Yes	24	17732	65	10	NW Atlantic
NS-20	Halifax	20-Oct-01	Grasmere Maersk	Cont	50698	Algeciras	Spain	C	USA	Yes	24	17732	77	7	NE Atlantic
NS-21	Halifax	20-Oct-01	Atlantic Companion	Ro/Ro	57255	Liverpool	UK	B	USA	No	35	23474	33	0	
NS-22	Halifax	23-Oct-01	Gitta Oldendorff	GenC	30150	Suez	Egypt	H	USA	Yes	18	12100	29	0	
NS-23	Halifax	27-Oct-01	Atlantic Cartier	Ro/Ro	58358	Liverpool	UK	B	No	No	36	23738	48	0	
NS-24	Halifax	27-Oct-01	Barbel P.	GenC	2301	Vera Cruz	Mexico	G	USA	Yes	11	1360	81	0	
NS-25	Halifax	30-Oct-01	MH Baker	BulkC	23955	New York, NY	USA	A	USA	No	14	18429	86	100	Camden, NJ, USA
NS-26	Halifax	30-Oct-01	Providence Bay	Cont	50350	Rotterdam	Netherlands	B	USA	Yes	19	17028	40	0	
NS-27	Halifax	31-Oct-01	CSL Atlas	BulkC	41173	Newington, NH	USA	A	USA	Yes	14	31626	91	100	NW Atlantic
NS-28	Halifax	31-Oct-01	Zim America	Cont	37209	Barcelona	Spain	C	USA	Yes	21	13250	58	6	NW Atlantic
NS-29	Little Narrows	02-Nov-01	Gypsum Baron	BulkC	12272	Stony Pt, NY	USA	A	No	No	20	7155	70	100	Stony Pt, NY, USA
NS-30	Halifax	03-Nov-01	Atlantic Concert	Ro/Ro	57255	Liverpool	UK	B	USA	No	35	23474	51	14	Liverpool, UK
NS-31	Pt Tupper	08-Nov-01	Madison	Tank	23842	Searsport, ME	USA	A	No	No	14	17200	96	100	Searsport, ME, USA
NS-32	Little Narrows	09-Nov-01	AV Kastner	BulkC	12702	Jacksonville, FL	USA	G	USA	No	24	8301	100	100	Jacksonville, FL, USA
NS-33	Hantsport	10-Nov-01	Gypsum Baron	BulkC	12272	Baltimore, MD	USA	A	Can	No	20	7155	87	100	Baltimore, MD, USA
NS-34	Halifax	11-Nov-01	Atlantic Compass	Ro/Ro	57255	Liverpool	UK	B	Other	No	35	23474	41	9	Liverpool, UK
NS-35	Pt Tupper	14-Nov-01	Eagle Baltimore	Tank	57456	New York, NY	USA	A	Other	Yes	10	43876	88	100	NW Atlantic
NS-36	Pugwash	15-Nov-01	Cecilia Desgagnes	BulkC	5756	Searsport, ME	USA	A	Other	Yes	10	1690	42	100	NW Atlantic
NS-37	Pt Tupper	21-Nov-01	Eagle Boston	Tank	57546	New York, NY	USA	A	Can	Yes	10	43826	90	100	NW Atlantic
NS-38	Little Narrows	22-Nov-01	AV Kastner	BulkC	12702	Jacksonville, FL	USA	G	USA	No	24	8301	100	100	Jacksonville, FL, USA
NS-39	Hantsport	27-Nov-01	Gypsum King	BulkC	12272	Baltimore, MD	USA	A	Can	Yes	26	8099	76	100	NW Atlantic + W Central Atlantic
NS-40	Pt Tupper	04-Dec-01	Georgia S	BulkC	20053	Burlington, NJ	USA	A	IMO	Yes?	15	15411	72	100	NW Atlantic?
NS-41	Little Narrows	05-Dec-01	Gypsum Baron	BulkC	12272	Norfolk, VG	USA	A	Can	No	20	7155	87	100	Norfolk, VG, USA
NS-42	Halifax	09-Dec-01	Sophia Britannia	Cont	50501	Marsaxlokk	Malta	C	IMO	Yes	25	13954	80	0	
NS-43	Halifax	15-Jan-02	Melfi Atlantic	GenC	4793	Moa	Cuba	G	USA	Yes	14	1673	68	0	
NS-44	Hantsport	31-Jan-02	Gypsum King	BulkC	12272	Stony Pt, NY	USA	A	Can	No	26	8099	76	100	Stony Pt, NY, USA
NS-45	Pt Tupper	08-Feb-02	Saraband	Tank	31248	New Haven, CT	USA	A	USA	No	29	19011	59	100	New Haven, CT, USA
NS-46	Hantsport	24-Feb-02	Gypsum King	BulkC	12272	Boston, MA	USA	A	Can	No	26	8099	76	100	Boston, MA, USA
NS-47	Pt Tupper	24-Feb-02	Georgia S	BulkC	20053	Wilmington, NC	USA	G	USA	Yes	15	15411	73	100	NW Atlantic
NS-48	Halifax	25-Feb-02	Melfi Atlantic	GenC	4793	Havana	Cuba	G	IMO	Yes	14	1715	91	39	Havana, Cuba + W Central Atlantic

Appendix 4 - Sampling log indicating sampling date for each ship, origin of ballast water, sampling method (SP=Sounding Port, BWP=Ballast Water Pump) and sample volume obtained.

Sampling Date	Arrival Port	Vessel Name	Port of Origin	Country of Origin	FAO	Sample ID	Source of Ballast Water	Source Latitude	Source Longitude	Source Region	Water Type	Water Age(d)	Sampling Method	Volume (liters)
23-Sep-01	CHLX	Maersk Wind	Southampton	UK	B	NS-01-A	Baltimore, MD			A	Port	23	SP	50
						NS-01-B	NE Atlantic	49.32 N	16.33 W	B	Oceanic	65	SP	50
23-Sep-01	CHLX	Charlotte C	Antwerp	Belgium	B	NS-02-A	NW Atlantic	46.57 N	31.15 W	A	Oceanic	5	SP	50
						NS-02-B	NW Atlantic	46.57 N	31.15 W	A	Oceanic	5	SP	50
						NS-02-C	NW Atlantic	46.17 N	34.18 W	A	Oceanic	5	SP	50
23-Sep-01	BCBC	Margara	Riverhead, NY	USA	A	NF-01-A	Riverhead, NY			A	Port	4	SP	50
						NF-01-B	Riverhead, NY			A	Port	4	SP	50
						NF-01-C	Riverhead, NY			A	Port	4	SP	50
26-Sep-01	BCBC	Bering Sea	Houston, TX	USA	G	NF-02-A	NW Atlantic	41.23 N	62.14 W	A	Oceanic	2	HAT	50
						NF-02-B	NW Atlantic	41.23 N	62.14 W	A	Oceanic	2	HAT	50
						NF-02-C	NW Atlantic	41.23 N	62.14 W	A	Oceanic	2	HAT	50
26-Sep-01	CHLX	Zim Italia	Barcelona	Spain	C	NS-03-A	NW Atlantic	42.00 N	38.00 W	A	Oceanic	3	SP	50
						NS-03-B	NE Atlantic	40.00 N	21.00 W	B	Oceanic	4	SP	50
26-Sep-01	CHLX	Stuttgart Express	Le Havre	France	B	NS-04-A	NE Pacific	48.45 N	173.38 W	E	Oceanic	44	BWP	40
						NS-04-B	Thamesport, UK			B	Port	10	BWP	40
						NS-04-C	Le Havre, France			B	Port	5	BWP	40
27-Sep-01	BARG	Lagarfoss	Isafiordur	Iceland	B	NF-03-A	Reykjavik, Iceland			B	Port	6	BWP	50
						NF-03-B	Reykjavik, Iceland			B	Port	6	BWP	50
						NF-03-C	Reykjavik, Iceland			B	Port	6	BWP	50
28-Sep-01	CHLX	Lovisa Gorthon	Puerto Limon	Costa Rica	G	NS-05-A	W Central Atlantic	29.28 N	70.24 W	G	Oceanic	3	SP	50
						NS-05-B	W Central Atlantic	29.48 N	70.15 W	G	Oceanic	3	SP	50
						NS-05-C	W Central Atlantic	25.30 N	72.05 W	G	Oceanic	4	SP	50
29-Sep-01	CPTP	Wilana	Philadelphia, PA	USA	A	NS-06-A	Philadelphia, PA			A	Port	3	SP	50
						NS-06-B	Philadelphia, PA			A	Port	3	SP	50
						NS-06-C	NW Atlantic	41.10 N	66.13 W	A	Oceanic	1	SP	50
30-Sep-01	CPTP	MH Baker	Camden, NJ	USA	A	NS-07-A	Camden, NJ			A	Port	4	SP	45
						NS-07-B	Camden, NJ			A	Port	4	SP	47
						NS-07-C	Camden, NJ			A	Port	4	SP	50
30-Sep-01	CDAL	Stig Gorthon	Veracruz	Mexico	G	NB-01-A	W Central Atlantic	33.43 N	76.17 W	G	Oceanic	4	SP	50
						NB-01-B	W Central Atlantic	33.43 N	76.17 W	G	Oceanic	4	SP	50
						NB-01-C	NW Atlantic	47.35 N	63.07 W	A	Coastal	1	BK	50
01-Oct-01	CBDN	Okoltchitza	Casablanca	Morocco	F	NB-02-A	NW Atlantic	37.36 N	31.59 W	A	Oceanic	6	SP	50

						NB-02-B	E Central Atlantic	34.21 N	11.52 W	F	Oceanic	10	BK	50
						NB-02-C	E Central Atlantic	34.21 N	11.52 W	F	Oceanic	10	BK	50
03-Oct-01	CHLX	New York Express	Le Havre	France	B	NS-08-A	NW Atlantic	47.23 N	36.53 W	A	Oceanic	2	BWP	40
						NS-08-B	NW Atlantic	47.23 N	36.53 W	A	Oceanic	2	BWP	40
						NS-08-C	NW Pacific	47.14 N	170.39 E	D	Oceanic	79	BWP	40
04-Oct-01	CHNT	Gypsum Baron	Baltimore, MD	USA	A	NS-09-A	Baltimore, MD			A	Port	3	SP	50
						NS-09-B	Baltimore, MD			A	Port	3	SP	50
						NS-09-C	Baltimore, MD			A	Port	3	SP	50
05-Oct-01	CBDN	TK Istanbul	Alsen, NY	USA	A	NB-03-A	NW Atlantic	41.30 N	67.08 W	A	Coastal	3	SP	50
						NB-03-B	NW Atlantic	41.30 N	67.08 W	A	Coastal	3	SP	50
						NB-03-C	NW Atlantic	41.00 N	68.15 W	A	Coastal	3	SP	40
06-Oct-01	CBDN	Marinor	Southport, NC	USA	G	NB-04-A	NW Atlantic	37.26 N	72.10 W	A	Oceanic	4	SP	50
						NB-04-B	NW Atlantic	39.02 N	70.09 W	A	Oceanic	16	SP	50
						NB-04-C	W Central Atlantic	34.27 N	75.05 W	G	Oceanic	18	SP	50
06-Oct-01	BCBC	MT Aquidneck	Portsmouth, NH	USA	A	NF-04-A	Providence, RI			A	Port	5	SP	50
						NF-04-B	Providence, RI			A	Port	8	SP	50
						NF-04-C	Providence, RI			A	Port	7	SP	50
08-Oct-01	CHLX	Cosco Norfolk	New York, NY	USA	A	NS-10-A	NW Atlantic	40.12 N	39.57 W	A	Oceanic	12	BWP	40
						NS-10-B	Felixstowe, UK			B	Port	20	BWP	40
						NS-10-C	NW Atlantic	40.12 N	39.57 W	A	Oceanic	12	BWP	40
08-Oct-01	CHLX	Georgia S	Wilmington, DE	USA	A	NS-11-A	NW Atlantic	39.14 N	72.50 W	A	Coastal	2	SP	50
						NS-11-B	NW Atlantic	39.14 N	72.50 W	A	Coastal	2	SP	50
						NS-11-C	NW Atlantic	39.14 N	72.50 W	A	Coastal	2	SP	50
08-Oct-01	BCBC	Isola Gialla	Jacksonville, FL	USA	G	NF-05-A	NW Atlantic	37.08 N	67.55 W	A	Oceanic	3	SP	50
						NF-05-B	NW Atlantic	37.32 N	66.59 W	A	Oceanic	3	SP	50
						NF-05-C	NW Atlantic	38.12 N	66.08 W	A	Oceanic	3	SP	50
09-Oct-01	CHLX	Shanghai Express	Le Havre	France	B	NS-12-A	NW Pacific	48.16 N	174.49 E	D	Oceanic	42	BWP	40
						NS-12-B	NW Pacific	45.12 N	162.21 E	D	Oceanic	43	BWP	40
						NS-12-C	NW Pacific	41.02 N	151.36 E	D	Oceanic	44	BWP	34
10-Oct-01	CHLX	Zim Korea	Barcelona	Spain	C	NS-13-A	NW Atlantic	40.50 N	40.10 W	A	Oceanic	3	SP	50
						NS-13-B	NW Atlantic	42.31 N	52.30 W	A	Oceanic	2	SP	50
						NS-13-C	NE Atlantic	38.06 N	21.20 W	B	Oceanic	5	SP	20
10-Oct-01	CHLX	BBC Chile	Houston, TX	USA	G	NS-14-A	NW Atlantic	36.10 N	71.31 W	A	Oceanic	3	SP	50
						NS-14-B	W Central Atlantic	30.52 N	76.19 W	G	Oceanic	4	SP	50
						NS-14-C	NW Atlantic	36.29 N	71.13 W	A	Oceanic	3	SP	50
11-Oct-01	BARG	Skogafoss	Reykjavik	Iceland	B	NF-06-A	Reykjavik, Iceland			B	Port	6	BWP	50
						NF-06-B	Reykjavik, Iceland			B	Port	6	BWP	50
						NF-06-C	Reykjavik, Iceland			B	Port	6	BWP	50

11-Oct-01	CHLX	Mariel	Moa	Cuba	G	NS-15-A	NW Atlantic	41.00 N	66.50 W	A	Oceanic	29	SP	50
11-Oct-01	CHNT	Gypsum King	Norfolk, VG	USA	A	NS-16-A	NW Atlantic	41.10 N	68.58 W	A	Coastal	1	SP	50
						NS-16-B	NW Atlantic	39.09 N	72.04 W	A	Coastal	2	SP	50
13-Oct-01	CHLX	Blue Sky	Cuxhaven	W. Germany	B	NS-17-A	NW Atlantic	46.58 N	32.15 W	A	Oceanic	5	SP	50
						NS-17-B	NW Atlantic	46.58 N	32.15 W	A	Oceanic	5	SP	50
						NS-17-C	NW Atlantic	46.58 N	32.15 W	A	Oceanic	5	SP	50
13-Oct-01	CHLX	Maren Maersk	Rotterdam	Netherlands	B	NS-18-A	NE Atlantic	60.25 N	16.54 W	B	Oceanic	4	BWP	50
						NS-18-B	NE Atlantic	50.27 N	29.46 W	B	Oceanic	3	BWP	50
						NS-18-C	NE Atlantic	50.38 N	18.04 W	B	Oceanic	4	BWP	50
13-Oct-01	CHLX	Gerd Maersk	Algeciras	Spain	C	NS-19-A	NW Atlantic	41.41 N	44.44 W	A	Oceanic	2	SP	50
						NS-19-B	NW Pacific	43.22 N	155.45 E	D	Oceanic	6	SP	50
15-Oct-01	CBDN	Marneborg	Philadelphia, PA	USA	A	NB-05-A	Philadelphia, PA			A	Port	4	SP	50
						NB-05-B	Philadelphia, PA			A	Port	5	SP	50
						NB-05-C	Philadelphia, PA			A	Port	4	SP	50
16-Oct-01	BCBC	MT Iliad	New York, NY	USA	A	NF-07-A	New York, NY			A	Port	5	HAT	50
						NF-07-B	New York, NY			A	Port	5	HAT	50
						NF-07-C	New York, NY			A	Port	5	HAT	50
17-Oct-01	CDAL	Ada Gorthon	Philadelphia, PA	USA	A	NB-06-A	NW Atlantic	39.00 N	70.00 W	A	Oceanic	4	BWP	50
						NB-06-B	NW Atlantic	39.00 N	70.00 W	A	Oceanic	4	BWP	50
						NB-06-C	NW Atlantic	39.00 N	70.00 W	A	Oceanic	4	BWP	50
19-Oct-01	BHCE	Green Austevoll	New Bedford, MA	USA	A	NF-08-A	NW Atlantic	53.11 N	41.58 W	A	Oceanic	13	FHOSE	50
						NF-08-B	NW Atlantic	53.19 N	41.41 W	A	Oceanic	9	FHOSE	50
						NF-08-C	NW Atlantic	56.58 N	32.31 W	A	Oceanic	11	FHOSE	50
20-Oct-01	CHLX	Grasmere Maersk	Algeciras	Spain	C	NS-20-A	Arabian Sea	14.54 N	58.23 E	H	Oceanic	18	BWP	40
						NS-20-B	NW Pacific	40.49 N	153.04 E	D	Oceanic	55	BWP	40
						NS-20-C	NE Atlantic	37.47 N	16.32 W	B	Oceanic	4	BWP	40
20-Oct-01	CHLX	Atlantic Companion	Liverpool	UK	B	NS-21-A	Liverpool, UK			B	Port	7	SP	50
21-Oct-01	BSNF	MV Radeplein	Norfolk, VG	USA	A	NF-09-A	NW Atlantic	60.45 N	36.59 W	A	Oceanic	39	SP	50
						NF-09-B	NW Atlantic	60.38 N	37.20 W	A	Oceanic	39	SP	25
						NF-09-C	NW Atlantic	60.24 N	38.12 W	A	Oceanic	39	SP	30
21-Oct-01	CDAL	Alida Gorthon	Richmond, VG	USA	A	NB-07-A	NW Atlantic	38.43 N	72.21 W	A	Oceanic	4	SP	50
						NB-07-B	NW Atlantic	39.27 N	70.41 W	A	Oceanic	4	SP	50
						NB-07-C	NW Atlantic	39.27 N	70.41 W	A	Oceanic	4	SP	50
22-Oct-01	CBDN	Valga	Camden, NJ	USA	A	NB-08-A	NW Atlantic	39.54 N	70.30 W	A	Oceanic	4	SP	40
						NB-08-B	Camden / NW Atlantic	43.60 N	62.27 W	A	Coastal	3	SP	40
						NB-08-C	Camden, NJ			A	Port	5	SP	40
22-Oct-01	BWIF	Vancouver Spirit	Portland, ME	USA	A	NF-10-A	Portland, ME			A	Port	7	HAT	50

						NF-10-B	Portland, ME			A	Port	7	HAT	50
						NF-10-C	Portland, ME			A	Port	7	HAT	50
23-Oct-01	CHLX	Gitta Oldendorff	Suez	Egypt	H	NS-22-A	NW Atlantic	39.39 N	33.42 W	A	Oceanic	4	BWP	18
						NS-22-B	Gulf of Aden	13.17 N	48.18 E	H	Oceanic	19	BWP	18
24-Oct-01	BARG	Lagarfoss	Reykjavik	Iceland	B	NF-11-A	Reykjavik, Iceland			B	Port	5	BWP	50
						NF-11-B	Reykjavik, Iceland			B	Port	5	BWP	50
						NF-11-C	Reykjavik, Iceland			B	Port	5	BWP	50
25-Oct-01	BSNF	Emma	Copenhagen	Denmark	B	NF-12-A	NW Atlantic	51.25 N	45.45 W	A	Oceanic	5	HAT	50
						NF-12-B	NW Atlantic	51.25 N	45.45 W	A	Oceanic	5	HAT	50
						NF-12-C	NW Atlantic	50.25 N	42.07 W	A	Oceanic	7	HAT	50
27-Oct-01	CHLX	Atlantic Cartier	Liverpool	UK	B	NS-23-A	Gothenburg, Sweden			B	Port	289	SP	40
						NS-23-B	Baltimore, MD			A	Port	171	SP	40
						NS-23-C	Gothenburg, Sweden			B	Port	289	SP	40
27-Oct-01	CHLX	Barbel P	Veracruz	Mexico	G	NS-24-A	Gulf of Mexico	28.48 N	91.16 W	G	Coastal	20	SP	50
						NS-24-B	Gulf of Mexico	28.48 N	91.16 W	G	Coastal	20	SP	50
						NS-24-C	Bay of Campeche	19.16 N	95.36 W	G	Coastal	9	SP	50
28-Oct-01	CBDN	Viljandi	Baltimore, MD	USA	A	NB-09-A	St. Petersburg, Russia			B	Port	27	SP	50
29-Oct-01	BCBC	Ostankino	New York, NY	USA	A	NF-13-A	NW Atlantic	42.19 N	64.58 W	A	Oceanic	2	SP	50
						NF-13-B	NW Atlantic	44.59 N	58.50 W	A	Coastal	1	SP	50
						NF-13-C	NW Atlantic	44.03 N	60.51 W	A	Coastal	1	SP	50
30-Oct-01	CHLX	MH Baker	Burlington, NJ	USA	A	NS-25-A	Camden, NJ			A	Port	4	SP	50
						NS-25-B	Camden, NJ			A	Port	4	SP	50
						NS-25-C	Camden, NJ			A	Port	4	SP	50
30-Oct-01	CHLX	Providence Bay	Rotterdam	Netherlands	B	NS-26-A	E Central Pacific	11.43 N	93.10 W	J	Oceanic	169	SP	50
						NS-26-B	North Sea	51.50 N	02.00 W	B	Oceanic	10	SP	50
31-Oct-01	CHLX	CSL Atlas	Newington, NH	USA	A	NS-27-A	NW Atlantic	43.05 N	68.51 W	A	Coastal	1	SP	50
						NS-27-B	NW Atlantic	43.04 N	69.09 W	A	Coastal	2	SP	50
31-Oct-01	CHLX	Zim America	Barcelona	Spain	C	NS-28-A	Barcelona, Spain			C	Port	24	SP	40
						NS-28-B	NW Atlantic	40.15 N	40.51 W	A	Oceanic	2	SP	40
31-Oct-01	BWIF	Vancouver Spirit	Portland, ME	USA	A	NF-14-A	Portland, ME			A	Port	3	HAT	50
						NF-14-B	Portland, ME			A	Port	3	HAT	50
						NF-14-C	Portland, ME			A	Port	3	HAT	50
02-Nov-01	CLIT	Gypsum Baron	Stony Pt, NY	USA	A	NS-29-A	Stony Pt, NY			A	Port	4	SP	50
						NS-29-B	Stony Pt, NY			A	Port	4	SP	50
						NS-29-C	Stony Pt, NY			A	Port	4	SP	50
03-Nov-01	CHLX	Atlantic Concert	Liverpool	UK	B	NS-30-A	Liverpool, UK			B	Port	7	SP	50

						NS-30-B	Liverpool, UK			B	Port	7	SP	50
						NS-30-C	Baltimore, MD			A	Port	30	SP	50
08-Nov-01	CPTP	Madison	Searsport, ME	USA	A	NS-31-A	Searsport, ME			A	Port	1	HAT	50
						NS-31-B	Searsport, ME			A	Port	1	HAT	50
						NS-31-C	Searsport, ME			A	Port	1	HAT	50
09-Nov-01	CLIT	AV Kastner	Jacksonville, FL	USA	G	NS-32-A	Jacksonville, FL			G	Port	6	SP	50
						NS-32-B	Jacksonville, FL			G	Port	6	SP	50
						NS-32-C	Jacksonville, FL			G	Port	6	SP	50
10-Nov-01	CHNT	Gypsum Baron	Baltimore, MD	USA	A	NS-33-A	Baltimore, MD			A	Port	3	SP	50
						NS-33-B	Baltimore, MD			A	Port	3	SP	50
						NS-33-C	Baltimore, MD			A	Port	3	SP	50
11-Nov-01	CHLX	Atlantic Compass	Liverpool	UK	B	NS-34-A	Antwerp, Belgium			B	Port	10	BWP	50
						NS-34-B	Gothenburg, Sweden			B	Port	13	BWP	50
						NS-34-C	Liverpool, UK			B	Port	7	BWP	50
12-Nov-01	BCBC	Nordscot	Portland, ME	USA	A	NF-15-A	NW Atlantic	43.40 N	58.18 W	A	Oceanic	1	HAT	50
						NF-15-B	NW Atlantic	43.17 N	59.27 W	A	Oceanic	1	HAT	50
						NF-15-C	NW Atlantic	43.40 N	58.18 W	A	Oceanic	1	HAT	50
13-Nov-01	BSNF	MV Radeplein	Norfolk, VG	USA	A	NF-16-A	NW Atlantic	58.53 N	41.29 W	A	Oceanic	15	SP	50
						NF-16-B	NW Atlantic	58.53 N	41.29 W	A	Oceanic	15	SP	50
14-Nov-01	CDAL	Ada Gorthon	Tilbury	UK	B	NB-10-A	NE Atlantic	48.00 N	27.00 W	B	Oceanic	5	BWP	50
						NB-10-B	NE Atlantic	48.00 N	27.00 W	B	Oceanic	5	BWP	50
						NB-10-C	NE Atlantic	48.00 N	27.00 W	B	Oceanic	5	BWP	50
14-Nov-01	CPTP	Eagle Baltimore	New York, NY	USA	A	NS-35-A	NW Atlantic	40.23 N	72.25 W	A	Coastal	2	HAT	50
						NS-35-B	NW Atlantic	40.23 N	72.25 W	A	Coastal	2	HAT	50
						NS-35-C	NW Atlantic	40.38 N	66.58 W	A	Oceanic	1	HAT	50
15-Nov-01	CWIF	Hamane Spirit	Portland, ME	USA	A	NF-17-A	NW Atlantic	45.36 N	57.50 W	A	Coastal	1	SP	50
						NF-17-B	NW Atlantic	45.56 N	56.52 W	A	Coastal	1	SP	50
						NF-17-C	NW Atlantic	44.56 N	60.08 W	A	Coastal	1	SP	50
15-Nov-01	CPUG	Cecilia Desgagnes	Searsport, ME	USA	A	NS-36-A	NW Atlantic	43.38 N	67.32 W	A	Coastal	2	BWP	50
						NS-36-B	NW Atlantic	43.25 N	66.41 W	A	Coastal	2	BWP	50
						NS-36-C	NW Atlantic	43.18 N	66.18 W	A	Coastal	2	BWP	50
16-Nov-01	CCHN	Akademikis Zavarickis	St. Petersburg	Russia	B	PE-01-A	NW Atlantic	46.00 N	40.22 W	A	Oceanic	4	BWP	20
16-Nov-01	CSUM	Green Malloy	Philadelphia, PA	USA	A	PE-02-A	NW Atlantic	37.03 N	58.54 W	A	Oceanic	11	BWP	50
						PE-02-B	NW Atlantic	36.05 N	40.37 W	A	Oceanic	14	BWP	50
						PE-02-C	NW Atlantic	36.18 N	36.41 W	A	Oceanic	15	BWP	50
16-Nov-01	CBDN	Bow Flower	Providence, RI	USA	A	NB-11-A	NE Atlantic	37.01 N	19.15 W	B	Oceanic	14	FHOSE	50
						NB-11-B	NE Atlantic	37.01 N	19.15 W	B	Oceanic	14	FHOSE	50

						NB-11-C	NW Atlantic	40.33 N	67.36 W	A	Coastal	2	FHOSE	50
18-Nov-01	CBDN	Kapitonas Stulpina	Tampa, FL	USA	G	NB-12-A	NW Atlantic	37.48 N	69.15 W	A	Oceanic	5	SP	20
						NB-12-B	NW Atlantic	37.32 N	56.13 W	A	Oceanic	25	SP	50
21-Nov-01	CPTP	Eagle Boston	New York, NY	USA	A	NS-37-A	NW Atlantic	40.26 N	73.26 W	A	Coastal	2	SP	50
						NS-37-B	NW Atlantic	40.26 N	70.00 W	A	Coastal	1	SP	50
						NS-37-C	NW Atlantic	41.37 N	66.41 W	A	Coastal	1	SP	50
21-Nov-01	BCBC	Nordscot	Boston, MA	USA	A	NF-18-A	NW Atlantic	42.56 N	60.13 W	A	Oceanic	1	HAT	50
						NF-18-B	NW Atlantic	42.56 N	60.13 W	A	Oceanic	1	HAT	50
						NF-18-C	NW Atlantic	43.28 N	58.55 W	A	Oceanic	1	HAT	50
22-Nov-01	CLIT	AV Kastner	Jacksonville, FL	USA	G	NS-38-A	Jacksonville, FL			G	Port	6	SP	50
						NS-38-B	Jacksonville, FL			G	Port	6	SP	50
						NS-38-C	Jacksonville, FL			G	Port	6	SP	50
24-Nov-01	BARG	Ras Sedr	Inagua	Bahamas	G	NF-19-A	Kingston, Jamaica			G	Port	10	SP	50
						NF-19-B	Kingston, Jamaica			G	Port	10	SP	50
						NF-19-C	Kingston, Jamaica			G	Port	10	SP	50
26-Nov-01	BCBK	Joh. Gorthon	Richmond, VA	USA	A	NF-20-A	NW Atlantic	40.00 N	69.00 W	A	Coastal	3	SP	50
						NF-20-B	NW Atlantic	40.00 N	69.00 W	A	Coastal	3	SP	50
						NF-20-C	NW Atlantic	40.00 N	69.00 W	A	Coastal	3	SP	50
27-Nov-01	CHNT	Gypsum King	Baltimore, MD	USA	A	NS-39-A	NW Atlantic	41.28 N	68.45 W	A	Coastal	1	SP	50
						NS-39-B	NW Atlantic	39.37 N	71.20 W	A	Coastal	2	SP	50
28-Nov-01	BCBC	Turmoil	New York, NY	USA	A	NF-21-A	NW Atlantic	42.55 N	58.47 W	A	Oceanic	1	HAT	50
						NF-21-B	NW Atlantic	42.19 N	60.53 W	A	Oceanic	1	HAT	50
						NF-21-C	NW Atlantic	42.19 N	60.53 W	A	Oceanic	1	HAT	50
28-Nov-01	BWIF	Singapore Spirit	Delaware City, DE	USA	A	NF-22-A	NW Atlantic	39.24 N	67.24 W	A	Oceanic	2	SP	50
						NF-22-B	NW Atlantic	39.21 N	70.03 W	A	Oceanic	3	SP	50
						NF-22-C	NW Atlantic	39.23 N	66.21 W	A	Oceanic	2	SP	50
30-Nov-01	CDAL	Stig Gorthon	Ponta Delgada	Portugal	B	NB-13-A	NW Atlantic	41.44 N	41.07 W	A	Oceanic	6	SP	50
						NB-13-B	NW Atlantic	41.44 N	41.07 W	A	Oceanic	6	SP	50
						NB-13-C	NW Atlantic	40.52 N	37.22 W	A	Oceanic	7	BK	50
30-Nov-01	CBDN	Salvador	Baltimore, MD	USA	A	NB-14-A	New Orleans			G	Port	56	SP	50
						NB-14-B	New Orleans			G	Port	56	SP	40
04-Dec-01	CPTP	Georgia S	Burlington, NJ	USA	A	NS-40-A	NW Atlantic	37.55 N	74.14 W	A	Oceanic	2	SP	50
						NS-40-B	NW Atlantic	37.55 N	74.14 W	A	Oceanic	2	SP	50
						NS-40-C	NW Atlantic	37.55 N	74.14 W	A	Oceanic	2	SP	50
04-Dec-01	BCBK	Ingrid Gorthon	Rotterdam	Netherlands	B	NF-23-A	NW Atlantic	51.22 N	48.30 W	A	Oceanic	1	SP	50
						NF-23-B	NW Atlantic	51.22 N	48.30 W	A	Oceanic	1	SP	50
						NF-23-C	NW Atlantic	51.29 N	50.07 W	A	Oceanic	1	SP	50
05-Dec-01	CLIT	Gypsum Baron	Norfolk, VA	USA	A	NS-41-A	Norfolk, VG			A	Port	4	SP	50

						NS-41-B	Norfolk, VG			A	Port	4	SP	50
						NS-41-C	Norfolk, VG			A	Port	4	SP	50
07-Dec-01	BCBC	Nordeuropa	Boston, MA	USA	A	NF-24-A	NW Atlantic	46.00 N	56.00 W	A	Coastal	1	HAT	50
						NF-24-B	NW Atlantic	46.00 N	56.00 W	A	Coastal	1	HAT	50
						NF-24-C	NW Atlantic	46.00 N	56.00 W	A	Coastal	1	HAT	50
08-Dec-01	BSNF	Bavaria	Houston, TX	USA	G	NF-25-A	NW Atlantic	36.52 N	69.19 W	A	Oceanic	4	SP	50
						NF-25-B	NW Atlantic	36.52 N	69.19 W	A	Oceanic	4	SP	50
						NF-25-C	NW Atlantic	36.52 N	69.19 W	A	Oceanic	4	SP	50
09-Dec-01	CHFX	Sophia Britannia	Marsaxlokk	Malta	C	NS-42-A	Marsaxlokk, Malta			C	Port	9	SP	50
						NS-42-B	NE Atlantic	36.29 N	15.19 W	B	Oceanic	5	SP	50
						NS-42-C	NE Atlantic	37.04 N	26.21 W	B	Oceanic	4	SP	50
11-Dec-01	CBDN	Tofton	Wilmington, NC	USA	G	NB-15-A	NW Atlantic	37.25 N	72.00 W	A	Oceanic	3	SP	50
						NB-15-B	NW Atlantic	37.25 N	72.00 W	A	Oceanic	3	SP	50
						NB-15-C	NW Atlantic	37.25 N	72.00 W	A	Oceanic	3	SP	50
16-Dec-01	BCBC	Nordeuropa	Bridgeport, CT	USA	A	NF-26-A	NW Atlantic	42.25 N	58.38 W	A	Oceanic	1	HAT	50
						NF-26-B	NW Atlantic	42.25 N	58.38 W	A	Oceanic	1	HAT	50
						NF-26-C	NW Atlantic	42.25 N	58.38 W	A	Oceanic	1	HAT	50
16-Dec-01	BWIF	Front Sunda	Philadelphia, PA	USA	A	NF-27-A	NW Atlantic	41.28 N	64.48 W	A	Oceanic	2	SP	50
						NF-27-B	NW Atlantic	41.28 N	64.48 W	A	Oceanic	2	SP	50
18-Dec-01	BCBC	MT Burgas	New York, NY	USA	A	NF-28-A	NW Atlantic	44.49 N	58.06 W	A	Oceanic	3	HAT	50
						NF-28-B	NW Atlantic	44.49 N	58.06 W	A	Oceanic	3	HAT	50
						NF-28-C	NW Atlantic	44.49 N	58.06 W	A	Oceanic	3	HAT	50
20-Dec-01	CCHN	Tasman Start	Ilyichevsk	Ukraine	C	PE-03-A	E Central Atlantic	31.22 N	23.52 W	F	Oceanic	10	SP	40
						PE-03-B	E Central Atlantic	31.22 N	23.52 W	F	Oceanic	10	SP	30
23-Dec-01	BWIF	Orkney Spirit	Portland, ME	USA	A	NF-29-A	Portland, ME			A	Port	3	HAT	50
						NF-29-B	Portland, ME			A	Port	3	HAT	50
04-Jan-02	BWIF	Front Sun	Philadelphia, PA	USA	A	NF-30-A	NW Atlantic	39.41 N	69.43 W	A	Oceanic	4	HAT	50
						NF-30-B	NW Atlantic	39.56 N	68.51 W	A	Coastal	4	HAT	50
						NF-30-C	NW Atlantic	41.41 N	63.20 W	A	Oceanic	4	HAT	50
06-Jan-02	BCBC	Nordscot	Boston, MA	USA	A	NF-31-A	NW Atlantic	46.00 N	56.00 W	A	Coastal	1	HAT	50
						NF-31-B	NW Atlantic	46.00 N	56.00 W	A	Coastal	1	HAT	50
						NF-31-C	NW Atlantic	46.00 N	56.00 W	A	Coastal	1	HAT	50
15-Jan-02	CHFX	Melfi Atlantic	Moa	Cuba	G	NS-43-A	W Central Atlantic	29.80 N	71.10 W	G	Oceanic	22	SP	50
						NS-43-B	W Central Atlantic	28.04 N	71.59 W	G	Oceanic	4	SP	50
						NS-43-C	W Central Atlantic	28.04 N	71.59 W	G	Oceanic	4	SP	50
21-Jan-02	BCBC	Ratna Abba	New York, NY	USA	A	NF-32-A	New York, NY			A	Port	7	HAT	50
						NF-32-B	New York, NY			A	Port	7	HAT	50
						NF-32-C	New York, NY			A	Port	7	HAT	50

31-Jan-02	CHNT	Gypsum King	Stony Pt, NY	USA	A	NS-44-A	Stony Pt, NY			A	Port	3	SP	50
						NS-44-B	Stony Pt, NY			A	Port	3	SP	50
08-Feb-02	CPTP	Saraband	New York, NY	USA	A	NS-45-A	New Haven, CT			A	Port	4	SP	50
						NS-45-B	New Haven, CT			A	Port	4	SP	50
						NS-45-C	New Haven, CT			A	Port	4	SP	50
24-Feb-02	CHNT	Gypsum King	Boston, MA	USA	A	NS-46-A	Boston, MA			A	Port	1	SP	50
						NS-46-B	Boston, MA			A	Port	1	SP	50
						NS-46-C	Boston, MA			A	Port	1	SP	35
24-Feb-02	CPTP	Georgia S	Wilmington, NC	USA	G	NS-47-A	NW Atlantic	38.31 N	70.49 W	A	Oceanic	2	SP	50
						NS-47-B	NW Atlantic	38.31 N	70.49 W	A	Oceanic	2	SP	50
						NS-47-C	NW Atlantic	38.31 N	70.49 W	A	Oceanic	2	SP	50
25-Feb-02	CHFX	Melfi Atlantic	Havana	Cuba	G	NS-48-A	Havana, Cuba			G	Port	5	SP	50
						NS-48-B	W Central Atlantic	29.54 N	79.21 W	G	Oceanic	4	SP	50
						NS-48-C	Havana, Cuba			G	Port	5	SP	50

Appendix 5: List of phytoplankton taxa observed, their frequency of occurrence, mean and maximum cell concentration, salinity preference, geographic affiliation (Indigenous), and toxic/harmful status. Mar = Marine, Brack = Brackish-water, Harm = Harmful.

Class Taxa	Salinity Preference	Indigenous	Toxic/ Harmful	Freq	Mean	Max
Chlorophyte						
Arthrodesmus incus	Brack	?	No	1	0.5	0.5
Arthrodesmus sp	Brack	?	No	1	0.8	0.8
Pediastrum boryanum	Brack	?	No	25	4.9	54.0
Pediastrum duplex	Brack	?	No	49	4.3	40.5
Pediastrum simplex	Brack	?	No	30	3.2	15.0
Scenedesmus acuminatus	Brack	?	No	1	3.3	3.3
Scenedesmus bijuga alternans	Brack	?	No	3	1.3	1.4
Scenedesmus opoliensis	Brack	?	No	2	1.3	1.9
Scenedesmus quadricauda	Brack	?	No	33	5.1	27.0
Scenedesmus quadricauda maximus	Brack	?	No	2	4.5	7.5
Staurastrum chaetoceras	Brack	?	No	1	0.9	0.9
Staurastrum natator	Brack	?	No	1	0.5	0.5
Staurastrum paradoxum	Brack	Yes	No	18	5.1	21.0
Chrysophyte						
Dinobryon sertularia	Brack	?	No	3	9.7	21.5
Synura uvella	Brack	?	No	2	16.6	25.2
Cyanophyte						
Anabaena sp	Brack	?	?	2	2.2	3.8
Chroococcus sp	Brack	?	?	10	11.4	27.6
Merismopedia punctata	Brack	Yes	?	1	3.5	3.5
Merismopedia sp	Brack	?	?	8	10.1	31.5
Oscillatoria sp	Brack	?	?	5	148.6	540.0
Diatom						
Achnanthes brevipes	Mar	No	No	5	6.1	20.4
Achnanthes taeniata	Brack	Yes	No	3	9.6	25.0
Actinocyclus tenuissimus	Mar	Yes	No	24	680.7	5176.8
Actinoptychus senarius	Mar	?	No	56	22.6	812.0
Actinoptychus splendens	Mar	No	No	3	0.8	1.4
Amphiprora alata	Mar	Yes	No	28	8.9	71.3
Amphiprora ornata	Brack	?	No	4	3.8	6.9
Amphora robusta	Mar	No	No	1	0.9	0.9
Asterionellopsis glacialis	Mar	Yes	No	28	214.7	4536.0
Asterionellopsis kariana	Mar	No	No	1	5.8	5.8
Asteromphalus flabellatus	Mar	No	No	1	0.9	0.9
Aulacoseira granulata	Brack	?	No	17	333.3	3220.0
Aulacoseira granulata angustissima	Brack	?	No	38	334.5	3816.0
Bacillaria paxillifera	Mar	Yes	No	10	72.6	412.5
Bacteriastrum delicatulum	Mar	No	No	43	13.8	168.0
Bacteriastrum elongatum	Mar	No	No	5	10.5	42.7
Bacteriastrum furcatum	Mar	No	No	3	3.1	4.3
Bacteriastrum hyalinum	Mar	No	No	19	15.5	156.4
Bacteriosira bathyomphala	Mar	Yes	No	2	1.7	2.3
Bellerochea horologicalis	Mar	No	No	27	27.0	97.5
Bellerochea malleus	Mar	Yes	No	7	20.8	49.7

Biddulphia alternans	Mar	Yes	No	27	8.9	49.7
Biddulphia obtusa	Mar	No	No	13	5.5	14.0
Biddulphia pulchella	Mar	No	No	1	0.6	0.6
Biddulphia reticulum	Mar	No	No	1	3.5	3.5
Biddulphia rhombus	Mar	No	No	5	2.2	3.8
Campylodiscus sp	Mar	?	No	2	2.3	3.3
Campylosira cymbelliformis	Mar	No	No	6	53.0	136.5
Catacombus gaillonii	Mar	Yes	No	7	1.8	3.7
Cerataulina pelagica	Mar	Yes	No	13	5.7	14.4
Cerataulus turgida	Mar	No	No	2	11.9	16.3
Chaetoceros affinis	Mar	Yes	No	27	44.2	497.7
Chaetoceros affinis willei	Mar	Yes	No	2	11.5	21.3
Chaetoceros atlanticus	Mar	Yes	No	11	3.6	9.3
Chaetoceros borealis	Mar	Yes	No	27	41.5	175.2
Chaetoceros brevis	Mar	Yes	No	5	29.6	93.8
Chaetoceros compressus	Mar	Yes	No	36	162.2	2281.5
Chaetoceros concavicornis	Mar	Yes	Harm	26	26.9	81.2
Chaetoceros constrictus	Mar	Yes	No	9	63.4	159.9
Chaetoceros convolutus	Mar	Yes	Harm	6	8.5	27.2
Chaetoceros curvisetus	Mar	Yes	No	36	333.1	10168.0
Chaetoceros danicus	Mar	Yes	No	11	34.9	273.0
Chaetoceros debilis	Mar	Yes	No	27	361.1	4920.0
Chaetoceros decipiens	Mar	Yes	No	63	444.4	16728.0
Chaetoceros decipiens singularis	Mar	No	No	2	45.8	63.0
Chaetoceros densum	Mar	No	No	3	61.3	127.1
Chaetoceros diadema	Mar	Yes	No	4	35.3	110.5
Chaetoceros didymus	Mar	Yes	No	13	27.8	56.0
Chaetoceros diversus	Mar	No	No	8	11.7	32.5
Chaetoceros furcellatus	Mar	Yes	No	1	40.2	40.2
Chaetoceros laciniosus	Mar	Yes	No	7	86.0	391.5
Chaetoceros laevis	Mar	No	No	6	6.3	15.3
Chaetoceros lorenzianus	Mar	Yes	No	24	62.0	496.0
Chaetoceros messanensis	Mar	No	No	6	6.4	14.6
Chaetoceros mitra	Mar	?	No	2	22.3	37.5
Chaetoceros peruvianus	Mar	No	No	28	5.4	22.8
Chaetoceros pseudobrevis	Mar	Yes	No	14	114.5	408.0
Chaetoceros pseudocrinitus	Mar	Yes	No	9	26.4	71.4
Chaetoceros pseudocurvisetus	Mar	Yes	No	1	272.0	272.0
Chaetoceros radicans	Mar	Yes	No	3	99.0	163.2
Chaetoceros rostratus	Mar	No	No	3	15.4	27.2
Chaetoceros similis	Mar	Yes	No	9	52.0	115.2
Chaetoceros simplex	Mar	Yes	No	42	57.7	1258.0
Chaetoceros sp	Brack	No	No	4	39.6	84.5
Chaetoceros subtilis	Brack	Yes	No	15	67.6	592.0
Chaetoceros teres	Mar	Yes	No	2	103.0	192.0
Chaetoceros tortissimus	Mar	No	No	1	416.0	416.0
Climacodinium frauenfeldianum	Mar	No	No	5	9.8	27.8
Climacosphenia moniligera	Mar	Yes	No	1	8.4	8.4
Climacosphenia sp	Mar	?	No	1	1.2	1.2
Closterium sp	Brack	?	No	1	0.9	0.9
Corethron criophilum	Mar	Yes	No	20	11.1	50.0

Coscinodiscus argus	Mar	?	No	9	42.2	307.5
Coscinodiscus asteromphalus	Mar	Yes	No	31	7.4	33.6
Coscinodiscus centralis	Mar	Yes	No	13	6.8	18.3
Coscinodiscus granii	Mar	?	No	7	110.2	335.8
Coscinodiscus radiatus	Mar	Yes	No	69	14.9	200.0
Cyclotella sp	Brack	?	No	14	69.9	288.8
Cyclotella striata	Brack	Yes	No	6	72.4	144.0
Cylindrotheca closterium	Mar	Yes	No	74	9.7	86.8
Cylindrotheca gracilis	Mar	Yes	No	28	10.6	47.6
Cymatopleura librile?	Brack	?	No	1	1.4	1.4
Cymatosira lorenziana	Mar	No	No	11	21.6	86.3
Dactyliosolen fragilissimus	Mar	Yes	No	24	1097.7	13320.0
Dactyliosolen phuketensis	Mar	No	No	2	6.5	11.3
Detonula confervacea	Mar	Yes	No	1	19.2	19.2
Detonula pumila	Mar	No	No	2	6.8	9.9
Diatoma tenuis	Brack	?	No	1	6.3	6.3
Diploneis bombus	Mar	Yes	No	1	1.5	1.5
Diploneis sp	Brack	?	No	9	4.6	14.0
Ditylum brightwelli	Mar	Yes	No	112	41.3	2044.0
Ditylum sol	Mar	No	No	1	15.4	15.4
Donkinia carinatum	Mar	?	No	4	2.6	3.5
Ephemera planamembranacea	Mar	Yes	No	1	0.4	0.4
Epithemia turgida	Brack	?	No	5	4.4	7.0
Eucampia cornuta	Mar	No	No	1	0.8	0.8
Eucampia groenlandica	Mar	Yes	No	2	26.6	51.2
Eucampia zoodiacus	Mar	Yes	No	31	107.9	1312.5
Eupodiscus radiatus	Mar	No	No	4	5.5	16.1
Fragilaria striatula	Mar	Yes	No	4	48.4	102.5
Fragilariopsis cylindrus	Mar	Yes	No	1	120.0	120.0
Fragilariopsis doliolus	Mar	No	No	1	6.9	6.9
Grammatophora angulosa	Mar	Yes	No	6	31.0	90.0
Guinardia delicatula	Mar	Yes	No	36	30.2	140.0
Guinardia flaccida	Mar	Yes	No	59	27.3	306.0
Guinardia striata	Mar	No	No	17	47.7	435.2
Gyrosigma acuminatum	Brack	Yes	No	18	4.7	13.8
Gyrosigma balticum	Brack	Yes	No	17	13.0	143.5
Gyrosigma fasciola	Mar	Yes	No	38	12.7	217.6
Gyrosigma prolongatum	Mar	No	No	4	11.5	25.6
Helicotheca tamesis	Mar	Yes	No	16	5.0	14.0
Hemiaulus hauckii	Mar	No	No	7	1.5	3.1
Hemiaulus membranaceus	Mar	No	No	15	4.3	9.2
Hemiaulus sinensis	Mar	No	No	6	8.1	13.0
Lauderia annulata	Mar	Yes	No	29	54.1	326.3
Leptocylindrus danicus	Mar	Yes	No	2	5.6	7.2
Leptocylindrus minimus	Mar	Yes	No	5	437.7	1680.0
Licmophora abbreviata	Mar	Yes	No	14	1.6	4.1
Lioloma delicatulum	Mar	No	No	1	3.8	3.8
Lioloma pacificum	Mar	No	No	8	6.4	18.9
Lithodesmium undulatum	Mar	No	No	17	4.8	32.0
Manguinea fusiformis?	Mar	No	No	4	2.2	4.5
Manguinea rigida?	Mar	No	No	2	9.3	16.8

Melosira arctica	Mar	Yes	No	2	27.8	41.5
Melosira moniliformis	Mar	Yes	No	4	13.3	19.0
Melosira nummuloides	Mar	Yes	No	35	12.2	150.0
Membraneis challengeri	Mar	No	No	4	11.8	17.4
Meridion circulare	Brack	Yes	No	1	20.1	20.1
Meuniera membranacea	Mar	No	No	4	5.6	7.1
Navicula directa	Mar	Yes	No	2	2.3	3.3
Navicula distans	Mar	Yes	No	1	13.5	13.5
Navicula kariana frigida	Mar	Yes	No	12	3.6	13.6
Navicula lyroides	Mar	Yes	No	1	0.8	0.8
Navicula septentrionalis	Mar	Yes	No	2	4.0	5.2
Nitzschia closterium	Brack	?	No	2	1.6	2.6
Nitzschia longissima	Mar	Yes	No	61	37.0	1098.0
Nitzschia macilenta?	Mar	?	No	2	4.4	5.4
Nitzschia oblonga?	Mar	?	No	1	1.8	1.8
Nitzschia rectilonga	Mar	Yes	No	23	19.2	325.5
Nitzschia sigma	Brack	?	No	20	3.6	7.0
Nitzschia sigmoidea	Brack	?	No	14	3.3	10.7
Odontella aurita	Mar	Yes	No	32	30.6	338.0
Odontella longicruris	Mar	No	No	13	3.6	7.5
Odontella mobiliensis	Mar	No	No	27	4.4	15.0
Odontella regia	Mar	Yes	No	7	5.1	11.4
Odontella sinensis	Mar	No	No	33	7.1	48.0
Paralia sulcata	Mar	Yes	No	60	68.5	675.5
Pinnularia ambigua	Mar	?	No	1	1.4	1.4
Pinnularia stauntonii	Mar	No	No	17	5.7	27.0
Plagiotropis lepidoptera	Mar	No	No	14	5.0	18.0
Planktoniella sol	Mar	No	No	3	2.9	7.0
Pleurosigma angulatum	Mar	Yes	No	64	7.6	40.0
Pleurosigma cuspidatum	Mar	?	No	2	3.9	7.0
Pleurosigma elongatum	Mar	No	No	13	5.6	21.0
Pleurosigma latum	Mar	?	No	4	3.9	7.0
Pleurosigma marinum	Mar	?	No	1	7.0	7.0
Pleurosigma normanii	Mar	No	No	41	8.3	45.0
Pleurosigma rigidum	Mar	Yes	No	6	4.3	13.0
Pleurosigma strigosum	Brack	Yes	No	5	2.0	4.0
Podosira stelliger	Mar	No	No	3	3.6	7.3
Porosira glacialis	Mar	Yes	No	3	17.3	28.5
Proboscia alata	Mar	Yes	No	92	13.5	624.0
Proboscia eumorpha	Mar	No	No	3	4.1	7.5
Pseudo-nitzschia australis?	Mar	No	Toxic	2	6.9	6.9
Pseudo-nitzschia delicatissima	Mar	Yes	Toxic	27	212.6	1770.3
Pseudo-nitzschia fraudulenta	Mar	Yes	Toxic	56	87.1	967.1
Pseudo-nitzschia lineola?	Mar	No	?	7	415.3	1837.5
Pseudo-nitzschia multiseries	Mar	Yes	Toxic	70	396.5	13636.0
Pseudo-nitzschia pseudodelicatissima	Mar	Yes	Toxic	3	36.5	95.5
Pseudo-nitzschia seriata	Mar	Yes	Toxic	1	3.0	3.0
Pseudo-nitzschia subpacific	Mar	No	?	24	53.4	386.8
Pseudoleyanella lunata	Mar	No	No	3	89.5	240.0
Pseudosolenia calcar avis	Mar	No	No	5	4.6	6.8
Raphoneis amphiceros	Mar	Yes	No	19	2.2	9.8

Rhabdonema arcuatum	Mar	Yes	No	3	2.7	3.5
Rhizosolenia hebetata hebetata	Mar	Yes	No	23	11.1	66.4
Rhizosolenia hebetata semispina	Mar	Yes	No	28	9.2	42.2
Rhizosolenia imbricata	Mar	Yes	No	64	21.2	249.0
Rhizosolenia pungens	Mar	Yes	No	78	33.4	954.5
Rhizosolenia setigera	Mar	Yes	No	79	89.4	1480.0
Rhizosolenia styliformis	Mar	No	No	9	14.1	97.9
Roperia tesselata	Mar	No	No	3	63.1	101.5
Skeletonema costatum	Mar	Yes	No	141	3246.6	195400.0
Stephanopyxis nipponica	Mar	No	No	6	28.9	99.0
Stephanopyxis palmeriana	Mar	No	No	3	1.8	3.3
Stephanopyxis turris	Mar	No	No	16	6.4	22.5
Striatella unipunctata	Mar	Yes	No	2	2.0	3.5
Surirella elegans	Brack	?	No	10	4.5	13.8
Surirella ovalis	Brack	?	No	28	11.1	65.6
Surirella striatula	Brack	?	No	4	9.8	28.0
Synedra ulna	Brack	Yes	No	6	7.7	18.0
Thalassionema bacillare	Mar	No	No	3	8.9	22.3
Thalassionema nitzschoides	Mar	Yes	No	90	204.9	4225.0
Thalassiosira angulata	Mar	Yes	No	4	32.1	86.5
Thalassiosira anguste-lineata	Mar	Yes	No	57	169.5	1704.5
Thalassiosira baltica	Mar	Yes	No	3	3.3	7.4
Thalassiosira bioculata	Mar	Yes	No	2	8.5	12.6
Thalassiosira eccentrica	Mar	?	No	63	115.7	1544.2
Thalassiosira gravida	Mar	Yes	No	4	309.2	754.8
Thalassiosira hyalina	Mar	Yes	No	6	155.9	471.0
Thalassiosira leptopus	Mar	?	No	21	10.7	47.0
Thalassiosira nordenskioeldii	Mar	Yes	No	16	365.2	2475.2
Thalassiosira oestrupii venrickae	Mar	No	No	14	174.8	630.5
Thalassiosira pacifica	Mar	Yes	No	22	46.4	201.8
Thalassiosira punctigera	Mar	No	No	9	38.8	105.0
Thalassiosira rotula	Mar	Yes	No	6	67.3	226.7
Thalassiosira tenera	Mar	Yes	No	3	4.3	8.4
Thalassiothrix longissima	Mar	Yes	No	11	2.8	4.4
Trachyneis aspera?	Mar	?	No	1	1.4	1.4
Triceratium favus	Mar	Yes	No	11	4.5	13.8
Triceratium spinosum	Mar	No	No	2	0.7	1.0
Tryblionella marginulata?	Mar	?	No	1	3.7	3.7
Tryblionella sp	Mar	?	No	1	0.7	0.7
Dictyochophyte						
Dictyocha fibula	Mar	Yes	?	59	6.9	45.0
Dictyocha octonaria	Mar	No	?	6	1.7	3.1
Dictyocha speculum	Mar	Yes	Harm	93	16.9	220.0
Dinoflagellate						
Alexandrium sp1	Mar	?	?	1	53.6	53.6
Alexandrium sp2	Mar	?	?	2	103.2	195.0
Amphidinium sp	Mar	?	No	1	6.9	6.9
Amphisolenia bidentata	Mar	No	No	1	0.7	0.7
Amylax triacantha	Mar	Yes	No	3	6.6	8.3
Ceratium arcticum	Mar	Yes	No	10	4.9	14.0
Ceratium arietinum	Mar	No	No	4	3.4	6.3

Ceratium azoricum	Mar	No	No	3	2.2	3.8
Ceratium candelabrum	Mar	No	No	1	0.4	0.4
Ceratium extensum	Mar	No	No	1	1.0	1.0
Ceratium furca	Mar	No	No	24	14.1	82.7
Ceratium fusus	Mar	Yes	No	119	33.1	431.7
Ceratium gibberum	Mar	No	No	1	0.4	0.4
Ceratium horridum	Mar	Yes	No	6	15.6	82.1
Ceratium inflatum	Mar	No	No	23	4.1	12.8
Ceratium lineatum	Mar	Yes	No	56	29.2	182.7
Ceratium longipes	Mar	Yes	No	38	4.7	22.5
Ceratium longirostrum	Mar	No	No	1	1.7	1.7
Ceratium macroceros	Mar	Yes	No	40	9.7	123.8
Ceratium massiliense	Mar	No	No	1	0.3	0.3
Ceratium minutum	Mar	No	No	33	22.6	214.5
Ceratium pentagonum	Mar	No	No	10	3.9	12.0
Ceratium platycorne	Mar	No	No	1	0.4	0.4
Ceratium setaceum	Mar	No	No	11	3.1	8.3
Ceratium teres	Mar	No	No	13	4.2	8.3
Ceratium tripos	Mar	Yes	No	65	8.3	140.3
Corythodinium tesselatum	Mar	No	No	3	4.6	10.0
Dinophysis acuminata	Mar	Yes	Toxic	23	26.5	156.8
Dinophysis acuta	Mar	No	Toxic	8	3.2	6.5
Dinophysis caudata	Brack	No	Toxic	10	2.8	8.0
Dinophysis dens	Mar	No	?	7	4.7	19.5
Dinophysis fortii	Mar	No	Toxic	4	9.8	32.5
Dinophysis mitra	Mar	No	Toxic	1	1.6	1.6
Dinophysis norvegica	Mar	Yes	Toxic	38	137.6	3291.8
Dinophysis pulchella	Mar	No	?	3	1.1	1.3
Dinophysis punctata	Mar	Yes	?	13	3.0	12.2
Dinophysis rotundata	Mar	Yes	Toxic	37	5.4	28.9
Dinophysis sp	Mar	No	?	12	36.0	189.8
Dinophysis tripos	Mar	Yes	Toxic	7	5.2	13.0
Diplosalis lenticulata	Mar	Yes	No	1	1.5	1.5
Ensiculifera carinata	Mar	Yes	No	1	7.5	7.5
Fragilidium sp	Mar	?	No	1	3.2	3.2
Goniodoma polyedricum	Mar	No	No	2	1.0	1.6
Gonyaulax birostris	Mar	No	?	1	0.4	0.4
Gonyaulax digitale	Mar	Yes	No	13	67.3	516.3
Gonyaulax polygramma	Mar	No	No	6	10.4	32.8
Gonyaulax scrippsae	Mar	No	No	1	1.7	1.7
Gonyaulax spinifera	Mar	Yes	No	1	1.5	1.5
Gonyaulax turbynaii	Mar	No	?	1	1.6	1.6
Gonyaulax verior	Mar	Yes	No	1	215.0	215.0
Gyrodinium fusiformis	Mar	Yes	No	1	6.8	6.8
Heterocapsa triquetra	Mar	Yes	No	2	14.5	27.2
Microcanthodinium claytonii	Mar	Yes	No	4	3.7	7.0
Oblea rotunda	Mar	?	No	3	9.9	21.0
Ornithocercus heteroporus	Mar	No	No	2	0.8	1.1
Oxytoxum milneri	Mar	No	No	1	1.2	1.2
Oxytoxum scolopax	Mar	No	No	12	2.3	6.4
Podolampas palmipes	Mar	No	No	9	3.4	6.5

Prorocentrum compressum	Mar	Yes	?	45	6.0	41.3
Prorocentrum gracile	Mar	Yes	No	100	683.9	13335.0
Prorocentrum micans	Mar	Yes	No	13	570.5	6103.5
Prorocentrum minimum	Mar	Yes	Toxic	2	1.2	1.4
Prorocentrum scutellum	Mar	No	?	1	7.0	7.0
Protoceratium reticulatum	Mar	Yes	Toxic	1	0.8	0.8
Protoperidinium achromaticum	Mar	Yes	No	12	64.8	666.4
Protoperidinium bipes	Mar	Yes	No	2	2.7	3.8
Protoperidinium brevipes	Mar	Yes	No	19	7.0	24.0
Protoperidinium cerasus	Mar	Yes	No	48	11.9	81.6
Protoperidinium conicoides	Mar	Yes	No	5	7.7	14.0
Protoperidinium conicum	Mar	Yes	No	7	4.2	6.8
Protoperidinium crassipes	Mar	?	Toxic	5	4.1	7.3
Protoperidinium curtipes	Mar	?	?	12	9.2	49.5
Protoperidinium depressum	Mar	Yes	No	16	2.3	6.3
Protoperidinium diabolum	Mar	No	No	3	4.8	9.5
Protoperidinium divergens	Mar	Yes	No	11	3.6	11.3
Protoperidinium granii	Mar	Yes	No	4	9.2	32.0
Protoperidinium islandicum	Mar	?	No	3	7.7	14.1
Protoperidinium laticeps	Mar	Yes	No	16	9.2	40.8
Protoperidinium leonis	Mar	Yes	No	11	8.2	28.4
Protoperidinium minutum	Mar	Yes	No	1	13.5	13.5
Protoperidinium mite	Mar	Yes	No	3	9.2	18.9
Protoperidinium oblongum	Mar	Yes	No	7	3.3	6.2
Protoperidinium obtusum	Mar	?	No	1	19.2	19.2
Protoperidinium oceanicum	Mar	?	No	1	2.9	2.9
Protoperidinium ovatum	Mar	Yes	No	4	7.0	18.0
Protoperidinium pallidum	Mar	Yes	No	10	5.6	18.9
Protoperidinium pellucidum	Mar	Yes	No	17	7.6	24.8
Protoperidinium pentagonum	Mar	Yes	No	9	2.4	3.9
Protoperidinium pyriforme	Mar	Yes	No	3	21.9	52.5
Protoperidinium saltans	Mar	?	No	1	0.7	0.7
Protoperidinium steineii	Mar	Yes	No	43	9.2	57.6
Protoperidinium subcurvipes	Mar	?	No	2	7.5	13.2
Protoperidinium subinerme	Mar	Yes	No	6	11.8	23.8
Pyrocystis lunula	Mar	Yes	No	3	2.0	2.5
Roscoffia capitata	Mar	No	No	2	0.8	0.9
Scrippsiella trochoidea	Mar	Yes	No	19	24.7	222.8
Euglenophyte						
Phacus obicularis	Brack	?	No	2	2.5	3.5
Prasinophyte						
Halosphaera viridis	Mar	Yes	No	2	2.5	3.4
Pterosperma marginatum	Mar	Yes	No	1	4.2	4.2
Pterosperma moebii	Mar	Yes	No	18	4.6	32.5
Pterosperma nationalis	Mar	Yes	No	19	5.4	13.4
Pterosperma polygonum	Mar	Yes	No	2	3.9	7.0
Pterosperma sp	Mar	?	No	1	0.8	0.8
Prymnesiophyte						
Coccolithus pelagicus	Mar	?	No	1	1.7	1.7
Unknown						
Unidentified cyst 103	?	?	?	2	4.8	6.0

Unidentified cyst 159	?	?	?	2	4.4	7.0
Unidentified cyst 181	?	?	?	1	6.4	6.4
Unidentified cyst 19	Brack	?	?	9	15.7	77.3
Unidentified cyst 26	?	?	?	5	1.7	3.8
Unidentified cyst 38	?	?	?	3	3.3	4.7
Unidentified cyst 94	?	?	?	1	1.4	1.4
Unidentified cyst 98	?	?	?	2	1.6	1.7
Unidentified cyst 99	?	?	?	1	1.7	1.7

Appendix 6: List of microzooplankton taxa observed, their frequency of occurrence, mean and maximum concentration (individuals/liter), salinity preference, risk status, and geographic affiliation (Indigenous). Mar = Marine, Brack = Brackish-water.

Class Species	Salinity Preference	Indigenous	Harmful	Freq	Mean Conc	Max Conc
Echinoderm						
Unidentified echinopluteus	Mar	?	?	1	0.3	0.3
Foraminiferan						
Ammonia sp	Brack	?	No	11	2.1	7.0
Nematode						
Unidentified nematode	Mar	?	No	39	8.4	156.0
Ostracod						
Unidentified ostracod	Brack	?	No	15	63.0	566.1
Protozoan						
Polyasterias problematica	Mar	Yes	No	3	1.2	1.9
Vanella simplex	Mar	Yes	No	1	1.3	1.3
Radiolarian						
Gazelletta hexanema	Mar	?	No	1	1.4	1.4
Rotifer						
Keratella cochlearis	Brack	?	No	31	25.9	390.0
Keratella sp	Brack	?	No	4	0.7	0.9
Keratella valga	Brack	?	No	1	18.0	18.0
Nothulca striata	Brack	?	No	2	0.7	0.9
Polyartha trigla	Brack	?	No	2	2.3	3.8
Tintinnid						
Acanthostomella norvegica	Mar	Yes	No	10	6.1	21.0
Amphorella quadrilineata	Mar	?	No	21	3.3	14.0
Amphorellopsis acuta	Mar	?	No	21	4.9	32.5
Codonellopsis nipponica	Mar	?	No	9	9.5	26.0
Dadayiella ganymedes	Mar	?	No	16	2.3	11.9
Dictyocysta lepida	Mar	?	No	1	1.4	1.4
Dictyocysta polygonata	Mar	?	No	5	23.2	104.0
Dictyocysta verticosa	Mar	?	No	5	1.4	2.1
Epiplocyclis lata	Mar	?	No	2	3.6	3.8
Epiplocyclis undella	Mar	?	No	1	1.1	1.1
Favella campanula	Mar	Yes	No	6	2.4	4.7
Helicostemella kilensis	Mar	Yes	No	26	4.0	16.5
Leprotintinnus nordquisti	Mar	?	No	1	2.5	2.5
Parafavella elegans	Mar	Yes	No	21	4.2	10.8
Parafavella gigantea	Mar	Yes	No	6	1.4	2.9
Parafavella jorgensii	Mar	?	No	5	2.2	3.3

Parafavella obtusangula	Mar	Yes	No	11	1.9	4.5
Parafavella ventricosa	Mar	?	No	2	0.7	0.7
Parundella pellucida	Mar	?	No	3	2.0	3.2
Protorhabdonella curta	Mar	?	No	25	2.4	8.0
Protorhabdonella simplex	Mar	?	No	1	0.6	0.6
Ptychocylis acuta	Mar	Yes	No	1	1.6	1.6
Ptychocylis obtusa	Mar	Yes	No	3	2.2	4.0
Rhabdonella conica	Mar	?	No	3	1.4	1.4
Rhabdonella elegans	Mar	?	No	8	1.4	2.2
Rhabdonella poculum	Mar	?	No	4	1.5	2.8
Rhabdonella spiralis	Mar	?	No	9	1.4	3.2
Rhabdonellopsis apophysata	Mar	?	No	5	1.0	1.2
Salpingella acuminata	Mar	Yes	No	16	4.5	19.5
Salpingella laminata	Mar	Yes	No	6	4.1	7.0
Salpingella minutissima	Mar	?	No	1	9.8	9.8
Salpingella ricta	Mar	?	No	1	7.0	7.0
Stenosemella nivalis	Mar	?	No	2	14.9	23.2
Stenosemella ventricosa	Mar	?	No	2	3.8	6.4
Strombidium striata	Mar	Yes	No	1	3.5	3.5
Tintinnopsis aperta	Mar	?	No	1	1.2	1.2
Tintinnopsis baltica	Mar	Yes	No	13	21.9	90.0
Tintinnopsis beroidea	Mar	Yes	No	13	10.5	81.7
Tintinnopsis brasiliensis	Mar	?	No	3	7.8	19.5
Tintinnopsis brevicollis	Mar	?	No	27	12.9	108.0
Tintinnopsis campanula	Mar	Yes	No	2	3.2	4.2
Tintinnopsis karajacensis	Mar	?	No	1	0.8	0.8
Tintinnopsis kofoidi	Mar	?	No	9	12.2	49.6
Tintinnopsis lohmanii	Mar	?	No	6	2.6	4.2
Tintinnopsis pseudocylindri	Mar	?	No	1	1.3	1.3
Tintinnopsis rapa	Mar	Yes	No	21	112.8	756.0
Tintinnopsis sufflata	Mar	?	No	12	30.5	174.0
Tintinnopsis tubulosoides	Mar	Yes	No	4	36.5	112.8
Tintinnus apertus	Mar	?	No	1	4.2	4.2
Tintinnus fraknoii	Mar	?	No	1	0.8	0.8
Tintinnus lusus-undae	Mar	?	No	49	3.7	29.0
Tintinnus pacifica	Mar	?	No	2	4.8	8.3
Tintinnus rectus	Mar	?	No	2	2.4	2.5
Undella biorbiculata	Mar	?	No	2	2.3	3.3
Undella claparedei	Mar	?	No	4	3.5	5.6
Undella columbiana	Mar	?	No	3	4.0	5.4
Undella ellipsoidea	Mar	?	No	9	2.9	7.2
Undella perpusilla	Mar	?	No	3	2.1	3.8
Xystonella treforti	Mar	?	No	2	1.1	1.4
Unknown						
Unidentified ascidian?	?	?	?	1	1.8	1.8
Unidentified casing?	?	?	?	20	4.6	62.1
Unidentified red?	?	?	?	2	1.2	1.4
Unidentified star?	?	?	?	2	2.5	3.7

Appendix 7: List of zooplankton taxa observed, their frequency of occurrence, mean and maximum density (individuals/liter) and their geographic affiliation.

Phylum / Class / Subclass / Order	Taxa	Freq	Mean Conc ind/l	Max Concl ind/l	Geographic Region	Salinity Preference
Arthropoda						
Crustacea						
	Invertebrate nauplii	1	0.14	0.14		
Branchiopoda						
Cladocera						
	Bosmina longirostris	2	14.42	28.71	Americas, Europe, Asia	Fresh
	Bosminidae	1	0.28	0.28	Americas, Europe, Asia	Fresh
	Chydorinae	1	4.00	4.00	Cosmopolitan	Fresh
	Cladocera	1	0.42	0.42		Ocean
	Evadne sp	3	0.20	0.42	Cosmopolitan	Ocean
	Podon sp	2	0.27	0.43	northern, temperate	Ocean
	unid. freshwater	1	4.00	4.00		Fresh
Cirripedia						
Thoracica						
	Barnacle cyprid	1	0.10	0.10		Ocean
	Barnacle nauplii	19	1.43	3.44		Ocean
Copepoda						
Calanoida						
	copepod nauplii	55	12.49	505.00		Ocean
	Acartia clausi	26	2.42	32.33	temperate Atlantic,Pacific	Coastal
	Acartia danae	1	0.04	0.04	Atlantic, Pacific Oceans	Coastal
	Acartia longiremis	4	0.86	2.66	temperate Atlantic	Coastal
	Acartia tonsa	1	8.14	8.14	temperate Atlantic,Pacific	Coastal
	Acartia sp	2	0.04	0.06		Coastal
	Calanus finmarchicus	7	0.10	0.63	Cosmopolitan	Ocean
	Calocalanus pavo	1	0.04	0.04	Cosmopolitan	Ocean
	Candacia curta	1	0.02	0.02	temperate Atlantic	Ocean
	Centropages hamatus	4	0.25	0.66	temperate Atlantic,Pacific	Ocean
	Centropages kroyeri	1	0.26	0.26	temperate Atlantic Indian Ocean,Mediterrean	Ocean
	Centropages sp	13	0.26	1.18		Ocean
	Centropages typicus	8	2.85	32.00	temperate Atlantic, Mediterrean, North Sea	Ocean
	Clausocalanus furcatus	5	0.83	4.00	Cosmopolitan	Ocean
	Clausocalanus sp	4	0.21	0.96	Cosmopolitan	Ocean
	Corycella rostrata	1	0.02	0.02	Cosmopolitan	Ocean
	Eurytemora herdmani	6	1.28	5.31	temperate Atlantic	Coastal
	Eurytemora hirundoid	2	0.28	0.42	temperate Atlantic, Pacific	Coastal
	Eurytemora lacustris	1	3.53	3.53	temperate Atlantic	Coastal
	Eurytemora sp	2	6.12	8.67	temperate waters	Coastal
	Metridia longa	1	0.02	0.02	North Atlantic, Indian Oceans	Ocean
	Metridia lucens	3	0.02	0.02	Cosmopolitan	Ocean
	Microcalanus sp	5	1.21	5.67	northern waters	Ocean
	Nannocalanus minor	1	0.02	0.02	N Atlantic, Pacific,	Ocean

					Indian Oceans, Mediterrean	
	Paracalanus sp	14	1.08	17.00	Cosmopolitan	Ocean
	Pleuromamma gracilis	1	0.04	0.04	Atlantic, Pacific Indian Oceans, Mediterrean	Ocean
	Pseudocalanus sp	20	0.50	4.10	temperate Atlantic,Pacific	Ocean
	Pseudodiaptomus coronatus	3	0.65	1.00		
	Tortanus discaudatus	2	2.09	4.08	temperate Atlantic	Coastal
	Tortanus sp	1	0.08	0.08	temperate Atlantic	Coastal
	Unidentified calanoid juveniles	40	2.42	88.00		
Cyclopoida	*Cyclopidae*	1	3.00	3.00		Fresh
	Cyclopina sp	2	0.43	0.74	NE Atlantic	Ocean
	Halicyclops magniceps	1	5.86	5.86	Cosmopolitan	Brackish
	Mecynocera clausi	3	0.07	0.10	Atlantic, Pacific, Indian, Mediterrean	Ocean
	Oithona atlantica	1	0.04	0.04	Cosmopolitan	Ocean
	Oithona similis	42	3.66	53.00	Cosmopolitan	Ocean
	Oithona sp	8	1.24	18.00	Cosmopolitan	Ocean
	Oncaea borealis	1	0.04	0.04	Cosmopolitan	Ocean
	Oncaea conifera	1	0.06	0.06	Cosmopolitan	Ocean
	Oncaea sp	15	0.80	7.33	Cosmopolitan	Ocean
	Temora longicornis	21	0.50	2.29	temperate Atlantic, North Sea, Mediterrean, Indian	Ocean
	Unidentified cyclopoids	2	0.18	0.28	?	Ocean
Harpacticoda	*Aegisthus aculeatus*	1	1.00	1.00	Atlantic, Pacific	Ocean
	Aegisthus sp	1	6.16	6.16	?	Ocean
	Clytemnestra rostrata	1	1.10	1.10	Cosmopolitan	Ocean
	Clytemnestra scutellata	10	9.28	102.00	Cosmopolitan	Ocean
	Clytemnestra sp	9	2.41	10.67	Cosmopolitan	Ocean
	Euterpina acutifrons	11	2.62	78.67	Cosmopolitan	Ocean
	Euterpina sp	1	0.04	0.04	Cosmopolitan	Ocean
	Halithalestris croni	2	0.28	0.50	northern waters	Ocean
	Microsetella norvegi	29	1.46	4.00	Cosmopolitan	Ocean
	Microsetella rosea	1	0.12	0.12	Cosmopolitan	Ocean
	Microsetella sp	4	0.28	0.71	Cosmopolitan	Ocean
	Unidentified harpacticoids	20	0.30	2.57	?	
Malacostraca						
Amphipoda	Amphipod-unid juveniles	1	0.20	0.20	?	Ocean
Cumacea	*Cyclaspis varians* (cumacea)	1	0.17	0.17	Atlantic	Coastal
Decapoda	Decapod zoea	2	0.03	3.00	?	Ocean
Isopoda	Isopoda	1	0.02	0.02	?	Coastal
Mysidacea	Mysid larvae	2	0.29	0.42	?	Ocean
Ostracoda						
Myodocopa	*Conchoecia sp*	1	0.02	0.02	North Atlantic	Ocean
Bryozoa						
Gymnolaemata						
Ctenostomata	Cyphonaute larvae	6	0.26	0.42		Ocean
Ctenophora	Ctenophore juvenile	1	0.02	0.02		Ocean
Echinodermata	Echinoderm juvenile	1	0.02	0.02		Coast/Ocean
	Echinoderm larvae	2	0.13	0.20		Coast/Ocean
Mollusca						
Bivalvia	Bivalve larvae	6	0.17	1.20		Coast/Ocean
Gastropoda						

Opisthobranchia						
Thecosomata	*Limacina helicina*	3	0.56	1.00	Temperate Atlantic	Ocean
	Limacina sp	2	0.86	1.63	Temperate Atlantic	Ocean
Annelida						
	Polychaeta larvae	13	0.44	2.50	cosmopolitan	Ocean

Appendix 8: Ballast water samples: source, FAO region of origin, diversity and abundance of phytoplankton (cells/liter) and zooplankton (individuals/liter). The age of each sample, as well as the temperature and salinity are indicated.

Sam Code	Ship Name	No	Region	FAO region	Age	Temp°C	Sal °/oo	PhyTaxa	Phy Conc	Zoo Taxa	Zoo Conc
NB-01-A	Stig Gorthon	20	W Central Atlantic	G	4	14.0	35.3	31	76.7	15	3.6
NB-01-B	Stig Gorthon	21	W Central Atlantic	G	4	15.0	35.2	28	56.8		
NB-02-A	Okoltchitza	23	NW Atlantic	A	6	14.0	36.4	6	4.7		
NB-02-C	Okoltchitza	25	E Central Atlantic	F	10	17.0	36.6	6	3.3		
NB-03-A	TK Istanbul	32	NW Atlantic	A	3	15.0	28.6	27	1422.9	10	9.3
NB-03-B	TK Istanbul	33	NW Atlantic	A	3	15.0	28.9	12	115.8		
NB-03-C	TK Istanbul	34	NW Atlantic	A	3	14.0	29.6	9	13.3		
NB-04-A	Marinor	35	NW Atlantic	A	4	14.0	35.4	42	329.2		
NB-04-B	Marinor	36	NW Atlantic	A	16	14.0	35.0	6	5.5		
NB-04-C	Marinor	37	W Central Atlantic	G	18	13.5	36.2	6	7.8		.
NB-05-A	Marneborg	64	Philadelphia	A	4	14.0	0.1	11	2046.5	5	35.7
NB-05-B	Marneborg	65	Philadelphia	A	5	13.0	13.3	29	3243.5		
NB-05-C	Marneborg	66	Philadelphia	A	4	12.0	0.2	15	2666.6		
NB-06-A	Ada Gorthon	67	NW Atlantic	A	4	18.5	0.5	15	6043.7	4	0.6
NB-06-B	Ada Gorthon	68	NW Atlantic	A	4	18.5	0.4	19	5990.6		
NB-06-C	Ada Gorthon	69	NW Atlantic	A	4	18.5	0.4	24	5648.5		
NB-07-A	Alida Gorthon	74	NW Atlantic	A	4	10.0	35.1	26	108.9		
NB-07-B	Alida Gorthon	75	NW Atlantic	A	4	10.0	30.8	29	129.6		
NB-08-A	Valga	77	NW Atlantic	A	4	10.0	34.2	13	46.5		
NB-08-B	Valga	78	NW Atlantic	A	3	11.0	19.6	6	258.4		
NB-08-C	Valga	79	Camden NJ	A	5	10.5	1.0	3	12.3		
NB-09-A	Viljandi	112	St Petersburg Russia	B	27	9.5	28.9	34	4948.3	7	2.7
NB-10-A	Ada Gorthon	140	NE Atlantic	B	5	10.0	35.0	23	166.0		
NB-10-B	Ada Gorthon	141	NE Atlantic	B	5	10.5	35.8	12	41.8		
NB-10-C	Ada Gorthon	142	NE Atlantic	B	5	8.0	34.7	35	93.9	6	1.5
NB-11-B	Bow Flower	154	NE Atlantic	B	14	9.0	30.5	31	17098.2		
NB-11-C	Bow Flower	155	NW Atlantic	A	2	9.0	30.8	36	12537.0	10	26.5
NB-12-A	Kapitonas Stulpina	156	NW Atlantic	A	5	5.0	35.7	9	216.2		
NB-12-B	Kapitonas Stulpina	157	NW Atlantic	A	25	5.0	35.5	2	1.4		
NB-13-A	Stig Gorthon	189	NW Atlantic	A	6	3.5	36.3	15	56.0		
NB-13-A	Stig Gorthon	190	NW Atlantic	A	6	4.0	35.6	29	133.8		
NB-14-A	Salvador	192	New Orleans	G	56	4.0	0.2	10	21.8		.

NB-14-B	Salvador	193	New Orleans	G	56	4.0	0.3	6	19.3		.
NB-15-A	Tofton	203	NW Atlantic	A	3	4.0	34.5	46	182.7		.
NB-15-B	Tofton	204	NW Atlantic	A	3	4.0	35.5	39	96.6	10	11.3
NF-01-A	Margara	82	Riverhead NY	A	4	17.0	28.6	35	958.2	9	39.5
NF-01-B	Margara	83	Riverhead NY	A	4	15.0	28.6	25	3557.3	.	.
NF-02-A	Bering Sea	85	NW Atlantic	A	2	16.0	15.3	22	209.6	.	.
NF-02-C	Bering Sea	87	NW Atlantic	A	2	16.0	9.9	25	101.3	.	.
NF-03-A	Lagarfoss	88	Rekjavik Iceland	B	6	14.0	33.1	38	4304.3	.	.
NF-03-B	Lagarfoss	89	Rekjavik Iceland	B	6	15.0	32.1	42	3976.6	17	7.8
NF-03-C	Lagarfoss	90	Rekjavik Iceland	B	6	15.0	31.8	36	4849.7	.	.
NF-04-A	MT Aquidneck	91	Providence RI	A	5	17.0	30.0	36	4265.6	.	.
NF-04-C	MT Aquidneck	93	New Haven CT	A	7	16.0	27.8	30	218372.0	8	5.4
NF-05-A	Isola Gialla	94	NW Atlantic	A	3	15.0	35.4	18	487.9	.	.
NF-05-B	Isola Gialla	95	NW Atlantic	A	3	15.0	35.5	28	892.6	.	.
NF-05-C	Isola Gialla	96	NW Atlantic	A	3	14.0	35.8	32	558.3	.	.
NF-06-A	Skogafoss	97	Rekjavik Iceland	B	6	21.0	32.6	27	368.5	.	.
NF-06-B	Skogafoss	98	Rekjavik Iceland	B	6	18.0	31.2	40	1130.5	9	2.7
NF-06-C	Skogafoss	99	Rekjavik Iceland	B	6	20.0	31.7	37	679.9	.	.
NF-07-A	MT Iliad	100	New York NY	A	5	17.0	29.3	40	456.1	.	.
NF-07-B	MT Iliad	101	New York NY	A	5	16.5	26.6	22	355.3	.	.
NF-07-C	MT Iliad	102	New York NY	A	5	17.0	23.7			5	87
NF-08-A	Green Austevoll	103	NW Atlantic	A	13	21.0	32.1	43	41.0	.	.
NF-08-B	Green Austevoll	104	NW Atlantic	A	9	16.0	28.8	27	7294.5	.	.
NF-08-C	Green Austevoll	105	NW Atlantic	A	11	14.0	32.7	38	1499.4	.	.
NF-09-A	MV Radeplein	164	NW Atlantic	A	39	12.0	33.8	2	9.4	.	.
NF-09-B	MV Radeplein	165	NW Atlantic	A	39	12.0	33.4	11	725.9	.	.
NF-10-A	Vancouver Spirit	167	Portland ME	A	7	11.0	31.7	40	9595.7	16	5.3
NF-10-C	Vancouver Spirit	169	Portland ME	A	7	10.0	31.8	24	13434.9	.	.
NF-11-A	Lagarfoss	170	Rekjavik, Iceland	B	5	11.0	34.3	24	518.3	.	.
NF-11-B	Lagarfoss	171	Rekjavik, Iceland	B	5	11.0	34.2	24	365.8	13	9.6
NF-11-C	Lagarfoss	172	Rekjavik, Iceland	B	5	10.0	34.3	21	195.7	.	.
NF-12-A	Emma	173	NW Atlantic	A	5	10.0	34.5	19	271.7	6	0.9
NF-12-C	Emma	175	NW Atlantic	A	7	10.0	35.0	26	87.5	.	.
NF-13-A	Ostankino	176	NW Atlantic	A	2	13.0	30.0	39	432.3	.	.
NF-13-C	Ostankino	178	NW Atlantic	A	1	13.0	30.6	43	336.6	8	32.4
NF-14-B	Vancouver Spirit	180	Portland ME	A	3	10.0	31.5	27	14424.9	.	.
NF-14-C	Vancouver Spirit	181	Portland ME	A	3	10.0	31.9	26	7141.1	.	.

NF-15-A	Nordscot	182	NW Atlantic	A	1	10.0	32.5	32	1824.6	.	.
NF-15-B	Nordscot	183	NW Atlantic	A	1	10.0	32.2	56	5534.1	.	.
NF-16-A	MV Radeplein	185	NW Atlantic	A	15	7.0	34.7	13	58.3	.	.
NF-16-B	MV Radeplein	186	NW Atlantic	A	15	7.0	34.8	7	162.3	.	.
NF-17-A	Hamane Spirit	206	NW Atlantic	A	1	8.0	31.8	33	6706.5	.	.
NF-17-B	Hamane Spirit	207	NW Atlantic	A	1	8.0	31.7	35	11998.5	14	34.6
NF-17-C	Hamane Spirit	208	NW Atlantic	A	1	8.0	31.1	43	7170.2	.	.
NF-18-A	Nordscot	209	NW Atlantic	A	1	9.0	31.6	53	19690.0	.	.
NF-18-B	Nordscot	210	NW Atlantic	A	1	8.0	31.3	43	14523.8	.	.
NF-18-C	Nordscot	211	NW Atlantic	A	1	9.0	32.3	46	8084.1	.	.
NF-19-A	Ras Sedr	212	Kingston Jamaica	G	10	7.0	32.9	8	70.0	.	.
NF-19-B	Ras Sedr	213	Kingston Jamaica	G	10	7.5	28.2	20	211.3	.	.
NF-19-C	Ras Sedr	214	Kingston Jamaica	G	10	7.0	33.2	11	50.2	.	.
NF-20-A	Joh Gorthon	215	NW Atlantic	A	3	7.0	32.0	27	932.5	.	.
NF-20-B	Joh Gorthon	216	NW Atlantic	A	3	9.0	32.5	56	809.6	.	.
NF-20-C	Joh Gorthon	217	NW Atlantic	A	3	10.0	32.6	40	779.2	3	2.2
NF-21-A	Turmoil	218	NW Atlantic	A	1	9.0	33.7	42	600.2	13	14.8
NF-21-B	Turmoil	219	NW Atlantic	A	1	8.5	32.6	46	692.2	.	.
NF-22-A	Singapore Spirit	221	NW Atlantic	A	2	11.0	36.1	64	601.7	.	.
NF-22-B	Singapore Spirit	222	NW Atlantic	A	3	11.0	36.3	63	1672.1	6	2.5
NF-22-C	Singapore Spirit	223	NW Atlantic	A	2	10.0	35.8	66	900.5	.	.
NF-23-A	Ingrid Gorthon	224	NW Atlantic	A	1	2.0	21.5	13	48.5	.	.
NF-23-C	Ingrid Gorthon	226	NW Atlantic	A	1	8.0	13.4	9	107.1	4	2.6
NF-24-A	Nordeuropa	227	NW Atlantic	A	1	7.5	31.4	23	40294.4	.	.
NF-24-C	Nordeuropa	229	NW Atlantic	A	1	7.0	32.3	26	1165.6	.	.
NF-25-A	Bavaria	235	NW Atlantic	A	4	4.0	36.7	35	114.8	7	0.6
NF-25-C	Bavaria	237	NW Atlantic	A	4	4.0	36.5	23	54.0	.	.
NF-26-A	Nordeuropa	238	NW Atlantic	A	1	5.5	31.5	56	1727.2	9	6.9
NF-26B	Nordeuropa	239	NW Atlantic	A	1	5.5	31.5	48	1488.8	.	.
NF-27-A	Front Sunda	241	NW Atlantic	A	2	9.0	33.1	45	1020.0	.	.
NF-27-B	Front Sunda	242	NW Atlantic	A	2	9.0	33.1	41	485.1	.	.
NF-28-A	MT Burgas	243	NW Atlantic	A	3	6.0	32.6	30	2296.5	.	.
NF-28-B	MT Burgas	244	NW Atlantic	A	3	6.5	32.5	11	367.2	.	.
NF-28-C	MT Burgas	245	NW Atlantic	A	3	6.0	33.1	25	95.8	.	.
NF-29-A	Orkney Spirit	246	Portland ME	A	3	5.5	32.0	42	5458.5	.	.
NF-29-B	Orkney Spirit	247	Portland ME	A	3	5.0	32.0	43	6343.0	13	26
NF-30-A	Front Sun	248	NW Atlantic	A	4	6.0	31.3	30	329.3	.	.

NF-30-B	Front Sun	249	NW Atlantic	A	4	5.0	29.4	46	697.6	9	5.5
NF-30-C	Front Sun	250	NW Atlantic	A	4	5.0	29.9	36	326.3	.	.
NF-31-A	Nordscot	251	NW Atlantic	A	1	2.0	31.3	37	2072.3	.	.
NF-31-C	Nordscot	253	NW Atlantic	A	1	2.0	31.5	37	525.8	.	.
NF-32-A	Ratna Abba	254	New York NY	A	7	3.0	25.8	31	1799.0	7	1.3
NF-32-B	Ratna Abba	255	New York NY	A	7	3.0	26.4	23	1040.4	.	.
NS-01-A	Maersk Wind	1	Baltimore MD	A	23	18.0	26.7	16	23.7	.	.
NS-01-B	Maersk Wind	2	NE Atlantic	B	65	19.0	35.9	13	25.1	.	.
NS-02-A	Charlotte C	3	NW Atlantic	A	5	18.5	34.0	24	37.4	9	3.7
NS-02-B	Charlotte C	4	NW Atlantic	A	5	18.0	35.9	9	5.0	.	.
NS-02-C	Charlotte C	5	NW Atlantic	A	5	18.5	34.0	18	21.8	.	.
NS-03-A	Zim Italia	6	NW Atlantic	A	3	19.5	35.5	5	6.7	.	.
NS-03-B	Zim Italia	7	NE Atlantic	B	4	19.0	35.8	5	20.6	.	.
NS-04-A	Stuttgart Express	8	NE Pacific	E	44	19.0	32.8	27	122.9	.	.
NS-04-B	Stuttgart Express	9	Thamesport UK	B	10	17.0	31.6	13	45.1	12	20.1
NS-04-C	Stuttgart Express	10	Le Havre FR	B	5	18.0	24.7	22	92.4	10	18.1
NS-05-A	Lovisa Gorthon	11	W Central Atlantic	G	3	18.5	36.7	13	26.0	6	1.7
NS-05-B	Lovisa Gorthon	12	W Central Atlantic	G	3	18.5	35.4	17	210.7	.	.
NS-05-C	Lovisa Gorthon	13	W Central Atlantic	G	4	21.0	36.8	13	74.8	.	.
NS-06-A	Wilana	14	Philadelphia PA	A	3	19.0	2.1	15	113.4	7	147.3
NS-06-B	Wilana	15	Philadelphia PA	A	3	19.0	1.8	14	135.1	.	.
NS-06-C	Wilana	16	NW Atlantic	A	1	18.0	31.2	37	161.6	13	732
NS-07-A	MH Baker	17	Camden NJ	A	4	17.0	3.3	13	518.9	.	.
NS-07-B	MH Baker	18	Camden NJ	A	4	18.0	29.8	20	742.7	.	.
NS-07-C	MH Baker	19	Camden NJ	A	4	18.0	0.5	14	998.1	4	218
NS-08-B	New York Express	27	NW Atlantic	A	2	17.0	34.1	38	410.0	.	.
NS-08-C	New York Express	28	NW Pacific	D	79	16.5	32.7	36	1548.0	.	.
NS-08 A	New York Express	26	NW Atlantic	A	2	18.0	32.4	29	1119.3	.	.
NS-09-A	Gypsum Baron	29	Baltimore MD	A	3	16.0	12.5	20	986.3	.	.
NS-09-B	Gypsum Baron	30	Baltimore MD	A	3	17.0	12.4	24	7146.3	.	.
NS-10-A	Cosco Norfolk	38	NW Atlantic	A	12	17.5	24.6	36	3830.1	.	.
NS-10-B	Cosco Norfolk	39	Felixstowe UK	B	20	16.0	25.7	39	17322.9	16	80.4
NS-10-C	Cosco Norfolk	40	NW Atlantic	A	12	17.0	33.8	31	236.8	.	.
NS-11-A	Georgia S	41	NW Atlantic	A	2	17.0	2.4	6	1000.8	.	.
NS-11-C	Georgia S	43	NW Atlantic	A	2	16.5	2.4	8	2323.8	.	.
NS-12-A	Shanghai Express	44	NW Pacific	D	42	16.0	33.4	31	100.7	5	0.5
NS-12-B	Shanghai Express	45	NW Pacific	D	43	15.5	32.4	19	72.7	.	.

NS-12-C	Shanghai Express	46	NW Pacific	D	44	15.0	34.1	24	121.8	.	.
NS-13-B	Zim Korea	48	NW Atlantic	A	2	15.0	33.4	11	18.1	11	6.5
NS-13-C	Zim Korea	49	NE Atlantic	B	5	13.0	36.6	7	27.1	4	1.3
NS-14-B	BBC Chile	51	W Central Atlantic	G	4	14.0	32.8	4	44.8	.	.
NS-14-C	BBC Chile	52	NW Atlantic	A	3	15.0	32.3	11	191.0	.	.
NS-15-A	Mariel	53	NW Atlantic	A	29	17.0	34.5	3	9.5	.	.
NS-16-A	Gypsum King	54	NW Atlantic	A	1	15.0	32.2	26	94.4	.	.
NS-16-B	Gypsum King	55	NW Atlantic	A	2	14.5	32.2	30	19898.8	.	.
NS-17-A	Blue Sky	56	NW Atlantic	A	5	14.0	35.6	5	15.1	.	.
NS-17-C	Blue Sky	58	NW Atlantic	A	5	16.0	34.3	7	3.6	.	.
NS-18-A	Maren Maersk	59	NE Atlantic	B	4	13.0	34.5	29	76678.2	.	.
NS-18-B	Maren Maersk	60	NE Atlantic	B	3	14.0	26.5	35	17299.7	10	115.3
NS-18-C	Maren Maersk	61	NE Atlantic	B	4	15.0	34.5	39	19155.8	14	12.3
NS-19-A	Gerd Maersk	62	NW Atlantic	A	2	15.0	36.4	17	57.4	.	.
NS-19-B	Gerd Maersk	63	NW Pacific	D	6	15.0	34.2	3	5.6	.	.
NS-20-A	Grasmere Maersk	70	Arabian Sea	H	18	17.0	35.9	5	3.7	3	13.8
NS-20-B	Grasmere Maersk	71	NW Pacific	D	55	18.0	34.4	2	1.2	3	1.6
NS-20-C	Grasmere Maersk	72	NE Atlantic	B	4	19.0	36.4	7	6.2	.	.
NS-21-A	Atlantic Companion	73	Liverpool UK	B	7	17.0	16.8	3	5.3	.	.
NS-22-A	Gitta Oldendorff	80	NW Atlantic	A	4	16.5	36.1	18	40.3	.	.
NS-22-B	Gitta Oldendorff	81	Red Sea	H	19	17.0	36.3	21	6725.0	.	.
NS-23-A	Atlantic Cartier	106	Gothenberg Sweden	B	289	12.0	4.0	2	21.1	.	.
NS-23-B	Atlantic Cartier	107	Antwerp Belgium	A	171	12.0	11.6	2	3.6	.	.
NS-23-C	Atlantic Cartier	108	Gothenberg Sweden	B	289	12.0	4.2	21	468.6	.	.
NS-24-A	Barbel P	109	Gulf of Mexico	G	20	12.0	28.2	28	457.8	.	.
NS-24-B	Barbel P	110	Gulf of Mexico	G	20	11.5	34.5	22	382.0	3	6.2
NS-24-C	Barbel P	111	Bay of Campech	G	9	11.0	32.0	12	20.6	.	.
NS-25-A	MH Baker	113	Burlington NJ	A	4	13.0	1.2	10	714.2	.	.
NS-25-B	MH Baker	114	Burlington NJ	A	4	13.0	1.0	11	487.9	.	.
NS-26-A	Providence Bay	116	E Central Pacific	J	169	16.0	34.7	14	19.3	.	.
NS-26-B	Providence Bay	117	North Sea	B	10	19.0	34.4	28	204.2	10	2.2
NS-27-A	CSL Atlas	118	NW Atlantic	A	1	10.0	31.0	31	2281.9	.	.
NS-27-B	CSL Atlas	119	NW Atlantic	A	2	10.0	31.2	31	1618.1	.	.
NS-28-A	Zim America	120	Bacelona Spain	C	24	14.5	35.6	11	12.3	9	3.5
NS-28-B	Zim America	121	NW Atlantic	A	2	12.0	37.0	7	12.3		.
NS-29-A	Gypsum Baron	122	Stony Pt NY	A	4	13.0	7.3	13	320.6		.
NS-29-B	Gypsum Baron	123	Stony Pt NY	A	4	13.0	7.3	17	106.1		.

NS-29-C	Gypsum Baron	124	Stony Pt NY	A	4	16.0	6.8			10	19.3
NS-30-A	Atlantic Concert	125	Liverpool UK	B	7	12.0	29.0	17	39.8	8	20
NS-30-B	Atlantic Concert	126	Liverpool UK	B	7	12.0	29.0	14	20.9		.
NS-30-C	Atlantic Concert	127	Baltimore MD	A	30	12.0	24.3	3	1.7		.
NS-31-A	Madison	128	Searsport ME	A	1	10.0	31.6	35	12173.0		.
NS-31-B	Madison	129	Searsport ME	A	1	10.0	31.7	23	6111.0		.
NS-31-C	Madison	130	Searsport ME	A	1	10.5	31.7	23	4331.5	.	.
NS-32-A	AV Kastner	131	Jacksonville Fl	G	6	11.0	8.8	28	3352.0	9	28.1
NS-32-B	AV Kastner	132	Jacksonville Fl	G	6	11.0	3.9	29	4191.3	.	.
NS-32-C	AV Kastner	133	Jacksonville Fl	G	6	11.0	3.9	29	7120.8	.	.
NS-33-A	Gypsum Baron	134	Baltimore MD	A	3	12.0	14.8	25	1140.2	.	.
NS-33-C	Gypsum Baron	136	Baltimore MD	A	3	12.0	15.2	20	1610.8	6	1.2
NS-34-A	Atlantic Companion	137	Antwerp Belgium	B	10	11.0	19.9	28	400.6	.	.
NS-34-B	Atlantic Companion	138	Gothenburg Sweden	B	13	11.0	26.1	21	1311.8	6	0.8
NS-34-C	Atlantic Companion	139	Liverpool UK	B	7	11.0	29.2	23	135.4	7	1.1
NS-35-A	Eagle Baltimore	143	NW Atlantic	A	2	12.0	32.7	35	1235.3	.	.
NS-35-C	Eagle Baltimore	145	NW Atlantic	A	1	12.0	33.4	44	313.0	.	.
NS-36-A	Cecilia Desgagnes	146	NW Atlantic	A	2	7.5	33.0	26	495.9	.	.
NS-36-B	Cecilia Desgagnes	147	NW Atlantic	A	2	9.0	33.3	18	849.5	.	.
NS-36-C	Cecilia Desgagnes	148	NW Atlantic	A	2	8.0	32.6	27	612.3	.	.
NS-37-A	Eagle Boston	158	NW Atlantic	A	2	10.0	25.1	21	292.6	.	.
NS-37-B	Eagle Boston	159	NW Atlantic	A	1	10.0	25.3	16	267.1	.	.
NS-37-C	Eagle Boston	160	NW Atlantic	A	1	12.0	25.3	25	265.4	.	.
NS-38-A	AV Kastner	161	Jacksonville FL	G	6	8.0	24.9	44	695.2	.	.
NS-38-B	AV Kastner	162	Jacksonville FL	G	6	9.0	25.5	52	798.5	11	113.5
NS-38-C	AV Kastner	163	Jacksonville FL	G	6	8.5	25.6	45	1018.9	.	.
NS-39-A	Gypsum King	187	NW Atlantic	A	1	11.0	28.3	45	2306.4	.	.
NS-39-B	Gypsum King	188	NW Atlantic	A	2	11.0	36.1	19	568.1	.	.
NS-40-A	Georgia S	194	NW Atlantic	A	2	9.0	0.5	6	422.9	6	18.3
NS-40-C	Georgia S	196	NW Atlantic	A	2	9.5	1.5	6	634.9	.	.
NS-41-A	Gypsum Baron	197	NW Atlantic	A	4	8.5	25.4	25	1711.5	.	.
NS-41-B	Gypsum Baron	198	NW Atlantic	A	4	8.0	25.5	24	1027.2	11	37.3
NS-41-C	Gypsum Baron	199	NW Atlantic	A	4	8.0	25.5	22	2120.2	.	.
NS-42-A	Sophia Britannia	200	Marsaxlokk Malta	C	9	14.0	37.1	3	20.4	.	.
NS-42-B	Sophia Britannia	201	NE Atlantic	B	5	12.0	36.4	12	139.3	.	.
NS-42-C	Sophia Britannia	202	NE Atlantic	B	4	13.0	36.5	17	55.0	.	.
NS-43-A	Melfi Atlantic	232	W Central Atlantic	G	22	7.0	28.1	3	2.4	.	.

NS-43-B	Melfi Atlantic	233	W Central Atlantic	G	4	6.0	33.1	19	990.4	4	1.4
NS-43-C	Melfi Atlantic	234	W Central Atlantic	G	4	6.0	33.1	14	346.1	.	.
NS-44-A	Gypsum King	257	Stony Pt NY	A	3	5.0	6.4	17	1022.9	.	.
NS-44-B	Gypsum King	258	Stony Pt NY	A	3	5.0	6.3	21	1070.7	.	.
NS-45-A	Saraband	259	New Haven CT	A	4	3.0	28.2	22	4906.9	.	.
NS-45-B	Saraband	260	New Haven CT	A	4	2.0	28.3	17	4655.0	.	.
NS-45-C	Saraband	261	New Haven CT	A	4	2.0	28.1	21	7193.9	.	.
NS-46-A	Gypsum King	262	Boston MA	A	1	4.0	31.2	37	27312.2	.	.
NS-46-C	Gypsum King	264	Boston MA	A	1	3.5	29.7	33	23680.0	10	100.8
NS-47-A	Georgia S	265	NW Atlantic	A	2	3.0	26.7	45	4883.8	.	.
NS-47-B	Georgia S	266	NW Atlantic	A	2	2.5	32.0	9	121.2	.	.
NS-48-A	Melfi Atlantic	268	Havana Cuba	G	5	5.0	34.1	6	97.9	.	.
NS-48-B	Melfi Atlantic	269	W Central Atlantic	G	4	4.5	36.1	8	115.7	.	.
NS-48-C	Melfi Atlantic	270	Havana Cuba	G	5	4.5	36.0	9	317.4	.	.
PE-01-A	Akademikis Zavarikis	149	NW Atlantic	A	4	10.0	31.6	33	941.4	9	12.9
PE-02-A	Green Malloy	150	NW Atlantic	A	11	21.0	23.8	25	715.9	.	.
PE-02-B	Green Malloy	151	NW Atlantic	A	14	12.0	22.2	33	2609.3	.	.
PE-02-C	Green Malloy	152	NW Atlantic	A	15	7.0	26.2	42	2736.7	6	0.2
PE-03-A	Tasman Start	230	E Central Atlantic	F	10	7.0	36.6	8	21.9	.	.
PE-03-B	Tasman Start	231	E Central Atlantic	F	10	3.0	36.7	4	19.0	.	.

Appendix VII

GIS MAPPING OF MARINE VESSEL BALLAST WATER EXCHANGE ENDPOINT DATA IN ATLANTIC CANADA, FOR THE 2002 SHIPPING SEASON

Report to:

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GIS Mapping of Marine Vessel Ballast Water Exchange Data in Atlantic Canada, for the Year 2002 Shipping Season

ABSTRACT

The geographical information system (GIS) mapping of geo-referenced ballast water exchange volume endpoints recorded on Ballast Water Report Forms submitted to Marine Safety, Transport Canada, provides insight in ballast activities reported off Eastern Canada during the year 2002.

Vessel movement tracks and seasonal computer-modelled potential (interpolation) surface thematic maps rendered location information on preferred vessel exchange corridors and delineated high-value areas for ballast exchange volumes (reported endpoints) for vessel traffic approaching Eastern Canada from the United States, Europe and other international departure points.

The same Transport Canada ballast water data provided for a comparative, statistical analysis of shipping trends and patterns for Eastern Canada, with years 1998 and 2000.

A compact disk containing a digital copy of the GIS Mapping of Marine Vessel Ballast Water Exchange Endpoint Data in Atlantic Canada, for the 2002 Shipping Season report, the project database, the GIS-based (MapInfo format) vessel movement tracks and the computer-modelled potential (interpolation) surface thematic maps and the project metadata is contained on the project CD at the back cover of this report.

GIS Mapping of Marine Vessel Ballast Water Exchange Data in Atlantic Canada, for the Year 2002 Shipping Season

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GIS Mapping of Marine Vessel Ballast Water Exchange Data in Atlantic Canada, for the Year 2002 Shipping Season

1.0 INTRODUCTION

Commercial shipping ballast water quality and ballast water exchange has become a significant global issue over the last number of decades. During this period, oceanographers and environmental managers have witnessed the introduction of ballast water transported non-native species and pathogens into new areas, threatening indigenous life forms, the local ecology and human health. The result of these impacts has been the development of international policy to maintain standards for ballast water quality and exchange management. Notwithstanding, from a Canadian perspective, there has been little spatial examination of the actual volumes of commercial shipping ballast water released into the marine environment using the GIS spatial environment, specifically with vessel traffic reported approaching Atlantic Canadian ports.

The purpose of this report is to enlarge an earlier GIS ballast water exchange mapping application conducted for Transport Canada by Geocentric Mapping Consulting [1.] . The previous work prepared geo-referenced ballast water exchange activity endpoints in an MS Access database and derived a geographical information system (GIS) software-based thematically coloured marine vessel movement (ship track) map and a modeled contour map. Transport Canada supplied the data for the month of December 2001; the hardcopy data was contained on faxed Ballast Water Management Report Forms submitted to Transport Canada by marine vessel approaching Canada's Eastern Economic Zone (EEZ). The map outputs for December ballast exchange delineated common ballast water exchange areas for marine vessels transiting to Eastern Canadian and Gulf of St. Lawrence ports. The thematic mapping provided the basis for GIS mapping of the year 2002 data set of ballast water management report form data, with the plan of providing a bi-monthly, seasonal map display of ballast water exchange management activity by marine vessels entering Eastern Canada.

This study is similar to the earlier December 2001 mapping application in that the data was recorded in a database structure derived in the initial study, and the database attribute information (geo-referenced ballast water volume reported exchanged point locations) was mapped using similar modeling and programming techniques in the GIS environment. Discussions included in this report will include an overview of marine ballast water exchange and common exchange methods, a description of the data collected and data preparation for import to the GIS spatial environment, and a review of the GIS techniques used to derive ballast water thematics followed with a discussion of the resulting GIS map outputs. The report concludes with a comparative statistical review of year 2002 data with previous years (1998, 2000) and the report summary comments.

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1. GIS Mapping of Marine Vessel Ballast Water Exchange Data in Atlantic Canada submitted to Transport Canada, Dartmouth, NS by Geocentric Mapping Consulting, Falmouth, NS, January 2003.

2.0 MARINE VESSEL BALLAST WATER EXCHANGE

2.1 Definition of Ballast Water Exchange and Ballast Water Issues

Ballast water is the fresh or salt water carried by ships to provide stability and to adjust a vessel's trim for optimal steering and propulsion. The use of ballast water varies among vessel types, among port systems, and according to cargo and sea conditions. Ballast water often originates from ports and other coastal regions in one area, which are rich in planktonic organisms, and is discharged in new areas. As a result, a diverse mix of organisms is transported and released around the world with the ballast water of ships.

Today, ballast water appears to be the most important vectors for marine species transfer throughout the world. The discharge of ballast water or sediment into the waters of port states may result in the establishment of harmful aquatic organisms and pathogens, which may pose threats to indigenous human, animal and plant life, and the marine environment. Although other media have been identified as being responsible for transferring organisms between geographically separated water bodies, ballast water from ships appears to be among the most prominent.

2.2 Types of Ballast Exchange Common to Commercial Shipping

Ballast water exchange is a process of releasing the ballast taken aboard the ship in one area and discharging the water in a different geographic area. Vessels typically undertake two forms of ballast exchange, empty/refill or flow through of tanks. The exchange type employed is dependent on the quality of the ballast water in the hold(s). If the sea water quality is suspected of containing harmful pathogens or non-indigenous flora or fauna, the flow through method is used. Flow through exchange has the ballast water tanks exchanged by pumping seawater in gradually to dilute the poor quality ballast water before it is released to the ocean environment. This in effect has seawater filling or "flowing through" the ballast tanks(s) two or three times over tank capacity before dilution is complete.

To describe the vessel that is undergoing flow though exchange: the vessel is steaming along with the ballast tank deck covers open and sea water is being pumped into the tanks which overflow out of the holds over the deck of the ship. The empty/refill type of exchange is similar to flow through in that the deck is covered with ballast water being replaced by seawater. The difference is the volume taken into the tank(s) equals that expelled onto the ship deck; better quality source ballast water allows the empty/refill an option to the vessel's master.

Other than ballast water quality and harmful non-indigenous species contained therein, the second issue of concern is ballast water exchange location. Preferred locations for ballast exchange are discussed in the guidelines below.

2.3 Ballast Water Management Guidelines

The development and maintenance of guidelines for conducting ballast water exchange is officiated by the International Marine Organization (IMO), London, UK and 139 signatories countries, with each signatory having a ballast water management policy in-line with the IMO document. Canada is a participant in the international ballast management program through the Canadian Shipping Act, which contains provisions for enabling legislation. However, there are no regulations in force, and based on consultation with stakeholders under the auspices of the Canadian Marine Advisory Council, transport Canada established ballast water management guidelines, published as TP13617.

In Canada, ballast water management issues are administered jointly by Transport (as lead agency) in cooperation with Canadian Coast Guard and Fisheries & Oceans Canada. The purpose of the IMO Resolution 868, ballast water guidelines coordinated by IMO and participating countries, is to reduce environmental and health problems resulting from harmful aquatic organisms and pathogens carried from one place to the other in ship's ballast water. The Ballast Water Management Plan provides for safe and effective procedures for ballast water management and a means for keeping records to document the vessel's ballast water management practices. All vessels bound for signatory ports are required to submit Ballast Water Management Report Form reports to domestic agencies. In Canada, the report forms are commonly faxed to Transport Canada, which reviews and approves the ballast water information reported.

A portion of the guidelines is dedicated to advising preferred ballast exchange locations to mariners. However, based on the available scientific data available to date, no alternative exchange zone has been established in waters under Canadian jurisdiction on the east coast of Canada. Internationally, exchange is preferred in open ocean where seawater depth exceeds 2000 meters.

2.4 Transport Canada and the Ballast Water Reporting Form

The ballast water management reporting form provides vessels active in Canada's 200-mile EEZ boundary zone with the means for reporting their ballast water situation on board, prior to arrival at a Canadian port. The Canadian Ballast Water Management Guidelines are consistent with the International Marine Organization (IMO) regulations. All ships arriving at a Canadian port are contacted by Marine Communications and Traffic Services (MCTS) and requested to respond to a ballast water questionnaire developed in cooperation with Transport Canada, Marine Safety. Any enforcement action is initiated by Transport Canada, as appropriate.

The format of the ballast water management form submitted to Transport Canada varies slightly, however details provided is consistent between forms.

3.0 PROJECT DATA AND DATA PROCESSING

3.1 Acquisition of Ballast Water Management Form Data

The ballast water reporting data for the year 2002 was provided by Marine Safety, Transport Canada, Dartmouth, NS. The data consisted of 3448 faxed, hard copies of ballast information received from vessel approaching the Atlantic Canada from foreign ports. The formats of the ballast water management report forms provided (Australian, American, United Kingdom, vessel owner designed, for example) varied slightly in recording. The variation was insignificant, however minor changes (additional fields) were made to the database structure used in the initial study.

3.2 Description of Ballast Water Management Report Form

The ballast water reporting form describes the ballast water management program for the vessel from its departure point. Submission of the form to Transport Canada is a requirement under the Canadian Shipping Act. The layout format of the reporting form varies per vessel, however, it consists of six sections that include Section 1 - Vessel Information, Section 2 - Voyage Information, Section 3 - Ballast Water Usage and Capacity, Section 4 - Ballast Water Management and Compliance, Section 5 - Ballast Water History and Section 6 - Responsible Officer's Signature.

A variation of this format is Section 1 - Vessel Information, Section 2 - Ballast Water, Section 3 - Ballast Water Tanks (includes Total Number of Tanks Aboard, No. of Tank in Ballast with a field describing No. of Tanks Not Exchanged), Section 4 - Ballast Water History, Section 5 - Ballast Water Compliance information and Section 6 - Responsible Officer's Signature.

A sample of the most common Ballast Water Reporting Form is shown in Figure 1. below.

MATHILDE MÆRSK

BALLAST WATER REPORTING FORM

IS THIS AN AMENDED BALLAST REPORTING FORM YES [ ] NO [X]

1. VESSEL INFORMATION

Vessel Name:	MATHILDE MAERSK
IMO Number:	8618308
Owner:	MAERSK LINE
Type:	CONTAINER
GT:	52191
Call sign:	OUUU2
Flag:	DANISH

2. VOYAGE INFORMATION

Arrival Port:	HALIFAX
Arrival Date:	01-12-01
Agent:	MAERSK LINE
Last Port: ROTTERDAM	Country of Last Port: NETHERLANDS
Next Port: NEWARK	Country of Next Port: U.S.A.

3. BALLASTER WATER USAGE AND CAPACITY

Specify Units Below (cmt, MT,LT,ST)

Total Ballast on Board		
Volume	Units	No. of Tanks in Ballast
8750	MT	16
Total Ballast Water Capacity		
Volume	Units	Total No. of Tanks on Ship
21658	CBM	44

4. BALLAST WATER MANAGEMENT

Total No. Ballast Water tanks to be discharged: MAX 4 DEPEND ON CARGO OPERATION

Of tanks to be discharge, how many: Underwent Echange: 4 Underwent Alternative Management: NIL

Please specify alternative method(s) used, if any:

If no ballast treatment conducted, state reason why not: SIDE 11 P & S HEELING TANKS FOR INTERNAL USE ONLY 1200 M/T

Ballast management plan on board? YES [X] NO [ ] Management plan implemented? YES [X] NO [ ]

IMO ballast water guidelines on board [res.A.868(20)]? YES [X] NO [ ]

6. BALLAST WATER HISTORY: Record all tanks to be deballasted in port state of arrival; IF NONE, GO TO #6 (Use additional sheets as needed)

Tanks/ Holds List multiple sources/tanks separately	BW SOURCES				BW MANAGEMENT PRACTICES						BW DISCHARGES			
	DATE DD/MM/YY	PORT or LAT. LONG	VOLUME (units)	TEMP (units)	DATE DD/MM/YY	ENDPOINT LAT. LONG	VOLUME (units)	% Exch	METHOD (ER/FT/ALT)	SEA HT. (m)	DATE DD/MM/YY	PORT or LAT. LONG	VOLUME (units)	SALINITY (units)
DB 56 P	21/11/01	FELIXSTOWE	367	14 C	27/01/01	50 35 N 17 30 W	367	100%	ER	5	01/12/01	HAL		1,025
DB 56 S	28/10/01	OAKLAND	367	18 C	27/12/01	50 35 N 17 30 W	367	100%	ER	5	01/12/01	HAL		1,025
ST 78 P	13/11/01	NEWARK	415	14 C	27/12/01	50 35 N 17 30 W	415	100%	ER	5	01/12/01	HAL		1,025
ST 78 S	06/11/01	BALBOA	415	24 C	27/12/01	50 35 N 17 30 W	415	100%	ER	5	01/12/01	HAL		1,025

Ballast Water Tank Codes: Forepeak=FP, Aftpeak=AP, Double Bottom=DB Wing=WT, Topside=TS, Cargo Hold=CH, Other=0

6 RESPONSIBLE OFFICER'S NAME AND TITLE, PRINTED AND SIGNATURE: Chief Officer TEDDY VAGN PEDERSEN

MATHILDE MÆRSK

Figure 1. Sample of typical Ballast Water Reporting Form submitted to Marine Safety, Transport Canada; reporting marine vessel ballast management practices.

3.2.1 Description of Ballast Water Management Report Form Sections

The ballast water reporting form is comprised of six reporting sections. A detailed description of the contents of the form is presented below:

Section One - Vessel Information: The vessel is required to provide the vessel name, IMO (International Marine Organization) number, vessel owner, vessel type, gross tonnage, call sign and flag under which the vessel is registered.

Section Two - Voyage Information: The vessel is required to submit the name of the arrival port, arrival date, the ship's agent, last port and the next port after the arrival ported listed above.

Section Three - Ballast Water Usage and Capacity: The vessel specifies the total ballast on board, total ballast water capacity, volume units and number of tanks in ballast.

Section Four - Ballast Water Management: The reporting vessel specifies the total number ballast water tanks to be discharged, the number of tanks are to be discharged, the number of tanks undertaking exchange, the vessel acknowledges if a ballast water management plan is on board and if the management plan is implemented, and the vessel acknowledges if the IMO ballast water guidelines on board.

Section Five - Ballast Water History: The ballast water history section is entered in data table. The table records the location of the vessel ballast water tanks/holds, tank ballast water sources (date, port or Latitude/Longitude, volume and ballast source temperature), ballast water management practices (date, ballast water exchange endpoint - Latitude/Longitude, ballast water volume exchanged, % exchanged, method of exchange - E/R (empty/refill)/FT (Flow Through)/ALT (Alternate Method), and sea height) and ballast discharges (date, Port or Latitude/Longitude, volume and salinity).

Section Six - Responsible Officer's Name and Title, Printed and Signature: The Ballast Water Report Form is a legal document and is endorsed by the officer responsible for the ballast management plan.

A review of the faxed ballast report form data set indicated recordable data on each of the 3448 fax sheets. Further, data recorded in Section Five - Ballast History provided a chronology of the ship's movement and ballast activity (latitude/longitude recorded by the vessel's officer) as it made for an Atlantic Canadian destination.

Similar to December project work, the reporting of the vessel's geo-referenced ballast exchange endpoint volume data made the data suitable for database preparation and import as a point location file into the spatial, geographical information systems (GIS) environment.

3.3 The Ballast Water Management Report Database

3.3.1 Ballast Water Management Report Database Description

To prepare maps representative of ballast water management activities by marine vessel approaching Eastern Canadian ports, a database populated with faxed information was required. The previous December 2001 project work had developed a ballast water information database structure using MS Access database management software; this database structure was used for data entry of the year 2002 data. A description of the data structure with slight modifications to the December 2001 version is provided in the following section. The modifications were necessary to enlarge the database reporting capability and make possible the development of a concurrent Vessel Traffic/Vessel

Shipping Patterns on the East Coast of Canada 2002 Shipping Season statistical data summary report.

3.3.2 Ballast Water Management Report Database Structure

The database structure was developed to provide thematic map-building attributes in the GIS environment and to prepare the Vessel Traffic/Vessel Shipping Patterns on the East Coast of Canada 2002 Shipping Season statistical summary report.

After reviewing the form, slight modifications to the existing relational database structure were made. The two tables of the relational database consisted of a Trip Information table and a Ballast Water History table, with the key field joining the tables being the project assigned Transport Canada Sheet Number (TC_Sheet#). The tabular relationship provided complete information for each record in the database and reduced repeated data entry.

The parameters selected from the faxed Reporting Forms for the database structure are shown in Table 1 by database table name and Ballast Water Management Report Form Section Number .

Database Table Name	**Database Field**	**Comments**
Trip_Information	TC_Sheet#	Project assigned to each fax
	Type (Vessel)	Section 1 - Type Vessel
	IMO#	Section 1
	GT	Section 1 - Gross Tonnage
	Arrive Port	Section 1[2.]
	Arrive Date	Section 1[2.]
	Last Port	Section 1[2.]
	Next Port	Section 1[2.]
	Total#Tanks	Section 3, Total #Tanks
	#Tanks_in_Ballast	Section 3, #of Tanks in Ballast
	#TanksX_reported	Section 3, #of Tanks in Ballast
	#TanksX_recorded	Section 5, # of Tanks Exchanged
	#Tank_notX	Section 3[3.] , # Tanks Not Exchanged
	#TankD_reported	Section 3[3.] , # of Tanks Discharged
	#TankD_recorded	Section 5, Number of Tanks Discharged
	Trip_comments	Comment field.

2. Section 2, depending on Ballast Water Management Report Form format

3. Data not recorded by vessel , depending on Ballast Water Management Report Form format

Database Table Name	Database Field	Comments
Ballast_Water_History		All fields Section 5
	Volume Units	Ballast Volume Unit -cbm,MT
	BWS_Date	Source Ballast Date
	BWS_Port	Source Ballast Port
	BWS_Volume_Tank	Source Tank Volume
	BWE_Date	Ballast Exchange Endpt. Date
	LATDEG_BWE_Endpt	Exch. Endpoint geo-reference
	LATMIN_BWE_Endpt	Exch. Endpoint geo-reference
	LONDEG_BWE_Endpt	Exch. Endpoint geo-reference
	LONMIN_BWE_Endpt	Exch. Endpoint geo-reference
	BWE_Volume_Tank	Ballast Tank Volume
	BWD_Date	Discharge Tank Date
	BWD_Port	Discharge Tank Port
	BWD_Volume	Discharge Tank Volume

Table 1. Ballast Water Management Database relational data structure.

Additional refinements to the two data table structures were MS Access database field input masks, validation rules and data entry forms for both databases. With the data structure designed for each database, inputting the data in the MS Access database followed.

3.4 Populating the Ballast Water Management Database

Database entry of the 3448 faxed ballast water management sheets consisted of reviewing each sheet and keying the data in MS Access data entry form containing fields from the two relational tables. The information read from the forms ranged from legible typed to hand-written data information, which was of fair to good quality. One sheet was removed because the information was unclear. Several of the poorer quality sheets reflected the quality of the fax equipment used for transmission to Transport Canada, and not the reporting entered by the vessel's officer.

The types of ballast water management report sheets consisted predominantly of Annex 1 - International Marine Organization compliant report forms. Other report forms was Canadian Coast Guard MCTS Ballast Water Compliance Forms documenting vessels entering Eastern Canada, company report forms (Thenamaris (Ships Management) Inc., Maersk, Eagle Baltimore, for example), hard copies of emailed and telexed information submitted by vessels.

The reports sheet read for data entry provided mostly complete ballast water management information to the Trip_Info and Ballast_Water_History database tables. There were instances where the report sheet was partially completed by the vessel's officer; it was common for the #Tanks Exchange Reported to be blank in Section 3 and #Tank Exchanged Recorded to be completed in Section 5. Another example of partially recording ballast activity was not reporting Ballast Water Discharge in Section 5. Previous discussions with Transport Canada clarified the issue of ballast water discharge not recorded on the faxed material; ballast discharge occurs, although not reported by the vessel.

Instances of partially completed ballast water information form were keyed into the database as read. Entering the data as shown, eliminated the subjectivity of data entry and provided information on how complete the ballast management information is when submitted to Transport Canada. Special attention was paid to data entry into the Trip_Info data table; if ballast exchange was not reported in Section 3, a character representing blank (or Null) data was recorded. Likewise, if ballast exchange was not recorded in Section 5 - Ballast Management History, a Null indicating character was placed in the proper Trip_Info database field. For example, if the ballast exchange information was blank in Section 3 and Section 5, the characters N and G were placed in the #TanksX_reported and #TanksX_recorded fields The reporting and recording of ballast discharge information was entered the same in the #TankD_reported and #TankD_recorded fields. Other fields such as Total#Tanks, #Tanks_in_Ballast and #Tank_notX were subject to similar coding in the database. Also, instances where the ballast water related data was not part of Report Form because of form format was recorded. (Table 1.). The coding provided a report on the completeness of marine vessel ballast water submissions (Appendix A), to Transport Canada.

3.4.1 Database Fields in the Ballast_Water_History Database

Similar attention was made of the geo-reference entered in Section 5 - Ballast Water History when entering Ballast Water Exchange Endpoint Latitude and Longitude. Several formats of recording were determined. Most of the Ballast Water Exchange Endpoint recording was degrees-decimal minutes or more commonly, degrees-minutes. A third, less common format was degrees-minutes-decimal seconds. The data in the former two formats were keyed into Latitude_degrees, Longitude_degrees, Latitude_minutes, Longitude_minutes, Latitude_decimal_minutes, and Longitude_decimal_minutes database fields. The third type, minutes-decimal seconds, was manually adjusted to decimal minutes and entered in the Latitude_decimal_minutes, Longitude_decimal_ minutes fields respectively.

Manipulations to generate Latitude_decimal and Longitude_decimal in preparation for import to the GIS were completed in the Query function of MS Access. Query processing in the database will be discussed below.

In regard to geo-reference, the datum for the geo-reference was not recorded on the forms. An inquiry to Transport Canada on datum suggested the each reporting vessel could use a different datum. The geocentric latitude/longitude GRS 80 datum was selected as suitable when importing the data to the GIS.

When entering ballast water volume exchanged care had to be taken since the volume exchanged recorded on the sheet could have been a multiple of the volume exchanged. This was common when the ballast exchange method was flow through, where as much as 300% of ballast tank capacity is pumped through tanks. The volume recorded in the database in this instance would be 100% of tank volume, not three times the volume.

3.4.2 Ballast Water Management Database Summary

The 3,448 Ballast Water Reporting Forms created 16,456 database records in the Ballast_Water_History data table and 3,448 records in the Trip_Info data table. Included in the two data tables were reports submitted from marine vessels destined for America, France (St. Pierre & Miquelon), West Canadian ports (Vancouver, Churchill, Manitoba and North West Territories) and Canadian to Canadian ports. The American data entered included ports bordering the Great Lakes, as well as United States Eastern Seaboard ports such as Boston and New York. Voyages between Atlantic Canadian ports were part of the data. Duplicate records, voyages to non-Eastern Canadian ports, Canadian domestic trips, and other incomplete records (null arrival date, arrival port, etc.) were removed from the Ballast_Water_History data table, leaving 14,542 records.

Similar records were removed from the Trip_Info data table (442 records). A number of the duplicates were the MCTS Centre Reports - St. John's and Halifax. An effort was made to match up MCTS Centre material with the corresponding Ballast Water Management Report form. The effort was somewhat diminished by the lack of information on the MCTS forms and the fact that the database did not record the name of the vessel as part of the record. The reasoning behind not recording the vessel name was to reduce data entry and that vessel names may change, but not the IMO identification. Removing the number of duplicate and non-study area records reduced the Trip_Info database to 3,006 records.

The final step to preparing the database for the GIS was joining the Ballast_Water_ History and Trip_Info data tables in the database, using a one to many relational join. The key field in the join was the TC_Sheet# field. The output from the join produced 3,006 Trip_Info records matched with 14,542 Ballast Water History records, with every record providing at least partial information.

A summary of the completeness of the Ballast Water Management Database is provided in Appendix A.

3.5 Database Manipulations to Prepare the Data for the GIS

To prepare the import of the Ballast Water Exchange data set to MapInfo, manipulations in the query function of MS Access were necessary. A series of data conversions and an extraction of a geo-referenced subset of data were completed.

The first step in the manipulations was to convert and concatenate the fields for latitude/longitude degrees, minutes, decimal minutes to latitude decimal minutes and longitude decimal minutes; this was followed by the standardizing the database volume units for ballast water source, exchange and discharge to cubic metres. Light Ton values were converting by a factor of (0.9842 LT = 1 MT)(.975) and Metric Tons by a factor of 1.035 cbm = 1MT, provided cubic metres.

The final step of manipulations was to filter the data set to include only those records containing open ocean ballast water exchange endpoint geo-reference reported. Several MS Access queries were performed on the 14,542 records to identify records with having these criteria. Queries extracting records with:

(1). LATDEG_BWE_Endpt >0
(2). LATDEG_BWE_Endpt=0 and LATMIN_BWE_Endpt >0
(3). LATDEG_BWE_Endpt=0, LATMIN_BWE_Endpt =0 and
LONDEG_BWE_Endpt>0
(4). LATDEG_BWE_Endpt <0.

The output from this procedure produced a data set of 8,487 records (58.36% of 14,542 records) representing 1427 (47.47%) of Ballast Water Reporting Forms. The derived data set contained open ocean ballast exchange records for vessels transiting to Atlantic Canadian ports from Europe and points south (America, Panama, Caribbean, and South America) during the year 2002. Database records not selected were records without geo-referenced ballast exchange endpoint positions, having no ballast water to exchange, having the position of exchange reported but no volume recorded, or having old ballast data recorded.

Examination of the 8487 sets of mappable point data on each of the ballast exchange reports indicated the ballast activity endpoint positions reported varied from one to 26 geo-referenced positions. The average number of locations reported was five positions, some of which reported the same location for each of the ballast exchange endpoints reported to Transport Canada.

Inspection of 8,487 points revealed null for ballast water exchange volumes reported for 160 records, no ballast water exchange date reported (5 records) and incomplete latitude/longitude coordinates (14 records). The data set was reduced to 8308 locations.

The import of the geo-referenced data into MapInfo GIS as a point layer with database attributes followed the MS Access query activity.

4.0 MAP CREATION IN MAPINFO GIS

4.1 Importing the Database into MapInfo GIS

The 8308 records from MS Access were imported into MapInfo Professional GIS software. The point data layer created was viewed in the MapInfo map window using the FAO Standardized Oceans Regions map for reference (Figure 2). The point data layer distribution showed 97% of the point data within FAO Zones A, B,G and F. The distribution is shown in the Table 2 below.

FAO Zone	Points	Percentage of Total Points
A	5055	62.5
B	2096	25.95
F	114	1.4
G	812	10.05
D,E,F,H,J,M	231	2.85

Table 2. Distribution of ballast water endpoints reported by vessel approaching Eastern Canada, classified by FAO standardized ocean regions.

The GIS overlay of the FAO Oceans Regions assisted in defining the study area. The area selected for the project study area was defined as an area bounded by -090W/15N and 00(Greenwich)/65N. This area captured 96 % (8014) of 8308 project data points. The outlying points in the data set were ballast water exchange endpoints located in the Pacific Ocean, off the east coast of northwest Africa and below the equator, in the South Atlantic. Since the outlying points would distort the GIS modeling (potential surface mapping) to be undertaken, 294 points were removed from the data set. The 294 points represented data from 52 ballast water reporting forms.

With the peripheral points in the data set removed, the data set of 8014 points was prepared for MapInfo ship track creation and SPANS GIS Potential mapping analysis.

Preceding the modeling, the imported point file was parsed to bi-monthly intervals. Parsing provided subsets, permitting an examination of ballast water exchange during the six bi-monthly periods for year 2002. The six point subsets extracted are shown in Table 3. by duration and point count/Ballast Water Management Report Form counts.

File Name	File Interval	Point Count / Report Forms
JFpts	01/01/2002 - 28/02/2002	1046 / 193
Mapts	01/03/2002 - 30/04/2002	1290 / 220
MJpts	01/05/2002 - 30/06/2002	1478 / 245
Japts	01/07/2002 - 31/08/2002	1553 / 278
Sopts	01/09/2002 - 31/10/2002	1459 / 258
NDpts	01/11/2002 - 31/12/2002	1188 / 216
Total Points / Report forms	N/A	8014 / 1410

Table 3. GIS point file bi-monthly point counts with 1412 Ballast Water Management Report forms representing 8014 plottable Ballast Water Exchange data.

4.2 Creation of the Vessel Ballast Exchange Track Movement Maps in MapInfo GIS

The intent of the Vessel Ballast Exchange Track Movement Maps is to display the ballast exchange endpoints reported by the vessel on the ballast exchange form as a series of points connected by a line (polyline). The resulting line represents the vessel's movement track while undertaking ballast exchange. Once the vessel track is created, it is "joined" in MapInfo to data from Sections 1 to Section 5 of the MS Access database, giving the track attributes that can be used to generate line attribute-based thematics. For example, the ship tracks can be classified and coloured according to the line's attribute - BWE_Volume_Tank.

The creation of the ballast exchange tracks was completed using MapInfo SQL and MapBasic programming software. The tasks were as follows:

1. In MapInfo SQL, extract from the ballast water exchange point file the TC Sheet# and the Sum of ballast volumes for each Ballast Exchange Report Form Sheet. The SQL result was two columns: one column of TC Sheet# and another sum of ballast exchange volumes. Save the .tab file as TCSheet_BallastVolumes.

2. In SQL, take TCSheet_BallastVolumes and remove sum of ballast exchange volumes field. Save as DOS .txt file. The .txt is a single column of numbers.

3. In MapBasic, create a program to read the DOS .txt file listing the single column of numbers (TC Sheet#) from Step 2; after reading the column of TC Sheet#, MapBasic places all records in ballast water exchange point file with a common TC Sheet# in a separate MapInfo .tab file, with the records sorted by the longitude field. This procedure produces plottable track files in MapInfo GIS.

4. In MapBasic, modify the MapInfo utility conndot.mbx to continuously read the DOS .txt file listing the TC Sheet# from Step 2; with each TC Sheet# read, a .tab file is called and opened and the sorted (by longitude) ballast exchange points contained are plotted, one polyline (with TC Sheet# attribute) at a time.

   After each polyline is plotted in the map window, the line is linked to the attributes from Sections 1to Section 3 of the original data set. The result of running the MapBasic routine is a ballast exchange movement tracks (polylines) with attributes.

5. In MapInfo, create a classified colour thematic map based on the Ballast Water Volume Exchange attribute attached to each ship movement track.

The GIS derived bi-monthly Ballast Water Exchange Movement Track outputs is discussed below.

4.3 GIS Potential Mapping in SPANS Analytical GIS

To compliment the plotting of the vessel movement exchange tracks (polylines), a technique to create potential thematic mapping surface representative of the ballast water exchange volumes based on geo-referenced ballast water exchange endpoint values was chosen. The SPANS modeling algorithm generates a surface by applying a sampling radius to each point in the data layer. The function generates a gridded surface representation with the value of each variable raster cell based on the value of each point whose sampling radius overlaps the centre of the cell. The function applies a weight based on the distance from the centre of the cell to each point used in calculating the output value. The greater the distance a raster cell is from the point, the less influence that point has in determining the output value. The user controls the effect distance has on determining the output value by specifying the size of the sampling radius and a rate of decay. The user also specifies the number of points closes to the centre of the variable raster cell to be considered in the calculation of an output value.

Other parameter settings include the sample radius inner, outer sample radius and decay rate. The inner sample radius setting is an area where the decay rate is constant when the weighted average computation is applied. The outer sampling radius decay rate can be set between .1 to 1.0 (constant) allowing the user to select the relationship between weight inversely proportional to distance and decay rate with distance, to obtain the most representative raster cell value.

The potential mapping chosen because the modeling process lends well to unevenly distributed data, such as ballast water exchange points (on a small scale, cartographically) which is non-continuous data typified by a high degree of variance and uneven distribution.

The creation of the potential mapping layers required the use of PCI SPANS Analytical GIS, a GIS variable raster modeling and display software.

The preparation of the bi-monthly potential maps started with a simple aggregation of the ballast water exchange endpoint point file. The aggregation technique was necessary because the point data had multiple values at a given point geo-reference, each with its own volume value. The aggregation algorithm summed the multiple values on the same point location. The reduction in the number points due to Simple Aggregation is shown in Table 4.

File Name	Bi-monthly Interval	Point Count / Agg. Point Count
AggJFpts	01/01/2002 - 28/02/2002	1046 / 619
AggMApts	01/03/2002 - 30/04/2002	1290 / 659
AggMJpts	01/05/2002 - 30/06/2002	1478 / 842
AggJApts	01/07/2002 - 31/08/2002	1553 / 874
AggSOpts	01/09/2002 - 31/10/2002	1459 / 774
AggNDpts	01/11/2002 - 31/12/2002	1188 / 686

Table 4. Aggregate points created for each bi-monthly interval, using MapInfo Vertical Mapper.

The next step of the GIS processing was to create an interpolated continuous surface grid layer based on the aggregated seasonal GIS point layers. The continuous surface is the output of the interpolation algorithm estimating grid values using ballast exchange endpoint volumes read from the point table.

The selection of SPANS GIS modeling capability over the MapInfo Vertical Mapper (used for the December 2001 data set mapping) software for point value interpolation was the parameters of the SPANS modeling algorithm better suited the data distribution. The SPANS outputs had tighter interpolation around the known values and did not populate the large areas of ocean having thin point data with modeled ballast water exchange values.

The SPANS potential map algorithm parameter values were entered into the algorithm to reflect the geographic distribution and variance in point values. The classification interval for the map output was the system default of 2331.3 cbm. The parameter settings are shown in Table 5.

Parameter	**Value**
Function	Weighted Average of Z-Values
Inner Radius (km)	10
Outer Radius (km)	50
Decay Rate	.5
Frequency	1
Maximum Neighbours	25

Table 5. SPANS Potential Mapping Surface parameter settings for modeling the reported ballast water exchange endpoint values.

The resultant seasonal ballast water exchange thematic potential map output is reviewed below in a discussion of project map outputs.

4.4 Discussion of Project Map Outputs

4.4.1. Distribution of Point Data

The GIS distribution of the 8014 recorded ballast water exchange point data provides a spatial view of the geo-referenced, recorded data by the marine vessel. In addition to the FAO ocean regions compilation, the points were classified by a scheme of location within Canada's Eastern Economic Zone and points beyond the 200 mile limit. A GIS query yielded 1091 reported ballast exchange endpoints (13.61% of the 8014 total data points) within Canada's EEZ. The points outside the EEZ were data located predominately along the US Eastern Seaboard and the mid-Atlantic Ocean, steaming from European ports.

The data points within Canada's EEZ was further classified by Area within the 200 mile boundary. The Area I, Area II, Area III and Area IV was a classification scheme used in a year 2000 vessel traffic/ vessel shipping patterns statistical study[4] completed by Transport Canada. A plot showing the distribution of points within the Areas 1 to 4 is shown in Figure 3.

4. Vessel Traffic/Vessel Shipping Patterns on the East Coast of Canada 2000 Shipping Season, Transport Canada, 2002.

A MapInfo point in polygon query provided values for the point data distribution for year 2002 per Area. The data was un-aggregated, consisting of all points for 2002. The output is shown in Table 6.

Area	**Points**	**# Vessels**
I	35	15
II	987	219
III	37	11
IV	29	12
Totals	1088	257

Table 6. Points distribution with Canadian EEZ by Area used in shipping pattern report for year 2000.

The GIS reports 1088 points captured within the defined areas. The remaining 3 points (total points, 1091) were located off northern Labrador, outside of Area IV. Two hundred fifty-seven marine vessels reported the 1088 points. Table 6 indicates Area II, encompassing ports east of Yarmouth to the northern tip of Cape Breton, is the most active ballast water exchange area for marine vessels, reporting 987 points from 219 vessels. The arrival port for these vessels includes ports in Nova Scotia, New Brunswick, Newfoundland, Gulf of St. Lawrence, Quebec and Great Lakes.

Having determined the year 2002 point distribution, the bi-monthly data sets were mapped in the GIS. Summary data is tabulated below (Table 7).

Bi-monthly	Area I		Area II		Area III		Area IV	
	Pts	Vessels	Pts	Vessels	Pts	Vessels	Pts	Vessels
January - February	3	2	106	25	15	2	5	1
March - April	2	1	121	25	1	1	4	1
May - June	8	5	207	44	6	3	3	2
July - August	2	1	210	53	11	3	11	5
September - October	12	4	166	37	0	0	5	2
November - December	8	2	186	38	4	2	1	1
	35	15	987	219	37	11	29	12

Table 7. Bi-monthly points within Geographic Areas defined in shipping report for year 2000.

The bi-monthly data table indicates Area II is the active ballast water exchange area for vessels transiting into Eastern Canada, primarily from ports on the United States Eastern Seaboard. This statement is made in terms of ballast water exchange endpoints reported. The period of July-August has a value of 210 exchange endpoints recorded by 53 vessels reporting. The period of least activity report for all areas was January-February and March-April, with an average of 1.66 vessels report exchange in the first period and 1.00 vessels in the latter duration. The activity in Area II for the two periods was 25 vessels reporting ballast water exchange endpoints. Activity in Areas I, II, III increases slightly during the balance of the year with Area I ranging from 1 to 5 vessel reporting activity, Area II ranging from zero to 3 active vessels and Area IV reporting a range of 1 to 5 vessels exchanging in the remaining four bi-monthly periods of the year. During the same period, Area II reports an average of 37.5 ships reporting in the autumn-early winter to a bi-monthly high of 53 vessels reported for July-August.

4.4.2. Distribution of Ship Movement Tracks

The thematic vessel movement tracks created in the MapInfo GIS reflect the bi-monthly point data set, giving a GIS polyline representation to the series of ballast exchange endpoints recorded in the vessel's ballast exchange activity log. Each polyline contained a database field ballast water volumes exchanged sum, extracted from the point that generated the vessel movement track. The sum value attribute enabled thematic ship track map for each bi-monthly period based on a classification of ballast water exchange endpoint volumes.

The number of vessel movement tracks developed for each bi-monthly period was a function of the number of recorded ballast activity points reported. The length and direction of the track reflected the number of geo-referenced point data read into the MapBasic program and plotted in the spatial environment. Where ballast exchange was reported at a single location for all ballast tanks, no line was created and the track was of zero length. There were instances where two tracks were plotted to represent ballast exchange endpoints reported at during two periods during the vessel's transect. A compilation of the bi-monthly movement tracks created in MapInfo is listed in Table 8; the range of ballast water volumes exchanged is also reported.

Period	Pt. Count	Track Count	Tracks of Zero Length	Min. - Max. Volume (cbm)	Mean (cbm)
January - February	1046	193	59	40 - 95,157	8608.08
March - April	1290	220	99	40.67 - 97,772.51	9,668.43
May - June	1478	245	91	93.0 - 83,494	11,480.26
July - August	1553	278	112	20.7 - 83,473.3	12,493.4
September - October	1459	258	92	15 - 83,272.5	12,980.09
November - December	1188	216	81	110.745 - 97,607.8	14,707.59
Totals		1410	534		

Table 8. Compilation of bi-monthly vessel movement tracks data

From Table 8, the number of zero length tracks impacts on the number of tracks plottable and reduces the quantitative value of assessing the volume of ballast water exchanged by marine traffic approaching the Canadian Eastern Economic Zone. Qualitatively, the movement tracks provided information on dominant shipping corridors where ballast exchange activity is conducted by marine vessels; comments can be made about the vessel movement track orientation and volumes reported.

The six bi-monthly periods exhibited similar movement patterns to the December 2001 one-month (of data) GIS mapping study. The distribution of the exchange endpoint movement tracks displayed two preferred areas: mid-Atlantic ocean while steaming from European and the Mediterranean ports and the other along the east coast of North America, south-southwest of Nova Scotia. The former can be subdivided into ships departing European ports north of Spain and Spanish, Mediterranean and Northwest African ports. Each subdivision was well defined, with one area of preferred exchange endpoints bounded by a rectangle with corner points -40W/52N and -12W/46N and the other -38W/45N and -15W/34N. These rectangles enclose European vessel traffic destined mostly to Maritime Canada and the Gulf of St. Lawrence ports (Montreal, Trois Riviere, Quebec City, Sept Isles). The second area south of Nova Scotia is rectangular area bounded by -79W/32N in the southern United States and extends along the entire American East Coast and thinly into the Canadian EEZ. There are clear vessel traffic patterns from New York, Boston and American ports to the north of these cities. The traffic in this area is mostly American vessel transiting to the Bay of Fundy, Halifax, Pt. Tupper, Come By Chance -Whiffen Head, NL and the Gulf of St. Lawrence (Figure 4).

The thematic ballast exchange map in Figure 4 illustrates the different volumes reported by vessels transiting from Europe, Mediterranean and America. The distribution of volume shown in the map legend indicates the higher volumes reported are thematically coloured red. The legend in Figure 4 indicates 1136 tracks (80.5% of total, including zero length tracks) report ballast water exchange volumes between 0 and 19,600 cbm. Data extracted (from the mapping) using an intersect polyline query through the three zones provided the following information:

Map Area	#Tracks	Min. Volume	Max. Volume	Mean
Europe	120	332	97,772.51	25,215.17
Mediterranean	50	800	81,297.1	11,603.24
America	122	838	74,935.9	23,217.74

Table 9. Vessel movement Track counts in three zones; Europe, Mediterranean and America.

The intersection line for the vessel transiting south of Nova Scotia was the Canadian EEZ boundary. The boundary intersected 122 ship movement tracks crossing over the EEZ line reporting ballast exchange endpoint activity. The larger scale map viewed in Figure 5 shows vessel traffic eastward of the 1000 metre and 2000 metre isobathymetric contours. The 1000m contour is coloured pink in Figure 5. An intersect line drawn through the landward of the 1000m isoline found 69 vessels were transiting landward of the 1000 m interval contour during the year 2002.

Examining this query output resulted in 36 vessels being oil tankers (Type reported as Crude Oil Tanker, Tanker, Product Tanker and Tanker in the database), 24 Bulk Cargo, 5 General Cargo and 4 assorted carriers. The common last ports reported for the 69 vessels included 8 departure ports reporting more than 4 voyages during year 2002 to Eastern Canada. The departure ports included Newington, NH (4), Portland, ME (9), Bayway, NJ (10), New York, NY (11), Baltimore, MD (4) and Philadelphia/Trainer, PA (7). The remainder of the ports was located in the New England states, except for 1 departure from Charleston, SC.

A seasonal examination of the point information was conducted using aggregate points-based potential mapping, since the vessel track mapping provided a more visual, qualitative view of vessel traffic patterns with vessel traffic counts. Potential mapping modeled the same point data (but aggregated), mapping the distribution of seasonal ballast water exchange endpoints and revealing anomalous, high value areas.

4.4.2 Potential Mapping of Ballast Water Exchange Endpoint Volumes

The seasonal potential maps modeled in SPANS Analytical GIS were derived from bi-monthly point data subsets of the ballast water geo-referenced point file. The model required the points to be aggregated, since more than one geo-referenced point at the same point location was treated as a single non-aggregated value by the model algorithm. MapInfo Vertical Mapper software was used to create the simple aggregate point layer. The effect of aggregation was to substantial reduced the number of points for each season. The aggregate bi-monthly files used to generate the potential surface maps are in Table 10.

Bi-monthly	Unaggregated # of points	Aggregate # of points
January - February	1046	619
March - April	1290	659
May - June	1478	842
July - August	1553	874
September - October	1457	774
November - December	1188	686

Table 10. Bi-monthly summary of unaggregated points and aggregated points.

The potential surface map created a GIS layer containing polygons modeled on the parameter settings discussed above. The algorithm output provided a default classification scheme with interval of 2331.3 cubic metres. The map legend has the upper most interval of the scheme green coloured, and green polygons contain the attribute value equal to or greater than 9,325.2+ cubic metres volume reported exchanged.

Parameter settings influencing the potential surface (the value of the variable raster cell) were the endpoint value, the outer search radius of 50 kilometres and the nearest 25 neighbouring points.

4.4.3 Bi-monthly Potential Mapping Output Discussion

4.4.3.1. January-February Bi-monthly Period Potential Map

The thematic potential map for January-February reveals twelve scattered 9,325.2+ cbm ballast water exchange locations in the mid-Atlantic. This represents vessels reporting exchanged endpoints where total ballast volumes exchanged was greater than 9,325.2+ cbm, while transiting to Eastern Canada destinations. The ballast exchanged values for the points range from 10,238 to 48,531 cbm with mean 29,097 cubic metres. Most high value areas (83%) are isolated, being greater than 60 kilometres from a neighbouring ballast water exchange endpoint location. (Figure 6).

The area within Canadian EEZ for the same period contained 2 isolated green zones and two larger areas comprised of more than one aggregate point location (Figure 6a). One of the isolated areas is south of Anticosti Island which reflects two vessels, a bulker destined for Sept Iles from Salem, MA exchanging 10, 404 cbm and a motor tanker to arrive at Quebec City, QC from Philadelphia, PA exchanging 29,792 cbm. The second point, east of Pt. Tupper, reflects one vessel reporting the endpoint for exchanging 34,993 cbm from six ballast tanks, while heading for Whiffen Head from Portland, ME.

The larger green areas with values greater than 9,325.2+ cbm are southwest of Nova Scotia. One zone is along the southern Canadian 200-mile limit boundary, and the other is closer to shore, southwest of Cape Sable. There are several 9,325+ cbm points responsible for each zone, with the modeled area around these points being influenced by the lesser valued points (less than 9,325.2 cbm) found to be within the model's 60 kilometer sampling radius.

The model output shows the green area along the EEZ boundary has 20% of its area inside the EEZ boundary, with the balance in US territorial waters. With the exception of a single aggregate point, all the other points responsible for the green endpoint exchange area are situated in American waters. The single aggregate point is located 1.1 kilometers inside the 200 Mile Limit and 2.8 kilometers east of the 2000 meter isobath. With the exception of this point, the northern boundary of the green area is based on ballast water exchange endpoints points located in American waters.

The high-value area southwest of Cape Sable reflects five vessels reporting ballast exchange endpoints within forty to seventy kilometers from Nova Scotian coastline. Of the five vessels, the same bulk cargo vessel (based on IMO number) reports ballast exchange endpoints for three voyages to Halifax (twice) and one to Pt. Tupper from Newington and Portsmouth, NH respectively. The bulker reports endpoints for ballast exchange volumes of 12,377 cbm, 12,481 cbm, and 12,658 cbm at these locations. The remaining points are bulk cargo ships destined for Halifax from Portland, ME and Brayton Pt., MA. The volumes reported are 17,207 cbm from 5 ballast tanks and 22,440 cbm from 7 tanks exchanged. A single point influences the southeast end of the high value green area, a tanker destined for Pt. Tupper from Bayway, NJ. The tanker reports 15,220 cbm at the exchange endpoint for two ballast tanks.

In total 130 ballast exchange endpoints (including high value points locations discussed above) with the EEZ, representing 30 voyages (95% from the USA) recording a ballast water exchange endpoint(s) within the Canadian 200-mile Limit. Fourteen of these voyages reporting exchange seaward of the 2000-metre isobath; of the remaining 15 voyages, 14 reported ballast exchange endpoints landward of the 2000-metre interval and one in the Laurentian region.

An overlay of the ship tracks for January-February over the potential map data for the same period displays a representation of the 30 voyages representing the 130 points. The overlay shows four tracks having no related endpoints crossing into US territorial waters.

This suggests, with the first endpoint reported for this group being 280 kilometres northeast of the EEZ, that exchange was initiated after crossing over the Canadian 200-mile limit. Fifteen other voyages reported endpoints in US territorial waters crossing into the Canadian EEZ. The remaining eleven ballast exchange endpoints recorded voyages where the ship tracks were zero length; occurring at the same geo-reference. Similar to the above, with ballast exchange commencement not reported, ballast exchange for a number of the eleven zero length ship tracks could have occurred within the Canadian EEZ.

4.4.3.2. March-April Bi-monthly Period Potential Map

The bi-monthly interval March-April potential map shows the mid-Atlantic to have more single point, high-value ballast exchange endpoints. The 31 single high-value points were less dispersed than the January-February display, with only 25% isolated anomalous areas (Figure 7). This reflects the slight increase in vessel traffic (315 points) reported for the period March-April over January-February (295 points). The remaining high-value polygons areas were less symmetric, sharing a common area boundary with neighbouring polygons. The high-values areas for the mid-Atlantic traffic ranged from 9,316 to 74,924 cbm, with a mean of 21,473 cbm.

The high-value exchange endpoint activity reported off Nova Scotia within the 200-Mile Limit showed non-symmetry isolated anomalous areas outside the EEZ boundary and two nearly adjacent green areas southwest of Cape Sable and one seaward of the 2000 metre isobath (Figure 7a). One of the adjacent areas represents two bulk cargo vessels from the New York City area destined for Halifax reporting exchange endpoint volumes of 12,962 and 22,548 cbm. A yellow area northwest of this area represents four vessels reporting exchange endpoints (one the vessels twice, separate voyages) between 6,993-9,325 cbm. Three of the vessels are bulk cargo, two destined for Halifax and one Auld's Cove from Portsmouth, NH and Newington, NH. The third vessel is a tanker headed for Whiffen Head from Portland, ME. The seaward high-value area is a single bulk cargo vessel from Sparrows Pt., MD destined for Sept Iles reporting 10,146 cbm exchanged.

The endpoint reporting inside the EEZ is less than the previous period (128 points), however the point locations are more defined along the coast of mainland Nova Scotia and parallel to the 2000 metre isobath, where US tankers were heading for Whiffen Head and Come By Chance, NL. The number of vessel voyages having exchange endpoints during March-April is 26 vessels, eleven tankers, two container ships and 13 bulk/general cargo vessels.

An overlay of ship tracks reports 26 ship tracks comprise the points within the EZZ, eight of which are zero length tracks. Nine vessel tracks begin in US Territorial waters and report the last endpoint of the voyage in Canadian waters. Nine tracks report the first endpoint within the Canadian EEZ and report others along the Nova Scotian coast or along the 2000-metre isobath.

4.4.3.2. May-June Bi-monthly Period Potential Map

The bi-monthly interval May-June potential map shows the mid-Atlantic to have more single point, high-value ballast exchange endpoints than the two previous bi-monthly periods, with 33 single high-value points (Figure 8). The range of ballast water exchange endpoint volumes was 9,860-64,152 cbm with an average value of 17, 432 cbm. The distribution pattern of the high-value points shows 69.7% located with +/−5 degrees of 49°N, with fourteen bulk cargo vessels (93%) destined for Sept Iles and Port Cartier, QC and one bulk cargo heading for Shelburne, NS. The vessels had origins in the Netherlands (8 ships), United Kingdom/France/Germany (5 ships) and Faroe Islands (1 ship). South of 49°N, bulk cargo vessels, some with origins in the Mediterranean, account for the 10 high-value ballast exchange endpoints between 40°N and 42°N latitude in the mid-Atlantic.

The mid-Atlantic data was less dispersed than previous bi-monthly periods, part of this reflects the 27% increase in data points for the May-June period with 701 points representing 131 vessels reported transiting from Europe to Eastern Canada. The majority of vessels were bulk/general cargo (37.5%), container ships (33%) and tankers (21%).

The high-value exchange endpoint activity reported off Nova Scotia within the 200-Mile Limit shows isolated and adjacent non-symmetry 9,325+ areas ninety kilometres southwest of Liverpool, NS and due east of Canso (Figure 8a). There is also a smaller high-value green area east of Halifax adjacent to a yellow 6,993-9,325 cbm-coloured area. The high-value area situated off Liverpool is two ships which report endpoints for all tanks exchanged at the single location; one bulk cargo destined for Halifax from Burlington, NJ and the other from New York to Whiffen Head.

East of Canso, two exchange endpoint locations contribute to the two high-value areas. The closest to Canso (40 kilometres southwest) is a tanker headed for Pt. Tupper exchanging 9 ballast tanks for a cumulative total of 17, 382 cbm. The other area (150 kilometres east of Canso) is the same tanker reported off Liverpool reporting another exchange endpoint for 4 tanks having volume 18,264 cbm.

The coast off Nova Scotia has more 6,993-9,325 cbm and 4662-6,993 cbm continuous areas. The pattern of tanker vessels (16 ships) transiting to Whiffen Head and Come By Chance is evident. These vessels are within 50 kilometres either side of the 2000 metre isobath. Other vessels (4 ships) in the group are bulk carriers, destined for Quebec ports.

An overlay of ship tracks reports 26 ship tracks comprise the points within the EZZ, eight of which are zero length tracks. Twenty-one vessel tracks begin in US Territorial waters and report endpoint(s) of the voyage in Canadian waters. Sixty-six percent of the vessels are bulk cargo destined for various Nova Scotia (Halifax, Pt. Tupper), Newfoundland (Lower Cove) and Laurentian ports (Quebec City, Contrecouer, Magdeleine Islands). The balance were tankers headed for Whiffen Head and Come By Chance, Newfoundland. The departure ports were Philadelphia and New England ports, to the north. The exceptions were Savannah, GA and Charleston, SC. Seventeen tracks (76% tankers) reported the first endpoint within the Canadian EEZ. Six vessels were zero length tracks, reporting all tanks exchanged at a single geo-referenced point. The range of the total endpoint volumes reported by the 17 vessels was 220 cbm to 57,266 cbm, with average volume for the endpoints 16,724 cbm. A tanker destined for Whiffen Head from Philadelphia, PA reported the 57,266 cbm.

4.4.3.4. July-August Bi-monthly Period Potential Map

The bi-monthly interval July-August potential map shows the mid-Atlantic to have a similar single point, high-value ballast exchange endpoints with May-June, 34 single high-value points (Figure 9). The range of ballast water exchange endpoint volumes was 9,756-64,152 cbm with an average value of 22,089 cbm. The distribution pattern of the high-value points shows 62% located with +/−5 degrees of 49°N, with twelve bulk cargo vessels destined for Sept Iles and Port Cartier, QC. The vessels had origins in the Netherlands (6 ships), United Kingdom/France/Belgium (3 ships) and Spain (2 ships).

Similar to the previous period, the data was less dispersed than earlier bi-monthly periods, partially reflecting the 636 points (including above) representing 125 vessels reported transiting from Europe to Eastern Canada. The majority of vessels were bulk/general cargo (42%), container ships (34%) and tankers (11%). Other vessels were tugs, lift vessels and supply ships.

South of 49°N, bulk cargo vessels, some with origins in the Mediterranean account for the high-value ballast exchange endpoints between 40°N and 42°N latitude in the mid-Atlantic. The 123 points representing 35 vessels transiting from Spain and Mediterranean ports. The majority of traffic is bound for Halifax (37%) and Laurentian ports (63%). Vessel types were 62% container ships, 23% bulk/general cargo and 14% tankers.

The traffic pattern for the mid-Atlantic for July-August suggests vessels in the above grouping (and points north) has two routes for approaching Eastern Canada: the Strait of Belle Isle and the Gulf of St. Lawrence. The traffic has noticeably shifted northwards during the interval, nearer the most eastward demarcation of the 2000 metre contour.

The high-value exchange endpoint activity reported off Nova Scotia within the 200-Mile Limit shows nearly adjacent non-symmetric 9,325+ areas varying from 50 to 100 kilometres along the Nova Scotian coastline between Cape Sable and Canso (Figure 9a). Numerous vessels account for each high-value area. Southeast of Cape Sable, eleven tankers report exchange endpoints, with the same tanker (IMO# 9111632) reporting exchange at this location over five voyages during the bi-monthly interval. Departure is from Bayway NJ and Riverhead, USA, bound for Whiffen Head.

Twelve endpoints representing 10 tanker exchange endpoints comprise the larger high-value area to the north, along the coastline. The tankers are destined for Whiffen Head and Come By Chance, from New England states. The mean volume exchanged at the endpoints was 16,832 cbm. The high-value area north of this area is east of Canso. Three tankers report average endpoint of exchange as 14,614 cbm. An overlay of the ship tracks GIS layer shows many points in each high-value areas to be along the same ship track.

The ship track overlay also reveals 63 vessels crossing over the EEZ reporting ballast exchange endpoints in US territorial water and inside the EEZ. Twenty-four ship tracks are reported having the ship track origin first reported inside the Canadian 200-mile limit.

4.4.3.5. September-October Bi-monthly Period Potential Map

The bi-monthly interval September-October potential map shows the mid-Atlantic to have a similar single point, high-value ballast exchange endpoints with bi-monthly periods May-June and July-August; 47 high-value areas with an average of 18,245 cbm (Figure 10). Similar to previous periods, the distribution pattern of the high-value point derived areas shows fifteen bulk cargo vessels destined for Sept Iles and Port Cartier, QC within the +/−5 degrees of 49°N. The vessels had origins in the Netherlands (9 ships), United Kingdom/France/Belgium/Germany/Denmark (5 ships) and Spain (1 ships). The remaining ships were a supply and a container ship headed for Halifax.

Similar to the previous period, the data was less dispersed than earlier bi-monthly periods. Fewer ballast exchange endpoints were recorded (525) representing 103 vessels (including above) reported transiting from Europe to Eastern Canada. The majority of vessels were container ships (43.6%), bulk/general cargo (41.7%), and tankers (8%). Other vessels were passenger and supply ships.

South of 49°N, bulk cargo vessels, most with origins in the Mediterranean account for the 7 high-value ballast exchange endpoints between 40°N and 42°N latitude in the mid-Atlantic; the mean value of exchange endpoint is 12,511 cbm.

The high-value exchange endpoint activity reported off Nova Scotia within the 200-Mile Limit shows two extensive non-symmetric 9,325+ zones lying off 40 to 80 kilometres) the Nova Scotian coastline between Cape Sable and Sheet Harbour, NS (Figure 10a). Similar to the previous bi-monthly period, numerous vessels account for each high-value area. The area paralleling the southeast coast reports 16 high-value points, average value 16,348 with range 1,193 to 38,804 cbm. The points represent 13 ballast water management reports to Transport Canada. Three vessels are type bulk cargo and 10 tanker voyages, with the same tanker (IMO# 9123192) reporting exchange at this location over four voyages and another tanker over three voyages, during the bi-monthly interval. Departure was from port Philadelphia/Trainer PA north to Portland, ME bound for Port Tupper and Whiffen Head.

The high-value area east of Halifax has four oil carriers averaging 12,222 cbm. An overlay of the ship tracks for the period indicate a number of the vessels reporting an exchange endpoint in this zone did the same in the other area previously discussed.

The ship track overlay also reveals 45 vessels crossing over the EEZ reporting ballast exchange endpoints in US territorial water and inside the EEZ. The number is fewer than report for the previous period. Sixteen ship tracks are reported having the ship track origin first reported inside the Canadian 200-mile limit.

4.4.3.6. November-December Bi-monthly Period Potential Map

The bi-monthly interval November-December potential map shows the mid-Atlantic to have a slightly similar pattern with bi-monthly periods January-February. This is reflected in the large isolated high-values areas, which make up 63% of the thirty-eight 9,325.2+ cbm ballast water exchange locations in the mid-Atlantic (Figure 11). The distribution pattern of the high-value point derived areas shows a percentage (26%) of high-value exchange endpoints at 60°N between longitudes -15°W and -46W. The areas represent six-bulk/general cargo vessels exchanging while transiting through the area destines for the Quebec north-shore - Sept Iles and Port Cartier. The number of areas (16 locations) reporting high-value endpoints within the +/−5 degrees of 49°N is less dense fewer than July-August and September-October. The exchange at the endpoints shows a range of 10,212 to 83,494 cbm, with a mean of 22,747 cbm. The eight vessels had origins in the Netherlands (5 ships), United Kingdom/France/Poland (3 ships).

Similar to the January-February, the data set was dispersed, with fewer ballast exchange endpoints recorded (306) representing 60 vessels (including above) reported transiting from Europe to Eastern Canada. The majority of vessels were bulk/general cargo (48%), container ships (38%), and tankers (6%). Other vessels were a supply ship and types unknown.

South of 49°N, bulk cargo vessels, most with origins in the Mediterranean account for the seven high-value ballast exchange endpoints between 40°N and 42°N latitude in the mid-Atlantic; the mean value of exchange endpoint is 13,529 cbm. In total thirty-seven were located in the geographic area. The majority of vessels were container ships (48.6%), bulk/general cargo (32.4%), and tankers (13.5%). Other vessels were types unknown.

The high-value exchange endpoint activity reported off Nova Scotia within the 200-Mile Limit shows eight 9,325+ zones lying off the Nova Scotian coastline between Cape Sable and Sheet Harbour, NS (Figure 11a). The areas can be grouped into two zones based on distance from the coastline. Three high-value areas are within 40-80 kilometres, each having more than one high-value point, except for the single point in the most northern anomaly off Sheet Harbour. The mean value for points was 14,958 cbm. The points represent three oil tankers from Portland, ME destined for Whiffen Head. One of the vessels (IMO# 9181534) reported exchange endpoints in the area over two voyages. The next area of high-value areas is 150 kilometres off the coast to the 200-Mile Limit. Of the five areas, two border /cross-over the EEZ off southwest Nova Scotia (comprised of nine points, mean -12,045 cbm), one is 150 kilometres east of Liverpool, NS (comprised of four points, mean - 14,118cbm) and two are located east of the 2000 metres isobath (one point 50,582 cbm and the other 16,757 cbm). The former two areas report six tanker and three bulk cargo voyages responsible for the high-value areas. Of the tanker voyages, one tanker made four of the six transits; destinations were Pt. Tupper and Whiffen Head, with last ports Bayway, NJ and Trainer, PA. The two high-value zones east of the 2000 isobath were locations where vessels reported all tanks exchanged at a single location. Both tankers were bound for Whiffen Head and Come By Chance from New York, NY and Philadelphia, PA.

The ship track overlay also reveals 50 vessels crossing over the EEZ reporting ballast exchange endpoints in US territorial water and inside the EEZ; an 11% increase compared to the previous period. Fourteen ship tracks are reported having the ship track origin first reported inside the Canadian 200-mile limit.

In comparison to September-October bi-monthly period, November-December potential maps show the largest high-value areas. A comparison of all the bi-monthly periods in one image is shown in Figure 12.

4.4.3.7. Bi-monthly Period Potential Map Area Analysis

The areas generated by the model reflect the aggregate point locations, the model parameters and the ballast water exchange endpoint volume attribute information. The intervals in the table (Table 11.) are Class 1 - 0.0-2331.3 cbm, Class 2 - 2331.3-4662.6 cbm, Class 3 - 4662.6-6,993.9 cbm, Class 4 - 6,993.0-9,325.2, and Class 5 - 9,325.2+ cbm. The source of the area summary data was the potential map for each bi-monthly period.

Bi-month Period	January-February	March-April	May-June	July-August	September - October	November December
	(km^2)	(km^2)	(km^2)	(km^2)	(km^2)	(km^2)
Class						
1	2,651,453	2,499,327	2,656,236	2,722,593	2,496,485	2,103,716
2	492,0707	488,482	726,082	750,991	563,609	663,909
3	119,962	268,420	327,006	349,988.	334,977	382,470
4	44,039	112,124	139,690	257,592	193,825	232,949
5	189,973	372,639	421,328	400,936	570,650	472,010
Total Area	3,517,026	3,769,755	4,343,675	4,548,328	4,192,892	3,870,666

Table 11. Bi-monthly summation of potential map areas, classified by ballast water exchange endpoints volumes. area

The above table shows Classes 2 (2331.3 - 4662.6 cbm) through Class 5 (9325+ cbm) area representations increasing from January-February to July-August. The increase reflects the increased traffic and the higher ballast water exchange endpoint volumes. The square kilometres area coverage of the fifth classification (9325+ cbm) decreased slightly in July-August, followed by the highest value reported (570,650 km^2) in September-October. The November-December period was higher than the preceding July-August interval, and less aggregate points (686) than previous bi-monthly periods.

5.0 VESSEL TRAFFIC AND SHIPPING PATTERNS ON THE EAST COAST OF CANADA, FOR THE YEAR 2002 SHIPPING SEASON

The ballast water management report database provided an opportunity to examine vessel traffic and shipping patterns and compare results with previous analysis[5,6] conducted using ECAREG data for years 1998 and 2000, supplied by the Eastern Canada Region - Traffic Services branch of Canadian Coast Guard.

In addition, the Transport Canada ballast water exchange 2002 data set permitted a tabulation of partial ballast conditions by vessels transiting into Eastern Canada, an attribute not clearly defined in the ECAREG data set.

5.1 Methodology of Analysis

The ballast water analysis for year 2002 follows the methodology used by Harvey et al (1999)[7]. The data used in the statistical analysis was the Ballast Water Management Report forms submitted to Marine Safety, Transport Canada during the year 2002 shipping season.

From previous database discussion, the Trip_Info and the Ballast_Water_History tables of the database contained the data from Sections 1. to Section 5 of the faxed Ballast Water Report forms. Data table parameters included the Vessel's IMO Number, Vessel Type, Vessel Gross Tonnage (GT), Total # of Ballast Tanks, Total # Tanks in Ballast, Number of Tanks Reported Exchanged, Number of Tanks Recorded Exchanged, # Tanks

[5] CEF Consulatnts Ltd, 2000. Vessel Traffic/Vessel Shipping Patterns on the East Coast of Canada.

[6] Marine Safety, Transport Canada, 2001. Vessel Traffic/Vessel Shipping Patterns on the East Coast of Canada 2000 Shipping Season.

[7] Harvey, M., M. Gilbert, D. Gauthier and D.M.Ried, 1999. A preliminary assessment of risks for the ballast water-mediated introduction of nonindiginous marine organisms in the Eustary and Gulf of St. Lawrence. Can. Tech. Rep. Fish. Aqat. Sci. 2268:x +56p.

Not Exchanged (where available, because of Report format), #Tanks Reported Discharged, #Tanks Recorded Discharged, Arrival Port, Arrival Date, Last Port and Next Port. The Trip_Info and the Ballast_Water_History data table was used for the shipping season statistical analysis.

The data set was restricted to vessels reporting the Last Port as foreign and vessels reporting ballast on board as full or partial, or carrying all cargo[8]. The full ballast condition existed for a vessel when the Report information reported where Total # of

Ballast Tanks - Total # Tanks in Ballast equaled zero or 1 tank in ballast. The one tank usually being a forepeak tank vessel to maintain maneuverability or ballast un-pumpables. Partial ballast reflected Total # of Ballast Tanks - Total # Tanks greater than 1 and in cargo equaled zero reported for Total # Tanks of Ballast.

In plots, null values were not included as the value distorted percentage in ballast condition.

Following the preparation format for the 2000 shipping study[6], the arrival ports were classified by ballast condition before being regrouped into four geographic areas corresponding to: Bay of Fundy and SW Nova Scotia having Yarmouth as its eastward limit (Area 1), mainland Nova Scotia and Cape Breton (Area II), Prince Edward Island, Gulf of St. Lawrence side of New Brunswick and Quebec, Saint Lawrence Basin and Great Likes (Area III) and the ports on the Island of Newfoundland (Area IV).

Only ports having greater than two vessels visiting the port were used. Ports in close proximity were grouped, such as Halifax-Dartmouth and Saint John-Canaport. To examine seasonal patterns, vessels were further categorized by vessel type and season: winter (January-March), spring (April-June), summer (July-August), and autumn (September-December). Lastly, vessels were classified by the country of their last port of call to determine the general transport routed between the Eastern Atlantic Canadian ports and other regions of the world.

5.2 Year 2002 Shipping Season Results Discussion

During the 2002 shipping season, 3,006 vessels departed foreign ports, including US ports outside the 200 nautical limit of the Exclusive Economic Zone (EEZ) limit, arriving at Canadian ports located on the east coast of Canada, St. Lawrence River, and Great Lakes (Figure 13). The number of ships arrived in year 2002 was less than the 5504 foreign vessels reported in 2000. Transport Canada advised the difference reflects that all vessels arriving from outside the Canada EEZ report to the Canadian Coast Guard. A number of these vessels have no ballast on board. The ships having no ballast would not submit an IMO-compliant Ballast Water Report Form to Transport Canada. Transport

[8] Fifty-nine vessels reporting null ballast activity included in data set.

Canada also advised, other submissions to Marine Safety could have been misplaced, and were not included in the project data set. Recognizing these conditions constrain the intended comparative analysis between the two databases; further comments comparing the ECAREG and the Ballast Water Report database will illustrate the differences in terms of what each reports and are not be interpreted as a true comparison.

During 2002, 3006 vessels transited into Eastern Canada destined for ports in Atlantic Canada, Quebec and Ontario. Of the total records, 73% (2135) visited 28 ports located in the Atlantic Region. The number of port arrivals is fewer than visited in 1998 (67) and 2000 (35).

Of the Atlantic provinces arrivals (2135 vessels) not all reported complete ballast water management information detailing full ballast, partial ballast or in cargo conditions. A total of 59 vessels reported null for Total # Tanks on Board and #Tanks in Ballast on board on the Report form. The 59 records were recorded as null contained other attribute information (vessel type, last port) that provided in ballast information. The records remained in the data set for the arrival and departure, vessel type, seasonal and origin of departure statistical compilation.

Of the 2135, the majority of vessels (55%) were destined for Area II. The primary arrival ports were Halifax (74%) and Pt. Tupper area (including Auld's Cove and Mulgrave) with 17% of arrivals. On a percentage basis Halifax had a higher share of foreign arrivals compared with years 1998 (49%) and 2000 (36%) ECAREG reporting. The shipping volume to Halifax, however, is lower than 1998 (1352 ships) and 2000 (1218), with 869 vessels reporting partial ballast (782), full ballast (54) or in cargo (33) conditions on board.

The Pt. Tupper area had 196 ship arrivals during 2002. This is an increase of 55% over 1998 (109) and a 35% (265) decrease over 2000 ECAREG reporting. Vessels arriving in the Pt. Tupper area during 2002 reported partial ballast (177), full ballast (10) and in cargo (9) conditions on board.

Geographic Area I was the arrival destination for 28% of vessels entering Atlantic Canada. A large number of vessels were destined for Saint John (493), Hantsport (100) and Bayside (23). The ballast water reporting data revealed 98.6% of vessel destined for Saint John, 100% destined for Hantsport and 91% destined for Bayside to be in partial ballast. Statistically, Area I was found to have less shipping volume than years 1998 (30%) and 2000 (37%). One factor contributing to fewer vessels was no records were reported for Yarmouth in the 2002 Ballast Water Management Report form data set. The port of Yarmouth contributed 344 arrivals to Area I in year 2000.

Other areas of importance for foreign arrivals were Come By Chance (85 ships) with 94% in partial or full ballast and 6% in cargo, Whiffen Head (93 ships) with 100% in partial or full ballast. Corner Brook (28 ships) with 100% in partial or full ballast. The number of arrivals for all Area IV ports are similar to the other geographic areas with in having fewer counts of vessels compared to years 1998 and 2000 ECAREG data. The one arrival reporting a large difference with year 2000 data was St. John's (21 ships) with 95% in partial or full ballast; St. John's reported 93 ships in 2000 ECAREG data.

Consistent with previous studies a number of smaller ports in all geographic areas make up a high percentage of port arrivals, including those in Newfoundland, Prince Edward Island and Nova Scotia. In Newfoundland, Botwood (14 ships) with 100% in partial ballast, Lower Cove (15 ships) with 60% in partial ballast and 40% in full ballast, Stephenville (6 ships), 100% in partial ballast, Argentia (18 ships) with 94% vessels in partial ballast and 6% full ballast, Marystown (2 ships) in partial ballast, Bay Roberts (23 ships), 91 % in partial ballast and 9% in full ballast. All ports reported fewer vessels than previous years of ECAREG data.

In Nova Scotia, Little Narrows (30 ships) reporting 97% in partial ballast and 3% in full ballast. The Little Narrows arrivals were lower than year 2000, which had 33 ships. Liverpool (17 ships) with 100% in partial ballast condition reported an increase of 41% over the 12 vessels arriving last year. Pictou (3 ships) with 100% in partial ballast reported a decrease of 80% in vessel traffic compared to the ECAREG data set. Shelburne (19 ships) with 78% in partial ballast and 12% in full ballast. The port of Shelburne indicates a 26% increase in traffic over year 2000. Pugwash (5 ships) with 100% in full ballast had no comparative data from previous years.

In the Gulf basin, New Brunswick and Prince Edward Island, Area III ports Belledune (25 ships) with 20 in partial ballast, 4 in full ballast and 1 in cargo. The vessel arrivals for this port decreased 35% from year 2000, as it did for Dalhousie (52% decrease with 22 ships) with 73% in partial ballast, 4% in full ballast and 23% in cargo.

The Prince Edward Island ports Charlottetown (4 ship) reported 75% in partial and 25% full ballast and Summerside (3 ships) with 66% in full ballast and 33% in cargo. The Prince Edward Island port showed similar decreased port arrivals than year 2000 (13 ships and 6 ships respectively).

For comparison of port arrivals and percentage ballast condition with previous years ECAREG data results were tabulated (Table 12).

Area	Port	Arrival 1998	% in ballast	Arrival 2000	% in ballast	Arrival 2002	% in ballast[9]
1	Bayside			48	65	23	100
1	Hantsport			119	100	100	100
1	Saint John			534	49	486	98.6
2	Aulds Cove			N/A	N/A	20	87
2	Halifax			1215	13	836	96.2
2	L.Narrows			33	100	30	100
2	Liverpool			12	83	17	100
2	Mulgrave			78	63	3	100
2	Pictou			15	88	3	100
2	Pt. Tupper	109	66	137	69	164	96.5
2	P.Hawkesb.			50	80	N/A	N/A
2	Pugwash			N/A	N/A	5	100
2	Sheet Hbr.			15	46	11	100
2	Shelburne			37	3	19	100
2	Sydney			6	50	17	74
2	Yarmouth			344	0	N/A	N/A
3	Charlott'n			13	61	4	100
3	Summerside			6	75	2	67
3	Souris			3	100	N/A	N/A
3	Belledune			57	37	24	96
3	Dalhousie			42	38	17	77
3	Magd. Islds			N/A	N/A	5	100
3	New Castle			8	0	N/A	N/A
4	Argentia			36	11	18	100
4	B.Roberts			34	9	5	83
4	Botwood			27	93	14	100
4	Bull Arm			13	8	N/A	N/A
4	CB Chance			139	85	80	94
4	Concptn Bay			15	80	N/A	N/A
4	C. Brook	113	55	58	47	28	100
4	Hbr. Grace			16	56	N/A	N/A
4	Holyrood			13	0	N/A	N/A
4	Lower Cove			19	100	15	100
4	Marystown			5	0	2	100
4	St. John's			93	20	21	95
4	Stephenville			21	85	6	100
4	WhiffenHead			52	100	93	100

Table 12. Atlantic Canadian arrival ports for shipping years 1998, 2000 and 2002, with percentage of ships in ballast.

[9] Includes partial and full ballast conditions; in cargo vessels not included.

Figure 14 illustrates the percentage partial and full ballast activity by vessels entering Eastern Canada. The data presented includes ballast activity for Quebec and Ontario (the complete 3006 record data set).

5.2.1 Shipping Season Vessel Types

The vessel type data was standardized to six vessel types including Bulk, Tanker, Container, General Cargo, Passenger and Other vessels, which included heavy lift, tugs, seismic and other service vessels. A lookup table exhibiting all vessel type descriptions and classification scheme was developed (Appendix A).

The vessel type data results included all ports (3006, including Quebec and Ontario) in Eastern Canada.

The data indicated the highest percentage (35.76%) of marine traffic entering Eastern Canada was container ships. Areas II (656 ships, mainly the port of Halifax) and Area III (305 ships, mainly the port of Montreal, and St. Lawrence ports) accounted for the higher percentage of container ships.

Tanker traffic entering Eastern Canada was the second highest vessel type with 28% of vessels. Areas I (350 ships, mainly Saint John), Area II (209 ships, mainly Halifax and Pt. Tupper) and Area IV (185 ships, mainly Come By Chance and Whiffen Head) made up the group.

The distribution of bulk carriers was the third highest group with 22.65% of vessels. Areas with high bulk cargo traffic included Areas III (314 ships, mainly Quebec ports of Sept Iles, Port Cartier, Montreal, Quebec City and other upper St. Lawrence ports), Area II (198 ships, mainly Halifax, Pt. Tupper, Little Narrows, Auld's Cove, Sheet Harbour and Liverpool) and Area I (148 ships, mainly Hantsport, Bayside and Saint John).

General cargo ship entering Eastern Canada totaled 248 vessels (8.28%). The vessel types were highest in Area III (119 ships, mostly Quebec ports and lesser, Belledune and Dalhousie), Area II (60 ships, mainly Halifax, Shelburne, Sheet Harbour, Sydney ports). Area I and Area IV contributed less than 15% general cargo traffic for year 2002, respectively.

The summaries by the four geographic areas by vessel type are contained in Table 13.

Area	Vessel Types						
No.	Bulk	Tanker	Container	General	Passenger	Other	Total
I	148	350	71	36	16	12	633
II	198	209	656	68	48	24	1203
III	314	94	305	111	7	43	874
IV	21	185	43	34	8	5	296
Total	681	838	1075	249	79	84	3006

Table 13. Vessels entering Eastern Canada in year 2000, by vessel type.

The data in the above table is shown in Figure 15.

A filter to remove the St. Lawrence River area influence on the Area III resulted in 92.5% of the data being Quebec ports traffic, leaving 66 arrivals to the New Brunswick and Prince Edward Island ports in Area III. Bulk cargo vessels (15 ships) visiting Belledune and Dalhousie, New Brunswick accounted for all arrivals except for one in Summerside. Similarly, 100% (8 ships) of tankers and container vessels (15 ships) in year 2002 landed in these two ports.

5.2.2 Seasonal Variation of Vessel Traffic

The Seasonal Variation of vessel traffic in the Eastern Canada areas provided results in Table 14.

Area	Seasonal Intervals				
No.	Spring	Summer	Fall	Winter	Total
I	151	179	146	157	633
II	308	319	300	276	1203
III	241	222	236	175	874
IV	71	81	89	55	296
Total	771	801	771	663	3006

Table 14. Quarterly seasonal variation in vessel traffic.

A graph of seasonal percentages (Figure 16.) reveals seasonal variation between geographic areas. In all areas, the patterns were slightly different. Area IV - Newfoundland shows the highest traffic in the fall seasonal (30.07%), compared to least port activity in winter (18.58%). Area I (28.28%) and Area II (26.51%) indicate the July-

September season as the dominant period for arrivals; however, in Area I the winter period (24.8%) reports the second highest volume while Area II reports spring with 25.60% of vessels in year 2002. Area II reports the winter (23.09%) to be a period of lesser activity similar, to Area IV. Area III - Laurentian (including Quebec and Ontario

ports) indicates highest volumes in spring (27.57%) and fall (26.88%). Least traffic in Area IV is in winter with 20.02% arrivals. The winter trend for Area IV was similar to the year 2000 result.

A further filtering of data by number of arrival by type in each season (Figure 17) revealed Fundy and Newfoundland have traffic dominated by tankers in all seasons, although the volume arriving in each area is different. Over eighty tankers arrived in Area I (mostly Saint John) during every season, while in Newfoundland tanker traffic was lowest in winter (31 vessels) and continued to increase in spring (45 ships) and summer (48 ships) to a high of 61 vessels reporting for the autumn.

The Laurentian and Scotian areas showed bulk cargo and container shipping dominate the port activities in these areas. Bulk cargo and container vessels were the most arrivals in Area III in all seasons. Arrivals in Laurentian were mainly ports such as Sept Iles, Port Cartier and the urban centres Quebec City and Montreal. Likewise, container ship arrivals were highest for all seasons in Area II, with Halifax receiving most of the traffic.

The tables below were plotted in Figure 17.

Area I	**Season**			
Type	Winter	Spring	Summer	Fall
Bulk	40	37	39	34
Tanker	84	88	87	88
Container	17	14	21	18
General	8	9	15	6
Pass. & other	8	3	17	0
Totals	157	151	179	146

Table 15. Area I season counts (633 total for all seasons) of ships arriving by vessel type.

Area II	**Season**			
Type	Winter	Spring	Summer	Fall
Bulk	39	51	52	56
Tanker	49	40	67	52
Container	171	179	150	155
General	11	22	16	20
Pass. & other	7	16	34	16
Totals	277	308	319	299

Table 16. Area II season counts (1203 total for all seasons) of ships arriving by vessel type.

Area III	**Season**			
Type	Winter	Spring	Summer	Fall
Bulk	59	87	77	91
Tanker	19	27	28	20
Container	63	70	78	75
General	26	46	26	38
Pass. & other	9	11	13	11
Totals	176	241	222	235

Table 17. Area III season counts (874 total for all seasons) of ships arriving by vessel type.

Area IV	**Season**			
Type	Winter	Spring	Summer	Fall
Bulk	3	6	7	5
Tanker	31	45	48	61
Container	15	10	6	12
General	5	8	10	11
Pass. & other	1	2	3	0
Totals	55	71	74	89

Table 18. Area IV season counts (296 total for all seasons) of ships arriving by vessel type.

5.2.3 Foreign Vessel Origins

The foreign vessel traffic into Canada's Eastern Economic Zone in 2002 originated from 66 countries located in North and South America, Europe, Asia and Africa. The majority of foreign traffic originated from the east coast of the United States, the west coast of Europe and northern South America and the Caribbean islands (Table 19). Other regions contributed 10 or less port arrivals, making up 67% of the departure points and only 133 arrivals. This trend is consistent with years 1998 and 2000 analysis.

The breakdown of vessel traffic in the four East Coast geographic areas of activity based on vessel origin shows the largest portion of total traffic to all Areas except Area III was from the United States with 53.35%. American tanker and bulk cargo vessels accounted for 92% of volume arriving in Area I, mainly in Saint John and Hantsport.

Area II had 49.04% of ships from America, mostly tankers from ports Philadelphia north to Searsport, ME; most of the container ships vessels in this percentage made port in Area II enroute to West Europe. The container traffic into Scotian from West Europe (35.83%) was mostly from United Kingdom, Spain, Netherlands and France. Italy was a large contributor to the 4.82% from the Mediterranean The Caribbean/Americas consisted of 5.82%, mainly bulk/general cargo and containers.

Area III had a different pattern with 54.69% of vessels being bulk and container ships from Western Europe ports, with most container traffic berthing at Montreal. Quebec City had an even ratio (50/50) of container/cargo to tanker vessels arriving. The majority of bulk vessels into Area IV from West Europe was destined for the Quebec north shore ports of Sept Iles, Port Cartier and Port Alfred. America accounted for 25.71% of arrivals in Laurentian area. The cargo/container traffic arriving mostly at ports between Matane and Montreal made up 76.8% of volume, with tankers 16 percent.

In Area IV, United States had 67.91% of arrivals, mainly tanker traffic from ports Jacksonville, FL north to Portland, ME, with the return voyages to the Eastern Seaboard. The traffic arriving from north Europe and west Europe was mostly bulk, general, multipurpose, container with fewer tankers.

Area	Departure Origin	Percent
United States	1,596 (53.09)	53.09
Caribbean, S. America	179 (5.95)	5.95
N. Europe	94 (3.13)	3.13
W. Europe	967 (32.17)	32.17
Mediterranean (includes M. East)	97 (3.23)	3.23
Africa	39 (1.30)	1.30
Asia	33 (1.10)	1.10
At sea	1 (0.03)	0.03

Table 19. The origins of vessels entering Eastern Canada from different areas of the world.

5.2.4 Origin of Ballast Water Destined for Eastern Canada

In addition to revealing the ballast condition of vessels entering Eastern Canadian ports, the Ballast Water Management Report provided information on the source of ballast and ballast exchange activities, and ballast water discharge.

The ballast water source was reported by vessels transiting into Eastern Canada from sixty- four countries and the open ocean, with more than one departure point from several countries. Sources were located in North and South America, Europe, Asia and Africa. Since vessels contained ballast water from various international ports, compilation was by the origin of ballast in individual tanks. Further, whether the source ballast water was exchanged while in transit to Eastern Canada was extracted. The data represented 14,542 ballast water source records from the Ballast_Water_History data table, reflecting 3006 voyages to Eastern Canada.

The ballast water information was grouped into similar groupings as the year 2000 study: North America, Central and South America, Caribbean, Europe (including Mediterranean countries), Africa, Asian and Middle East. (Appendix A)

The majority of the ballast water source in ships ballast tanks was the United States with 7177 (49.35%) tanks, representing 1131 vessels from 132 US ports. Of the 7177 tanks reported with ballast water, a total of 3373 (47%) tanks reported ballast exchanged enroute (in the open ocean) to Eastern Canada by 549 vessels. Conversely, 612 vessels did not exchange 3804 tanks. Thirty vessels reported tanks conducted exchange, while other ballast tanks onboard remained un-exchanged with original source ballast during the voyage to Eastern Canada.

Europe accounted for 2,663 (18.31%) of ballast water in ballast tanks; representing 549 vessels from 138 ports. Of the 2,663 tanks, 2419 (90.84%) tanks were exchanged enroute to Canada. Conversely, 87 vessels did not exchange 244 tanks. Twenty-nine vessels reported tanks conducted exchange, while other ballast tanks onboard remained un-exchanged with original source ballast during the voyage to Eastern Canada.

The open-ocean was reported as the ballast water source for 2125 tanks by 635 vessels, with 1009 tanks undergoing exchange as part of a ballast water management plan.

Ballast water sources from the Caribbean, Middle East, Africa, Asia and Canada totaled 935 tanks (6.43%). The percentage of tanks exchange for the group was 68.45% (640 tanks)

A portion of the data containing 1,642 records (11.29%) was ballast water source unknown or not provided.

A summary of the above discussion is shown in Table 20.

Area	# Tanks of Source Ballast Water	# Tank of Source Ballast Water Exchanged Enroute
United States	7,177 (49.35)	3,373 (47.00)
Canada	283 (1.95)	59 (20.85)
Caribbean, S. America	265 (1.82)	220 (83.01)
Europe (N., W., Mediter.)	2,663 (18.31)	2,419 (90.84)
Middle East	108 (0.74)	97 (89.81)
Africa	102 (0.74)	102 (100.00)
Asia	177 (1.22)	162 (91.52)
Open Ocean	2,125 (14.61)	1,009 (47.48)
Unknown/NULL	1,642 (11.29)	678 (41.29)

Table 20. Number of tanks of ballast water, by source, entering Eastern Canada in year 2002. The number of tanks exchanged enroute to Eastern Canada is shown the right column, percentage in parenthesis.

5.2.5 Ballast Condition of Vessels Entering Eastern Canada

The comparison of ballast condition by arrival port in the four geographic areas was examined earlier in Section 5.2. In Section 5.2, the data was reviewed in terms of the ballast condition being partial ballast, full ballast or in cargo. This section provides discussion on a percentage breakdown of the partial ballast condition of vessels destined for Eastern Canadian ports, by vessel origin.

5.2.5.1 Ballast Condition of Vessels Arriving at Area I Ports

American vessels accounted for 580 voyages to the ports of St. John, Bayside, Hantsport and other locations. Thirty-one American vessels (5.34%) reported full ballast, three ships (0.52%) with no ballast and 524 (90.35%) in partial ballast. For the vessels in partial ballast Table 21 shows 47.81% (261 ships) to be 75% or more in ballast approaching Area I.

Western Europe arrivals to Area I were 24 vessels. Twenty-one of twenty-nine vessels reported ballast, two full and 19 partial ballast. Ship with partial ballast greater than 50% were 11 container vessels, with origins in the United Kingdom and France. Vessel reporting less than 50% ballast were tankers (6) and container ships (2) from United Kingdom, France and Netherlands.

Arrivals from North Europe, Caribbean-South America, Mediterranean, Africa and Asia contribute a minor component of traffic and ballast water to Area I; most vessels arrived with less than 25% ballast.

A compilation of ballast conditions by area of origin for Area I is below.

Origin	Ship Count	Full Ballast 100%	No Ballast 0%	Partial Ballast >0 and <100%	No ballast Data
America	580	31 (5.34%)	3 (0.52)	524 (90.35%)	22 (3.79%)
West Europe	24	2 (8.3%)	2 (8.3%)	19 (79.17%)	1 (4.16%)
North Europe	16	1 (6.25%)	1 (6.25%)	14 (87.5%)	-
Carib. S.Amer.	9	1 (11.1%)	1 (11.1%)	4 (44.4%)	3 (33.3%)
Mediter.	2	-	-	2 (100%)	-
Africa	2	-	-	2 (100%)	-
Asia	-	-	-	-	-

Origin	Partial Ballast >0 and <= 25%	Partial Ballast >25% and <=50%	Partial Ballast >50% and <=75%	Partial Ballast >75% and <100%
America	29 (5.31%)	106 (19.41%)	128 (23.44%)	261 (47.80%)
West Europe	5 (26.32%	3 (15.78%)	8 (42.10%)	3 (15.78%)
North Europe	8 (57.14%)	5 (35.71%)	1 (7.14%)	-
Caribbean S. America	1 (25.0%)	1 (25.0%)	1 (25.0%)	1 (25.0%)
Mediterran.	2 (100%)	-	-	-
Africa	2 (100%)	-	-	-
Asia	-	-	-	-

Table 21. Ballast condition of vessels destined for Area I ports, with origin of departure.

5.2.5.2 Ballast Condition of Vessels arriving at Area II ports.

For Area II, American departures accounted for 590 arrivals. Fifty-five ships reported arriving in full ballast and seventeen with no ballast. Vessels in full ballast 26 (47%) were cargo, 16 (29.09%) containers and 13 (24%) tankers.

Sixty-five percent of vessels maintaining the no ballast condition were passenger vessels, with the remainder bulk cargo and tankers. Seven vessels did not report sufficient ballast data.

The percentages in partial ballast in Table 22 shows 34 (77%) vessels reporting >0 and <=25% partial ballast are passenger. Likewise, a similar majority of vessels (72.58%) are container ships in the >25 and <=50% and the >50-<=75% categories (58% container, 24% bulk cargo 24% and tankers below 15%). Most vessels (217 ships) have partial ballast between 75% and <100% on arrival; where bulk cargo vessels make up 36.86%, containers 33.17%, and tankers 28.11%.

The other major origin for vessels destined for Area II is Western Europe, with 446 vessels. Thirty vessels reported full ballast, the majority (22 ships) were car carriers or container ships from United Kingdom, Germany, Spain and France. The majority of traffic (377 vessels) was in partial ballast, with 267 of the ships (70.82%) in partial ballast being container ships. Of the 267 vessels, 199 (74.5%) arrived with greater than 50% ballast in tanks. Nine vessels reported no ballast on board; six of these ships were tankers and 3 bulk cargo.

Caribbean-South America (70 ships) and Mediterranean (51 ships) departure points account for less significant vessel traffic to Area II. Thirty-six vessels arrived from the Caribbean in partial ballast, with the majority (97%) of traffic bulk cargo or container. Five bulker vessels accounted for the seven ships arriving in full ballast. Conversely, 8 of the 13 vessels with zero ballast were bulk cargo ships; the five ships were tankers.

Of the vessels of Mediterranean origin arriving if Eastern Canada, 48 ships were partial ballast. Most vessels were container ships (39 ships) having partial ballast greater than 50 percent.

The Africa and Asian trade with Area II is below 15 ships visiting from each region; with at least half of vessels arriving with greater than 50 % partial ballast. The majority of vessels from these countries were bulk cargo (12 ships from Africa and Asia) and tanker (8 ships from Africa and Asia) traffic.

North Europe is another low traffic volume (20 vessels) for Area II. Sixteen ships arrived in partial ballast, with 56.25% (9 vessels) with partial ballast >0 and less than 25%. The common vessels types arriving in year 2002 were cargo (6 ships), tanker (5 ships) and container (3 ships).

A compilation of ballast conditions by area of origin for Area II is below (Table 22).

Origin	Ship Count	Full Ballast 100%	No Ballast 0%	Partial Ballast >0 and <100%	No ballast Data
America	590	55 (9.32%)	17 (2.8%)	511 (86.6%)	7 (1.18%)
West Europe	446	30 (6.73%)	9 (2.0%)	377 (84.5%)	30 (6.73%)
North Europe	20	-	2 (10.0)	16 (80.0%)	2 (10.0%)
Carib.- S.Amer.	70	7 (10.0%)	13 (18.5%)	36 (51.43%)	14 (20.0%)
Medit.	51	1 (1.96%)	-	48 (94.11%)	2 (3.92%)
Africa	14	-	4 (28.57%)	7 (50.0%)	3 (21.43%)
Asia	11	-	1 (9.09%)	9 (81.8%)	1 (9.09%)

Origin	Partial Ballast >0 and <= 25%	Partial Ballast >25% and <=50%	Partial Ballast >50% and <=75%	Partial Ballast >75% and <100%
America	34 (5.31%)	62 (19.41%)	198 (23.44%)	217 (47.80%)
W.Europe	33 (5.03%)	73 (19.36%)	150 (39.79%)	121 (32.09%)
North Europe	9 (56.25%)	1 (6.25%)	2 (12.5%)	4 (25.0%)
Carib. - S.America	1 (2.77%)	11 (30.55%)	10 (27.77%)	14 (38.88%)
Medit.	9 (18.75%)	-	15 (31.25%)	24 (50.0%)
Africa	4 (57.14%)	1 (14.28%)	-	2 (28.57%)
Asia	7 (77.7%)	1 (11.11%)	-	1 (11.11%)

Table 22. Ballast condition of vessels destined for Area II ports, with origin of departure.

5.2.5.3 Ballast Condition of Vessels Arriving at Area III Ports

In Area III, America departures accounted for 225 arrivals. Cargo ships accounted for 48% (14) of the 29 vessels arriving in full ballast and 75% (6) of vessels arriving with no ballast. The majority of vessels (112 -49.77%) arriving in Area III from America had greater than 50% partial ballast. Sixty-nine vessels were bulk carriers followed by tankers (17 ships) and container ships (25 ships).

Western Europe arrivals (463 vessels) to Area III were greater than United States voyages. Twenty-nine vessels reported full ballast and ten voyages reported no ballast on board. The number of vessels reporting partial ballast enroute was 392 ships (84.67%). The majority of vessels (239 ships) reported ballast less than 50 percentage. Of the 239 vessels, 181 were container ships, followed by 34 bulk cargo liners and 17 tankers. Vessels reporting greater than 50% partial ballast (143 ships) were bulk cargo (94), containers (42) and tankers (7).

The Caribbean-South American countries reported 89 visits to Area III ports in year 2002. Thirty-one vessels (includes 26 bulk cargo) reported no ballast enroute, mostly to St. Lawrence River ports. The majority of traffic (31 ships) had partial ballast less than 50 percent, with vessel types bulk cargo (24 ships) and tanker (7 ships); vessels having ballast greater than 50% were bulk cargo (7 ships) and containers (2 ships).

The origins North Europe (25 ships), Mediterranean (28 ships), Africa (22 ships) and Asia (22 ships) contributed little significant traffic volume to Area III. From these origins, more than 60% vessels reported partial ballast to be less than 50 percent of capacity. Vessel traffic in this group consisted of types cargo (43 ships), tankers (10 ships), and container (2 ships). A compilation of ballast conditions by area of origin for Area III is below (Table 23).

Origin	Ship Count	Full Ballast 100%	No Ballast 0%	Partial Ballast >0 and <100%	No ballast Data
America	225	29 (12.8%)	8 (3.5%)	158 (70.22%)	30 (13.33%)
West Europe	463	29 (6.36%)	10 (2.2%)	392 (84.67%)	32 (6.9%)
North Europe	25	2 (8.00%)	4 (16.0%)	19 (76.0%)	-
Carib. - S.Amer.	89	5 (56.18%)	31 34.8%)	44 (49.44%)	9 (10.11%)
Medit.	28	6 (21.43%)	3 (10.7%)	18 (64.28%)	2 (7.14%)
Africa	22	2 (9.09%)	5 (22.3%)	14 (63.63%)	1 (4.55%)
Asia	22	1 (4.55%)	4 (18.2%)	14 (63.63%)	3 (13.63%)

Origin	Partial Ballast >0 and <= 25%	Partial Ballast >25% and <=50%	Partial Ballast >50% and <=75%	Partial Ballast >75% and <100%
America	20 (12.65%)	26 (16.46%)	54 (34.18%)	58 (36.71%)
West Europe	108 (27.55%)	131 (33.41%)	70 (17.86%)	83 (21.17%)
North Europe	17 (89.47%)	1 (5.26%)	-	1 (5.26%)
Caribbean-S.America	23 (52.27%)	8 (18.18%)	7 (15.90%)	6 (13.63%)
Mediterrean	6 (33.33%)	3 (16.66%)	3 (16.66%)	6 (33.33%)
Africa	9 (64.28%)	1 (7.14%)	1 (7.14%)	3 (21.43%)
Asia	10 (71.43%)	2 (14.28%)	1 (7.14%)	1 (7.14%)

Figure 23. Ballast condition of vessels destined for Area III ports, with origin of departure.

5.2.5.4 Ballast Condition of Vessels Arriving at Area IV Ports

In Area IV, America departures accounted for 201 arrivals. Tankers accounted for 102 (70.83%) of the vessels in partial ballast (144), and 23 of the 30 ships in full ballast. The majority of these vessels had greater than 75% partial ballast, with 97 ships (95.09%) of the 102 reported.

Western Europe arrivals to Area IV were 34 vessels. Two vessels (one tanker, one bulk cargo) reported full ballast. Three ships (two tankers and one passenger) reported no ballast. Partial ballast accounted for 70.58% of total traffic, with less than 50% in ballast containing nine vessels of type tanker (4 ships), bulk cargo (1) and others (3). Vessels (15 ships) having greater than 50% partial ballast included container (8 ships), cargo (6 ships) and tankers (1).

North Europe reported similar visits (33 trips) as West Europe to Area IV. Twenty-seven vessels reported partial ballast on board, with the majority of vessels (21 ships) having greater than 50% ballast capacity. Vessel types in this group included containers (11 ships), bulk cargo (6 ships) and tanker/other vessels (4 ships).

The origins Caribbean (11 ships), Mediterranean (16 ships) and Africa (1 ship) account for little traffic to Newfoundland. The African vessel arrived in 100% ballast. The majority of vessels (18 ships) from the Caribbean and Mediterranean were in partial ballast; with greater than fifty percent (5 ships) of the Caribbean vessels having partial ballast greater than 50 percent, while the majority (9 ships) of Mediterranean vessels were less than 50% partial ballast. Six of these vessels were tankers.

No Asian traffic was reported to Area IV.

A compilation of ballast conditions by area of origin for Area IV is below (Table 24).

Origin	Ship Count	Full Ballast 100%	No Ballast 0%	Partial Ballast >0 and <100%	No ballast Data
America	201	30 (14.9%)	0 (0.0%)	144 (71.64%)	27 (13.33%)
West Europe	34	2 (6.66%)	3 (10.0%)	24 (80.0%)	5 (14.71%)
North Europe	33	1 (33.33%)	-	27 (81.81%)	5 (15.15%)
Carib.-S.Amer.	11	1 (9.09%)	2 (18.2%)	8 (72.72%)	-
Medit.	16	3 (18.75%)	2 (12.5%)	10 (62.5%)	1 (6.25%)
Africa	1	1 (100.0%)	-	-	-
Asia	-	-	-	-	-

Origin	Partial Ballast >0 and <= 25%	Partial Ballast >25% and <=50%	Partial Ballast >50% and <=75%	Partial Ballast >75% and <100%
America	3 (12.65%)	8 (16.46%)	22 (34.18%)	111 (36.71%)
West Europe	5 (20.83%)	4 (16.67%)	7 (29.16%)	8 (33.33%)
North Europe	1 (3.70%)	5 (18.51%)	9 (33.33%)	12 (44.44%)
Caribbean-S.America	2 (25.0%)	1 (12.5%)	4 (50.0%)	1 (12.5%)
Mediterrean	7 (70.0%)	2 (20.0%)	1 (10.0%)	-
Africa	-	-	-	-
Asia	-	-	-	-

Figure 24. Ballast condition of vessels destined for Area IV ports, with departure origin.

5.2.6 Ballast Water Discharge

A slight majority of records (51.23%) recording ballast water tank discharge in the Ballast_Water_History database (14,542 records), showed no data recorded (null). The 7525 records reporting discharge from ballast water tanks represented 1226 voyages into Eastern Canada; more than one location was recorded for discharge by 164 of the 1226 voyages. For example, vessels destined for Hantsport conducted discharge of tanks in the Bay of Fundy and at Hantsport, NS. Eighty-three vessels reported at sea discharge of 371 tanks. The summary of discharge locations in Eastern Canada is shown in Table 25.

Location of Discharge	#Vessels discharging in Port	Total #tanks discharged by vessels/ avg. volume per vessel (cbm)	#Vessels - no discharge in Port
St. John NB	280	1447 / 2,254	4
Belledune, Dalhousie, NB	20	121 / 588.02	2
Bay of Fundy	73	661 / 517.95	nil
Bayside, NB	7	84 / 1,417.02	1
Botwood, NL	12	12 / 566.77	nil
Come By Chance, NL	14	12 / 5,064.99	2
Corner Brook, NL	12	36 / 559.01	1
Lower Cove, NL	12	105 / 1,767.20	1
St. John's, NL	7	26 / 180.69	2
Stephenville, NL	12	55 / 548.79	nil
Whiffen Head, NL	69	360 / 10,041.43	2
Auld's Cove, NS	15	121 / 3,227.65	nil
Bras D'Or Lakes, NS	4	46 / 377.25	nil
Cabot Strait, NS	1	10/ 10	nil
Halifax, NS	159	778 / 1,185.90	3
Hantsport, NS	76	306 / 412.68	nil
Little Narrows, NS	4	28 / 954.84	nil
Liverpool, NS	5	19 / 1282.94	1
Pictou, NS	3	19 / 356.42	nil
Pt. Tupper, NS	101	517 / 6536.85	nil
Pugwash, NS	1	4 / 438.5	nil
Sheet Hbr, NS	8	54 / 3441.64	nil
Shelburne, NS	-	-	1
Sydney, NS	7	24 / 924.17	nil
QC, ON ports			11
At sea	85	371 / 775.18	nil

Table 25. Summary of Eastern Canadian ports (includes open ocean) receiving ballast water discharge.

6.0 PROJECT SUMMARY

Ballast Water Reporting Forms submitted to Marine Safety, Transport Canada, Dartmouth, Nova Scotia provided 3006 records for foreign marine vessels entering Eastern Canada during year 2002. In addition to each record providing information on marine vessel description, departure-arrival data and ballast description (number of tanks, vessel capacity), the Reporting Form provided information on vessel ballast source water, latitude-longitude positions for ballast water exchange volumes and endpoint locations, and ballast discharge.

The Report Form information was entered into a relational database consisting of two tables - Trip_Info and Ballast_Water_History, in MS Access database software. The geo-reference ballast water exchange endpoints (with volume exchanged attribute) were imported to the geographical information system spatial environment for thematic vessel movement track creation and potential surface modeling (inverse distance weighing and interpolation). The same data set was statistically compiled to evaluate year 2002 shipping patterns and compare the data with previous studies, from years 1998 and 2000.

The creation of the vessel tracks was completed using a MapInfo GIS programming software application that joined together reported endpoints as line to represent the vessels transect approaching Eastern Canada. The lines created had "attached" the ballast water volume exchanged reported at the endpoint, permitting thematic colouring. The lines represent joined endpoints of exchange; where the exchange commenced was not provided on the Ballast Water Reporting Form. Notwithstanding, the endpoints provide the vessel's course while approaching Eastern Canada. The tracks clearly delineated preferred ballast water exchange corridors approaching Eastern from America, Europe (North and Western) and the Mediterranean for year 2002.

An aggregated form of the same point data used to produce the tracks was applied to develop seasonal potential surface maps, using parameter settings best suited to the data character and distribution. High-values areas were shown along the southwest coast of Nova Scotia and paralleling the 2000 metre isobath, inside the Canadian Eastern Economic Zone. In some instances, ballast water exchange endpoint values responsible for the high-value areas, over time, were found to be related to the same vessel. The July-August and September-October bi-monthly intervals reflected the highest exchange activity, off the Nova Scotian coastline.

Statistically the database provided some comparative statistics to the previous years (1998 and 2000), ECAREG-based studies. The data set, though smaller in number of records because of the data collection formats and mandate differences between Transport Canada and Canadian Coast Guard, provided basically consistent results. The database provided new information on the types of vessels entering the for geographic regions by season; Area I - Tanker dominant all seasons, Area II - Container ships dominate all periods, Area III - Bulk/General Cargo and container vessels and Area IV -

Tankers dominate, with the heaviest period in the autumn. The data set allowed detailed discussion and compilation of the partial ballast condition of vessels entering Eastern Canada. Parsing the data by geographic region indicated, a significant number of vessels (> 70%) destined for Eastern ports have partial ballast on board.

The data has been prepared to permit future study of ballast issues. A detailed examination of American vessel traffic approaching the Atlantic Region is suggested. With America contributing 53% of total vessel traffic to Eastern Canada and traffic volume as high as 92% destined for geographic Area I is from the United States. The data can be queried to determine which American state is contributing the largest portion of ballast exchange activity, with source water originating in 132 American ports.

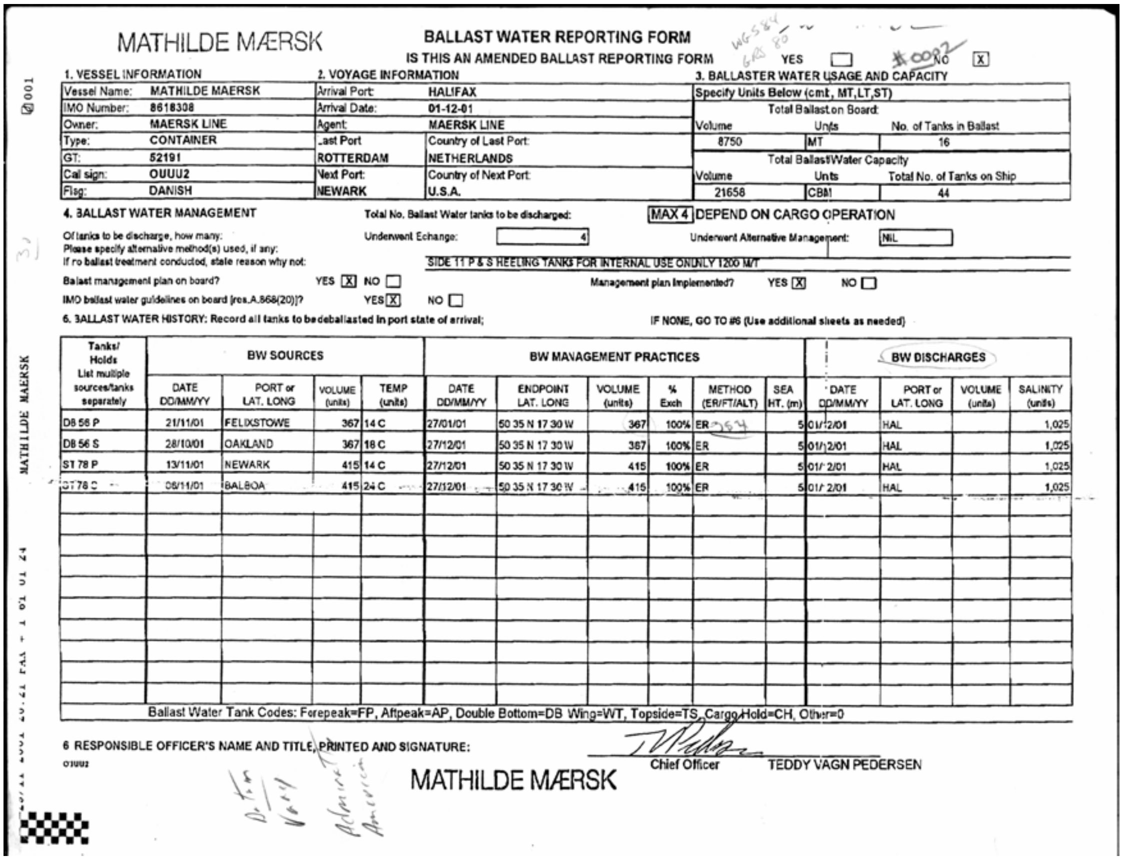
7.0 ACKNOWLEDGEMENTS

I would like to thank Mike Balaban, Marine Safety, Transport Canada for input during the project and for recognizing geographical information systems (GIS) as an analytical tool suited to examining geo-referenced ballast water exchange endpoint data.

I would also like to thank Geoff Howell and staff, Interpretation and Integration, Environment Canada for access to SPANS modeling software.

Lastly, Paul Brodie, onboard ballast water management systems researcher, for providing better understanding of ballast water/cargo management aboard marine vessels.

8.0 FIGURES - PROJECT MAPS



MATHILDE MÆRSK

BALLAST WATER REPORTING FORM

IS THIS AN AMENDED BALLAST REPORTING FORM YES [ ] NO [X]

1. VESSEL INFORMATION		2. VOYAGE INFORMATION	
Vessel Name:	MATHILDE MAERSK	Arrival Port:	HALIFAX
IMO Number:	8618308	Arrival Date:	01-12-01
Owner:	MAERSK LINE	Agent:	MAERSK LINE
Type:	CONTAINER	Last Port	Country of Last Port:
GT:	52191	ROTTERDAM	NETHERLANDS
Cal sign:	OUUU2	Next Port:	Country of Next Port:
Flag:	DANISH	NEWARK	U.S.A.

3. BALLASTER WATER USAGE AND CAPACITY

Specify Units Below (cmt, MT,LT,ST)		
Total Ballast on Board		
Volume	Units	No. of Tanks in Ballast
8750	MT	16
Total Ballast Water Capacity		
Volume	Units	Total No. of Tanks on Ship
21658	CBM	44

4. BALLAST WATER MANAGEMENT

Total No. Ballast Water tanks to be discharged: MAX 4 DEPEND ON CARGO OPERATION

Of tanks to be discharge, how many: Underwent Echange: 4 Underwent Alternative Management: NIL

Please specify alternative method(s) used, if any:

If no ballast treatment conducted, state reason why not: SIDE 11 P & S HEELING TANKS FOR INTERNAL USE ONLY 1200 M/T

Ballast management plan on board? YES [X] NO [ ] Management plan implemented? YES [X] NO [ ]

IMO ballast water guidelines on board [res.A.868(20)]? YES [X] NO [ ]

6. BALLAST WATER HISTORY: Record all tanks to be deballasted in port state of arrival; IF NONE, GO TO #6 (Use additional sheets as needed)

Tanks/ Holds List multiple sources/tanks separately	BW SOURCES				BW MANAGEMENT PRACTICES						BW DISCHARGES			
	DATE DD/MM/YY	PORT or LAT. LONG	VOLUME (units)	TEMP (units)	DATE DD/MM/YY	ENDPOINT LAT. LONG	VOLUME (units)	% Exch	METHOD (ER/FT/ALT)	SEA HT. (m)	DATE DD/MM/YY	PORT or LAT. LONG	VOLUME (units)	SALINITY (units)
DB 56 P	21/11/01	FELIXSTOWE	367	14 C	27/01/01	50 35 N 17 30 W	367	100%	ER	5	01/12/01	HAL		1,025
DB 56 S	28/10/01	OAKLAND	367	18 C	27/12/01	50 35 N 17 30 W	367	100%	ER	5	01/12/01	HAL		1,025
ST 78 P	13/11/01	NEWARK	415	14 C	27/12/01	50 35 N 17 30 W	415	100%	ER	5	01/12/01	HAL		1,025
ST 78 S	08/11/01	BALBOA	415	24 C	27/12/01	50 35 N 17 30 W	415	100%	ER	5	01/12/01	HAL		1,025

Ballast Water Tank Codes: Forepeak=FP, Aftpeak=AP, Double Bottom=DB Wing=WT, Topside=TS, Cargo Hold=CH, Other=0

6 RESPONSIBLE OFFICER'S NAME AND TITLE, PRINTED AND SIGNATURE: Chief Officer TEDDY VAGN PEDERSEN

MATHILDE MÆRSK

Figure 1. Sample of typical Ballast Water Reporting Form submitted to Marine Safety, Transport Canada reporting marine vessel ballast management practices.

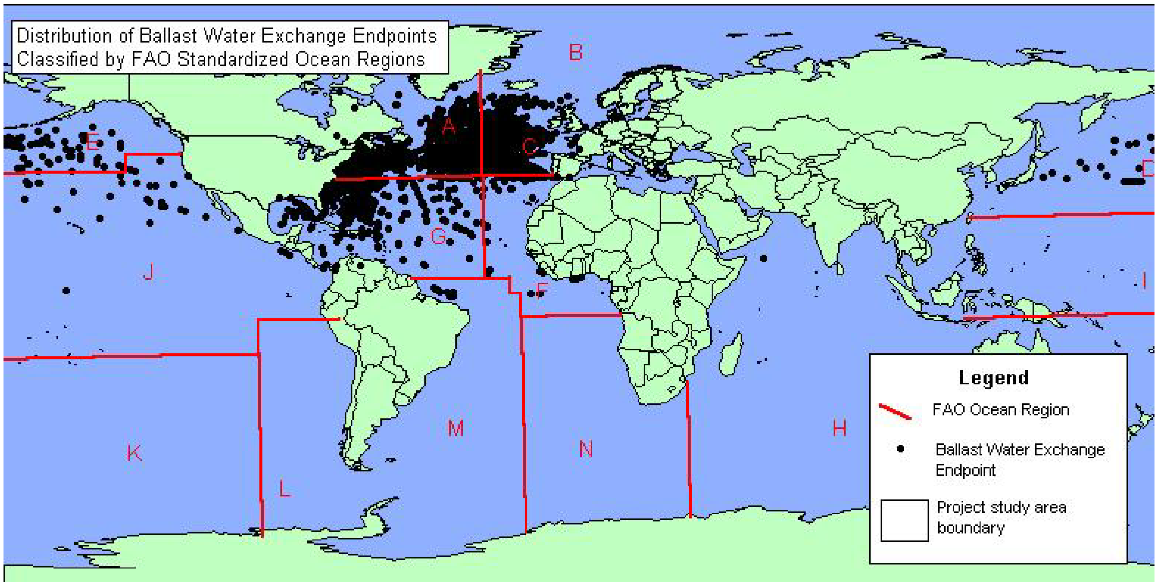


Figure 2. Ballast Water Exchange Endpoints reported on Ballast Water Management Report forms to Transport Canada for the year 2002, with FAO Ocean Regions overlay. Total points = 8308.

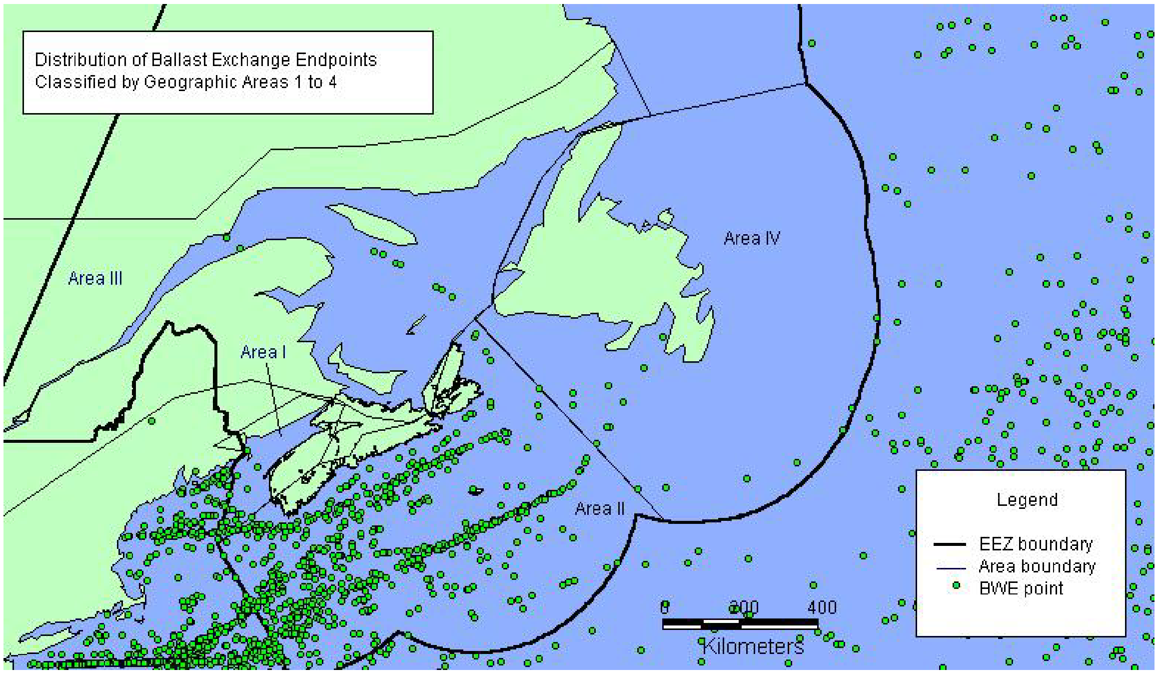


Figure 3. Distribution of ballast exchange endpoints within geographic areas 1 to 4, within the Canadian Eastern Economic Zone (EEZ), during year 2002.

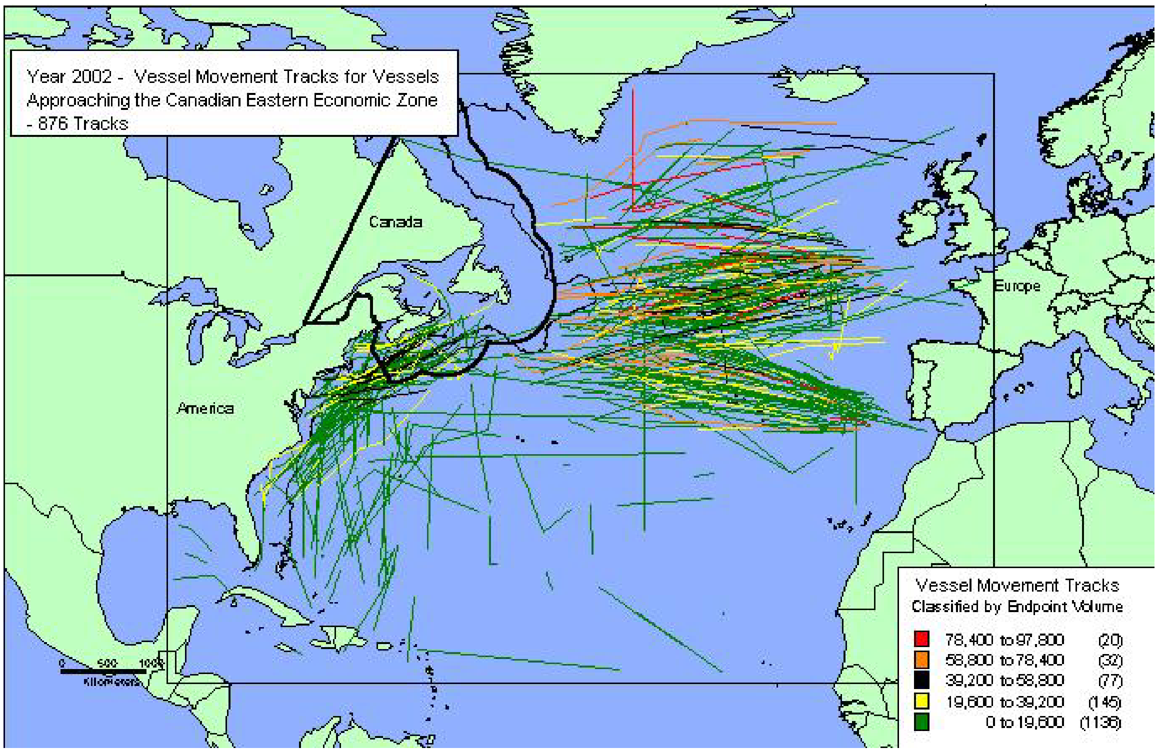


Figure 4. Vessel movement tracks for vessels approaching Eastern Canada during shipping season 2002.

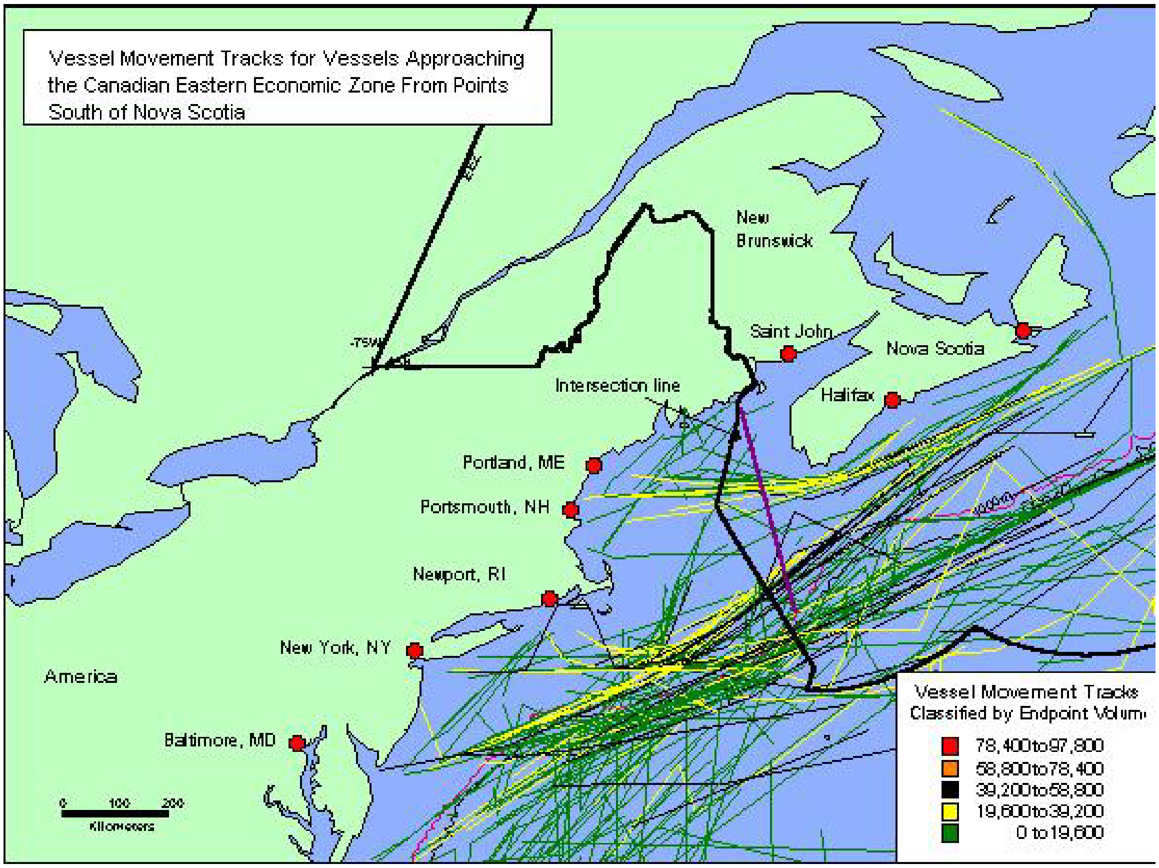


Figure 5. Vessel movement tracks for ships transiting into the Canadian Eastern Economic Zone (EEZ), south of Nova Scotia during year 2002.

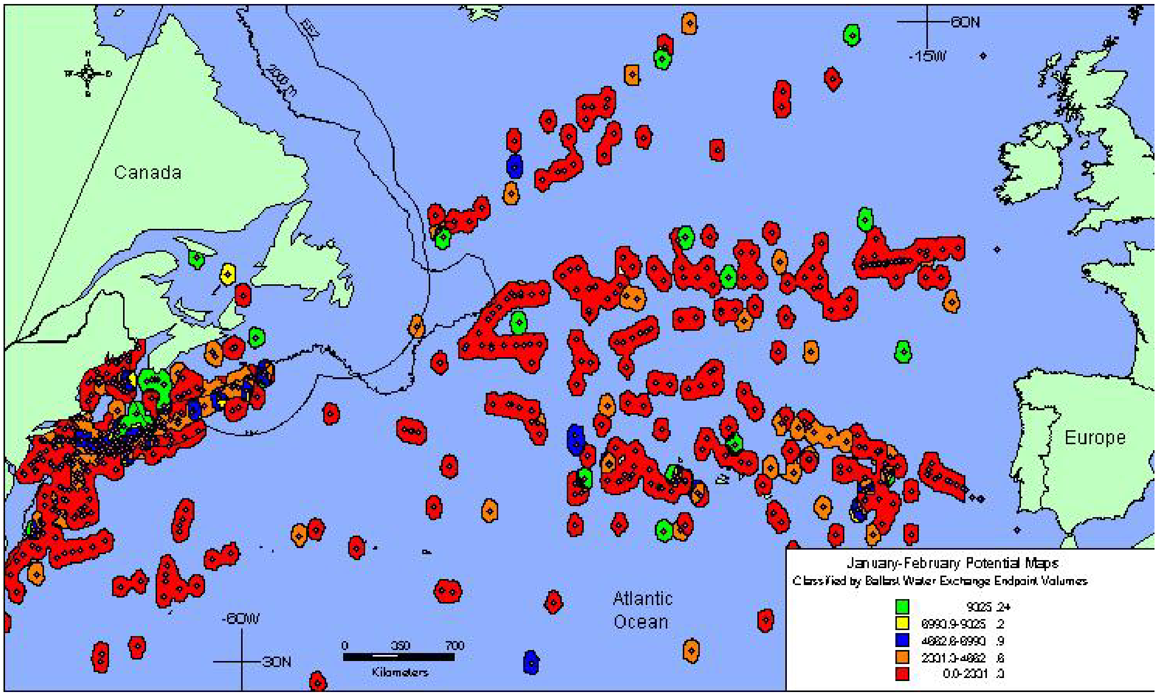


Figure 6. January-February potential surface map, with aggregated points.

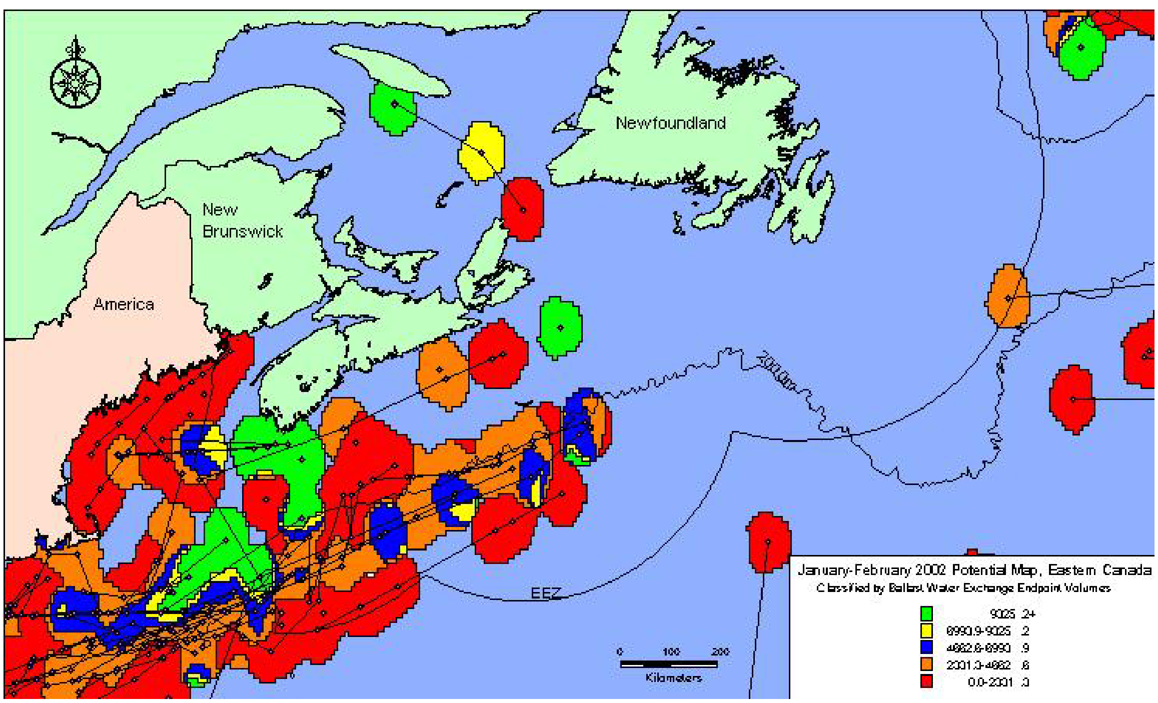


Figure 6a. Large scale view of January-February potential surface map in Eastern Canada, with aggregated points and vessel movements tracks.

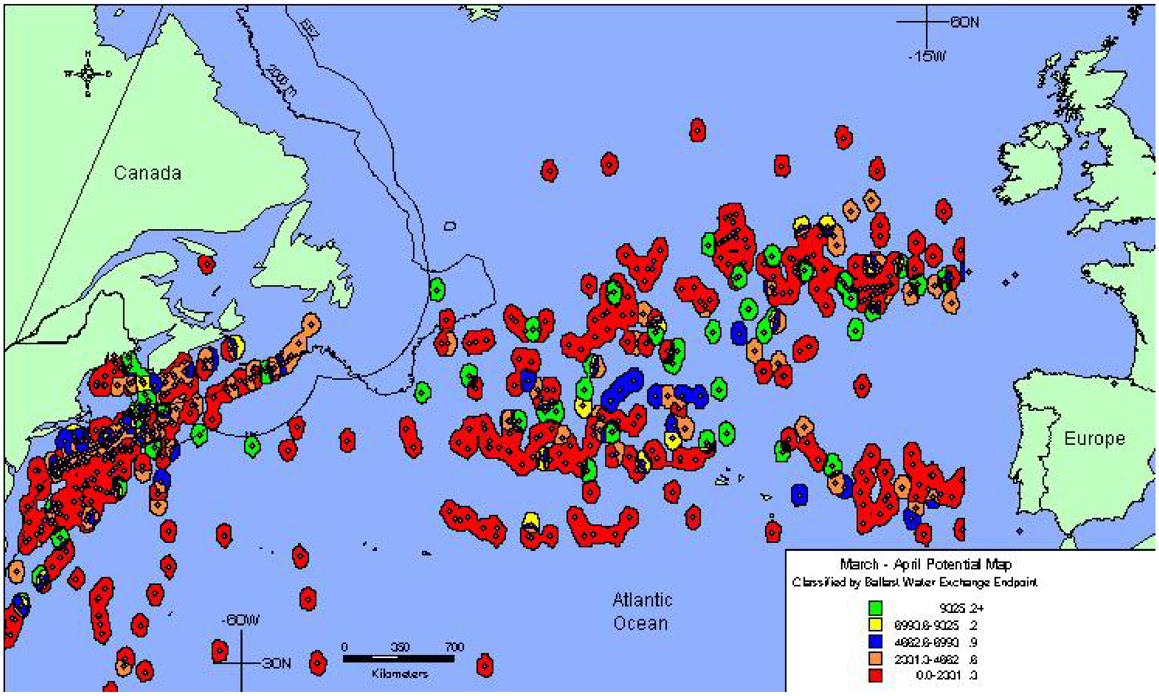


Figure 7. March-April potential surface map, with aggregated points.

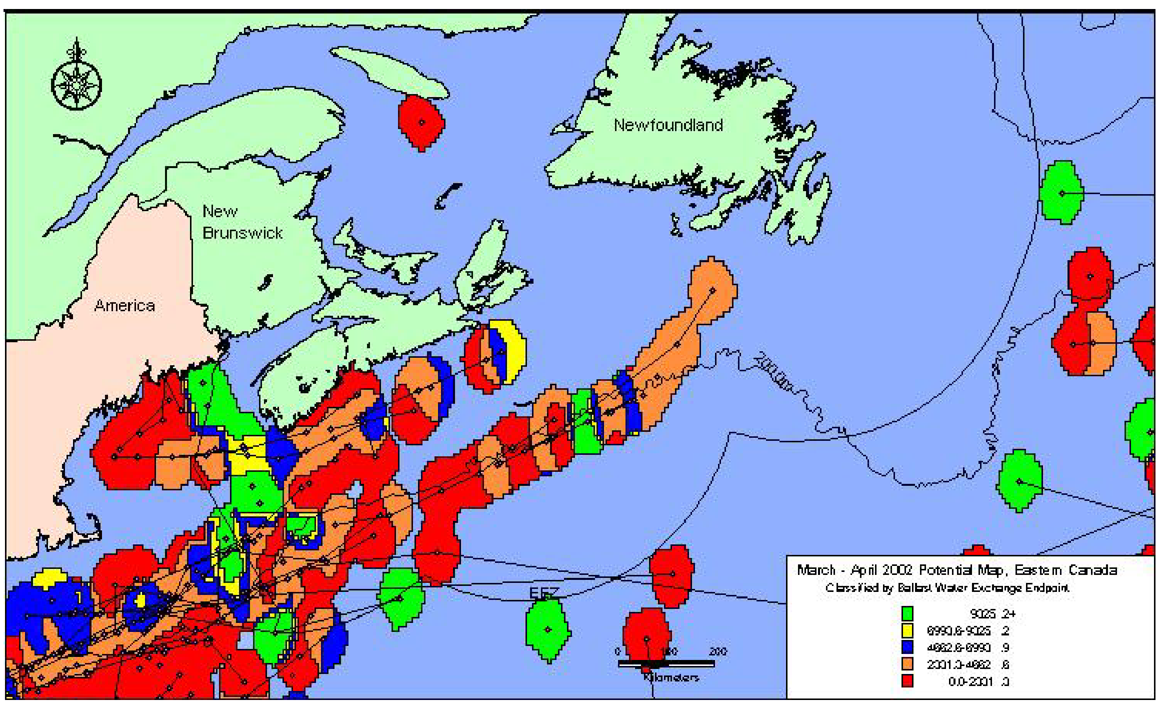


Figure 7a. Large scale view of March-April potential surface map in Eastern Canada, with aggregated points and vessel movements tracks.

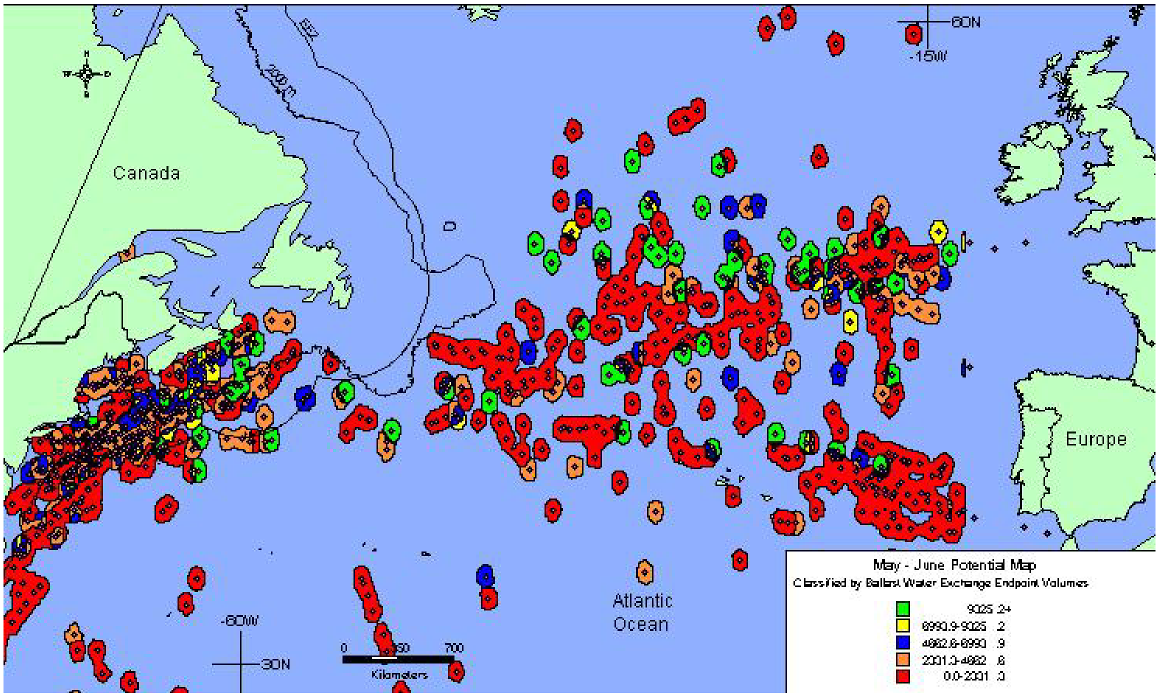


Figure 8. May-June potential surface map, with aggregated points.

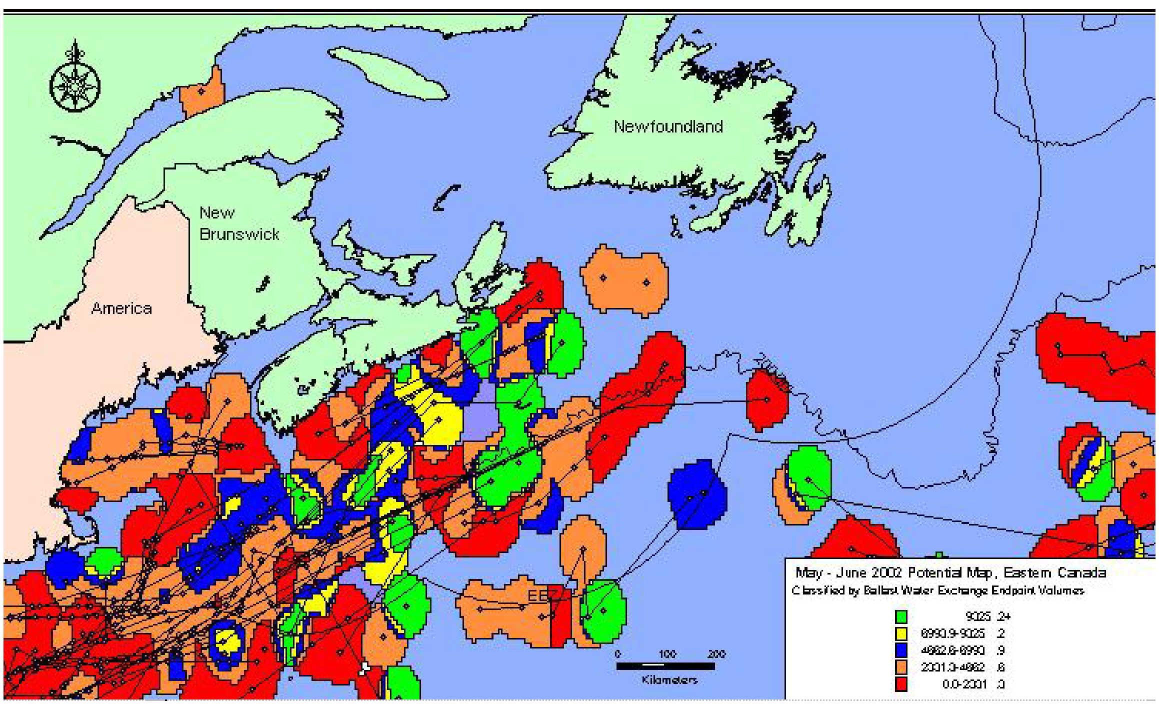


Figure 8a. Large scale view of May-June potential surface map in Eastern Canada,, with aggregated points and vessel movements tracks.

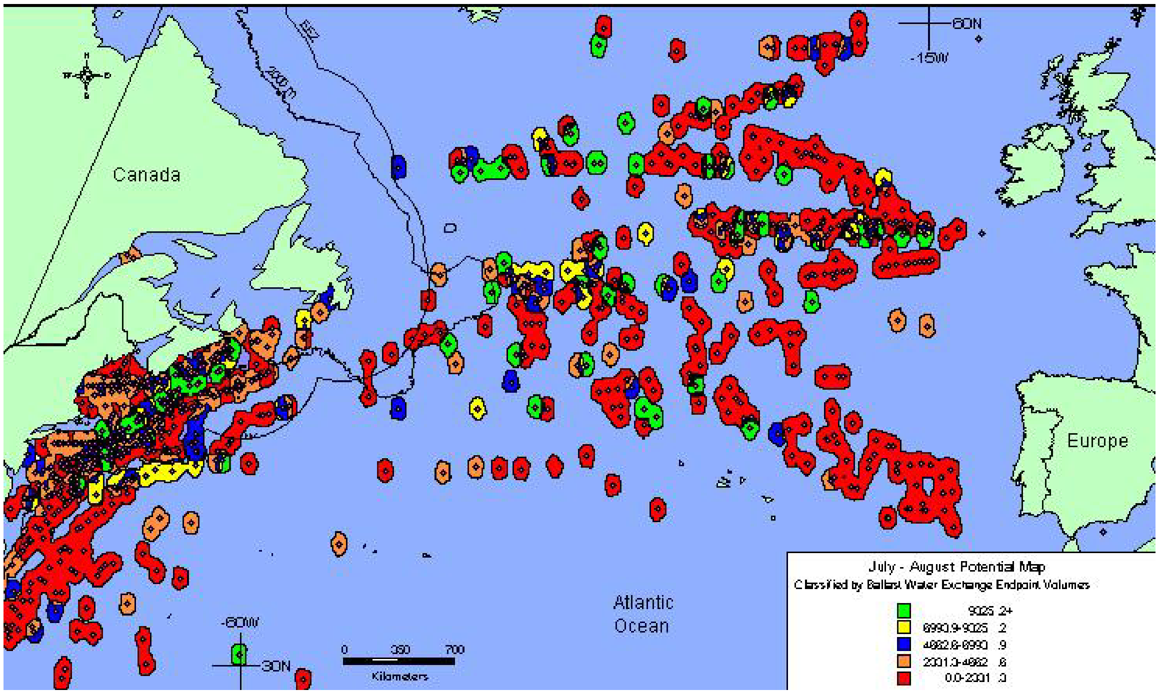


Figure 9. July-August potential surface map, with aggregated points.

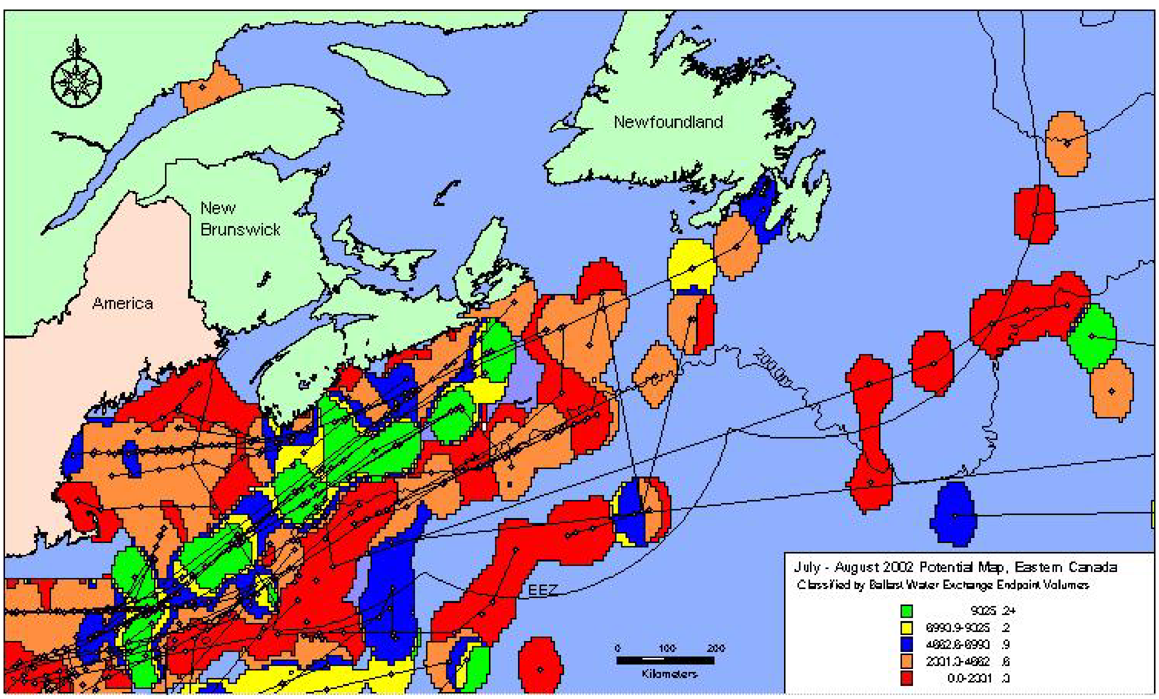


Figure 9a. Large scale view of July-August potential surface map in Eastern Canada,, with aggregated points and vessel movements tracks.

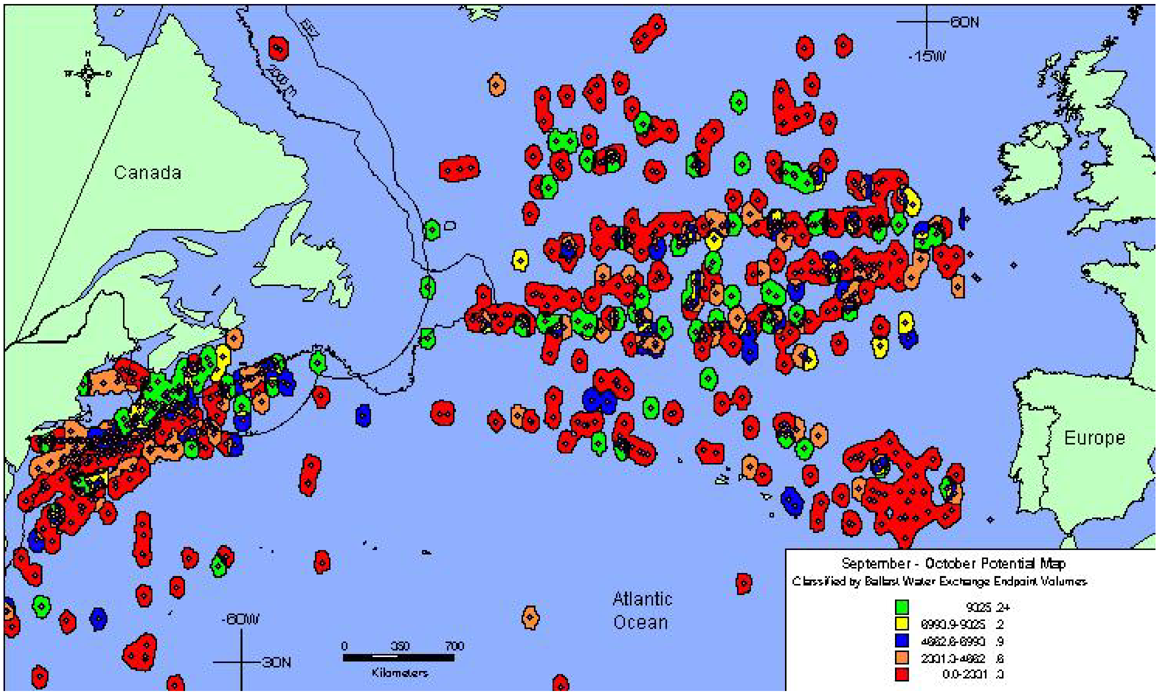


Figure 10. September-October potential surface map, with aggregated points.

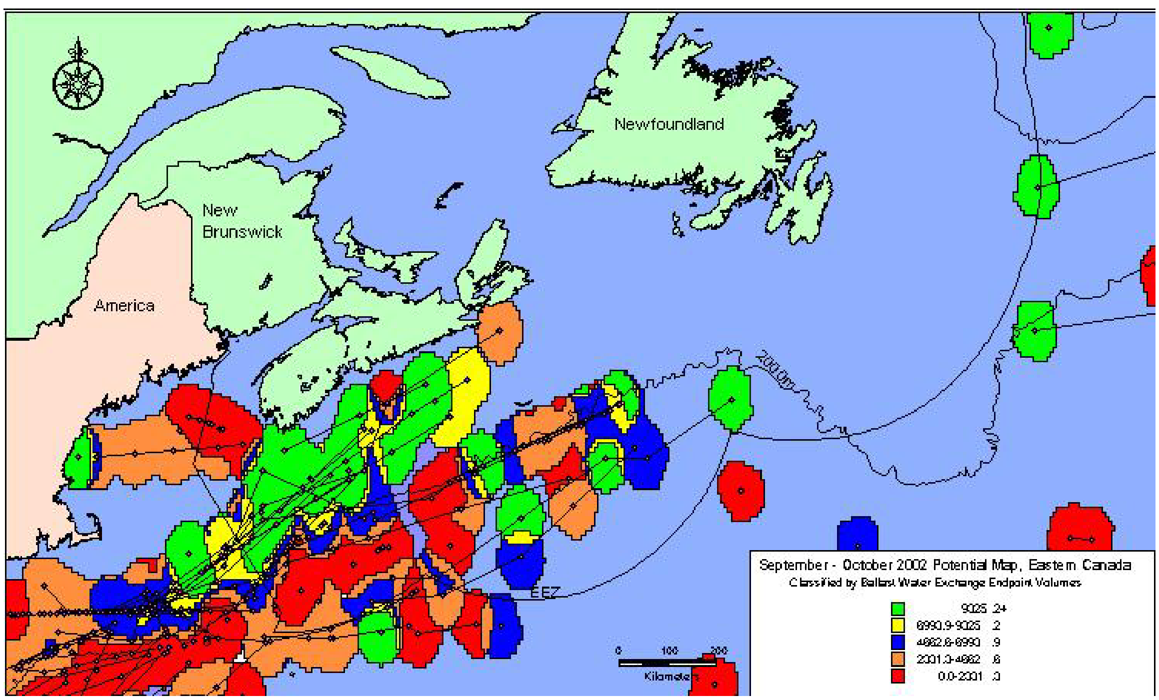


Figure 10a. Large scale view of September-October potential surface map in Eastern Canada, with aggregated points and vessel movements tracks.

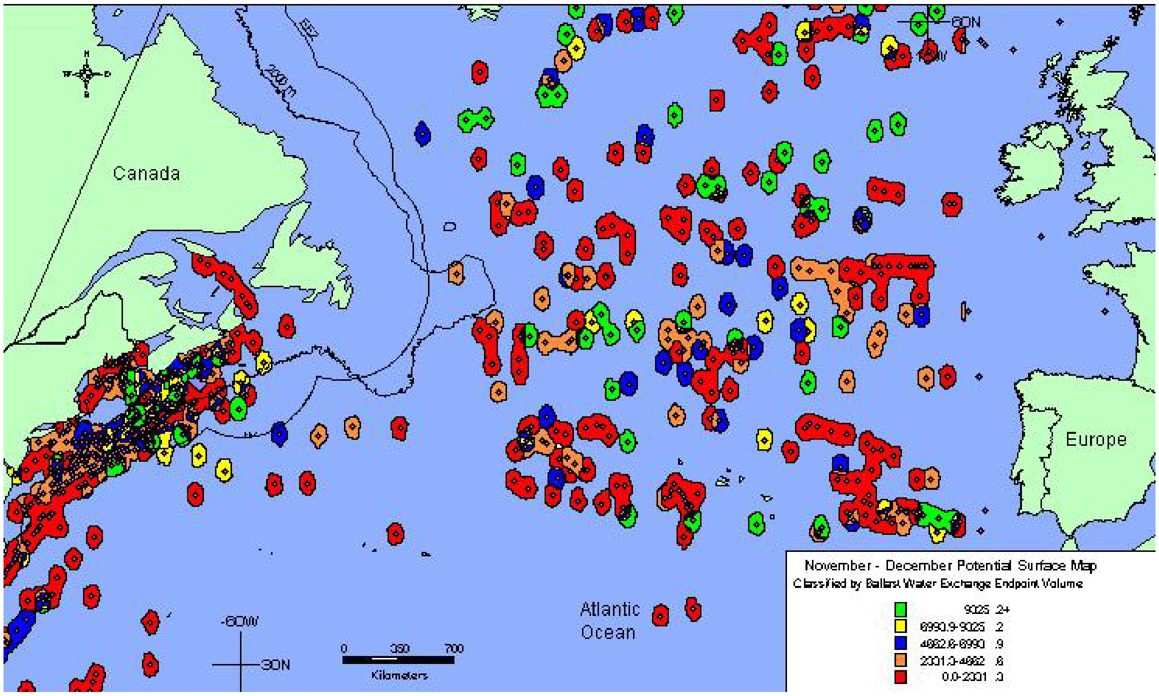


Figure 11. November-December potential surface map, with aggregated points.

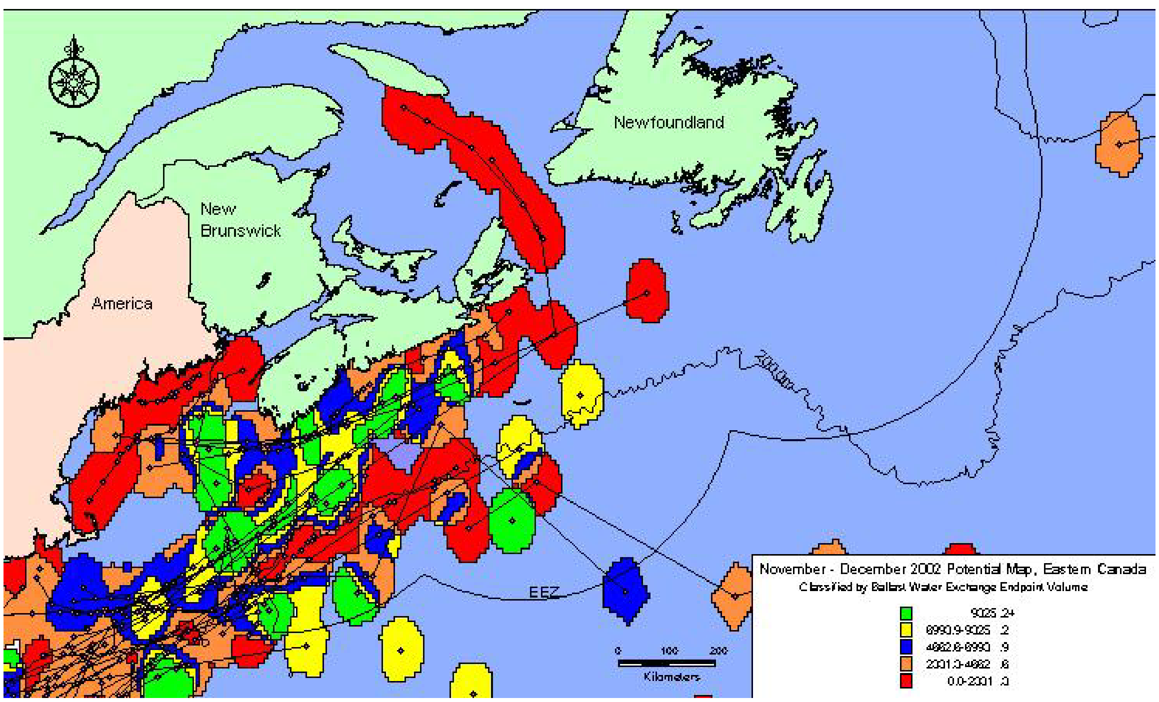


Figure 11a. Large scale view of November-December potential surface map in Eastern Canada, with aggregated points and vessel movements tracks.

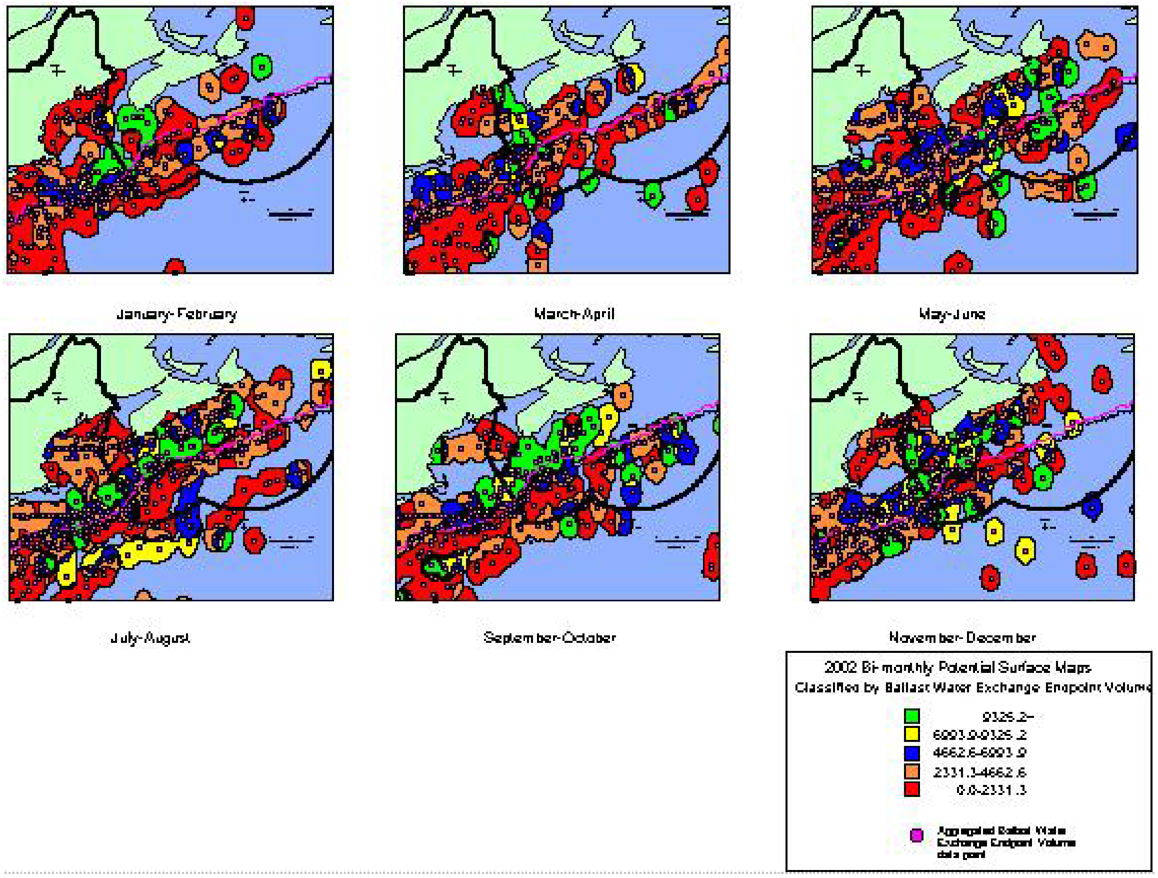


Figure 12. Summary figure illustrating January to December 2002 bi-monthly potential surface maps representing ballast water exchange endpoint volumes reported in the Canadian Eastern Economic Zone (off the coast of Nova Scotia) and along the US Eastern Seaboard.

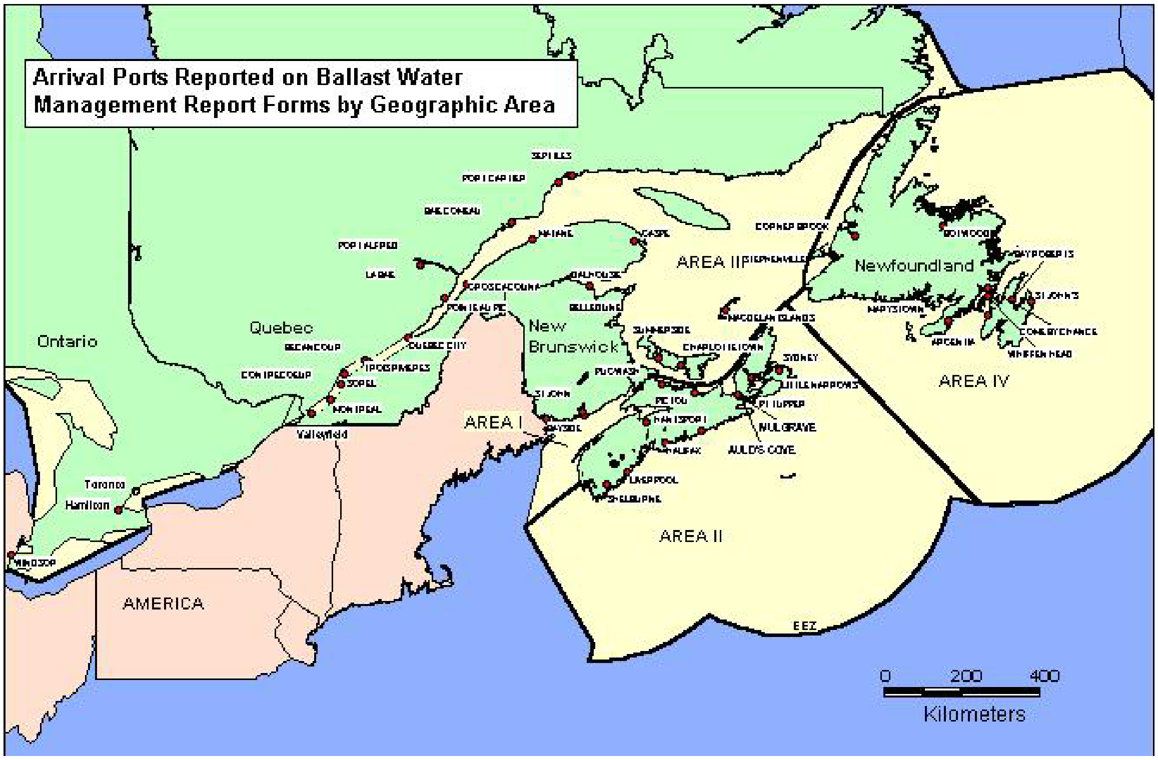


Figure 13. Eastern Canada arrivals ports reported on Ballast Water Report forms submitted to Transport Canada; not included are ports with two or less arrivals during the year 2002 shipping season.

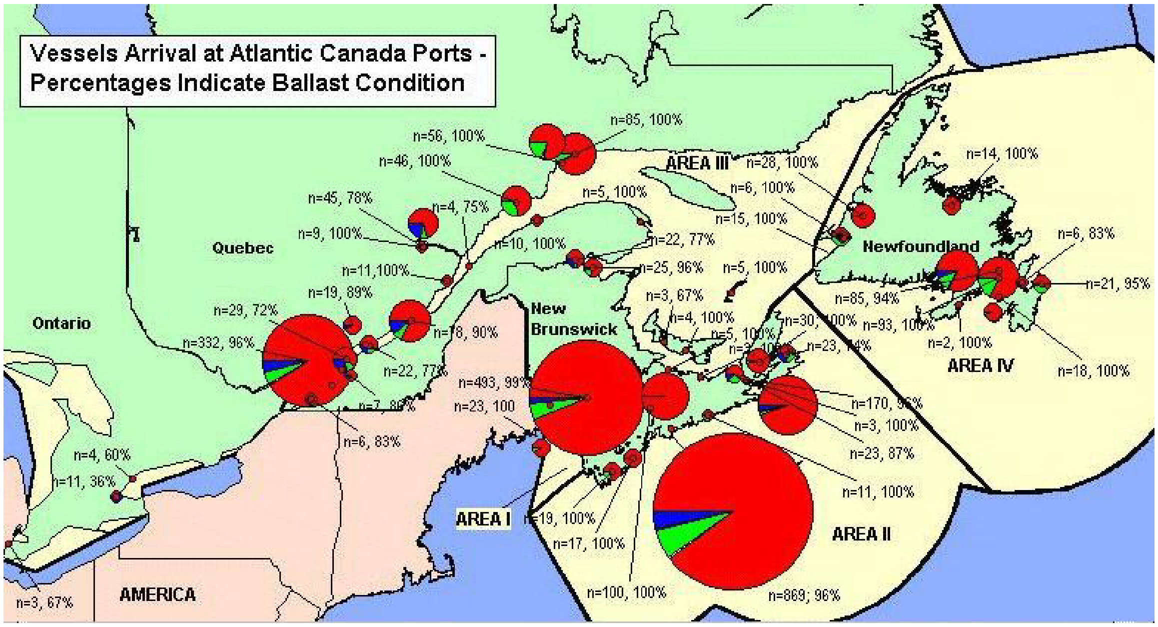


Figure 14. Percentage of vessels in ballast for Eastern Canada ports, including Quebec and Ontario arrivals. In the pie chart, red indicates partial ballast, green full ballast and blue in cargo.

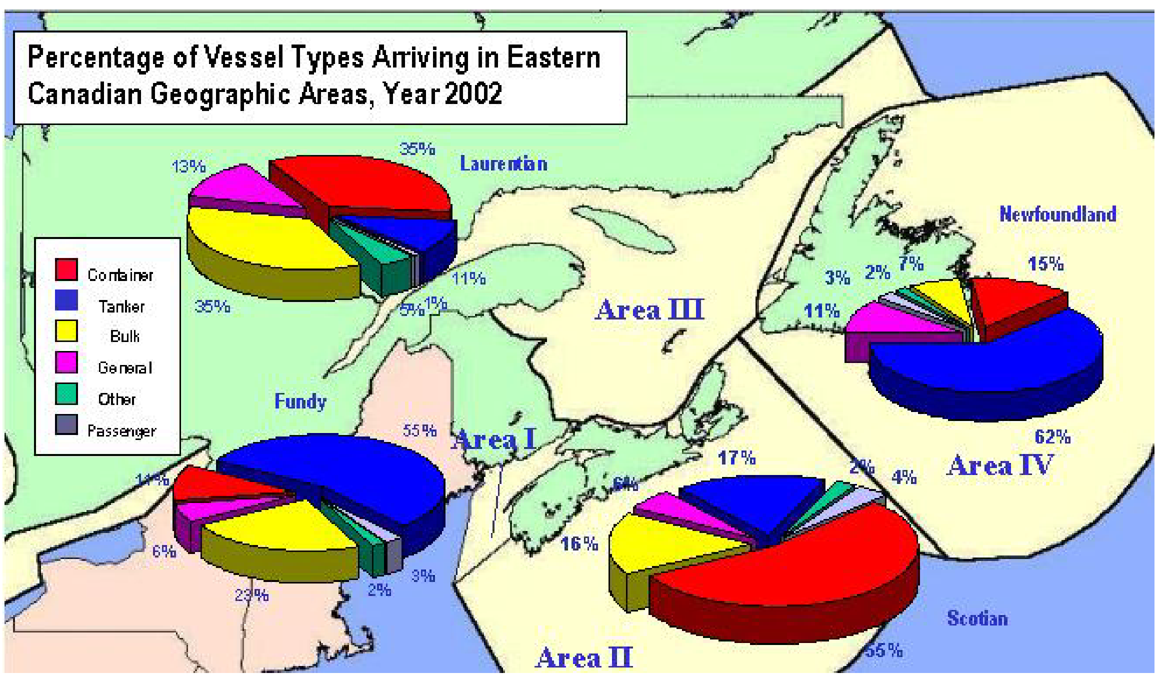


Figure 15. Percentages of Vessels arriving at ports in the four Eastern Canada geographic areas. Area I, n = 633; Area II, n = 1203; Area III, n = 874; Area IV, n = 296.

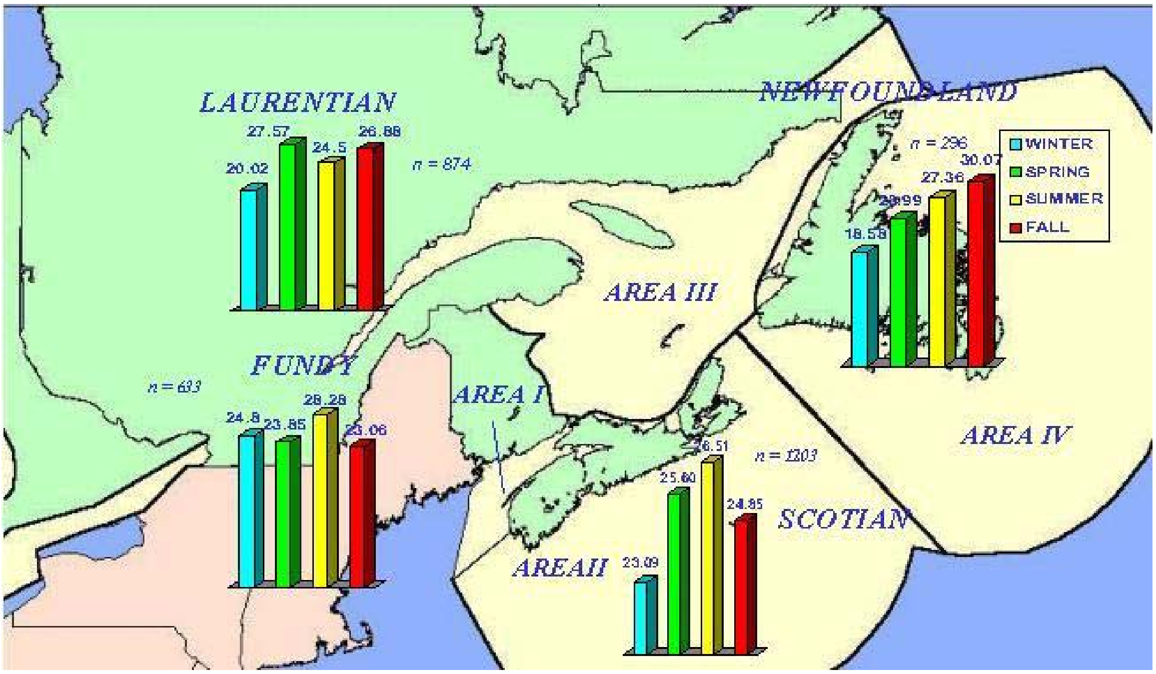


Figure 16. Seasonal Percentages of Arrivals to Eastern Canadian Geographic Areas, year 2002.

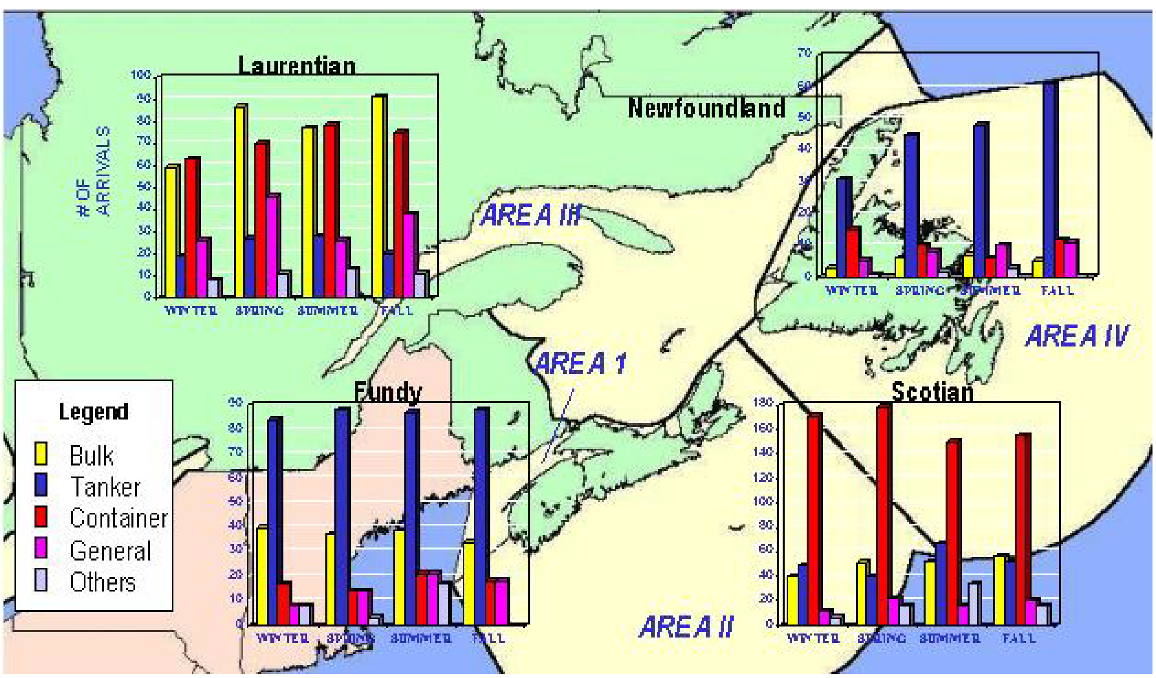


Figure 17. Vessel types arriving (# of arrivals) in Eastern Canadian Geographic Areas in year 2002, by season.

8.0 APPENDIX A

The 2002 Ballast Management Report Form Database Completeness Summary

This brief report summarizes the data in the 2002 Ballast Water Management Report Forms database and provides information on the completeness of recording ballast management practices by marine vessels that fax or email the Ballast Management Reporting Form to Transport Canada.

Description of 2002 Ballast Management Report Form Database

The database is a digital reflection of data reported Sections 1-4 [10] on the standard hardcopy fax Ballast Management Reporting Form sheets to Marine Safety, Transport Canada. The data is for the year 2002.

The database was created in MS Access 97. The MS Access (.mdb) file contains two data tables, one table recording marine vessel trip identification, arrival-destination locations, and dates information and the latter populated with ballast management details (ballast water source, exchange and discharge dates and locations). The database structure for each table is shown in Table 1. Ballast Water Management Database relational data structure.

The two tables were joined in MS Access using the key field - TCSheet# from each table. The join property specified was to "only include rows where the joined field (TCSheet#) from both tables are equal". Joining the tables provided for query environment to derive the database summary shown below.

[10] Ballast Water Management data may be shown in Section 5 on form depending on form submitted by the marine vessel.

Hardcopy Faxed Data Sheets Summary

The hardcopy Ballast Water Management Forms consisted of the following:

Number of hardcopy faxed sheets entered in the database	3448
Number of duplicates	254
Non-Eastern Canada destinations (America, FR, West Canada)	91
Canadian to Canadian domestic voyages	97
Total number of hardcopy faxed sheets	**3006**

MS Access - 2002 Ballast Management Report Form Database Summary:

The MS Access (.mdb) file contains two data tables: the Trip_Info table recording marine vessel trip identification, arrival-destination locations, and dates information and the Ballast_Water_History table populated with ballast management details (ballast water source, exchange and discharge dates and locations). A summary for the two tables is below:

Trip_Info Database Table Summary

Number of records containing full or partial trip identification, arrival-destination locations, and dates information - Section 1-3*. (No Duplicates).	3006

Ballast_Water_History Database Table summary

Number of records containing full or partial Ballast Management Report Form information - Section 4* (No Duplicates).	14,542

Database Completeness of Information Summary

The two above data tables were joined to provide information on the completeness of recording ballast management practices by marine vessel to Transport Canada. Each field in the dataset was queried for NULL data (no value entered where the sender should have submitted a value or text). The summary is provided below:

Total number of records containing full or partial trip identification, arrival-destination locations, and dates information - Section 1-3*. (No Duplicates).	3,194
Records removed from Database because Arrival_Port = AMERICA WEST CANADA OR FRANCE.	91
Arrival_Port = AMERICA	67
Arrival_Port = WEST CANADA.	7
Arrival_Port = FRANCE(ST. PIERRE)	17
Total number of records containing full or partial trip identification, arrival-destination locations, and dates information - Section 1-3*. (No Duplicates, AMERICA, WEST CANADA,FRANCE).	3,006

Section 1 - IMO Identification not provided:	**159**
No IMO shown on MCTS Centre Ballast Water Non-Compliance Report Sheet.	111
No IMO because UNCLEAR (not legible)	1
No IMO because shipping company Ballast Water Management Report Telex, email or form did not contain IMO#	47
Section 1 - Gross Tonnage (GT) not provided:	**60**
No GT (NULL) on Ballast Water Management Report or shipping company Ballast Water Management Report Telex, email or form did not contain GT.	56
No GT because MCTS Centre Ballast Water Non-Compliance Report Sheet.	4
Section 1 - Arrival Port not provided:	**nil**
Section 1 - Arrival Date not provided[11]:	**nil**
Section 1 - Last Port* not provided:	**nil**
Section 1 - Next Port* not provided:	**319**

[11] If the arrival date was not entered by the ship's officer, the Report's fax or submission date was taken as the arrival date.

Section 3 - No. of Ballast Tanks Exchanged:

Records with Null Ballast Information = NULL (N/A)	2
Records with Partially Completed Ballast Information[12]	
Total#_Tanks = NULL[3]	135
Total#_Tanks, Total#Tanks_inBallast = NULL[3]	88
Total#_Tanks, Total#Tanks_inBallast, #TanksExchangedReported =NULL[3]	83
Total#_Tanks, Total#Tanks_inBallast, #TanksExchangedReported, ,#TanksExchangedRecorded[13] = NULL[3]	83
Total#_Tanks, Total#Tanks_inBallast, #TanksExchangedReported, ,#TanksExchangedRecorded, #TanksDischargedReported[14]=NULL[3]	83
Total#_Tanks, Total#Tanks_inBallast, #TanksExchangedReported, ,#TanksExchangedRecorded, #TanksDischargedReported ,#TanksDischargedRecorded =NULL[3]	83

[12] Includes MCTS Centre Ballast Water Non-Compliance Report Sheet.

[13] #TanksExchangedRecorded indicates the recording of tanks exchanged in Section 5 - Ballast History.

[14] #TanksDischargedRecorded indicates the recording of tanks discharged in Section 5 - Ballast History.

Lookup Table - Classification of Vessels by TYPE

There were a number of different descriptors for vessels contained of the Ballast Water Management Report forms. In an effort to be consistent with the previous study groupings, the table below summarizes the various vessel types by classifications Bulk, Tanker, Container, General, Passenger and Other.

Bulk	Tanker	Container	General	Passenger	Other
BULK CARRIER	CHEM TANKER	CONTAINER SHIP	CARGO LINER	CLASS 7 PAK	DREDGE
BULK CARGO	CRUDE CARRIER	GENERAL CARGO/CS	CARGO	FLOATING RESORT	SEISMIC
BULK ORE	LPG/C	MULTI-PURPOSE CS	GENERAL CARGO	LIM PASS	CABLE
BULK ORE OBO	OIL TANKER	RO RO & CON	GENERAL* CARGO/C	LIM PASSENGER	DRILLSHIP
MERCHANT BULK	OT	RO RO	GENERAL* CARGO/CS	LMT PASSENGER	TUG
BULK	PCTC	RO RO CONTAINER	MG	PASSENGER	LIFT VESSEL
O BULK ORE	PRODUCT CARRIER	RO RO/ CAR	MULTI PURPOSE		DATA NOT RECORDED
OBO CARRIER	PRODUCT TANKER	RO/RO	RF		
OBO	VLCC	RORO	REEFER		
OPEN HATCH CARR		RR CAR CARRIER			
SELFUNLOAD ING BULKER		RR CONTAINER			
WOOD CARRIER					
WOODCHIP CARRIER					

* Defined as a multipurpose general cargo vessel capable of transporting containers.

The vessel type Fishing Vessel was included in the previous years studies because it was part of the ECAREG dataset; it was not part of the Ballast Water Management data set and was not included in the pie chart displays and discussions.

GIS Mapping of Marine Vessel Ballast Water Exchange Data in Atlantic Canada, for the Year 2002 Shipping Season

Summary of Year 2002 Arrivals Ports in Geographic Study Areas I to Area IV

AREA 1 - Bay of Fundy and southwest Nova Scotia, having Yarmouth as its eastern limit.

St. John
Canaport
Hantsport
Parrsboro
Bayside

AREA 2 - Nova Scotia and Cape Breton

Halifax, Dartmouth
Sheet Harbour
Pt Tupper
Pt. Hawkesbury
Mulgrave
Little Narrows
Shelburne
Liverpool
Sydney
Pictou
Pugwash

AREA 3 - Prince Edward Island, Gulf of St. Lawrence side of New Brunswick and Quebec, Saint Lawrence Basin and Great Lakes

Summerside
Charlottetown
Souris
Newcastle
Belledune
Dalhousie
Gaspe
Trois Rivieres
Becancouer
Quebec City
Montreal
Sept Isles
Chicoutimi

Summary of Year 2002 Arrivals Ports in Geographic Study Areas I to Area IV cont'd.

AREA 4 - East and West Coasts of Newfoundland
St John's
Lower Cove
Stephenville
Whiffen Head
Come by Chance
Bay Roberts
Marystown
Argentia
Botwood
Corner Brook
Harbour Grace
Holyrood

Ballast Water Source Countries - Groupings

Open Ocean

O or OE

North America

Canada
United States

Central and South America

Brazil
Ecuador
El Salvador
Honduras
Mexico
Panama
Peru

Caribbean

Bahamas
Bermuda
Cuba
Dominican Republic
Jamaica
St. Thomas
St. Vincent
St. Maarten
Trinidad

Europe
Belgium
Croatia
Denmark
Estonia
Finland

Ballast Water Source Countries - Groupings - Europe Cont'd

France
Germany
Greece
Greenland
Iceland
Italy
Malta
Netherlands
Norway
Poland
Portugal
Romania
Russia
Spain
Sweden
Turkey
Ukraine
United Kingdom (includes Ireland)

Middle East

Israel
Middle East
Quatar
Saudi Arabia
Syria
United Arab Emirates

Africa
Algeria
Congo
Egypt
Ghana
Morocco
Tunisia

Ballast Water Source Countries - Groupings

Africa

Mozambique
Nigeria
Senegal
South Africa

Asia

China
India
Japan
S. Korea
Singapore
Sri Lanka

Season Intervals

>=#01/01/02# And <=#31/03/02#	- Winter
>=#01/04/02# And <=#30/06/02#	- Spring
>=#01/07/02# And <=#30/09/02#	- Summer
>=#01/10/02# And <=#31/12/02#	- Fall

Appendix VIII

The Shipping Federation of Canada

Code of Best Practices for Ballast Water Management

RECOGNIZING that discharge of ballast water from ships is viewed as a principle vector for the introduction and spread of harmful aquatic organisms and pathogens,

RECOGNIZING the role shipowners and vessel operators can play in minimizing the introduction and spread of non-indigenous organisms and protecting the Great Lakes waters,

CONSIDERING the current status of technology for the treatment of ballast water and the need to develop standards against which to measure efficiency of management procedures;

VESSELS entering into the Great Lakes commit to the following Code of best Practices For Ballast Water Management.

1. to conduct ballast water management whenever practical and at every opportunity even if the vessel is not bound for a port where such a procedure may be required. This process will ensure that residual ballast on board will, to the greatest extent possible, be subjected to these practices. This process will also aid to minimize sediment accumulations in ballast tanks, and there mid-ocean exchange is practiced, subject fresh-water organisms to an extended exposure to salt water.

Where mid-ocean ballast water exchange is the, or one of the management practices used as required by IMO, USCG, Canadian or other regulations, the safety of the ship shall be a top priority and management shall be practiced according to recognized safe practices.

2.to regular inspection of ballast tanks and removal of sediment, if necessary, to at least the level comparable to that required by the vessel's Classification Society in order to conduct a "close-up" Enhanced Survey, Ballast Tank Structural and Coating Inspection.

3. to ballast water exchange procedures as provided for in US legislation and approved and enforced through United States Coast Guard Regulations.

4. to record keeping and reporting according to United States Coast Guard Regulations (ballast water report forms) – the master to record all uptake and discharge of ballast water in an appropriate log book; Ballast Water Report Forms to be completed and submitted as per Regulations; inspection and cleaning of ballast tanks to be recorded and records to be made available to inspectors upon

5. to provide information and logs to authorized inspectors and regulators for the purposes of verifying the vessel's compliance with this Code of Best Practices.

6. to apply a precautionary approach in the uptake of ballast water by minimizing ballasting operations under the following conditions:

a. In areas identified in connection with toxic algal blooms,outbreaks of known populations of harmful aquatic organisms and pathogens, sewage outfalls and dredging activity.

b. In darkness, when bottom dwelling organisms may rise in the water column.

c. In very shallow water.

d. Where a ship's propellers may stir up sediment.

e. In areas with naturally high levels of suspended sediments, e.g. river mouths, and delta areas, or in locations that have been affected significantly by soil erosion from inland drainage.

f. In areas where harmful aquatic organisms or pathogens are known to occur.

7. to the disposal of accumulated sediments as provided for in the existing IMO Ballast Water Protocols during ocean passages outside International Ballast Water Management Areas or as otherwise approved by Port State Authorities.

8. to foster and support scientific research sampling programs and analysis – Facilitate access to on board sampling and testing of ballast water and sediment including opening of ballast tank covers and safe access to ballast tanks following safety procedures for entering enclosed spaces. Sampling, testing and inspection to be planned and coordinated to fit within vessels' operational program and minimize any delays.

9. to cooperate and participate in standards development and treatment systems testing and approval processes, including, but not limited to mechanical management and treatment systems, and pesticide management systems as well as improved techniques for ballast water exchange and their scientific assessment.

10. to strive toward global, integrated ballast water management strategies in conformity with internationally agreed principles that respect national and regional aquatic ecosystems.

This Code of Best Practices is endorsed by the undersigned and represents our common goal to attain the highest standards of safe ballast water management to minimize the introduction and spread of aquatic nuisance species in the Great Lakes.

The Shipping Federation of Canada ***September 28, 2000***

Appendix IX

Ballast Water Exchange in the North Atlantic

A Background Paper for the Ballast Water Management Workshop
Halifax, Nova Scotia
October 27-28, 2003

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Copies of MIT Sea Grant publications may be ordered online, http://web.mit.edu/seagrant/pubs/order.html

Ballast Water Exchange in the North Atlantic

Introduction

Ballast water has been identified as one of the major vectors that introduce marine and coastal organisms to new localities. Marine bioinvasions have caused ecosystem degradation (e.g. *Caulerpa taxifolia* in the Mediterranean) and economic loss (e.g. *Mnemiopsis leidyi* in the Black Sea). One study estimates that across all taxa, over $127 billion is spent annually to control and manage invasive species (Pimentel et al. 2000). This amount underestimates the costs associated with marine introduced species. The number of scientific papers, books, and meetings on invasions sciences has increased over the past decade. The topics include marine bioinvasions research and management, ecological and economic impacts, patterns of distribution and dispersion, risk assessments, and vectors of introduction have (see e.g. Pederson, 2000, 2003) Human health may also be affected as microorganisms are spread by ballast water, including *Cholera vibrio* in temperate waters (Ruiz et al. 2000). Although there are several human-mediated vectors that may introduce new species, ballast water is a leading mechanism in the introduction of these species (Carlton 2001).

Ballast water is ubiquitous and unavoidable in the shipping industry. It is used for stability, to increase draft, alter trim, and optimize stress loads. Species enter ballast tanks through intake pumps or when ships "gravitate" water into holds. While grates may prevent pumping anything over a centimeter or two in diameter, nearly all marine taxa have a pelagic life stage, as resting stages, larvae, juveniles, or adults, which are small and easily pumped through the grate. Ballast water release and management are global issues that require international solutions. Currently the preferred option for reducing or preventing introductions from ballast discharge is to exchange ballast at sea, although new technologies to treat ballast water are being developed and tested throughout the world.

Various technologies are undergoing research, development, and testing to limit the number of species able to survive in ballast tanks. Examples include biocides (e.g. chlorine, ozone, osmium, and antifouling paints), mechanical removal (through filtration or centrifugation), physical destruction (by heat or UV radiation), and creation of azoic conditions (e.g., anoxia). Some treatments may target larger organisms such as plankton, juveniles or small adults, while others may be more effective against viruses and microbes. While few treatments have been thoroughly tested, there is a growing market for technological treatments, especially once performance standards are adopted (Pederson and Carlton 2002). One management option for ballast water exchange is the "complete" exchange of ballast water, at sea or in areas designated when at sea exchange is not possible.

This paper (1) reviews the current regulations and guidelines affecting ballast water exchange (BWE) and notes a few areas for future strengthening, (2) describes the risks to and concerns for the Gulf of St. Lawrence ecosystem, (3) summarizes vessel traffic and BWE in this region and in the Gulf of Maine, and (4) recommends coordination and cooperation to identify a regional ballast water approach for Canada and the U.S. that (a) examines the feasibility of alternate ballast exchange areas within the Exclusive

Economic Zone (EEZ) for the Northwest Atlantic, (b) supports continued data collection on ship traffic and ballast exchange, (c) continues support for research on risk assessment, and (d) supports development of alternative ballast water treatments.

Current Regulations and Guidelines

The United States and Canada have each adopted regulations (U.S.) and guidelines (Canada) to limit introductions into the Great Lakes, Gulf of St. Lawrence, and other territorial waters, while providing for the safety of ships and their crew members. In addition to these efforts, the International Marine Organization (IMO), the International Association of Independent Tank Owners (INTERTANKO), and the Marine Environmental Protection Committee (MEPC) have initiated efforts to manage ballast. The international community supports voluntary guidelines and is proposing standards for ballast water discharge that will serve as the performance measures for new ballast water treatment technologies. The international community has developed model ballast water management plans and each vessel is to have one on board. In addition, several monitoring activities and pilot projects to manage ballast have been initiated. Nonetheless, the lack of regulations or enforceable practices at the international level has frustrated those concerned about the growing number of introductions.

The U.S. has passed regulations that require ballast water exchange before entering the Great Lakes and the Hudson River and several states have passed or are considering passage of regulations that require reporting and/or management of ballast water. Under the National Invasive Species Act of 1996 (NISA P.L. 104-332), the United States requires vessels traveling to the Great Lakes and the Hudson River to exchange ballast water, recommends that exchange take place outside the 200 mile limit of the EEZ, and mandates all (not just those entering the Great Lakes) affected vessels to complete and submit a Ballast Water Reporting Form to the United States Coast Guard (USCG). Vessels traveling along the coast are exempted from both reporting and exchange. In July 2004, the USCG adopted more stringent regulations that require all vessels, including coastal traffic, to complete ballast water forms and all vessels crossing the EEZ to exchange ballast water at sea.

Canada has adopted guidelines encouraging vessels to exchange outside the EEZ, preferably in waters deeper than 2000 meters. Yet these guidelines allow vessels bound for ports along the Great Lakes, domestic Canadian voyages, or ships facing adverse conditions, to use the Gulf of St. Lawrence, in areas deeper than 300 meters and southeast of 63° W longitude, as an alternative exchange zone (Canadian Guidelines 2002). The guidelines require sequential exchange to be discharged until suction is lost using stripping pumps or eductors, while flow-through exchange must pump a volume three times that of the tank. Canada is currently reviewing its regulations.

Guidelines put forth by the Untied States and Canada, without enforcement, do not prevent comprehensively the introduction of species via ballast water. Locke et al. (1993) found that while voluntary measures reduced the risk of introduction, they did not eliminate risk because some ships did not comply and because even those that did could introduce viable species into the Great Lakes (see also Carver and Mallet 2002; Gollasch et al. 1996; Gollasch 2002). Discharging ballast water does not completely empty tanks of either water or sediment, so even vessels claiming no ballast on board (NOBOB) may carry organisms in various life stages. Vessels traveling only within the EEZ are exempt from reporting their ballast water management practices (Pederson and Carlton 2002). This gap in the record keeping does not recognize that an introduction may occur when a foreign[*] vessel arrives, and either does not exchange or only partially exchanges water, continues with a domestic leg of the voyage, and then exchanges water from the foreign source in a secondary or even tertiary port of call. Essentially, this means that even with full compliance, only a fraction of ships will be required to exchange ballast water, and not all vessels must report their practices, leaving a variety of possibilities for potentially introducing organisms.

In the United States, there are low reporting rates in areas of mandatory reporting. Ruiz et al. (2001) found about 30% compliance with reporting for the east coast of the United States. With a national average of 33% reporting, it is impossible to reliably extrapolate ballast water management practices for ships entering the United States. In western portions of the United States, this is compounded with inaccurate or dishonest reporting practices by admission of those submitting the report (Harkless 2003) Thus, even with the high western region compliance rate of 66.5% (Ruiz et al. 2002), the accuracy of the reports in the National Ballast Information Clearinghouse (NBIC) is questionable and further complicates analysis. Reasons given for the violations were many: anonymity of report author, responding to what the USCG expects, and lack of enforcement was among these responses.

On July 30, 2003, a proposed rulemaking, Mandatory Ballast Water Management Program for U.S. Waters (33 CFR part 151) was announced in the Federal Register (a final version was adopted July 28, 2004). The USCG (now transferred to the Department of Homeland Security) under the authority of the National Invasive Species Act (1996) evaluated the effectiveness of the voluntary ballast water management. It also had the authority to develop additional regulations to make the voluntary program a mandatory program. Because voluntary compliance is so low, the USCG has proposed new regulations that would affect all vessels (including those traveling within the EEZ) with ballast tanks entering U.S. ports or waters (Department of Homeland Security, 2003; 33 CFR part 151). The proposed rules address several important issues. It affects all vessels with ballast water tanks – both those traveling coastwise and entering those entering the EEZ. It provides four alternatives for ballast water management, but recognizes that ballast water exchange is the most likely option. It strikes the depth requirements for areas appropriate for BWE because there is no consensus has been made correlating depth with adverse environmental effects. The proposed rules specifically do not require vessels to deviate from voyage routes or schedules to conduct BWE, and if a vessel cannot practically meet any of the four ballast management options, it may discharge the operational minimum in locations other than the Great Lakes and the Hudson River, and a record of such circumstances must be kept (Department of Homeland Security, 2003).

Canada has found significantly higher rates of compliance with ballast water guidelines. According to a study conducted by Transport Canada, Marine Safety, in the second half

[*] For the purposes of this paper, the term 'foreign' shall refer to the country in question. That is, foreign vessels arriving to Canada may originate anywhere outside Canada, including the United States, while foreign vessels arriving to the United States may originate anywhere outside the United States, including Canada.

of 2001 Canada had compliance rates between nearly 70% to over 80% (RNT Consulting 2002). In part, these high compliance rates are due to investigations through boarding ships, and enforcement of guidelines (Balaban, pers. comm. 2003).

The Gulf of Maine and the Mid-Atlantic Bight

Both the Gulf of Maine and the Mid-Atlantic Bight are complex, highly dynamic areas that are driven by winds, tides, and buoyancy forcing. There are areas of upwelling and regions where coastal waves are trapped. Beeton et al. (1998) reviewed regions around the U.S. and examined them as potential back-up zones for ballast water exchange in the context of the physical oceanography of the region and potential to introduce marine organisms. Beeton et al. (1998) reviewed these areas based on the following criteria:

- Nearshore and inshore circulation that would impact shoreward transport of biota
- Wind stress, coastal buoyancy fluxes, tidal fronts, along coast currents, eddies, shingles and filaments, coastal-trapped waves, convergence and divergence, unpredictable flow reversals and other phenomena.
- The overarching criterion is the definition in the National Ballast Water Control Program as those "areas…if any, where exchange of ballast water does not pose a threat of infestation or spread of aquatic nuisance species in the Great Lakes and other waters of the United States." (Beeton et al. 1998, p. 15).

Risks and Concerns for the St. Lawrence Environment

The Estuary and Gulf of St. Lawrence (EGSL) that includes the Laurentian Channel was designated as a alternate ballast water exchange location for ships that were not able to exchange at sea before entering the Great Lakes (Figure 1). There is expressed concern that local environments are put at greater risk for introduction of species as a result of the increased use of this area, (especially the Laurentian Channel), as an alternate ballast water exchange zone. This area was and continues to be the focus of several scientific studies that examine ballast water composition and documentation of introduced species in the ballast released area (Harvey et al. 1999; Carver and Mallet 2002).

Risk assessments examine sources of ballast, the volume discharged, and the use of the EGSL for regular exchange compared with discharge elsewhere within or outside of the EEZ. Approximately 20% of traffic heading to the Gulf of St. Lawrence traverses warm waters (16-20°C) in the summer, and discharge ballast water into areas where summer temperatures of shallow areas fall within this range. Nearshore areas within the Laurentian Channel area provide a favorable environment for species originating from multiple sources, often further south. Moreover, a significant volume of ballast water, 11.5 million tons in 1995, is being discharged in the EGSL (Harvey et al. 1999). Ballast volumes are increasing along with ship capacities and ship size. Bourgeois et al. (2000) found that the ballast capacity bound for the EGSL in 1996 was twice that of 1978, including a listing of the number of source countries. Yet only 13% of ballast water discharged was determined to come from the previous port of call, resulting in unknown sources of ballast and decreasing the ability to predict specific invading species (Harvey et al. 1999). Furthermore, Locke et al. (1991) found that not all ships that discharge in the alternate exchange zone come from U.S. ports or justify their usage by reporting extreme circumstances.

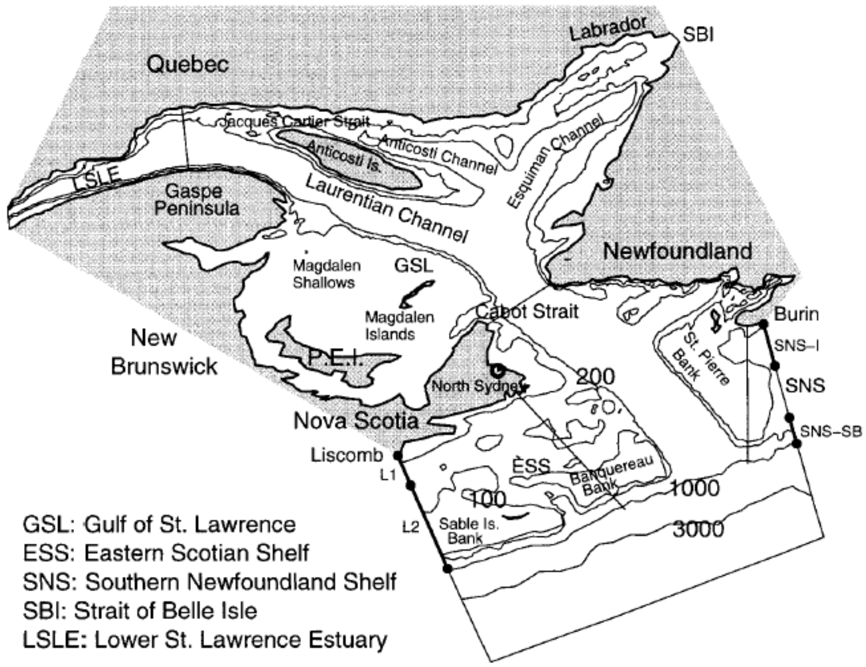


Figure 1: Map showing the study domain, bathymetry, and section locations; isobaths shown are 100, 200, 1000, and 3000 m. The Gaspé, Cabot Strait, Burin, and Banquereau sections are shown in solid lines. SNS-I and SNS-SB are the inner and shelf-break segments of the upstream SNS boundary. L1 and L2 are the inner and outer segments of the Liscomb line on the downstream ESS boundary (reprinted with permission from Han et al. 1999).

Various physical oceanographic features of the EGSL suggest that the region is significantly susceptible to introductions via ballast water exchange. Geographically, the area in question is small, and easily traversed in one day, while it may take two to three days to completely exchange ballast water. Currents within the region have been modeled with seasonal variability (see Figures 2a, 2b). The modeling studies demonstrate that EGSL currents carry particles, such as phytoplankton or zooplankton, towards coastal areas or trap them within the EGSL (Gilbert and Saucier 2000). This model identifies a few areas at particular risk at different times of the year, specifically Anticosti Island, the west coast of Newfoundland, Cape Breton, and Magdalen Islands (Gilbert and Saucier 2000). Suggestions have been made to move the alternate ballast water exchange zone eastward, beyond Magdalen Islands. Due to hydrology and current flow, released ballast water and the particles it might bring would still circulate and flow towards coasts (Han et al. 1999). This would effectively move the problem eastward, but not necessarily solve it.

Introductions of various species have indeed been found in the EGSL. A survey of ballast water discharged into the EGSL by 94 different ships showed that 60% of phytoplankton and 57% of zooplankton found were non-native (Harvey et al. 1999), although the zooplankton were not identified to species. Because identification was not to species, these values may be overestimates. A ballast water study conducted in 2000 for Transport Canada, Marine Safety analyzed ballast water discharged in three Nova Scotian ports and found 349 phytoplankton taxa and 75 microzooplankton organisms (excluding larger sized animals such as copepods). Of the total, 105 were classified as nonindigenous, five of which were classified as toxic non-indigenous phytoplankton, and were relatively rare. Another nine organisms were potentially harmful (Carver and Mallet 2002). Another survey reported significant health risks to the region in 1992, when it found 60% of the ballast water tanks surveyed at Magdalen Islands carried toxic algae in the ballast water (Gosselin et al. 1995). One model quantifying the risk of introducing species into the Gulf of St. Lawrence found that the greatest relative risks were in Area I, the river stretch of the St. Lawrence, and the Laurentian Channel (RNT Consulting 2002).

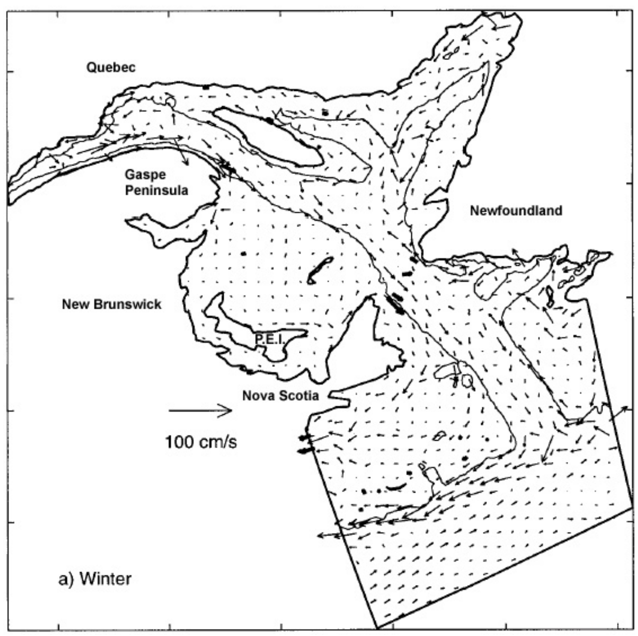


Figure 2a: Mean current (thin arrows) circulation for near-surface (averages between 5 and 30 m of the surface) waters within the Gulf of St. Lawrence region. Winter patterns are gathered from model solutions. Thick arrows represent observed near-surface (within 30 m of surface) currents (reprinted with permission and modified from Han et al. 1999).

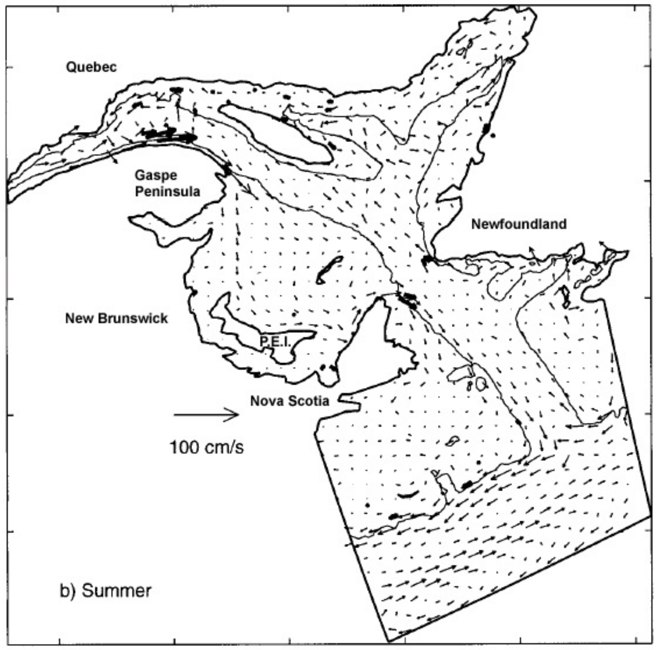


Figure 2b: Mean current (thin arrows) circulation for near-surface (averages between 5 and 30 m of the surface) waters within the Gulf of St. Lawrence region. Summer patterns are gathered from model solutions. Thick arrows represent observed near-surface (within 30 m of surface) currents (reprinted with permission and modified from Han et al. 1999).

Vessel Traffic and BWE in the Gulf of St. Lawrence and New England

Understanding the patterns of shipping traffic is vital to more precisely determining the risks from and solutions to introductions via BWE. Canadian vessel traffic studies divided the Atlantic region into four geographic areas defined by the distribution of international ports, and they correlate roughly to oceanographic subdivisions. The boundaries are: Area I - Bay of Fundy and southwest Nova Scotia (with Yarmouth as its eastward limit); Area II - Nova Scotia and Cape Breton Island; Area III - Prince Edward Island, the Gulf of St. Lawrence side of New Brunswick and Quebec, the Saint Lawrence Basin, and the Great Lakes; and Area IV – the east and west coasts of Newfoundland (Balaban 2001). For the United States, data are from the National Ballast Information Clearinghouse (NBIC, housed within the Smithsonian Environmental Research Center), which organizes data by state and then port.

In 2000, as Figure 3 depicts, 3,386 vessels arrived from foreign ports and visited 35 ports within Atlantic Canada. 47% of these foreign vessels were bound for ports within Area II, primarily in Halifax Harbour, while 37% entered Area I, bound mostly for Saint John, Yarmouth, and Hantsport (Balaban 2001). Figure 3 also shows that fewer ships were in ballast than carrying cargo for both Areas I and II. While the proportion of vessels in ballast was higher for ports with fewer vessels entering, the actual number was smaller. For example, while Saint John (n=534) had 49% in ballast and Hantsport (n=119) had 100% in ballast, Halifax-Dartmouth (n=1215) had 13% in ballast and Yarmouth (n=341) had 0% in ballast (Balaban 2001). This held true for small ports as well. Liverpool, NS (n=12) in Area I had 83% in ballast, Little Narrows, NS (n=33) in Area II had 100%

ballast, Lower Cove, NF (n=19) in Area III had 100% ballast, and Botwood, NF (n=27) in Area IV had 93% in ballast (Balaban 2001).

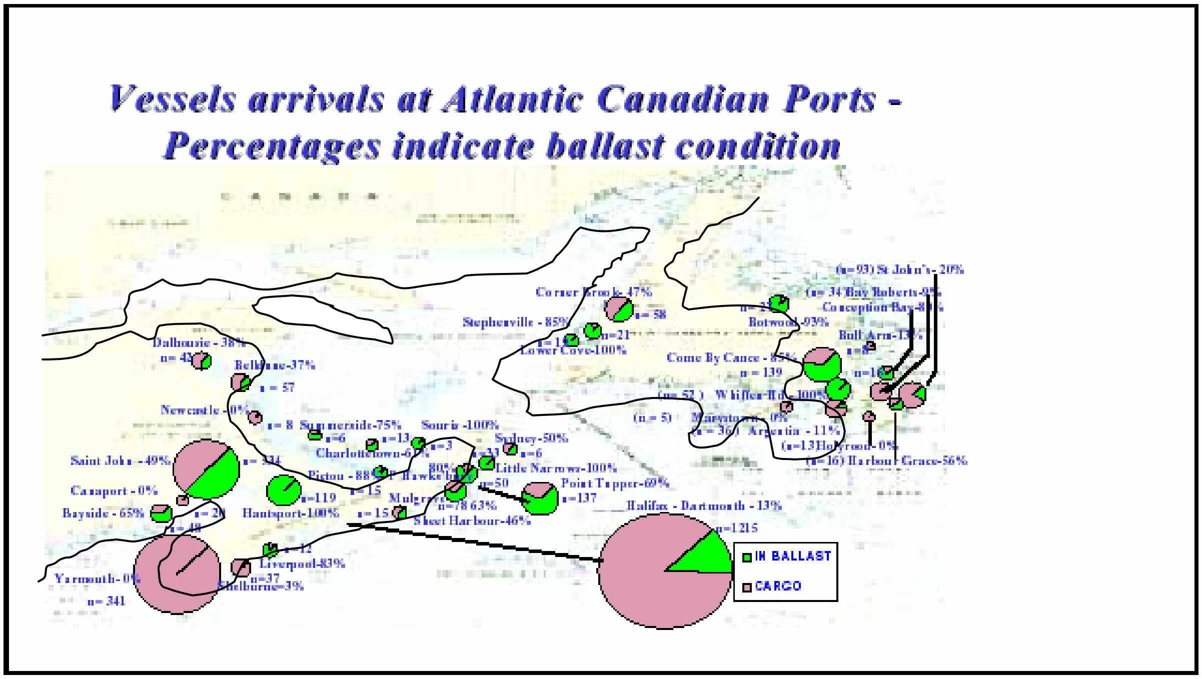


Figure 3: Foreign vessels arriving to Atlantic Canadian ports in 2000. Percentages indicate proportion of ships in ballast. Data source: ECAREG–VTS data (Balaban 2001).

The dominant vessel traffic differed for each Area in 2000, as depicted in Figure 4. While 25% and 40% of vessel traffic in Areas I and IV respectively were tankers, traffic in Area II was predominantly containers (41%), while 48% of Area III traffic was general cargo carriers (Balaban 2001). Fishing traffic was highest in Area IV (16% of ships) and that ‘Other’ vessels (which include ferries, passenger ships, tugs, and research vessels) were uncommon in Area III compared to elsewhere (Area I: 4.4%, Area II: 12.9%, and Area IV: 5.8%). The largest volume of BWE occurred around Newfoundland in Area IV, most discharged by tankers in the Placentia Bay area; this ballast water originated along the eastern United States, mostly New England (Balaban 2001).

Foreign vessels arriving in the Atlantic Region of Canada originated in 63 countries and from all continents except Australia and Antarctica. The majority came from the eastern United States (2118 ships, or 62% of vessels), the Gulf of Mexico, the Caribbean, and Europe, while other regions were minor contributors (Balaban 2001). Figure 5 shows a breakdown of origin for each of the four Areas in Atlantic Canada. A range of 22% of vessels in Area III to 84% of vessels in Area I originated in the United States, and 82% of ballast water pumped overboard at Canadian ports originated in the United States (Balaban 2001). Meanwhile, Western Europe contributed a range of 4% in Area I to 42% in Area III and 8% of ballast water discharged in Canadian ports (Balaban 2001). Overall, the northeast Atlantic contributed 13.5% of the total traffic. Note that for all areas, more traffic originated in Western Europe than in Northern Europe.

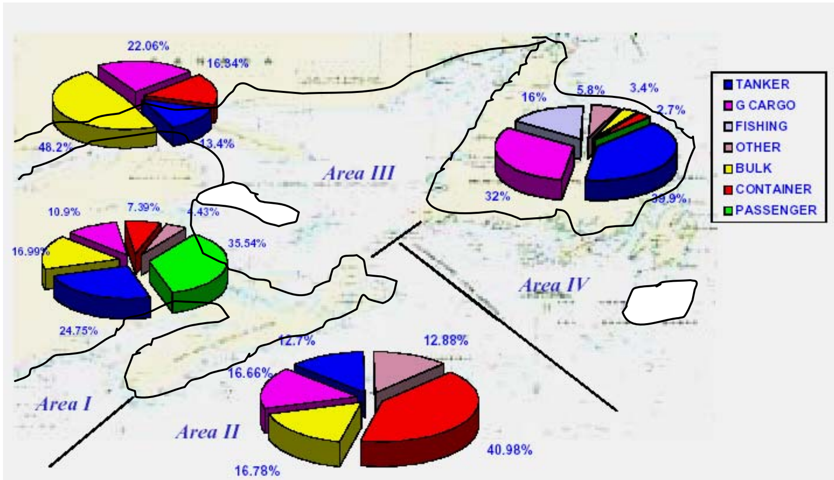


Figure 4: Breakdown of vessel types, in percentage of the number of vessels bound for Areas I – IV in the Atlantic Region of Canada. Data source: ECAREG –VTS data (Balaban 2001). Area I is the Laurentian Channel; Area II is Nova Scotia and Cape Breton Island; Area III is Prince Edward Island, the Gulf of Saint Lawrence side of New Brunswick and Quebec, the Saint Lawrence Basin and the Great Lakes; Area IV is the east and west coasts of Newfoundland.

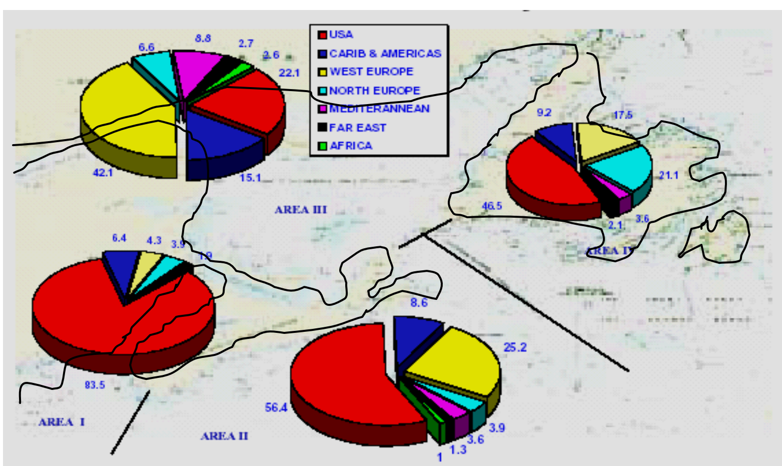


Figure 5: Origin of vessels (in percentage of arrivals) for Areas I – IV of Atlantic Canada. Data source: ECAREG –VTS data (Balaban 2001). See figure 4 for description of Areas I – IV.

RNT Consulting (2002) created a mathematical model to assess the risk of introducing species via ballast water. The study found that based upon vessel traffic and voyage length, the greatest potential for introductions for Atlantic Canada was from the North Atlantic coast (FAO Region A) and from Europe/Scandinavia (FAO Region B).

Specifically, the biggest risks were to the Laurentian Channel, Area I, and then the River Stretch (RNT Consulting 2002). The model only considered the potential for introduction, made no distinction between species, did not consider salinity, and ignored survival rates and adverse effects upon introduction. Further, it assumed that the only difference between the port of origin and the destination was travel time, rather than including any combination of environmental or logistical details unique to either port. Voyage length significantly affected the organism mortality within the ballast water, such that after 5 days in continuous transit, only 50% of species survived (RNT Consulting 2002). Several estimates suggest that the longer the duration of the voyage, the lower the risk for introductions due to high mortalities.

There were several recommendations made based on the data in the Carver and Mallett (2002) Report. These recommendations are:

Recommendations from Carver and Mallet (2002)

A. Continue to support the principle of ballast water exchange but delay the decision to establish an Alternative Ballast Water Exchange Zone off Nova Scotia until more data are available.

B. Discourage discharge of ballast water from brackish-water ports in the US into the Bras D'Or lakes (Little Narrows).

C. Develop educational materials to promote mid-ocean exchange and improve ballast water management practices, particularly for ships carrying water from Europe, Asia or the west coast of North America.

D. Support efforts to develop ballast water treatment methods.

Future research (from Carver and Mallett 2002)

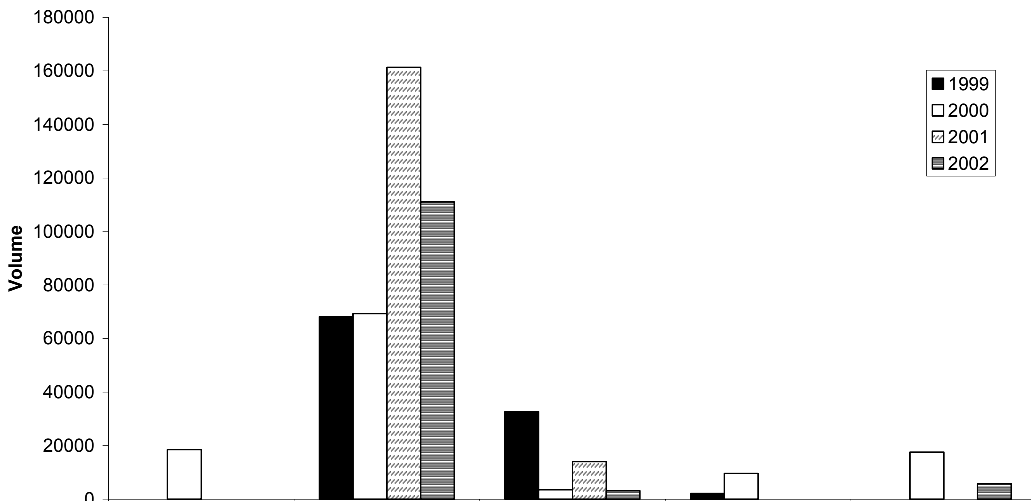
A. Expand the scope of sampling and develop sampling techniques to better assess the risks associated with other types of organisms including cysts, bacteria, parasitic protozoans, and benthic invertebrates.

B. Assess the risks associated with undertaking ballast water exchange in various regions and in different seasons.

C. Conduct surveys of potentially-impacted areas to determine whether non-indigenous taxa are being introduced.

Between August 1999 and December 2002, ships that entered the 22 New England ports from outside the EEZ discharged 658,827 m^3 of ballast (see Figure 6). The trends in shipping traffic and ballast water exchanges appear be different from that of Atlantic Canada. It is difficult to draw conclusions about where ballast water is frequently exchanged or where it originated in New England, because the rate of mandatory ballast management reporting is around 30%. Of the five coastal New England states, only Maine and Massachusetts had reports of ballast water discharge for all years in the study. Based upon the information that *is* available, we are able to make a few statements.

In New England, Maine received the most ballast water discharge, which generally increased across the three and a half years of study. Between August 1999 and December 2002, a total of 551,695 m^3, or 83.7% of the total volume of ballast, was discharged within the Maine ports of Bar Harbor, Bucksport, Eastport, Portland, and Searsport. Portland Harbor was the recipient of 503,992 m^3 ballast discharged, which is 91.3% of the volume discharged in Maine and 76.5% of the total volume discharged in New England (see Figure 7).

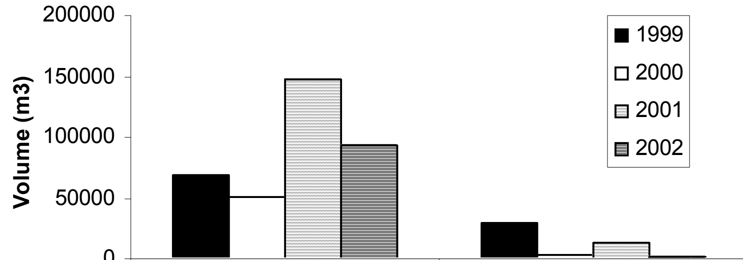


	Connecticut	Maine	Massachusetts	New Hampshire	Rhode Island
1999	0	68209	32746.36	2118	0
2000	18540	69348.4	3544	9634	17559
2001	0	161290.77	14033	0	0
2002	0	111078.68	3197	0	5761

Figure 6: Reported volumes (in m^3) of ballast water discharged in New England ports, arranged by state, during 1999-2002. Reports in 1999 spanned from July-December, while other years included all months. Reported volumes are based on low voluntary compliance rate (30%) recoded by the National Ballast Information Clearinghouse Database (http://invasions.si.edu/NBIC/nbic_database.htm, 2003; Ruiz et al. 2002).

Massachusetts reported the second greatest volume of ballast discharged between August 1999 and December 2002, with a total of 53,520 m^3, or 8.1% of the total volume discharged to New England (see Figure 6). The majority of ballast in Massachusetts was discharged in Boston (49,120 m^3, or 91.7%), which represents 7.5% of the total volume discharged in New England (see Figure 7). Based upon these data, Maine reported about

10 times more ballast discharged than Massachusetts, just as Portland, Maine reported roughly 10 times more ballast discharged than Boston, Massachusetts.



	Portland	Boston
1999	68209	30316
2000	51530.4	3544
2001	148324.77	13458
2002	94159.68	1802

Figure 7: A comparison of volume of ballast water discharged in the ports of Portland, Maine and Boston, Massachusetts. These two ports are reportedly the most significant New England contributors of ballast water to the Gulf of Maine. Data source: National Ballast Information Clearinghouse Database (http://invasions.si.edu/NBIC/nbic_database.htm 2003).

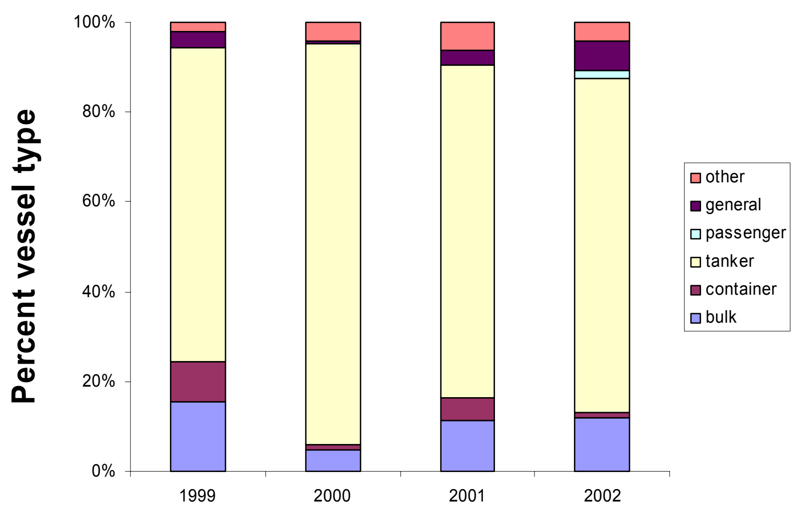


Figure 8a: Relative classification of vessel types to all ports within Maine. Data source: National Ballast Information Clearinghouse Database (http://invasions.si.edu/NBIC/nbic_database.htm 2003).

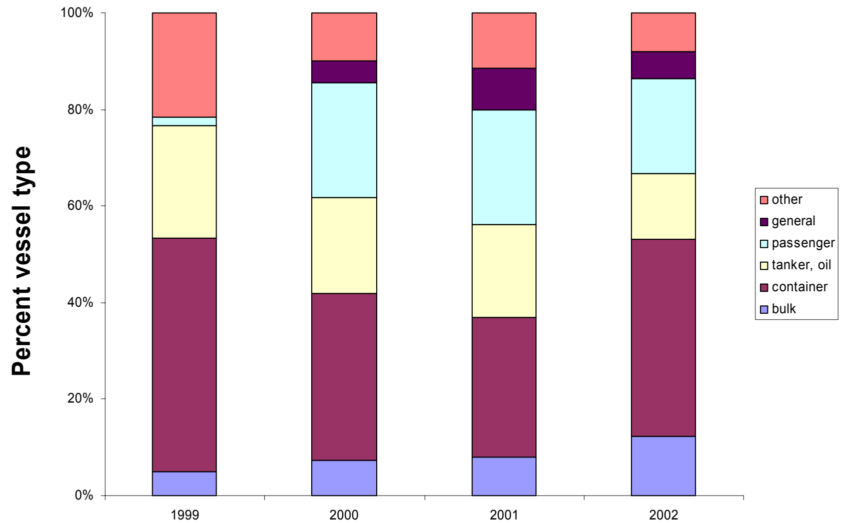


Figure 8b: Relative classification of vessel types to all ports within Massachusetts.
Data source: National Ballast Information Clearinghouse Database
(http://invasions.si.edu/NBIC/nbic_database.htm 2003).

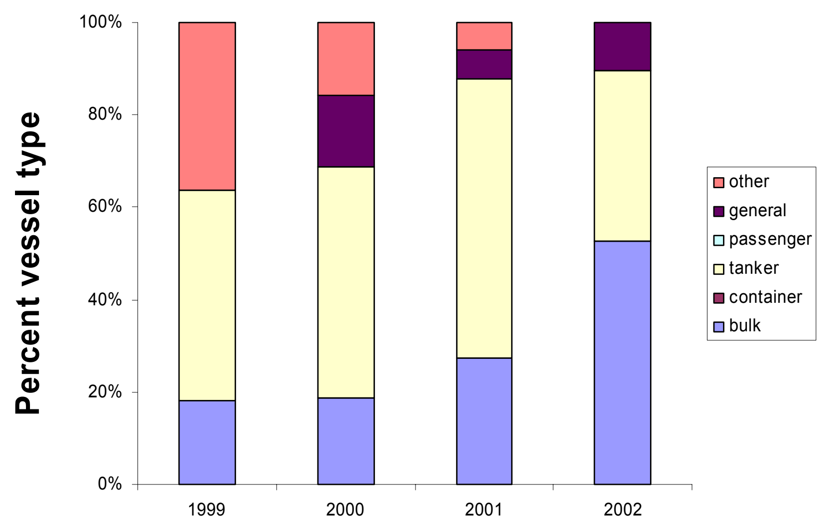


Figure 8c: Relative classification of vessel types to all ports within Connecticut.
Data source: National Ballast Information Clearinghouse Database
(http://invasions.si.edu/NBIC/nbic_database.htm 2003).

During the study period, the vessel types that reported data varied between New England states, but remained relatively consistent over time for each state. Maine ports (Figure 8a) saw mostly oil/bulk ore, which was reported as 46% in 2000 and 40% in 2002, and tankers, which comprised 44% of Maine traffic in 2000 and 34% in 2002. Because reports were only collected for half of 1999, and because data cannot be accurately extrapolated due to low reporting rates, vessel types for this year have been disregarded. Massachusetts ports were visited by the most relatively diverse vessel types. Of

Massachusetts traffic (Figure 8b), passenger vessels (including cruise ships) made up 22% in 2000 and 20% in 2002, tankers made up 10% in 2000 and 8% in 2002, and container ships made up 35% in 2000 and 40% in 2002. Connecticut traffic (Figure 8c) was mostly made up of oil/bulk ore (29% in 2000 and 2002), tankers (29% in 2000 and 12% in 2002), and bulk carriers (23% in 2000 and 59% in 2002). New Hampshire and Rhode Island vessel types were not analyzed in this manner due to the significantly lower volume of reported ballast carrying vessels. Given the low reporting response, these changes are not considered trends.

Within each state, vessel types varied among ports. In Massachusetts, for example, the ports of Boston, Gloucester, and Salem each showed a different type of vessel that most significantly contributed to their traffic. Massachusetts vessel frequency is based on 4 months of 1999 data and 12 months for 2000-2002 (Figure 9). Passenger vessel increased over the past couple of years and is consistent with the observations of a national survey (The Ocean Conservancy 2002). Boston is the most diverse port according to the data reported through the NBIC, with different frequencies for the smaller ports such as Gloucester (container and general cargo ships) and Salem (container and bulk cargo).

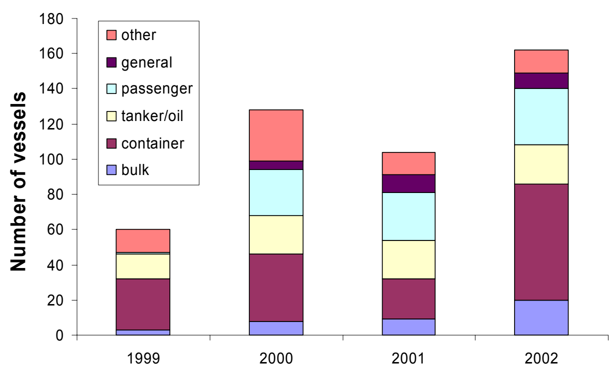


Figure 9. Breakdown of different types of vessels, in terms of frequency, contributing to shipping traffic Massachusetts between August 1999 and December 2002. Data source: National Ballast Information Clearinghouse Database (http://invasions.si.edu/NBIC/nbic_database.htm 2003).

However, the compliance rate limits interpretation. To more fully understand the risks of introducing non-native species to the New England environments via ballast water, more data must be gathered and analyzed. Rates of compliance with reporting guidelines or potential future regulations must increase substantially to gain a better sense of how much ballast water is discharged to New England and to understand better ballast water sources.

Summary

There are several challenges to reducing or preventing introductions from ballast water; the issue is global and regional. This white paper focuses on the regional component of ballast water management and offers recommendations for future action. The international community relies on voluntary compliance, which is not enforceable. Even in areas where activities are mandatory, e.g. reporting ballast water on board and treatment as required by the U.S. Coast Guard, without enforcement compliance remains low. The compliance rate is high in states and countries that enforce reporting requirements (e.g. California and Canada) and risk assessment is possible.

The lack of required ballast reporting and lack of ballast water treatment for vessels traveling within the EEZ is a weakness in the current regulations and guidelines. The reporting information will assist with identification of the extent of the contribution of coastwise traffic to ballast water discharge. A larger question about the exchange within the coastal area remains for both coastwise traffic and vessels unable to exchange at sea. A few locations have been identified as suitable for ballast exchange, e.g. the ESGL. More information is needed about risks associated with ballast exchange and the use of designated areas. This could include prohibiting ballast uptake in areas where highly invasive species are prevalent or avoiding discharge in environmentally sensitive areas.

Recommendations

1) Develop a regional ballast water management plan.
Ballast water concerns in Canada and the United States are closely related and linked. Due to the close proximity between the Gulf of St. Lawrence and the Gulf of Maine, species introduced to one may ultimately impact the other. The United States and Canada have a common interest in preventing the introduction of foreign species to the coasts of the Northwest Atlantic Ocean. Therefore, it may be most expedient to encourage cooperation, sharing of information, and coordination of efforts for both countries. Ultimately, this may best be implemented by an international Northwest Atlantic Regional Ballast Water Management Plan that is simple, clear, and establishes consistency among existing efforts. Such a regional plan would provide one set of regulations and clear enforcement procedures that promote more holistic protection rather than confusion and loopholes.

2) Make reporting ballast water practices mandatory for all vessel traffic.
It is vital to have information regarding the ballast water management practices of vessels entering ports within the United States and Canada, from both outside and within the EEZ of each country. Gaps in this record inhibit understanding the risk of introduction posed to each area and ultimately the prevention of these introductions. Voluntary ballast management reporting should become mandatory with appropriate enforcement measures as necessary for vessels arriving from ports outside and inside the EEZ.

3) Continue the advancement of ballast treatment technologies.
Several methods of ballast treatment, as mentioned earlier, are being developed to minimize the survival of species within ballast tanks. Though such solutions will likely be costly in the short run, efforts in research and development of technology and

standards should be pursued. Most likely, a combination of management efforts will be needed to most effectively minimize the risk of introducing foreign species.

4) Explore the potential for alternate areas for BWE, within the EEZ, to minimize introductions.

Based upon the studies discussed in this paper, recent data suggest that ballast water exchange may not decrease the number of all nonindigenous species (e.g. copepods may increase in number) in tanks. In addition, Canadian studies suggest that the Gulf of St. Lawrence may not be the most appropriate area for an alternate ballast water exchange zone. Due to the relatively high risk of invasion and the large volumes of vessel traffic and ballast water discharged in this region, the Gulf of St. Lawrence waters may not effectively prevent new marine introductions. In order to make a decision, scientific information on the physical and biological oceanography in the Gulf of Maine and the larger North Atlantic coastal region are needed as a first step. Thus information on water movement in these highly dynamic areas as well as biological data on sources of invasive species, dispersion potential, and other data are needed for risk assessment.

5) Risk Assessment

Research should focus on improved sampling technologies, improved species identification, and locations of species with potential to be transported to other areas. Other environmental features, such as salinity should also be considered when identifying an alternate ballast water exchange zone. Any factors that inhibit survival of species once introduced such be accounted for and further studied. Furthermore, proposed alternate ballast water exchange zone should primarily be available for coastwise traffic within the EEZ of the United States and Canada to facilitate and be considered as safety zones for vessels that are arriving from outside the EEZ. A good selection of an alternate BWE zones may minimize the possibility of introducing species and not simply displace introductions from one area to another. This is an area where additional research is needed to provide better guidance to managers.

In addition to these five recommendations, other specific recommendations are identified in the various reports listed in the literature cited section. As we gain greater understanding, our efforts and recommendations should reflect this new knowledge.

Literature Cited

Balaban M. 2001. *Vessel Traffic/Vessel Shipping patterns on the East Coast of Canada 2000 Shipping Season*. Transport Canada Marine Safety Technical Report. 13p.

Beeton AM, Carlton JT, Holohan BA, Wheless GH, Valle-Levinson A, Drake LA, Ruiz G, McCann L, Walton W, Frese A, Fofonoff P, Godwin S, Toft J, Hartman L, von Holle E. 1998. *Draft Ballast Exchange Study: Consideration of Back-up Exchange Zones and Environmental Effects of Ballast Exchange and Ballast Release.* National Sea Grant Program and US Environmental Protection Agency, Washington, D.C.

Bourgeois M, Gilbert M, and Cusson B. 2001. *Evolution du trafic maritime en provenance de l'étranger dans le Saint-Laurent de 1978 a 1996 et implications pour les risques d'introduction d'especes aquatiques non indigènes*. *Can. Tech. Rep. Fish and Aquat. Sci.* 2338: viii +34p.

Canadian Guidelines 2002. Guidelines for the Control of Ballast Water Discharge From Ships in Waters Under Canadian Jurisdiction. Revised September 20, 2002. Annex V Ballast Water Procedures for Vessels Proceeding to Ports on the East Coast of Canada. Revised January 9, 2003.

Carlton J. 2001. *Introduced Species in U.S. Coastal Waters*. Pew Charitable Trust, Washington, D.C.

Carver, CE and Mallett AL. 2002. *An Assessment of Risk of Ballast Water-Mediated Introduction of Non-Indigenous Phytoplankton and Zooplankton in Atlantic Canadian Waters.* Final Report, Transport Canada, Dartmouth, Nova Scotia.

Department of Homeland Security United States Coast Guard. 2003. Mandatory ballast water management program for U.S. waters: Notice of proposed rulemaking. Federal Register 68(146): 44691-44696.

Gilbert M and Saucier F. 2000. Suitability of the Gulf of St. Lawrence as a backup zone for ballast water exchange by foreign ships proceeding up the St. Lawrence Seaway. Presented at the 10th International Aquatic Nuisance Species and Zebra Mussel Conference. Toronto, Canada.

Gollasch S, Len J, Andrea H-G, and Dammer M. 1996. Introduction of non-indigenous organisms into the North and Baltic Sea: Investigations on the potential ecological impact by international shipping. Federal Environmental Agency, Berlin, Germany.

Gollasch S. 2002. The importance of ship hull fouling as a vector of species introductions in the North Sea. *Biofouling* 18: 105-121.

Gosselin S, LeVasseur M, Gauthier D. 1995. Transport and deballasting of toxic dinoflagellates via ships in the Grande Entrée lagoon of the Iles-de-la-Madeleine (Gulf of Saint-Lawrence, Canada). *In Harmful Algal Blooms, Proceedings of the Sixth International Conference on Toxic Marine Phytoplankton,* October 1993, Nantes, France. Ed. P. Lassus, G. Arzul, E. Erard-Le Denn, P. Gentien, C. Marcaillou-Le Baut. Lavoisier Publishing, France. 591-596.

Han G, Loder J, Smith P. 1999. Seasonal-mean hydrology and circulation in the Gulf of St. Lawrence and on the Eastern Scotian and Southern Newfoundland shelves. *J. Phys. Oceanogr*. 29:1279-1301.

Harkless K. 2003. How accurate is ballast water reporting? *Aquatic Invaders: The digest of National Aquatic Nuisance Species Clearinghouse* 14(1): 18-23.

Harvey M, Gilbert M, Gauthier D, Reid D. 1999. A preliminary assessment of risks for the ballast water-mediated introduction of nonindigenous marine organisms in the Estuary and Gulf of St. Lawrence. *Canadian Technical Report of Fisheries and Aquatic Science* 2268:x+56p.

Locke A, Reid D, Sprules W, Carlton J, Leeuwen Hv. 1991. Effectiveness of mid-ocean exchange in controlling freshwater and coastal zooplankton in ballast water. *Canadian Technical Report of Fisheries and Aquatic Science* 1822:vii+ 93p.

Locke A, Reid D, Leeuwen Hv, Sprules W, Carlton J. 1993. Ballast water as a means of controlling dispersal of freshwater organisms by ships. Canadian Journal of Fisheries and Aquatic *Science* 50: 2086-2093.

NISA, 1996. National Invasive Species Act (P.L. 104-332). As amended from NANPCA, the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990.

Pederson J. ed. 2000. *Marine Bioinvasions: Proceedings of the First National Conference*, January 24-27, 1999. MIT Sea Grant, Cambridge, Massachusetts

Pederson J. 2003. Marine Bioinvasions: Patterns, Processes and Perspectives. *Biological Invasions* 5:(1-2). Kluwer Academic Publishers, The Netherlands.

Pederson J and Carlton J. 2002. Ballast Water and Marine Bioinvasions: Hitchhiking Around the World. White Paper Presentation. i+6p.

Pimentel D, Lach L, Zuniga R, Morrison D. 2000. Environmental and economic costs associated with non-indigenous species in the United States. *Bioscience* 5(1).

RNT Consulting. 2002. *Quantification of risks of alien species introductions associated with alternative area for ballast water exchange in the Laurentian Channel of the Gulf of St. Lawrence*. ii+36p.

Ruiz G, Rawlings T, Dobbs F, Drake L, Mullady T, Huq A, Colwell R. 2000. Global spread of microorganisms by ships. *Nature* 408(6808):49-50.

Ruiz G, Miller A, Lion K, Steves B, Arnwine A, Collinetti E, Wells E. 2002. *Status and trends of ballast water management in the United States*: First Biennial Report of the National Ballast Information Clearinghouse. Smithsonian Environmental Research Center, Edgewater, Maryland.

The Ocean Conservancy 2002. *Cruise Control: A Report on How Cruise Ships Affect the Marine Environment.* Prepared by Michael Herz and Joseph Davis and edited by Tim Eichenberger. The Ocean Conservancy, Washington, D.C.

Appendix X

Quantification of Risks of Alien Species Introductions Associated with Alternative Area for Ballast Water Exchange in the Laurentian Channel of the Gulf of St. Lawrence

RNT Consulting Report 108

Submitted March 22, 2002

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Quantification of Risks of Alien Species Introductions Associated with Alternative Area for Ballast Water Exchange in the Laurentian Channel of the Gulf of St. Lawrence

Executive Summary

Canada has one of the longest navigable coastlines in the world, bordering the Atlantic, Arctic and Pacific Oceans, as well as the Great Lakes. Shipping is important to the Canadian national and international trade. Our coastal waters receive yearly over 52 million tonnes of ballast water from foreign ports around the world (Gauthier & Steel 1966). Millions of tonnes of ballast water are discharged into the Estuary and Gulf of St.Lawrence each year. Ballast water has been identified as one of the pathways by which alien aquatic species are introduced outside of their normal range. Under the current Canadian voluntary guidelines, all ships entering Canadian Waters are expected to exchange ballast water outside of the Exclusive Economic Zone (EEZ). The 2001, Transport Canada survey has shown that 77% of all ships entering the Gulf of St.Lawrence have exchanged ballast water in mid-ocean. Of the remainder, 8.5 % are ships, which declared that as they are coming up the North American coastline they are exempt from the need to exchange. Additional 13% do not have a clear reason for not exchanging and may in fact also be part of the coastal trade. Less then 1% of all ships surveyed declared safety as a reason for not doing the exchange.

The current guidelines make provisions for ballast water exchange in “back-up areas”, if exchange is not feasible offshore for safety reasons. Incoming foreign ships may exchange their ballast waters within the Gulf of St. Lawrence, in the Laurentian Channel southeast of Anticosti Island, where depth exceeds 300 m. The magnitude of the risk such ballast water exchanges pose, compared to risk from ballast water discharge in other areas of the Gulf of St.Lawrence was evaluated using a Probabilistic Risk assessment model. The risk was measure in terms of quantity of alien species introduced into various parts of the Gulf, including the Laurentian Channel, giving current shipping patterns and practices.

The relative risk to the Laurentian Channel is 0.5% of the quantity of alien species introduced in the Gulf and Estuary as a whole (including the Laurentian Channel). The model also calculates the quantity of alien species introduced into Area I, II,III,IV of the Gulf, the river stretch(RS) and the Fresh Water Estuary. It is clear that with current shipping patterns and practices the area of the Gulf with greatest risk of alien introductions is Area I (relative risk of over 51%), followed by the River Stretch (38.5%). The discharges to the Laurentian Channel represent negligible risk compared to discharges done in these areas. Even when the number of ships discharging in the Laurentian channel was assumed to be three times the number used in the model, the relative risk in the channel rose to just 1.79%.

Further, the model shows that the greatest potential for introductions comes from the North Atlantic Coast (FAO Region A), followed by FAO Region B which includes the European and Scandinavian coast of the North Atlantic.

The model as constructed is capable of simulating a number of “what if scenarios”. This can be very useful in testing the impacts of any new shipping guideline or regulations on the risk of alien introduction into the Gulf of St.Lawrence.

At this time, the model is restricted to predicting the risk of introductions. It does not incorporate the potential for survival of the alien species introduced. This refinement should be added if additional data can be obtained. Further, the possibility of introducing alien species into the Gulf of St.Lawrence on the hulls of incoming ships represents an additional risk to the one estimated by the model. In order to obtain a complete picture of the possibility of alien introductions by shipping, this component of the risk must be quantified.

1.0 Introduction

Canada has one of the longest navigable coastlines in the world, bordering the Atlantic, Arctic and Pacific Oceans, as well as the Great Lakes. Shipping plays an important role in Canadian national and international trade. Our coastal waters receive yearly over 52 million tonnes of ballast water from foreign ports around the world, compared to the 121 Mt, 69 Mt, > 43 Mt, and 5 Mt received respectively by Australia, the United States, the United Kingdom, and New Zealand (Gauthier & Steel 1966). In addition to this, the domestic and coastal shipping are responsible for the translocation of large quantities of ballast water.

Aquatic alien species invasions through ballast water discharges are now recognized as a serious problem threatening global biological diversity and human health worldwide. On November 27, 1997, the IMO (International Maritime Organization) Marine Environmental Protection Committee (MEPC) adopted Resolution A.868(20), "Guidelines for the Control and Management of Ships' Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens" The IMO recommends that all maritime nations of the world adopt and use these voluntary guidelines. This international initiative was preceded in Canada, by voluntary Guidelines introduced in May 1989 for the control of ballast water discharges from ships entering the Great Lakes and St. Lawrence Seaway. These guidelines were in turn prompted by a number of highly visible introductions of non-native fish, other aquatic species and pathogens, which have caused extensive environmental harm and economic hardship. On September 1, 2000, the guidelines introduced for the Great Lakes were extended as national Guidelines for all waters in Canada.

Currently, all ships entering Canadian Waters are expected to exchange ballast water outside of the Exclusive Economic Zone (EEZ). Those that are coming up the North American coastline frequently consider themselves exempted from the need to exchange.
The current guidelines make provisions for ballast water exchange in “back-up areas”, if ballast water exchange is not feasible offshore for safety reasons. The suitability of these areas for exchanges has yet to be fully assessed. Incoming foreign ships may exchange their ballast waters within the Gulf of St. Lawrence, in the Laurentian Channel southeast of Anticosti Island where depth exceeds 300 m (located east of 63°W longitude). This situation changes the risk for ballast water mediated introductions in this ecosystem. The magnitude of the risk such ballast water exchanges pose, compared to risk from ballast water discharge in other areas of the Gulf of St.Lawrence is the subject of the following report.

2.0 Review of Available Data

As of now, there is no evidence, or official reports, of successful ballast-water-mediated introductions of non-indigenous species to the Estuary or the Gulf of St.Lawrence (Gilbert 2002, pers.comm.). No non-indigenous species has been reported which would have environmental or socio-economic impacts comparable to those observed in the Great Lakes or elsewhere in the world. The apparent absence of successful ballast water-mediated introductions in the Estuary and Gulf may be a reflection of the harsh marine climate in this region or of the sparse biological monitoring in the last decade.

Available reports and databases were reviewed for data that could be used to construct the model. Number of personal interviews were conducted with leading scientists in the region. List of resources collected is included in Appendix A.

2.1 Summary of findings from the review of literature and personal interviews

Millions of tonnes of ballast water are discharged into the Estuary and into the Gulf each year (Gauthier and Steel 1996, Bourgeois et.al. 2001). The precise volume of discharge is difficult to establish for two main reasons:

1. The data acquisition system to document the origins and volumes of the ballast water relies on the voluntary response of ship officers. There is no verification.

2. The database of ballast water forms collected following the September 2000 extension of the voluntary guidelines has only been in existence since June 2001.

The 2001, Transport Canada survey (Appendix D) shows that 77% of all ships entering the Gulf of St.Lawrence have exchanged ballast water in mid-ocean. Of the remainder, 8.5 % are ships which declared that as they are coming up the North American coastline they are exempt from the need to exchange. Additional 13% do not have a clear reason for not exchanging and may in fact also be part of the coastal trade. Less then 1% of all ships surveyed declared safety as a reason for not doing the exchange.

The only vessels which could be confirmed to have exchanged in the Laurentian Channel are those proceeding to the Great Lakes. Appendix B contains the details of those ships obtained from the U.S.Coast Guard in Massena. Dominique Tapin, Director Marine Administration & Technology, Shipping Federation of Canada was contacted as were other shipping representatives and Transport Canada. No additional ships were identified as having conducted ballast water exchange in the Laurentian Channel until March 2002.

In mid-March 2002, Transport Canada forwarded an analysis of the ECAREG (Eastern Canada Region – Vessel Traffic Service) database done by G.Herbert from DFO. Data collected in 1997 shows 56 ships using the Laurentian Channel for ballast adjustment or discharge and 43 ships in the year 2000. Comparing the data collected for year 2000 (Appendix C) with the data received from the U.S. Coast Guard in Messina (Appendix B), shows an overlap of only 3 ships.

The other 9 vessels reported by Massina are not captured by the ECAREG database. Further examination of the year 2000 ECAREG Data shows some ships claiming to have no ballast on board (NOBOB), some which show partial ballast water discharge, some registering their intention to exchange but no confirmation that they have done so. Given the deadline for this report, a decision was made to base the model on the verified information from U.S.Coast Guard. The possibility of additional ships using the Laurentian Channel and the impact it would have on the relative risk of introducing alien species in this region was incorporated into a sensitivity analysis presented in Section 5.0, Discussion of Results.

What percentage of water actually exchanged when ships report "full" mid-ocean exchange is the subject of much discussion. Harvey et.al 1999 document that the percentage exchanged varied from 0 to 100% in a sample of 61 ships. The U.S.Coast Guard considers "full" exchange to mean that 80% of the ballast water was exchanged. In the absence of definitive data, this was the value used in the model.

All relevant reports examined reported high densities of live phytoplankton and zooplankton present in the ballast water being discharged in the Gulf. All studies found species in the ballast water are not currently present in the Gulf. Encysted life forms were found in the sediments of ballast water tanks. Taxonomy and population density information is sparse (Locke et.al 1991, 1993, Harvey et.al. 1999, Mallet 2001, Rao et.al 1994) The data gave values as to the possible densities of different species (within an order of magnitude) Origin of ballast water will influence the number of individuals present and the species composition. However, ballast water remnants and sediment are present in the ballast water tanks as ships travel from port to port. Therefore the biota of the last port of call does not necessarily corresponds entirely to the species present in the ballast water tank. This results in no two ships, even if coming from the same destination, having the same species composition or densities of individuals.
We did not feel the data was extensive enough to incorporate into the model in a meaningful way.

Very little information is available on possible presence and density of pathogens. However, the threat of introduction of toxic phytoplankton to local mussel farming industries prompted the Canadian Coast Guard (CCG) in 1982 to issue the Notice to Mariners #995. This yearly renewed notice prohibits ships bound for the Mines Seleine's pier, situated in the Grande Entrée Lagoon of the Îles-de-la-Madeleine, Gulf of St. Lawrence, from discharging their ballast waters within 10 nautical miles of the islands unless the water was taken on in a well-defined area off Canada's east coast, at a distance of 5 miles or greater from the shoreline (Gosselin et.al.1995).

The length of the voyage may affect the number of individuals present in the ballast water. The longer the voyage, the fewer species and individuals (M. Gilbert 2002 pers.com, J.Martin 2002pers.comm., Mallet 2001, MacIsaac 2002). Not enough information is available to correlate length of voyage with an exact decrease in population density of various taxa, but there is a significant decrease in both the number of species and a number of individual after 5 days in the ballast water tanks. After 10 days 75% decrease was observed (Gilbert 2002 pers.com).

2.2 Workshop with Stakeholders

A meeting was held on November 8th, 2001 in concert with the CMAC meetings in Ottawa. The list of participants and Minutes of the Meeting are included in Appendix E.

The stakeholders were identified by Transport Canada and Fisheries and Oceans Canada. Presentation was given by Mr. Ravishankar on the proposed Risk Methodology and the model under consideration. Ms. Claudi summarized the data available and the assumptions made in the construction of the model. Input was solicited from the 37 participants present. Valuable additional data was made available from several sources. Support was offered by the Shipping Federation of Canada. This support was gladly accepted.

The workshop was invaluable as the data and input received was used to improve the model.

3.0 Probabilistic Risk Model

The objective of the risk assessment undertaken was two fold:

1. To estimate the risk to the Gulf and Estuary, which includes the Laurentian Channel, from exchange and discharge of ballast water therein. The risk is measured in terms of the quantity of alien species introduced. The quantity is expressed as a fraction, in percentage, of the quantity of any alien species present in the ballast at origin. By definition, all alien species are considered undesirable. The introduction alone was considered, survival post-introduction was beyond the scope of this model.

2. To estimate the relative risk to the Larentian Channel. This is estimated as a fraction, expressed in percentage, of the risk to the Gulf and Estuary including the Larentian Channel.

3.1 Assumptions

The following assumptions were made either because of paucity of data available or to streamline the model:

1) Due to a paucity of data, there is no distinction made between different types of alien species. Consequently, all alien species, once introduced, are considered to have the same potential for adverse effect. Only the quantity of alien species introduced is considered as a measure of risk.

2) The effects of differences in salinity in the ballast water at the point of origin and the point of discharge in the Gulf are not considered due to lack of data. The difference affects survival once introduced but not the actual introduction.

3) The effects of the season when the exchange or discharge in the Gulf and Estuary takes place are not considered. This factor affects survival not the actual introduction and it was not pursued at this stage of the model.

4) The duration of a ship's voyage has an effect on the mortality of the alien species contained in the ballast. The longer is the voyage, the higher is the mortality rate. Based

on the limited data available, it is considered that any transit time that is less than 5 days has no mitigation effect, i.e., mortality rate in the ballast water tank is zero. The mortality rate for any transit time that is greater than five days is assumed to be 50%. This means, an exchange or discharge of ballast from a ship with a transit time of more than five (5) days would introduce only 50% of the amount of alien species that were present at origin. This assumption allows for taking into account the transit time and its effects while keeping the model relatively simple)considering the wide ranging transit time of the ships coming into the Gulf).

5) Ports of origin and destinations are of significance only in terms of transit time. The differences in climate and salinity are not considered.

6) It is assumed ships that exchange ballast either in mid-ocean or in the Laurentian Channel do a "full" exchange. In practical terms this means that on average a mid-ocean exchange replaces 80% of the ballast water taken on in the port of origin. That is, the fraction of alien species remaining in the ballast after a mid-ocean exchange is 20% of the amount that was present at origin. We assume that no mid-ocean species taken on during the exchange poses a threat to the coastal areas of the Gulf and, therefore, is not considered in this model.

7) An exchange in the Laurentian Channel is considered to replace 80% of the ballast water taken on in the port of origin. That is, the fraction of alien species remaining in the ballast after the exchange is 20% of the amount that was present at origin.

8) No distinction is made between different taxa. All species in all taxa are considered to pose an equal threat.

9) On the average, only 13 ships bound for the Great Lakes exchange ballast water in the Laurentian Channel. It is assumed that the remaining ships bound for the Great Lakes either exchange in mid-ocean or are NOBOB ships.

3.2 Model Description

Using the assumptions made in Section 3.1, the risk model was developed to calculate the risk to the Gulf and Estuary (including the Laurentian Channel) and to calculate the relative risk to the Laurentian Channel alone.

Briefly, the steps involved in the development of the model were as follows:

a) Enumerate the possible ways by which a discharge at ports in the Gulf and Estuary can occur.

b) Enumerate the possible ways by which an exchange in the Laurentian Channel can occur.

c) Determine for each possible way and thus in total, the quantity of alien species discharged at port, as a fraction of the quantity of alien species present at origin. This is the risk from discharge at port.

d) Determine for each possible way and thus in total, the quantity of alien species discharged in the Laurentian Channel, as a fraction of the quantity of alien species present at origin. This is the risk from exchange in the Laurentian Channel.

e) Determine also for each possible way and thus in total, the quantity of alien species discharged at port, as a fraction of the quantity of alien species present at origin in all ships from all FAO regions travelling to the Gulf and Estuary. This is the risk from discharge at port.

f) Determine for each possible way and thus in total, the quantity of alien species exchanged in the Laurentian Channel, as a fraction of the quantity of alien species present at origin in all ships from all FAO regions travelling to the Gulf and Estuary. This is the risk from exchange in the Laurentian Channel.

g) Using the above information, determine the total risk to the Gulf and Estuary and the relative risk to the Laurentian Channel.

The possible means of discharge or exchange is developed for a typical ship from originating region "i" to destination "j". For the purposes of this study, the originating regions are the FAO regions of origin A, B, C, G and all other regions that are collectively referred to herein as region O (Fig.2). The destination zones in the Gulf and Estuary are categorized as I, II, III, IV, 4, RS (River Stretch), FWE (Freshwater Estuary), and GL-LC. Destination GL-LC, which represents the Laurential Channel, is not really a destination zone but is considered as one for modelling purposes (Fig.3).

The many ways in which a discharge or an exchange can occur is enumerated using a method known as the Event Tree method. This method involves identifying the possible ways in which the amount of alien species introduced into the Gulf and Estuary (including the Laurentian Channel) could be mitigated. Then, for a typical ship going from region "i" to destination "j", considering the applicability and success and failures of each mitigation, the different paths or sequences are developed such that each path culminates in an introduction of alien species.

In this study, for each ship, there are three possible mitigating processes with respect to discharge in port. These are: the transit time being greater than five (5) days, mid-ocean exchange, and Laurentian Channel exchange. With respect to discharge in the Laurentian Channel, only the transit time is a possible mitigating process. This is because, only ships that did not exchange ballast in mid-ocean would possibly exchange in the Laurentian Channel.

Each mitigation process or system is modelled using a binary model for outcome. That is, each is considered either to be a success or a failure. So, if all combinations of N mitigation processes were possible, then there would be 2^N sequences. This means, given that we are considering three (3) possible mitigation processes, the maximum number of sequences possible would be $2^3 = 8$. However, as only ships that did not exchange in mid-ocean might exchange in the Laurentian Channel the possible sequences reduce to a total of six (6).

This is process is illustrated in the following figure which represents the event tree for a ship going from region "i" to destination "j".

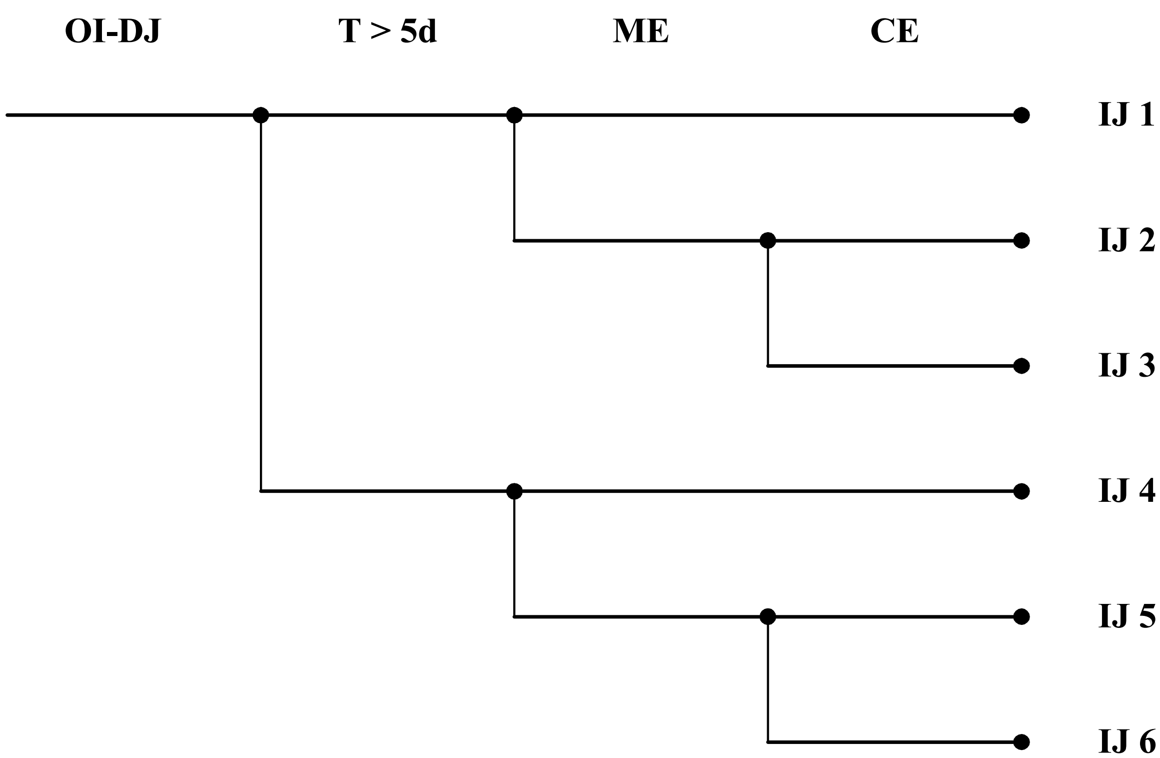


Figure 1: Event Tree for Region of Region I and Destination J – Discharge in Port

Top Line

OI-DJ	Ship from region "i" going to destination "j"
T > 5d	Transit time of the ship is greater than five (5) days
ME	Mitigation through mid-ocean exchange
CE	Mitigation through exchange in the Laurentian Channel

Right Column

IJ N	Sequence number N for a ship from origin "i" going to destination "j"

As described above, each mitigation process has two possible outcomes; corresponding to each mitigating process. Success is depicted by the top horizontal branch and failure by the bottom branch. The six sequences depict the following possibilities:

Sequence Number	Transit Time > 5days?	Mid-Ocean Exchange	Channel Exchange
IJ 1	Yes	Yes	Not Done
IJ 2	Yes	No	Yes
IJ 3	Yes	No	No
IJ 4	No	Yes	Not Done
IJ 5	No	No	Yes
IJ 6	No	No	No

Sequence IJ 1 represents the possibility that the transit time is greater than five (5) days and the ship exchanges ballast in mid-ocean. Therefore, it will not exchange ballast in the Laurentian Channel. Similarly, sequence IJ 6 can be interpreted to represent the possibility that the transit time is no more than five (5) days and the ship does not exchange ballast either in mid-ocean or in the Laurentian Channel.

Figure 1 depicts the model for risk from discharge at the ports. The same model with some modification can be used to obtain the risk from exchange in the Laurentian Channel. Only two of the six sequences, viz., sequences IJ 2 and IJ 5 represent the possibility of exchange in the Laurentian Channel. Based on this fact, quantity of alien species introduced in the Laurentian Channel can be calculated.

Appendix F presents the mathematical model that was used for calculating the risk estimates. Due to resource constraints, only mean estimates are provided, and uncertainty analysis was not performed. An uncertainty analysis is usually performed to quantify uncertainties in the input data and hence the results, which are point estimates. Where input data vary and could be considered to be random variables, their true values can only be estimated to a degree of certainty that depends on the sample used for estimation. The input data are usually mean values and, therefore, the results are also mean values. Quantifying the uncertainty will provide limits for the mean value. The limits are called confidence limits, as it can be stated with a defined level confidence that the true mean value of the result would fall within these limits.

Appendix G describes the sensitivity analyses that were done as a means of verifying the logic of the model.

3.3 Input Data

The input data on which the risk estimates are based, are given in Tables 1 to 4.

Table 1 gives the average number of ships from different FAO regions to the different parts of the Gulf. The data used is from Bourgeois et.al.2001. Their report covers the period 1978-1996. Although there are a total of 13 FAO regions, regions other than A, B, C, and G are combined together to form the so-called region “O” (for other) in their report. The average annual traffic from the different regions of the Gulf was also based on Bourgeois et.al 2001.
Of the average 13 ships bound for the Great Lakes (Appendix B), 11 are assumed to come from

FAO region A, one (1) from region G, and the rest are equally distributed among regions B, C and O. The Laurentian Channel is treated as a virtual port and is designated as GL-LC.

Table 1: Average Number of Ships Discharging or Exchanging in the Gulf Per Year
After Bourgeois et.al.2001

From Origin	Arriving At Destination						
	I	II	III	IV	RS	FEW	GL-LC
A	62.0	22.0	9.0	12.0	35.0	47.0	11.0
B	267.0	21.0	20.0	25.0	446.0	93.0	0.3
C	54.0	4.0	5.0	2.0	88.0	27.0	0.3
G	40.0	35.0	32.0	32.0	145.0	41.0	1.0
O	9.0	5.0	1.0	1.0	72.0	23.0	0.3

Table 2 gives the average ballast capacity of ships.

Table 2: Average Volume of Ballast, Tonnes Per Ship
After Bourgeois et.al.2001

From Origin	Arriving At Destination						
	I	II	III	IV	RS	FWE	GL-LC
A	14.40	0.70	0.20	0.30	7.3	3.5	2.30
B	14.40	0.70	0.20	0.30	7.3	3.5	2.30
C	14.40	0.70	0.20	0.30	7.3	3.5	2.30
G	14.40	0.70	0.20	0.30	7.3	3.5	2.30
O	14.40	0.70	0.20	0.30	7.3	3.5	2.30

Table 3 gives the likelihood of average transit time being greater than 5 days, the likelihood of mid-ocean exchange and the conditional likelihood of an exchange in the Laurentian Channel given there was no mid-ocean exchange. Ships from region A have an average transit time that is less than five days (D.Tapin pers.comm. 2002). Based on the distances, it is considered that all ships from regions B, C and O have an average transit time greater then five days. Again, based on distances, half of the ships from region G are considered to have an average transit time greater than five days. Recently communicated information indicates that on the whole about 78% of the ships that travel to the Gulf exchange ballast in mid-ocean Appendix D). For simplicity 75% average was used. Only a small percentage of ships from FAO region A exchange in mid-ocean. It is considered reasonable to expect that a much greater percentage of ships from FAO region G would exchange ballast in mid-ocean. Thus, allowing for the possibility that a small percentage of ships from FAO regions B, C and O might not exchange ballast in mid-ocean, a 90% probability of exchange in mid-ocean is assigned to these ships. The probability of mid-ocean exchange for ships from FAO regions A and G were derived assuming that the likelihood for ships from region G is four (4) times that of ships from region A. This leads to probabilities of 15% and 60% respectively for ships from regions A and G.

Currently, only ships that are bound for the Great Lakes exchange in the Laurentian Channel if they carry ballast and did not already exchange in mid-ocean. This means the conditional probability of a ballast exchange in the Laurentian Channel is one for these ships bound for the Great Lakes (destination GL-LC in Table 3) and zero for all other ships.

Table 3: Probability of Ballast Exchange or Treatment

(a): Probability of Average Transit Time > 5 days, $p_{T, ij}$							
From Origin	Arriving At Destination						
	1	2	3	4	RS	FWE	GL-LC
A	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	1.00	1.00	1.00	1.00	1.00	1.00	1.00
C	1.00	1.00	1.00	1.00	1.00	1.00	1.00
G	0.50	0.50	0.50	0.50	0.50	0.50	0.50
O	1.00	1.00	1.00	1.00	1.00	1.00	1.00

(b): Probability of Mid-Ocean Exchange, $p_{ME, ij}$							
From Origin	Arriving At Destination						
	1	2	3	4	RS	FWE	GL-LC
A	0.15	0.15	0.15	0.15	0.15	0.15	0.15
B	0.90	0.90	0.90	0.90	0.90	0.90	0.90
C	0.90	0.90	0.90	0.90	0.90	0.90	0.90
G	0.60	0.60	0.60	0.60	0.60	0.60	0.60
O	0.90	0.90	0.90	0.90	0.90	0.90	0.90

(c): Probability of Channel Exchange (given no mid-ocean exchange), $p_{CE, ij}$ %							
From Origin	Arriving At Destination						
	1	2	3	4	RS	FWE	GL-LC
A	0.00	0.00	0.00	0.00	0.00	0.00	1.00
B	0.00	0.00	0.00	0.00	0.00	0.00	1.00
C	0.00	0.00	0.00	0.00	0.00	0.00	1.00
G	0.00	0.00	0.00	0.00	0.00	0.00	1.00
O	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Table 4 gives the effectiveness of mitigation resulting from transit time being greater than five days, and exchange of ballast in mid-ocean and the Laurentian Channel. While not much data are available on the effect of transit time, there is evidence to suggest a 50% mortality rate for ship with a transit time greater than five days. The effectiveness of exchange in both mid-ocean and the Laurentian Channel is assumed to be 80%. That is, the quantity of alien species remaining in the ballast after an exchange is 20% of the quantity that was present in the ballast before the exchange. For the purposes of the model this is called the residual fraction.

Table 4: Mitigation Effectiveness

(a): Mitigation Effectiveness of Transit Time > 5 days – Residual Fraction							
From Origin	Arriving At Destination						
	I	II	III	IV	RS	FWE	GL-LC
A	0.50	0.50	0.50	0.50	0.50	0.50	0.50
B	0.50	0.50	0.50	0.50	0.50	0.50	0.50
C	0.50	0.50	0.50	0.50	0.50	0.50	0.50
G	0.50	0.50	0.50	0.50	0.50	0.50	0.50
O	0.50	0.50	0.50	0.50	0.50	0.50	0.50

(b): Mid-Ocean Exchange Effectiveness – Residual Fraction							
From Origin	Arriving At Destination						
	I	II	III	IV	RS	FWE	GL-LC
A	0.20	0.20	0.20	0.20	0.20	0.20	0.20
B	0.20	0.20	0.20	0.20	0.20	0.20	0.20
C	0.20	0.20	0.20	0.20	0.20	0.20	0.20
G	0.20	0.20	0.20	0.20	0.20	0.20	0.20
O	0.20	0.20	0.20	0.20	0.20	0.20	0.20

(c): Channel Exchange Mitigation Effectiveness – Residual Fraction							
From Origin	Arriving At Destination						
	I	II	III	IV	RS	FWE	GL-LC
A	0.20	0.20	0.20	0.20	0.20	0.20	0.20
B	0.20	0.20	0.20	0.20	0.20	0.20	0.20
C	0.20	0.20	0.20	0.20	0.20	0.20	0.20
G	0.20	0.20	0.20	0.20	0.20	0.20	0.20
O	0.20	0.20	0.20	0.20	0.20	0.20	0.20

4.0 Results

The results corresponding to the current situation where the only ships exchanging in the Laurentian Channel are those bound to the Great Lakes are provided in Tables 5 and 6. Both tables provide results for each possible combination of region of origin and destination zone, as well as marginal aggregates and the total aggregate.

Table 5(a) provides risk of introduction at port, Table 5(b) provides risk of introduction in the Laurentian Channel, and Table 5(c) and Table 5(d) provide total risk of introduction in the Gulf and Estuary including the Laurentian Channel. Table 5(c) provides the risk from region "i" to zone "j" as well as the marginal risk from each of region "i" and at each of zone "j". The risk from region "i" to zone "j" is given as a fraction of the ballast from region "i" that is exchanged or discharged in zone "j". The marginal aggregate risk is given as a fraction of ballast that is exchanged or discharged from region "i" or at zone "j". Table 5(d) provides the risk from region “i” to zone “j”, the marginal aggregate risk from each of region “i” and zone “j”, and the total risk to the Gulf and Estuary including the Laurentian Channel, all as a fraction of all the ballast from all regions that is exchanged or discharged in the Gulf and Estuary.

Referring to Table 5(a), the results in the table are to be interpreted as follows. They provide an estimate of risk of introduction resulting from discharge of ballast at port. The risk estimate for ships going from origin, say, region A to destination, say, zone II, is 88%. What this means is that the ballast discharged in zone II by a ship from region A would contain 88% of the quantity of alien species that were present in the ballast at origin. Similarly, the ballast discharged in zone IV by a ship from region C would contain 14% of the quantity of alien species that were present in the ballast at origin. Of course, GL-LC being the Channel and only a virtual port, the figures under the column GL-LC are all zero.

The estimate of marginal aggregate risk from ships originating in, say, region A, is 86.4%. This means that the sum total of the ballast discharged at ports in the Gulf and the Estuary by ships from region A would contain 86.4% of the quantity of alien species that were contained in the ballast of all the ships from region A at origin. The estimate of marginal aggregate risk from ships originating in, say, region B, is 14.0%, the same as the risk estimate at individual zones (except GL-LC).

Similarly, the estimate of marginal aggregate risk in a destination, say, zone II, is 42.8%. This means that the sum total of the ballast discharged at ports in zone II by ships from all the FAO regions would contain 42.8% of the quantity of alien species that were contained in the ballast of all the ships travelling to zone II from all the FAO regions.

Table 5(b) shows the risk of introduction in the Laurentian Channel. The results in this table also are to be interpreted in the same way as those in Table 5(a). For example, the ballast discharged in the Laurentian Channel by a ship from region A would contain 68% of the quantity of alien species that were contained in the ballast at origin. As mentioned previously, only ships that are bound for the Great Lakes currently exchange in the Laurentian Channel if they carry ballast and did not already exchange in mid-ocean. Thus, non-zero values are shown only under the column GL-LC. That is, only ships that are bound to the Great Lakes and that exchange in the Laurentian Channel are included here.

Table 5(c) shows the total risk to different parts of the Gulf and Estuary including the Laurentian Channel. As mentioned previously, this table provides the risk from region “i” to zone “j” as well as the marginal risk from each of region “i” and at each of zone “j”. The risk from region “i” to zone “j” is given as a fraction of the quantity of alien species present at origin in the ballast of ships from region “i” that is exchanged or discharged in zone “j”. The marginal aggregate risk for region “i” is the quantity of alien species discharged in the Gulf and Estuary, given as a fraction of the quantity of alien species present at origin in the ballast of ships from region “i”. Similarly, marginal aggregate risk for zone “j” is the quantity of alien species discharged in zone “j”, given as a fraction of the quantity of alien species present at origin in the ballast of all ships from all FAO regions travelling to zone “j”.The results in this table also are to be interpreted in the same way as those in Table 5(a). For example, the ballast discharged in the Gulf and Estuary including the Laurentian Channel by a ship from region B is estimated to contain 14% of the quantity of alien species contained in the ballast at origin. Similarly, the ballast discharged in zone II is estimated to contain 42.8% of the quantity of alien species contained in the ballast of all the ships travelling to zone II from all the FAO regions. Other results are to be similarly interpreted.

Table 5(d) shows the total risk to the Gulf and Estuary including the Laurentian Channel but as a fraction of all the ballast from all regions that is exchanged or discharged in the Gulf and Estuary. In addition to providing the risk from region "i" to zone "j" and the marginal aggregate risk from each of region "i" and zone "j", it provides the total risk to the Gulf and Estuary including the Laurentian Channel. The marginal risk can be obtained by a summation of the appropriate row or column, and the total risk can be obtained by a summation of either the row or column of marginal aggregate risk. The results in this table also are to be interpreted in the same way as those in Table 5(a). For example, the quantity of alien species discharged in the Gulf and Estuary by a ship from region B would be 8.09% of the quantity of alien species contained in the ballast of all the ships from all FAO regions at origin. Similarly, the quantity of alien species discharged in the Gulf and Estuary by a ship arriving in zone I would be 13% of the quantity of alien species that were contained in the ballast of all the ships from all FAO regions at origin. Other results are to be similarly interpreted.

Table 5: Risk of Introduction - Current Scenario

(a): Risk of Introduction at Port - Fraction of Quantity in Ballast at Origin								
From Origin	**Arriving At Destination**							**Risk from Origin, %**
	I	**II**	**III**	**IV**	**RS**	**FWE**	**GL-LC**	
A	88.0	88.0	88.0	88.0	88.0	88.0	0.0	**86.4**
B	14.0	14.0	14.0	14.0	14.0	14.0	0.0	**14.0**
C	14.0	14.0	14.0	14.0	14.0	14.0	0.0	**14.0**
G	39.0	39.0	39.0	39.0	39.0	39.0	0.0	**39.0**
O	14.0	14.0	14.0	14.0	14.0	14.0	0.0	**14.0**
Risk At Destination, %	**26.9**	**42.8**	**35.9**	**37.4**	**21.9**	**33.5**	**0.0**	

(b): Risk of Introduction in Laurentian Channel - Fraction of Quantity in Ballast at Origin								
From Origin	**Arriving At Destination**							**Risk from Origin, %**
	I	**II**	**III**	**IV**	**RS**	**FWE**	**GL-LC**	
A	0.0	0.0	0.0	0.0	0.0	0.0	68.0	**1.27**
B	0.0	0.0	0.0	0.0	0.0	0.0	4.0	**0.00**
C	0.0	0.0	0.0	0.0	0.0	0.0	4.0	**0.00**
G	0.0	0.0	0.0	0.0	0.0	0.0	24.0	**0.03**
O	0.0	0.0	0.0	0.0	0.0	0.0	4.0	**0.00**
Risk from Ships to Destination, %	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**59.7**	

Table 5 (Continued): Risk of Introduction – Current Scenario

(c): Total Risk of Introduction in Gulf and Estuary - Fraction of Quantity in Ballast at Origin								
From Origin	**Arriving At Destination**							
	I	**II**	**III**	**IV**	**RS**	**FWE**	**GL-LC**	
A	88.0	88.0	88.0	88.0	88.0	88.0	68.0	**87.6**
B	14.0	14.0	14.0	14.0	14.0	14.0	4.0	**14.0**
C	14.0	14.0	14.0	14.0	14.0	14.0	4.0	**14.0**
G	39.0	39.0	39.0	39.0	39.0	39.0	24.0	**39.0**
O	14.0	14.0	14.0	14.0	14.0	14.0	4.0	**14.0**
Risk from Ships to Destination, %	**26.9**	**42.8**	**35.9**	**37.4**	**21.9**	**33.5**	**59.7**	

(d): Total Risk of Introduction in Gulf and Estuary - Fraction of Total Quantity in Ballast From All Origins								
From Origin	**Arriving At Destination**							**Risk from Origin, %**
	I	**II**	**III**	**IV**	**RS**	**FWE**	**GL-LC**	
A	6.09	0.11	0.01	0.02	1.74	1.12	0.13	**9.24**
B	4.17	0.02	0.00	0.01	3.54	0.35	0.00	**8.09**
C	0.84	0.00	0.00	0.00	0.70	0.10	0.00	**1.65**
G	1.74	0.07	0.02	0.03	3.20	0.43	0.00	**5.51**
O	0.14	0.00	0.00	0.00	0.57	0.09	0.00	**0.80**
Risk At Destination	**13.00**	**0.20**	**0.04**	**0.06**	**9.75**	**2.10**	**0.14**	**25.29**

Table 6 provides risk of introduction in the Laurentian Channel relative to the total introduction in the Gulf and Estuary including the Laurentian Channel. As mentioned above, it is a very small 0.5%. This means that the quantity of alien species introduced in the Laurentian Channel is 0.5% of the quantity that is introduced in the Gulf and Estuary including the Laurentian Channel.

Table 6: Relative Risk of Introduction in the Laurentian Channel

Relative Risk of Introduction in Laurentian Channel, Fraction of Total Risk of Introduction in Gulf and Estuary								
From Origin	**Arriving At Destination**							**Risk from Origin, %**
	1	**2**	**3**	**4**	**RS**	**FWE**	**GL-LC**	
A	0.0	0.0	0.0	0.0	0.0	0.0	100.0	**1.4**
B	0.0	0.0	0.0	0.0	0.0	0.0	100.0	**0.0**
C	0.0	0.0	0.0	0.0	0.0	0.0	100.0	**0.0**
G	0.0	0.0	0.0	0.0	0.0	0.0	100.0	**0.1**
O	0.0	0.0	0.0	0.0	0.0	0.0	100.0	**0.0**
Risk from Ships to Destination, %	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**100.0**	**0.5**

5.0 Discussion of Results

In Table 5(a), the estimate of marginal aggregate risk from ships originating in region A, is 86.4%. This means that the sum total of the ballast discharged at port by ships from region A would contain 86.4% of the quantity of alien species that were present at origin. It is slightly less than the 88% risk at individual zones (except GL-LC) because the aggregate is based on all ships originating from region A, which includes ships from region A that are bound for the Great Lakes and that exchange in the Laurentian Channel. The estimate of marginal aggregate risk from ships originating in region B is 14.0%, the same as the risk estimate at individual zones (except GL-LC). This is because, very few ships from region B exchange in the Laurentian Channel and, therefore, do not significantly affect the aggregate estimate. Similar reasoning applies to other regions.

The estimate of marginal aggregate risk at zone II, is 42.8%. Risk here is expressed as a fraction of the quantity of alien species present in the ballast at origin of all ships arriving in zone II. This estimate is influenced by the distribution of ships arriving in the zone from different regions. Referring to Table 1, a vast majority of ships arriving in zone I are from region B, which have a transit time greater than five days, and 90% of these ships exchange ballast in mid-ocean. On the other hand, a vast majority of ships arriving in zone II are from regions A and G, and the transit time of all the ships from region A and 50% of the ships from region G are less than five days. Also, only 15% of the ships from region A and 60% of ships from region G would exchange in mid-ocean. This explains why the marginal aggregate risk in zone II is significantly higher than that in zone I. Similar reasoning explains the results for other zones.

From Table 5(b), the risk of introduction into the Laurentian Channel is the greatest from ships originating in region A and G. Again, risk here is expressed as a fraction of the quantity of alien species present in the ballast at origin of all ships exchanging in the Laurentian Channel. This is because, most of the ships that exchange in the Laurentian Channel come from these regions. Also, as mentioned above, the transit time of all the ships from region A and 50% of the ships from region G are less than five days; and, only 15% of ships from region A and 60% of ships from region G are considered to exchange ballast in mid-ocean. The marginal aggregate risk in the Laurentian Channel is 59.7%, i.e., the quantity of alien species discharged into the

Laurentian Channel is estimated as 59.7% of the quantity of alien species contained in the ballast of the 13 ships that exchange in the Laurentian Channel in a year. However, as explained below, the total risk to the Laurentian Channel is two orders of magnitude less than this.

From Table 5(c), ships that originate in region B are estimated to introduce 14% of the quantity of alien species contained in their ballast at origin. This low value is to be expected as their transit time is greater than five days and 90% of them exchange ballast in mid-ocean, both of which are significant mitigating factors. Ships that discharge in zone II introduce 42.8% of the quantity of alien species contained in the ballast of ships from all FAO regions at their origin. Again, risk here is expressed as a fraction of the quantity of alien species present in the ballast at origin. As mentioned in the previous paragraph, the ships that exchange in the Laurentian Channel introduce 59.7% of the quantity of alien species present in these (13) ships at origin. However, as the total ballast carried by these ships is very small compared to the total ballast of all other ships destined to a port in the Gulf and Estuary, the risk from exchange in the Channel is much smaller than what the 59.7% estimate might suggest. This is seen Table 6 which shows that the relative risk of introduction in the Laurentian Channel is 0.5%. This in itself is an overestimate of the true risk, as the model does not take into account the effect of survival aspect on introductions. From Appendix B it appears that about 50% of ships exchanging in the Laurentian Channel have fresh water or brackish ballast, making the survival of any introduced species unlikely. Further, Gilbert 2000 has shown that any particle discharged in the Laurentian Channel is either flushed out or takes days before it impinges on shore which mitigates its threat to coastal regions.

In Table 5(d), the total risk to the Gulf and Estuary including the Laurentian Channel is estimated to be 25.3%. That is, the quantity of alien species introduced into the Gulf and Estuary is estimated as 25.3% of the quantity of alien species contained in the ballast of the ships from all FAO regions at their origin. Ships from region A going to zone I constitute the single highest risk at 6.1% or about 25% of the total risk. The ships from region B going to zone II constitute the second highest risk at 4.2% or about 20% of the total risk. This is explained as follows. A vast majority of ships from region A do not exchange ballast in mid-ocean and about 30% of these ships discharge their ballast in zone I. About 40% of the ships from region B discharge their ballast in zone I, although a significant number of these ships exchange their ballast in mid-ocean. Ships arriving in zone I carry the most ballast on the average – 14.4 tonnes per ship.

The marginal aggregate total risk at zone I is the highest at 13%, or 50% of the total risk to the Gulf and the Estuary. The reason for this is as explained above. The second highest is the risk to the River Stretch at 9.8% or 38% of the total risk to the Gulf and Estuary. This stems from the fact that 54% of all the ships entering the Gulf travel to the River Stretch ports and they carry an average 7.3 tonnes of ballast per ship. The marginal aggregate risk in the Laurentian Channel is 0.14%, which is only 0.55% of the total risk to Gulf and Estuary including the Laurentian Channel (see below).

The marginal aggregate total risk from ships from region A is the highest at 9.2% followed closely by ships from region B at 8.1%. This is explained by the reasons given above.

In Table 6, the risk of introduction in the Laurentian Channel comes only from those ships that

are bound for the Great Lakes. The model considers that only ships that are bound for the Great Lakes exchange in the Laurentian Channel if they carry ballast and did not already exchange in mid-ocean. However, the marginal aggregate risk from each region is very small or nil. The quantity of alien species introduced in the Laurentian Channel is 0.5% of the quantity that is introduced in the Gulf and Estuary including the Laurentian Channel. This means that the quantity that is introduced at port is 99.5% of the quantity that is introduced in the Gulf and Estuary including the Laurentian Channel.
As there is a possibility that additional ships may be using the Laurentian Channel for ballast water exchange, sensitivity analysis was performed to examine the possible impact of this situation. The sensitivity analysis involved increasing the number of ships that discharge in the Laurentian Channel. The relative proportion of ships from different origins was kept the same as in Table 3, but the total number was increased to 43. This number was chosen based on information obtained in mid-March 2002 (Appendix C), which indicated that in the recent past as many as 43 ships on the average might have exchanged ballast in the Laurentian Channel. The results from this sensitivity analysis showed that:

- Risk of introduction at port = 25.0%
- Risk of introduction in the Laurentian Channel = 0.46%
- Total Risk = 25.5%
- Relative risk of introduction in the Laurentian Channel = 1.79%

Compared to the current situation, the risk at port is slightly less. This is because, while the quantity discharged at port remains the same, there are more ships exchanging in the Laurentian Channel and hence the total amount discharged or exchanged in the Gulf and Estuary increases. As ships that exchange ballast in the Laurentian Channel carry smaller ballast, this increase is small.

As can be expected, the risk of introduction in the Laurentian Channel increases. This increase is proportional to the increase in the number of ships exchanging in the Laurentian Channel and is still very small compared to the risks in other parts of the Gulf. In addition, the model is a simplified representation of reality in that it does not account for factors such as survival, dispersal and differences in seasons and salinity.

The results in Tables 5 and 6 provide estimates of the average risk. This is the outcome of using average values for the input data. Uncertainty analysis has not been performed at this time. It is not uncommon to perform uncertainty analysis, and it is recommended that it be part of any future analysis. As explained previously, an uncertainty analysis is usually performed to quantify uncertainties in the input data and hence the results, which are point estimates. Quantifying the uncertainty will provide limits for the mean value. The limits are called confidence limits, as it can be stated with a defined level confidence that the true mean value of the result would fall within these limits.

6.0 Conclusion

The risk from discharge and exchange of ballast water in the Gulf and Estuary including the Laurentian Channel was estimated. The over all risk to the Gulf and Estuary including the Laurentian Channel, as measured in this study, is estimated as 25.3%. The relative risk to the Laurentian Channel is estimated as 0.5%, i.e., the quantity of alien species introduced in the Laurentian Channel is 0.5% of the quantity of alien species introduced in the Gulf and Estuary as a whole (including the Laurentian Channel). Ships from region A going to zone I constitute the single highest risk at 6.1% or about 25% of the total risk. The ships from region B going to zone II constitute the second highest risk at 4.2% or about 20% of the total risk. The marginal aggregate total risk at zone I is the highest at 13%, or 50% of the total risk to the Gulf and the Estuary, followed by a risk of 9.8% or 38% at the River Stretch. The marginal aggregate total risk from ships from region A is the highest at 9.2% followed closely by ships from region B at 8.1%.

Due to a paucity of data and resource limitations, the risk model that was developed was simplified and does not account for such factors as survival, migration, and differences in salinity and season. The model was verified through a sensitivity analysis, but the verification is limited to the model logic and not the input data. Risk is measured in terms of the quantity of alien species introduced, expressed as a fraction of the quantity present in the ballast at origin. This does not account for the actual quantity of ballast discharged or exchanged, or distinguish between the taxa of alien species. Survival and transport of introduced species was not taken into account. While these factors lead to a conservative estimate, they should be addressed in future studies.

Despite the limitations of the current model, it does provide consistent methodology for evaluating risks of alien introductions from ballast water discharges. It shows that the greatest danger to the Gulf of St.Lawrence is posed by coastal shipping from Region A discharging in the ports of Zone I. Therefore, remedying this situation first would provide the greatest return on investment in terms of the environmental health of the Gulf.

The methodology used can be applied to different scenarios of shipping patterns and regulation to help in evaluation of the different options. Again, it provides for a consistent, science based approach to decision making.

Appendix A

Balaban, M. 2001. **Vessel traffic/vessel shipping patterns on the east coast of Canada, 2000 shipping season.**

Bourgeois, M.; Gilbert M.; Cusson B. 2001 **Evolution du traffic maritime en provenance de l'etranger dans le Saint-Laurent de 1978 a 1996 et implications pour les risques d'introduction d'especes aquatiques non indigenes. Rapp.tech.can.sci.halieut.aquat.2338:viii +34p.**

Gauthier D., Steel, D.A. 1996**. A synopsis of the situation regarding the introduction of nonindigenous species by ship-transported ballast water in Canada and selected countries. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2380:1-57**

Gilbert M.; Saucier, F.J. 2000. **Suitability of the Gulf of St. Lawrence as backup zone for ballast water exchanges by foreign ship proceeding up to the St. Lawrence Seaway. 10th International Conference on Aquatic Invasive Species, Toronto, February 2000.**

Gosselin, S.; Levasseur, M.; Gauthier, D. 1995. **Transport and deballasting of toxic dinoflagellates via ships in the Grande Entrée Lagoon of the Îles-de-la-Madeleine (Gulf of St. Lawrence, Canada). In Lassus P.,G.Arzul,E.Erard,P.Gentien & C.Marcaillou(eds.) Harmful Marine Algal Blooms pg.591-596**

Harvey M.; Gilbert, M.; Gauthier, D.; Reid, D.M. 1999. **A preliminary assessment of risks for the ballast water-mediated introduction of nonindigenous marine organisms in the Estuary and Gulf of St. Lawrence. Can.Tech.Rep.Fish.Aquat.Sci.,2268:x+56p.**

Lewis, D. 1994. **Canadian coast guard assessment of the potential for introduction of exotic species through exchange of industrial shipping ballast water. Aquatic Sciences Inc., St. Catharines, ON.**

Locke, A.; Reid, D.M. ; Sprules, W.G.; Carlton; J.T. ; van Leeuwen, H.C. 1991. **Effectiveness of mid-ocean exchange in controlling freshwater and coastal zooplankton ballast water. Can.Tech.Rep.Fish.Aquat.Sci.1822**

Locke, A.; Reid, D.M.; van Leeuwen; H.C.; Sprules; W.G.; Carlton, J.T. 1993. **Ballast water exchange as a means of controlling dispersal of freshwater organisms by ships. Can.J.Fish.Aquat.Sci.50:2086-2093**

Mallet Research Services 2001; **A preliminary assessment of the risks of ballast water mediated introduction of non-indigenous phytoplankton and zooplankton species into Nova Scotia waters. Report to Transport Canada Marine Safety Section.**

MacIsaac, H.J.; Robbins T.C; Lewis M.A. 2002 **Modeling Ships' Ballast Water as Invasion Threats to the Great Lakes. Presented at the 11th International Conference on Aquatic Invasive Species, Washington D.C. February 2002.**

Roy, S. 1994. **Analyse d'échantillons de sédiments provenant de réservoirs d'eau de ballast.**

Smith, T.E.; Kerr, S.R. 1992. **Introductions of species transported in ships' ballast waters: the risk to Canada's marine resources. Can.Tech.Rep.Fish.Aquat.Sci.1867:1-16**

Subba Rao, D.V.; Sprules, W.G.; Locke, A.; Carlton, J.T. 1994. **Exotic phytoplankton species from ships' ballast waters: risk of potential spread to mariculture on Canada's east coast. Can. Data Rep. Fish. Aquat. Sci. 937: iv + 51 p.**

Appendix B – Known Ballast water Exchange in the Laurentian Channel provided by U.S.Coast Guard in Messina

Vessel Name	Last Port of Call	Total Volume m3	Ballast water – most likely salinity
	1999		
Marinette	Sept Isles, Canada	530	Marine
Dora	Brayton Pt., MA	14105	Freshwater
Concord	Baltimore, MD	1079	Brackish/FW
Caro	Newark, DE	4666.5	Variable/mostly brackish
Cheremkhovo	Boston, MA	1127	Brackish
Santiago	St. Johns, Canada	1489.76	Marine
Clipper Antares	New London, CT	4770.1	Marine
Federal Saguenay	Baltimore, MD	15856.1	Brackish/FW
Hilal II	New York, NY	11289	Variable/mostly brackish
Finikas	Searsport, ME	3163	Marine
Argus	Wilmington, NC	2769	Freshawater
	2000		
Olympic Mentor	Baltimore, MD	1686	Brackish/FW
Lamda	Sheet Harbor,N. Scotia	1134	Marine
Daviken	Baltimore, MD	9594	Brackish/FW
Spring Laker	New Haven, CT	1662.36	Marine
Malene	Copenhagen, Denmark	238	Brackish/FW
Goviken	New Haven, CT	1632	Brackish/FW
Marilis T	Baltimore, MD	1152.08	Brackish/FW
Federal Bergen	Baltimore, MD	2576.1	Brackish/FW
Fullnes	Baltimore, MD	3919	Brackish/FW
Federal Asahi	New Haven, CT	1057	Brackish/FW
Dobrush	Norfolk, VA	8574	Brackish/Estuarine
Spring Laker	Philadelphia, PA	4841.94	Freshwater
	2001		
Federal Hunter	Camden, NJ	4436	Freswater
Spar Opal	New Haven, CT	940	Brackish/FW
Happy River	Providence, RI	3520	Brackish/Marine
Spar Jade	Philadelphia, PA	1610	Freshwater
NST Challenge	Providence, RI	5110	Freshwater
Federal Kivalina	Baltimore, MD	12233	Brackish/FW
Dimitris Y	Boston, MA	3913.2	Brackish
Adimon	Norfolk, VA	5430	Brackish/Estuarine
Mathile Oldendorf	Gaspe, Canada	4511.6	Marine?
Lucky Lady	Baltimore, MD	1164	Brackish/FW
Sylvia	Belledune, Canada	3907	Marine
Coral Trader	St. John, NB	1325	Marine

[1] Donor harbour salinities provided by M.Gilbert Fisheries and Oceans Canada

Appendix C

Record of Vessel Trips Using Laurentian Channel for Ballast Water Exchange – Summary from ECAREG Database for year 2000, provided by Glen Herbert, Oceans and Coastal Management Division, Fisheries and Oceans Canada (Maritimes Region), Bedford Institute of Oceanography

Stat_Report	TripNum2	Vess_Name	GrosTon	VesTyp
	553724	STAR STRONEN	12768	MG
	553724	STAR STRONEN	12768	MG
	553724	STAR STRONEN	12768	MG
(L)XCHD BAL WATER COMPLETED	553724	STAR STRONEN	12768	MG
(M) WILL EXCHANGE IN LAURENTIAN CHANNEL	553724	STAR STRONEN	12768	MG
(M)IOPPC EXP. 9 JUNE 2000	534062	MARINETTE	9261	MG
	534062	MARINETTE	9261	MG
(M)VESSEL WILL EXCHANGE BALLAST BETWEEN 61W-63W	534062	MARINETTE	9261	MG
(M) BAL EXCH COMPLETE POSN 4855N 06250W	534062	MARINETTE	9261	MG
	534062	MARINETTE	9261	MG
IOPPC EXP: 09 FEB 2001	532657	EMMAGRACHT	8448	MG
	532657	EMMAGRACHT	8448	MG
	532657	EMMAGRACHT	8448	MG
	532657	EMMAGRACHT	8448	MG
(M) Q1 ANSWERED TO SATISFACTION	532657	EMMAGRACHT	8448	MG
BALLAST EXCHANGED BETWEEN 61-63W.	532657	EMMAGRACHT	8448	MG
(M) JIGS 1 YES 2 YES	533786	PIETRO BARBARO	9383	TL
4916.5N 6352.7W CO 300 SPD 13KTS OPEN WATER	533786	PIETRO BARBARO	9383	TL
(M)WILLEXCHANCE IN LAURENTIEN CHANNE	533786	PIETRO BARBARO	9383	TL
EXCH BALLAST FM 4831N 6155W TILL 4857N 6300W	533786	PIETRO BARBARO	9383	TL
(M) COF EXPIRES JULY 30TH 2002	533786	PIETRO BARBARO	9383	TL
(M)IOPP-30/06/02,ISM-22/01/03,DOC-22/03/02	533786	PIETRO BARBARO	9383	TL
	533786	PIETRO BARBARO	9383	TL
	533786	PIETRO BARBARO	9383	TL
	533786	PIETRO BARBARO	9383	TL
	533786	PIETRO BARBARO	9383	TL
	533786	PIETRO BARBARO	9383	TL
4850.3N 6243.8W CO 300 SPD 13 KTS OPEN WATER	533786	PIETRO BARBARO	9383	TL
(L) CFM BAL XCHD BN 61/63W	535159	NELVANA	44340	MB
(M) BALLAST TO BE EXCHANGED IN LAURENTIAN CHANNEL	535159	NELVANA	44340	MB
	535159	NELVANA	44340	MB
	535159	NELVANA	44340	MB
BALLAST EXCHANGED IN LANRENTIAN CHANNEL	549915	NAVA MARIA	18604	MB
	549915	NAVA MARIA	18604	MB
(M) INTEND CHANGING BST LAURENTIAN CHANNEL	549915	NAVA MARIA	18604	MB
	549915	NAVA MARIA	18604	MB
(M) BAL WILL BE CHANGED BETWEEN 61/63W WILL ADVISE	538360	LAMDA *	9529	MB
	538360	LAMDA *	9529	MB

	538360	LAMDA *	9529	MB
BALLAST WAS EXCHANGED BETWEEN 61W & 63W.	538360	LAMDA *	9529	MB
	549544	DOBRUSH	17989	MB
	549544	DOBRUSH	17989	MB
(M)WILL BE EXCHANGED IN LAURENTIAN CHANNEL BTWN 61W+63W	549544	DOBRUSH	17989	MB
	552094	SHOU CHANG HAI	27766	MB
(M) COMMENCE EXCH BALLAST	552094	SHOU CHANG HAI	27766	MB
(M)VSL ADVSD AS PROC TO PORT WEST OF 63W-BAL TO BEEXCHANGED	552094	SHOU CHANG HAI	27766	MB
	552094	SHOU CHANG HAI	27766	MB
	552094	SHOU CHANG HAI	27766	MB
(M) EXP IOPPC 17 MAR 2004, ISM 20 MAR 2002, DOC 30 JAN 2002	552094	SHOU CHANG HAI	27766	MB
	534655	WELLINGTON KENT	7001	TT
	534655	WELLINGTON KENT	7001	TT
(M) EXCH BAL TANKS LAUR CHNL CGO TANKS EXCH ASHORE DESTN	534655	WELLINGTON KENT	7001	TT
	534655	WELLINGTON KENT	7001	TT
EXCHANGE BALLAST BETWEEN 4705N05956W AND 4855N06254W.	550236	BERNHARD OLDENDORFF	43332	MB
	550236	BERNHARD OLDENDORFF	43332	MB
	550236	BERNHARD OLDENDORFF	43332	MB
	548132	THORNHILL	22354	MB
(M) COMPLETED BST EXCHN IN LAURENTIAN CHANNEL	548132	THORNHILL	22354	MB
	548132	THORNHILL	22354	MB
	542300	DOUG MCKEIL	292	HT
BALLAST EXCHANGED BTWN 6130W AND 6230W	542300	DOUG MCKEIL	292	HT
(M) MASTER INFORMS ECAREG BALLAST DRAWN IN 15' BOSTON HBR	542300	DOUG MCKEIL	292	HT
(M) COMPLETED BAL EXCH BTN 4854.7N/6255.9W AT 11/2200Z	547436	DEVOLAN *	14558	MB
(M) EX IOPP 2000/NOV/07 ISMC 2003/03/28 ISM/D 2002/03/07	547436	DEVOLAN *	14558	MB
	547436	DEVOLAN *	14558	MB
(M) BALLAST WILL BE EXCHANGED LAURENTIAN CHNL 61W-63W	547436	DEVOLAN *	14558	MB
IN CONFORMITY.	547436	DEVOLAN *	14558	MB
	547436	DEVOLAN *	14558	MB
	551617	SPRING LAKER	17997	MB
	551617	SPRING LAKER	17997	MB
(M) BAL WILL BE EXCHNGD BTWN 61W-63W IN LAUREN. CHNL	551617	SPRING LAKER	17997	MB
WATER BAL. HAS BEEN EXCHG AS REQUIRED	551617	SPRING LAKER	17997	MB
	538053	KAPITAN VAGA	6030	MG
(M)WILL BE EXCHANGED IN LAURENTIAN CHANNEL	538053	KAPITAN VAGA	6030	MG
EXCHNG COMPLTD AT 1945LT PSN 4820N 6127W.	538053	KAPITAN VAGA	6030	MG
	538053	KAPITAN VAGA	6030	MG
	547568	STAR DRIVANGER *	27735	MG
COMPLIES - WILL EXCHANGE IN LAURENTIAN CHANNEL BTW 61/63W	547568	STAR DRIVANGER *	27735	MG
	547568	STAR DRIVANGER *	27735	MG
(N)UNABLE TO PUMP #5 TANK DUE STABILITY. NON COMP RPT SENT	547568	STAR DRIVANGER *	27735	MG
	543140	FOREST ENTERPRISE	10199	MG
	543140	FOREST ENTERPRISE	10199	MG
(M) CALLED CUSTOMS&IMMIGRATION RE ROGUE	543140	FOREST ENTERPRISE	10199	MG
(M) 1700MT BAL TAKEN IN US PORTS/XCHANGE IN LAURENTN CH.	543140	FOREST ENTERPRISE	10199	MG
(M) EXCH POSN 4854N 06255W	543140	FOREST ENTERPRISE	10199	MG

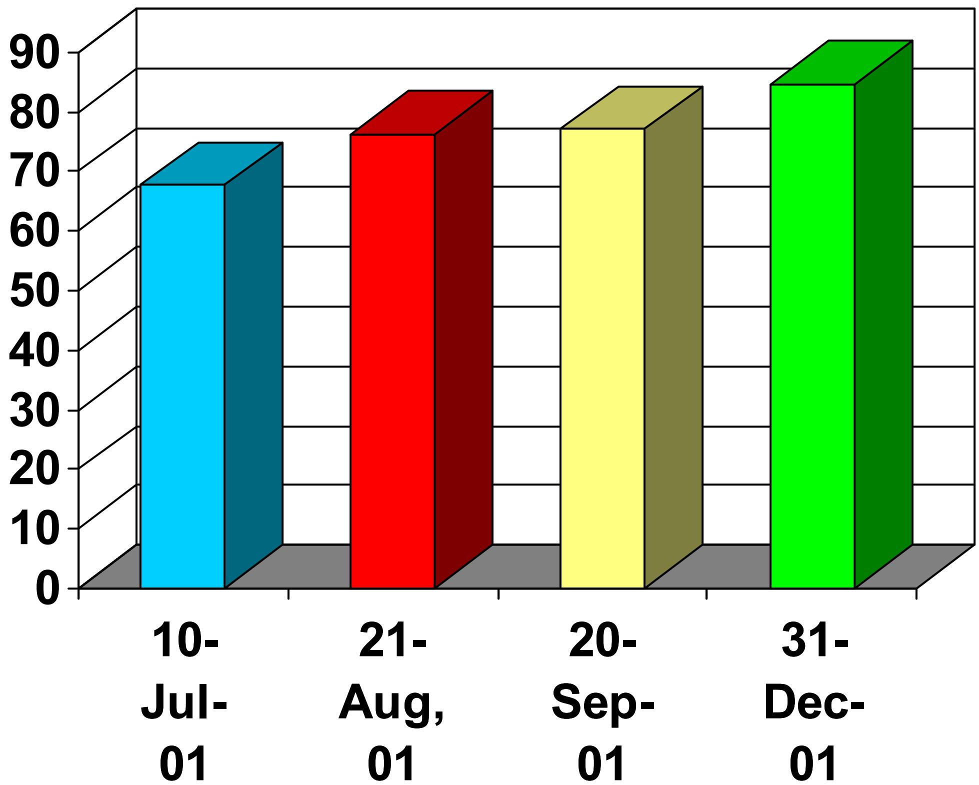
(M) 1800MT EXCH 3730N 06700W; WILL DISCH 600MT LAUR. CHNL	536878 VOLA	13834	MB
	536878 VOLA	13834	MB
	536878 VOLA	13834	MB
BALLAST EXCHANGED IN LAURENTIAN CHANNEL>300M 6103/6253.	553053 MILLENIUM EAGLE	17822	MB
BALLAST TO BE EXCHANGED IN LAURENTIAN CHANNEL >300M 61/63W	553053 MILLENIUM EAGLE	17822	MB
	553053 MILLENIUM EAGLE	17822	MB
	553053 MILLENIUM EAGLE	17822	MB
START TO EXCHG BALLAST PASSING 61W WILL TAKE 24HRS	531370 HENG SHAN	86192	MB
	531370 HENG SHAN	86192	MB
IOPPC EXP AUG 10/2004 ISM-DOC FEB 26/2003 SMC FEB 09/2000	531370 HENG SHAN	86192	MB
NO EXCHANGE OF BAL THIS TRIP - WILL CHANGE BTW 61/63W	531370 HENG SHAN	86192	MB
	531370 HENG SHAN	86192	MB
(M) WILL EXCHANGE BST IN LAURENTIAN CHANNEL	531699 ST. PETER Q1	22046	MB
	531699 ST. PETER Q1	22046	MB
	531699 ST. PETER Q1	22046	MB
	531699 ST. PETER Q1	22046	MB
	531788 BREMER SATURN	2854	MG
IOPPC 10.05.2000	531788 BREMER SATURN	2854	MG
WILL EXCHANGE 470TONS BALLAST IN LAURENTIAN CHANNEL	531788 BREMER SATURN	2854	MG
COMPLETED BALLAST EXCHANGE AT 4829N 06152W	531788 BREMER SATURN	2854	MG
	531788 BREMER SATURN	2854	MG
NEW ICE RECOMMENDED ROUTE #3 SENT VIA VCG	531788 BREMER SATURN	2854	MG
(L) ADVISED NEW ICE ROUTE NO. 4	531788 BREMER SATURN	2854	MG
	532457 MICHIGANBORG	6540	MG
	532457 MICHIGANBORG	6540	MG
IOPPC EXP 09 SEPT 2004 COC EXP 17.06.2002	532457 MICHIGANBORG	6540	MG
BALLAST TO BE EXCHANGED IN THE LAURENTIAN CHANNEL.	532457 MICHIGANBORG	6540	MG
ISM EXP 21-03-2005 ISM DOC 17-06-2002	532457 MICHIGANBORG	6540	MG
(M) EXCH LAURENTIAN CHANNEL	544659 VOORNEBORG	6130	MG
	544659 VOORNEBORG	6130	MG
ISM EXP JUNE 17 2002	544659 VOORNEBORG	6130	MG
	544659 VOORNEBORG	6130	MG
(M) IOPPC 2000/JUL/15 ISMC 2000/AUG/15 ISMD 2000/OCT/04	534891 BOW DE SILVER	6294	TT
(M) BST TAKEN IN PORT AM, WILL EXCH ACCORDING INSTRUCTIONS	534891 BOW DE SILVER	6294	TT
(M) TANKER TYPE OIL/MOLASSES/CHEMICAL II/III	534891 BOW DE SILVER	6294	TT
	534891 BOW DE SILVER	6294	TT
(M) BAL XCHD 4527/06014 TO 4818/06122 300630Z	534891 BOW DE SILVER	6294	TT
	534891 BOW DE SILVER	6294	TT
(M) COF 2000/JUL/15	534891 BOW DE SILVER	6294	TT
(M) IOPPC 09/01/2001 ISM 28/03/2003 DOC 16/02/2003	535224 EMMA OLDENDORFF	18220	MB
(M) EXCHANGED >2000M	535224 EMMA OLDENDORFF	18220	MB
(M) COMPLETED BAL XCHANG 1600Z 48.32N/062.01W	535224 EMMA OLDENDORFF	18220	MB
	535224 EMMA OLDENDORFF	18220	MB
	535224 EMMA OLDENDORFF	18220	MB
COMPLETED BALLAST EXCHANGE IN PX 4856N 06259W.	535415 YUAN ZHI	21392	MB
	535415 YUAN ZHI	21392	MB
	535415 YUAN ZHI	21392	MB

(M) EXP DATE IOPPC=25-03-2004,ISM=07-07-2003,DOC=14-10-2001	535415	YUAN ZHI	21392	MB
L)EXCHANGE OF BAL IN LAURENTION CHANEL COMPLETED 09/0100LT	535415	YUAN ZHI	21392	MB
(M)BAL TAKEN IN DELAWARE,WILL EXCH LAURENTIAN CH AND REPORT	535415	YUAN ZHI	21392	MB
(M) VESSEL TO PICK-UP CDN CHART FROM QBC-MTL AT DLES	535674	SILVER RIVER	8041	TT
(L)BAL OK.	535674	SILVER RIVER	8041	TT
(M) EXP IOPPC=25-06-2004, SMC=22-06-2000, DOC=11-06-2004	535674	SILVER RIVER	8041	TT
(M) NO BAL TO DISCHARGE BUT 426.8T TO EXCH IN LAURENTIAN CH	535674	SILVER RIVER	8041	TT
	535674	SILVER RIVER	8041	TT
	535674	SILVER RIVER	8041	TT
	535674	SILVER RIVER	8041	TT
	536724	HELLENIC CONFIDENCE	10984	MB
(M) NO BALLAST ON BOARD/WILL TAKE BALLAST IN CABOT STRAIT	536724	HELLENIC CONFIDENCE	10984	MB
	536724	HELLENIC CONFIDENCE	10984	MB
	540131	ARON	3410	MG
	540131	ARON	3410	MG
(L) 50 MT BALLAST WATER EXCHANGED 61W ET 63W.	540131	ARON	3410	MG
(M) 50 MTS WILL BE EXCHND IN LAUR. CH./WILL ADVISE	540131	ARON	3410	MG
IOPPC EXPIRY AUGUST 31/2000	540131	ARON	3410	MG
	541520	PANAM CRISTAL	5974	TT
(M)IOPPC 2001/01/17 ISM 2001/09/08 DOC 2002/05/28	541520	PANAM CRISTAL	5974	TT
(M) CERT. OF FITNESS 2001/01/17	541520	PANAM CRISTAL	5974	TT
(M) WILL COMPLY WITH BAL REG. AND ADVISE COMPLETED	541520	PANAM CRISTAL	5974	TT
COMPLETION OF BALLAST EXCHANGE 4810N/61W TO 4856/6259.	541520	PANAM CRISTAL	5974	TT
	541520	PANAM CRISTAL	5974	TT
	554171	MOEZELBORG	6540	MG
CHANGE WATER BALLAST ENTRE 4809N 6100W ET 4839N 6244W.	554171	MOEZELBORG	6540	MG
(M) WILL CHANGE BST IN LAURENTIAN CHANNEL	554171	MOEZELBORG	6540	MG
	554171	MOEZELBORG	6540	MG
(M) COMPLETED BALLASTING 4856N 06259.3W	542714	LAPPONIAN REEFER	7944	MR
(M) BAL TO BE EXCHANGED LAURENTIAN CHANNEL	542714	LAPPONIAN REEFER	7944	MR
	542714	LAPPONIAN REEFER	7944	MR
	542714	LAPPONIAN REEFER	7944	MR
(M) IOPPC EXPIRES JAN 23RD 2002	542714	LAPPONIAN REEFER	7944	MR
	543701	LYKES LEADER	13231	MG
	543701	LYKES LEADER	13231	MG
(L) VSL ADVD BALAST EXCHANGED IN LAURENTIAN CHANNEL.	543701	LYKES LEADER	13231	MG
(M) EX TOWER BRIDGE/C6KP4 UID 20023	543701	LYKES LEADER	13231	MG
(M) EXP IOPPC 14/OCT 2001	543701	LYKES LEADER	13231	MG
(M) IOPPC 2003/02/10	545193	FU AN CHENG	16801	MG
	545193	FU AN CHENG	16801	MG
	545193	FU AN CHENG	16801	MG
(M) WILL EXH LAURENTIAN CH. BST 1080MT BWTN 61W/63W	545193	FU AN CHENG	16801	MG
(L) BAL XCHDIN LAURENTIAN CHNL DEPTH EXCD 300 MTRS.	545193	FU AN CHENG	16801	MG
(M) SENT OVERDUE +4 HOUR MESSAGE VIA SYDNEY RADIO/VCO	545193	FU AN CHENG	16801	MG
	548229	TAIPAN	12758	TL
(M) NO BALLAST ON BOARD. INTENDS TAKING 150MT IN GULF.	548229	TAIPAN	12758	TL
	548229	TAIPAN	12758	TL

(M)IOPPC EXP: 31/10/01 COF:31/10/01 ISM:26/07/05	548229	TAIPAN	12758	TL
EXCHANGE BALAST FROM 4811N/06105W TO 4846N/06234W	548548	MARGARA	40705	TT
	548548	MARGARA	40705	TT
	548548	MARGARA	40705	TT
(M)IOPPC: 08/31/2004 ISM: 12/12/2004 DOC: 02/09/2003	548548	MARGARA	40705	TT
	552366	LING XIAN	31643	MB
(M)EXPY;IOPPC:30/11/2004.ISM:23/04/2002.DOC:28/08/2001	552366	LING XIAN	31643	MB
(M)INTEND TO EXCHANGE BALLAST TAKEN AT NEWARK BTWN 61 & 63W	552366	LING XIAN	31643	MB
	552366	LING XIAN	31643	MB
	553662	ATLANTIC SWAN	7285	TT
(L) XCGD COMPLETED IN LAURENTIAN CHANNEL	553662	ATLANTIC SWAN	7285	TT
(M) EXP IOPP 31 JUL 2005 ISM 16 JAN 2003 DOC 27 OCT 2002.	553662	ATLANTIC SWAN	7285	TT
(M) EXP INLS 31/07/05 COC 26/05/02 COF 31/07/05	553662	ATLANTIC SWAN	7285	TT
	553662	ATLANTIC SWAN	7285	TT
(L) VSL RQST CDN CHARTS FRM LES TO MTL (APL AVISE).	553662	ATLANTIC SWAN	7285	TT
(M) WILL EXCHNG BTWN 61-63W AND WILL RPRT PSN/TIME.	553662	ATLANTIC SWAN	7285	TT
	553746	EDEN	73016	MB
(M) EXCH BTWN 61W AND 63W.	553746	EDEN	73016	MB
	553746	EDEN	73016	MB
IOPPC 05/09 2001 ISM DOC 09/03 2004 SMC 12/09 2001	553746	EDEN	73016	MB
VSL TO EXCHANGE BALLAST BETWEEN 61W AND 63W	553746	EDEN	73016	MB
(M)WILL COMPLY& EXCH BAL IN LAURENTIAN CH BTWN 61W-63W...	554741	JING AN CHENG	16703	MG
(M)EXCH 3515N/7501W-3544N/7449W DEP 50M-1500M	554741	JING AN CHENG	16703	MG
(M)IOPPC 18/10/2002	554741	JING AN CHENG	16703	MG
	554741	JING AN CHENG	16703	MG
	554741	JING AN CHENG	16703	MG
(M) EX COMPLETED 4810.8/06102/4847.5/06236 IAW REGS	554741	JING AN CHENG	16703	MG
(M)ISMCERT/EXPIRY/OCT/05/2004 DOC/APR/08/2002	554741	JING AN CHENG	16703	MG
(M) SAFETY MANAGEMENT CERTIF EXP 23/06/2005.	547882	FEDERAL ASAHI	20659	MB
(M)BST ONBOARD TAKEN AT PHILADELPHIA, CHANGE LAURENTIANCHNL	547882	FEDERAL ASAHI	20659	MB
	547882	FEDERAL ASAHI	20659	MB
	547882	FEDERAL ASAHI	20659	MB

APPENDIX D -COMPLIANCE WITH CANADIAN BALLAST WATER GUIDELINES (%)

Provided by Marine Safety -Dartmouth



<u>Reasons for non-compliance</u>

409: total non-compliance reports (23%);
–108 did not comply but provided BW forms:
–151, on coastal voyages north-south route;
–138, no reason for not complying
–8, no BW exchange - bad weather;
–4, Safety/ hull stress

APPENDIX E

Minutes from the Workshop held in conjunction with the Canadian Marine Advisory Council, November 6, 2001 in Ottawa, Ontario

Laurentian Channel Workshop

Purpose:

- Consultation as part of CMAC, a binational forum, to obtain input for the development of a risk assessment assess the potential for introduction of alien species to the Gulf of St. Lawrence if the Laurentian Channel is an alternative ballast water exchange zone.

Workshop Overview:

- Explain the concept of probabilistic risk assessment (PRA).
- Obtain input to develop a risk analysis model for ballast water exchange in the Laurentian Channel.
- Discuss applicability to other geographic areas.
- Discuss Transport Canada's next regulatory step.
- Identify gaps in knowledge/data – What research is needed?

Outcomes:

- Agreed: The minimum volumes of ballast water exchanged in the Laurentian Channel will be based on the U Guard reports from Massena, NY.
- Agreed: For the purposes of developing the overall risk assessment model, there will be no separation of th Laurentian Channel from the Gulf or Estuary, although the risk posed by each area can be separated out.
- Agreed: Ports of origin for ballast water need to be considered.
- Agreed: Seasonal breakdown is a factor to be taken into consideration when developing the model.
- Agreed: Transit time is a factor to be taken into consideration when developing the model i.e., ≤ 5 days and
- Agreed: A risk assessment model will be constructed based on the best input data available. There will be a opportunity for fine tuning of the model when better data become available.

Other business following the workshop:

Janet Cavanagh introduced Brian Petrie, who provided an overview of the study that he has undertaken for Transp on circulation and dispersion patterns on the Continental Shelf off the coat of Nova Scotia.

Extensive discussion ensued over the request to the USCG for exemption from ballast water exchange for ships wi ballast water treatment systems.

APPENDIX F

Ballast Water Risk – Mathematical Model

The following describes the method of calculating risk. Refer to Figure 1 for the different sequences.

Let, for a ship originating in region "i" and destined for zone "j":

n_{ij} = number of ships per year

$p_{T, ij}$ = probability of transit time greater than 5days

$p_{ME, ij}$ = probability of mid-ocean exchange

$p_{CE, ij}$ = probability of channel exchange given no mid-ocean exchange

$q_{T, ij}$ = residual after being in transit for greater than 5 days as a fraction of the quantity in the ballast at origin, a voyage mitigation effectiveness

$q_{ME, ij}$ = residual after mid-ocean exchange

$q_{CE, ij}$ = residual after Channel exchange as a fraction of the quantity in the ballast prior to exchange, a measure exchange mitigation effectiveness

The various possibilities are represented in Figure 1.

Ships bound for the Great Lakes only pass through the Gulf and do not discharge at ports in the Gulf and Estuary. With the NOBOB ships, these ships would exchange ballast in the Laurentian Channel if they had not already exchanged ballast in The amount of alien species introduced in the Gulf and Estuary including the Lauentian Channel, therefore, is the sum of introduced at ports in the Gulf and Estuary and the amount introduced in the Laurentian Channel. Thus, the risk to the Gulf including the Laurentian Channel, as it is measured in this study, is the sum of the risk from discharge at ports and risk from the Laurentian Channel.

<u>Disch</u>

The expected frequency of each sequence weighted by associated mitigation effectiveness is estimated as follows:

$f_{ij,1} = (n_{ij}) \times (p_{T, ij}\ q_{T, ij}) \times (p_{ME, ij}\ q_{ME, ij})$

$f_{ij,2} = (n_{ij}) \times (p_{T, ij}\ q_{T, ij}) \times [(1\text{-}p_{ME, ij})\ p_{CE, ij}\ q_{CE, ij}]$

$f_{ij,3} = (n_{ij}) \times (p_{T, ij}\ q_{T, ij}) \times [(1\text{-}p_{ME, ij})\ (1\text{-}p_{CE, ij})]$

$f_{ij,4} = (n_{ij}) \times (1\text{-}p_{T, ij}) \times (p_{ME, ij}\ q_{ME, ij})$

$f_{ij,5} = (n_{ij}) \times (1\text{-}p_{T, ij}) \times [(1\text{-}p_{ME, ij})\ p_{CE, ij}\ q_{CE, ij}]$

$f_{ij,6} = (n_{ij}) \times (1\text{-}p_{T, ij}) \times [(1\text{-}p_{ME, ij})\ (1\text{-}p_{CE, ij})]$

Then, in terms of the *expected number* of ships weighted by mitigation effectiveness, the risk of introduction at port from a shi in region "i" and destined to zone "j" is given by:

$s_{ij} = \Sigma\ f_{ij, k}$ introductions per year, k = 1,6

Risk of introduction at port from ships originating from region “i” is estimated as:

$s_i = \Sigma s_{ij}$ introductions per year (summation over “j”) [i = A, B, C, G & O; j = I to FWE]

Risk of introduction at port from ships arriving at zone “j” is estimated as:

$s_j = \Sigma s_{ij}$ introductions per year (summation over “i”) [i = A, B, C, G & O; j = I to FWE]

The total risk of introduction at port in the Gulf and Estuary is estimated as:

$s = \Sigma s_i = \Sigma s_j$ introductions per year

Let w_{ij} = the average quantity of ballast in a ship from origin “i” to destination “j”.

Then, in terms of the *fraction* of the quantity of alien species contained in the ballast at origin, the risk of introduction at por originating from origin “i” and destined to region “j” is given by:

$$S_{ij} = (s_{ij}\ w_{ij})/(n_{ij}\ w_{ij})$$
$$= s_{ij}/n_{ij}$$

Risk of introduction at port from ships originating from origin “i” is estimated as:

$S_i = (\Sigma s_{ij}\ w_{ij})/(\Sigma n_{ij}\ w_{ij})$ (summation over j) [i = A, B, C, G & O; j = I to FWE]

Risk of introduction at port from ships arriving at zone “j” is estimated as:

$S_j = (\Sigma s_{ij}\ w_{ij})/(\Sigma n_{ij}\ w_{ij})$ (summation over “i”) [i = A, B, C, G & O; j = I to FWE]

Risk of introduction at port from all ships exchanging or discharging in the Gulf and Estuary is estimated as:

$S = (\Sigma s_{ij}\ w_{ij})/(\Sigma n_{ij}\ w_{ij})$ (summation over “i” and “j”)
(i = A, B, C, G & O; j = I to FWE)

Exchange in the Channel

Referring to Figure 1, for a ship from origin “i” destined to region “j”, there are two sequences that would discharge in the Cha are sequences IJ2 and IJ5.

$$h_{ij,2} = (n_{ij}) \times (p_{T,\ ij}\ q_{T,\ ij}) \times [(1-p_{ME,\ ij})\ p_{CE,\ ij}\ (1-q_{CE,\ ij})]$$

$$h_{ij,6} = (n_{ij}) \times (1-p_{T,\ ij}) \times [(1-p_{ME,\ ij})\ p_{CE,\ ij}\ (1-q_{CE,\ ij})]$$

Then, in terms of the *expected number* of ships weighted by mitigation effectiveness, the risk of introduction in the Channel originating in region “i” and destined to zone “j” is given by:

$c_{ij} = h_{ij,2} + h_{ij,6}$ introductions per year

Risk of introduction at port from ships originating from region “i” is estimated as:

$c_i = \Sigma c_{ij}$ introductions per year (summation over “j”) [i = A, B, C, G & O; j = I to GL-LC]

Risk of introduction in the Channel from ships arriving at zone “j” is estimated as:

$c_j = \Sigma c_{ij}$ introductions per year (summation over "i") [i = A, B, C, G & O; j = I to GL-LC]

The total risk of introduction in the Channel is estimated as:

$c = \Sigma c_i = \Sigma c_j$ introductions per year

Let w_{ij} = the average quantity of ballast in a ship from origin "i" to destination "j".

Then, in terms of the *fraction* of the quantity of alien species contained in the ballast at origin, the risk of introduction in the C ships originating from origin "i" and destined to region "j" is given by:

$$C_{ij} = (c_{ij}\, w_{ij})/(n_{ij}\, w_{ij}) \\ = c_{ij}/n_{ij}$$

The marginal aggregate risk of introduction in the Channel from ships originating from origin "i" is estimated as:

$C_i = (\Sigma c_{ij}\, w_{ij})/(\Sigma n_{ij}\, w_{ij})$ (summation over j) [i = A, B, C, G & O; j = I to GL-LC]

The marginal aggregate risk of introduction in the Channel from ships arriving at zone "j" is estimated as:

$C_j = (\Sigma c_{ij}\, w_{ij})/(\Sigma n_{ij}\, w_{ij})$ (summation over "i")
(i = A, B, C, G & O; j = I to GL-LC)

Risk of introduction in the Channel from all ships exchanging or discharging in the Gulf and Estuary is estimated as:

$C = (\Sigma c_{ij}\, w_{ij})/(\Sigma n_{ij}\, w_{ij})$ (summation over "i" and "j")
(i = A, B, C, G & O; j = I to GL-LC)

Total Risk

The total risk to the Gulf and Estuary, in terms of the *fraction* of the quantity of alien species contained in the ballast at origin, from origin "i" destined to region "j" is given by:

$$g_{ij} = (s_{ij}\, w_{ij} + c_{ij}\, w_{ij})/\, n_{ij}\, w_{ij} \\ = (s_{ij} + c_{ij})/n_{ij}$$

The marginal aggregate risk to the Gulf and Estuary from ships originating from origin "i" is estimated as:

$G_i = (\Sigma(s_{ij}\, w_{ij} + c_{ij}\, w_{ij}))/(\Sigma n_{ij}\, w_{ij})$ (summation over j)
(i = A, B, C, G & O; j = I to GL-LC)

The marginal aggregate risk to the Gulf and Estuary from ships arriving at zone "j" is estimated as:

$G_j = (\Sigma(s_{ij}\, w_{ij} + c_{ij}\, w_{ij}))/(\Sigma n_{ij}\, w_{ij})$ (summation over "i")
(i = A, B, C, G & O; j = I to GL-LC)

The total risk of introduction in the Channel from all ships exchanging or discharging in the Gulf and Estuary is estimated as:

$G = (\Sigma(s_{ij}\, w_{ij} + c_{ij}\, w_{ij}))/(\Sigma n_{ij}\, w_{ij})$ (summation over "i" and "j")
(i = A, B, C, G & O; j = I to FEW)

The total risk to the Gulf and the Estuary may also be estimated in terms of the fraction of the quantity of alien species cont ballast of all ships at origin travelling from all FAO regions to the Gulf and Estuary. This is calculated as follows:

Let,

$Q = (\Sigma n_{ij} w_{ij})$ (summation over "i" and "j")
(i = A, B, C, G & O; j = I to GL-LC)

Risk from ships from region "i" travelling to zone "j" is estimated as:

$$g'_{ij} = (s_{ij} w_{ij} + c_{ij} w_{ij})/ Q$$

The marginal aggregate risk from all ships from region "i" is estimated as:

$G'_i = (\Sigma(s_{ij} w_{ij} + c_{ij} w_{ij}))/Q$ (summation over j)
(i = A, B, C, G & O; j = I to GL-LC)

The marginal aggregate risk from all ships travelling to zone "j" is estimated as:

$G'_j = (\Sigma(s_{ij} w_{ij} + c_{ij} w_{ij}))/Q$ (summation over j)
(i = A, B, C, G & O; j = I to GL-LC)

The total risk of introduction in the Channel from all ships exchanging or discharging in the Gulf and Estuary is estimated as:

$G = \Sigma G'_i$ (summation over i = A, B, C, G & O)
$= \Sigma G'_j$ (summation over j = I to FEW)

<u>Relative Risk to the Channel</u>

The Risk to the Channel from exchanges in the Channel can be expressed relative to the total risk to the Gulf and Estuary fro This is the so-called Relative Risk and is estimated for a ship from origin "i" and destined to region "j" as:

$$r_{ij} = c_{ij}/(s_{ij} + c_{ij})$$

The total Relative Risk to the Channel from ships originating from origin "i" is estimated as:

$R_i = (\Sigma c_{ij} w_{ij})/(\Sigma(s_{ij} w_{ij} + c_{ij} w_{ij}))$ (summation over j)
(i = A, B, C, G & O; j = I to GL-LC)

The total Relative Risk to the Channel from ships arriving at zone "j" is estimated as:

$R_j = (\Sigma c_{ij} w_{ij})/(\Sigma(s_{ij} w_{ij} + c_{ij} w_{ij}))$ (summation over j)
(i = A, B, C, G & O; j = I to GL-LC)

The total Relative Risk to the Channel from all ships exchanging or discharging in the Gulf and Estuary is estimated as:

$R = (\Sigma c_{ij} w_{ij})/(\Sigma(s_{ij} w_{ij} + c_{ij} w_{ij}))$ (summation over "i" and "j")
(i = A, B, C, G & O; j = I to GL-LC)

APPENDIX G

Risk Model Verification

In order to verify the risk model, sensitivity analysis was performed. This was done by changing some of the variables one at a keeping the rest at their values shown in Tables 3 to 6. The variable selected were mitigation effectiveness of the transit time, exchange and exchange in the Laurentian Channel. The results are presented in Table B-1. The highlighted rows are the res Tables 1 and 2. A discussion follows.

Table B-1: Sensitivity Analysis

Variable	Mitigation Effectiveness – Residual Fraction	Risk at Port, %	Risk in Channel, %	Total Risk, %	Channel – Relative Risk, %
Transit Time	0.00	12.8	0.14	12.9	1.06
	0.25	19.0	0.14	19.1	0.72
	0.50	**25.1**	**0.14**	**25.3**	**0.55**
	0.75	31.3	0.14	31.5	0.44
	1.00	37.5	0.14	37.7	0.37
Mid-Ocean Exchange	0.00	16.8	0.14	16.9	0.82
	0.20	**25.1**	**0.14**	**25.3**	**0.55**
	0.40	33.5	0.14	33.6	0.41
	0.60	41.9	0.14	42.0	0.33
	0.80	50.2	0.14	50.4	0.27
	1.00	58.6	0.14	58.7	0.24
Channel Exchange	0.00	25.1	0.17	25.3	0.68
	0.20	**25.1**	**0.14**	**25.3**	**0.55**
	0.40	25.1	0.10	25.3	0.41
	0.60	25.1	0.07	25.2	0.27
	0.80	25.1	0.03	25.2	0.14
	1.00	25.1	0.00	25.1	0.00

Note:Mitigation Effectiveness is expressed in terms of fraction of residual alien species in the ballast after the e For example, an effectiveness of 0.6 means that after an exchange the ballast would contain 60% of the quan prior to the exchange.

Transit Time

As the residual fraction increases, i.e., as the impact of the transit time on mortality decreases, the risk at port increases. T expected, as the ballast water discharged at port will contain a greater percentage of the alien species that were present at ori

The risk of introduction in the Laurentian Channel changes negligibly because the risk stems mostly from ships from region A, transit time of less than five days, and also the size of their ballast is small.

As the risk at port increases and the change in the risk to the Laurentian Channel is negligible, the relative risk of introdu Channel decreases as the residual fraction increases. This result is as expected.

Mid-Ocean Exchange

As the portion of ballast water exchanged in mid-ocean decreases, i.e., the residual fraction increases, the risk at port increa
as in the case of Transit Time, this is an expected result.

The risk of introduction in the Laurentian Channel changes negligibly because, as in the previous case, the risk stems mostl
from region A, which has a transit time of less than five days, and also the size of their ballast is small.

As the risk at port increases and the change in the risk to the Laurentian Channel is negligible, the relative risk of introdu
Channel decreases as the residual fraction increases. This result is also as expected.

Laurentian Channel Exchange

As the portion of ballast water exchanged in Laurentain Channel decreases, i.e., the residual fraction of original ballast wate
and the risk of introduction at port does not change. This is because, currently ships that discharge at port do not exch
Laurentian Channel. This is an expected result.

The risk of introduction in the Laurentian Channel decreases as the portion of ballast water exchanged in Laurentain Channe
i.e., the residual fraction increases. At first glance, this might seem counter intuitive. What this means, however, is that as
fraction increases an exchange introduces a smaller proportion of alien species and retains in the ballast a higher proportion
species that was present at origin.

As there is no impact on risk at port and the risk to the Laurentain Channel decreases, the relative risk of introduction in
decreases as the portion of ballast water exchanged in Laurentain Channel decreases, i.e., the residual fraction increases.
also as expected.

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