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REPORT OF THE

ICES/IOC/IMO STUDY GROUP ON BALLAST WATER AND SEDIMENTS

The Hague, Netherlands
23–24 March 1998

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1 TERMS OF REFERENCE

The second meeting of the ICES/IOC/IMO Study Group on Ballast Water and Sediments (SGBWS) was held in The Hague, the Netherlands, 23–24 March 1998, with 42 participants from Australia, Canada, France, Georgia, Germany, Ireland, Israel, Italy, Lithuania, New Zealand, the Netherlands, Norway, Sweden, the United Kingdom, and the United States of America, and including representatives from the International Maritime Organization (IMO), the Intergovernmental Oceanographic Commission (IOC), and the International Chamber of Shipping (ICS) (see Annex 1 for a complete listing of meeting participants). This was the largest meeting of ballast water scientists ever convened, with nearly every ballast water research group in the world being represented.

Co-chairing the meeting were Dr J.T. Carlton (USA) representing ICES, Dr M. Nauke representing IMO, and Dr C. Bolch representing IOC. The Agenda was considered and approved and is attached as Annex 2.

The SGBWS was established by ICES Council Resolution in 1996 (ICES C. Res.1996/3:10). The terms of reference f(ICES C.Res.1997/2:12:10) for 1998 were to:

a) continue its work on international intercalibration of ballast water and sediment sampling methods;

b) discuss cooperative research programmes and databases;

c) discuss the results of ongoing research on new ballast management technologies;

d) continue to address other ship-mediated vectors in addition to ballast systems.

2 CONCERNS OF COOPERATING PARTIES

Dr J. Carlton reviewed the long-term interests of ICES and its Working Group on Introductions and Transfers of Marine Organisms (WGITMO), as well as the interests of other ICES working groups, such as the Working Group on Harmful Algal Bloom Dynamics (WGHABD. ICES has been concerned with ballast-water-mediated transportation and release of exotic species, resulting in the invasions of non-indigenous organisms, since the 1979 meeting of WGITMO in Conwy, Wales. It is has been a frequent topic of review, and an ICES-only study group on ballast water convened for a one-day session in 1991 in Helsinki to review the status of and interest in ballast water science at that time.

Dr J. Grooss reviewed the interests of the Intergovernmental Oceanographic Commission of UNESCO (Paris). The IOC is co-sponsoring the Study Group on Ballast Water and Sediments mainly via the Harmful Algal Bloom (HAB) Programme. The HAB Programme was established in 1992 and has developed into an important activity of IOC. The Intergovernmental Panel on Harmful Algal Blooms (IPHAB) meets every two years to set priorities. The IPHAB recognized from the beginning the need to obtain more knowledge on phytoplankton species carried by ballast water and the need to minimize the introduction of unwanted aquatic organisms and pathogens from ships' ballast water and sediments discharge. To address these major concerns, the IPHAB strongly supported the establishment of the Study Group on Ballast Water and Sediments. IOC and the IPHAB recognize the importance of providing, together with other organizations, a forum for scientists and managers to exchange information, ideas, and views on relevant topics and to formulate research needs and priorities.

Dr M. Nauke then reviewed the interests of the International Maritime Organization (IMO) with respect to the intersessional activities of IMO relevant to future developments of ballast water management and provisions and associated control issues. These activities include the adoption in November 1997 of IMO Assembly Resolution A868 (20) together with Guidelines for the Control and Management of Ships' Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens. In adopting these guidelines, the IMO Assembly agreed that every effort should be made by IMO's Marine Environment Protection Committee (MEPC) regarding the development of legally binding provisions on ballast water management in the form of an annex to the MARPOL 73/78 Convention, together with implementation guidelines thereto for consideration with a view to adoption by a Diplomatic Conference in the year 2000. In drawing attention to the various forms of IMO's legally binding and advisory implements, it was pointed out that the time span between the adoption of a new Annex to the MARPOL 73/78 Convention and its entry into force was in general approximately five years, but in regard to ballast water regulations probably about ten years pending the requirements of the 'entry into force provisions' that will be agreed by the Conference in 2000.

Dr Nauke further noted that, with regard to preparations for the Global Environment Facility (GEF) Project 'Removal of Barriers to the Effective Implementation of Ballast Water Control and Management Measures in Developing Countries', a number of fact-finding missions have been completed and the results are being incorporated into the final project proposal for submission to GEF in October 1998.

Under the aegis of the MEPC, which generally meets twice a year in London, a Working Group on Ballast Water has been meeting for the past several years to complete work on the updated guidelines, and now to begin work on the wording for the possible annex to MARPOL noted above. MEPC and the Working Group on Ballast meet next week in London.

3 CURRENT RESEARCH ACTIVITIES ON BALLAST WATER AND SEDIMENTS

Major portions of the two-day meeting were devoted to presentations and discussions on ICES Member Country and global research and management activities on ballast water and ballast sediments as a vector for the transportation, inoculation, and introduction of exotic marine, brackish water (estuarine), and freshwater organisms. A significant amount of time was also invested in efforts to continue the international intercalibration of ballast water and sediment sampling methods. A sense of the increased scale of this activity since the 1997 SGBWS meeting in La Tremblade, France, can be gained by noting that the 1997 meeting had 19 participants, while the present meeting had 42 participants.

Summaries of the presentations are contained in Annexes 3, 4, 5, and 6. Also included are brief abstracts of other research programmes submitted by SGBWS participants.

4 RISK ASSESSMENT AND BALLAST WATER MANAGEMENT

Dr C. Hewitt from the Centre for Research on Introduced Marine Pests (CRIMP), CSIRO Division of Marine Research, Tasmania (Australia) presented his and Dr K. Hayes' work on the application of risk assessment methodologies to ballast water management. A summary of their presentation follows:

Australia exports over 95 % of its commodities via shipping traffic, trading with a wide array of biologically different regions. This international traffic enters Australia in approximately 65 ports of first entry which then trade via secondary, coastwise traffic with one another. As a result, it has been recognized that the role of risk assessment and analysis is critical to the development of an Australia-wide management strategy. CRIMP hosted a Workshop on Risk Assessment and Marine Introductions in January 1995, with the express intent to identify the various aspects of risk associated with components of the invasion process. The current paradigm of the invasion process suggests that risks are aligned in a linear fashion and therefore can be modelled by a single assessment methodology. The underlying complexity in the invasion process, however, has led the ICES Working Group on Introductions and Transfers of Marine Organisms (WGITMO) to state that

'The general inability to certify a ship or port as free of harmful unwanted organisms provides further rationale for further studies to determine the best methods of (ballast) management and treatment pursuing quantitative risk assessment studies of ballast water uptake and release that involve transport of water and sediments both between (i) port systems of similar environmental conditions, and (ii) port systems of fundamentally different environmental conditions.'

The Australian Ballast Water Management Advisory Council (ABWMAC) Research Advisory Group (RAG) and the Australian Quarantine and Inspection Service (AQIS) are interested in pursuing the development of a Risk Assessment-based Decision Support System which will be an aid to ballast water management in a pro-active sense.

Current ecological risk assessment paradigms fall into two primary categories: engineering-driven Quantitative Risk Assessment (QRA), and biologically-driven Human Health Risk Assessment (HRA) and Ecological Risk Assessment (ERA) largely based on the concepts of ecotoxicology. QRA-style assessments have been used to analyse the risks associated with toxicant spills, including hazardous waste chemicals and radioisotopes. In contrast to these models, biologically-driven analyses have concentrated on the impacts of stressors or toxicants on humans (HRA) or targeted organisms (indicator species) as surrogates for the ecosystem. In both of these methodologies, the stressor is perceived to be of fixed size but dynamic in its propensity to spread. Agents are identified which act as vectors aiding in dispersal and specific probabilities are assigned to the various vectors. Risks are then evaluated either at the level of the individual (HRA) or at the level of the population (ERA).

These 'state-of-the-art' risk assessment methodologies appear to be incapable of resolving the intrinsic difficulties associated with the problem of shipping-related biological introductions. Such difficulties include:

- a paucity of data pertaining to several aspects of the shipping-related vector invasion problem;
- biologically complex (multispecies) invasion ensembles;

- the use of biological data which are often 'fuzzy' or variable;
- a lack of predictive ability relative to colonization success and ecological impacts;
- multiple components of the ballast water 'problem' which differ in scope and scale.

CRIMP has undertaken the development of a functioning, quantitative risk assessment (RA) framework that will model the potential for introduction of non-indigenous species by domestic and international Australian merchant shipping activity. This model will express the geographically distributed risk of inoculation and initial survival of specific target species in Australian waters in a quantitative manner with an explicit consideration of the associated uncertainties and significance of risk estimates.

The risk assessment is modular to mimic the invasion process and layered to allow more accurate assessment as data requirements are met. A targeted species approach has been adopted to sufficiently quantify the risks, however, the less data onerous aspects of the risk assessment are based on a non-targeted approach. The assessment model is iterative for each target species and uses Bayesian statistical principles.

The target species are identified external to the risk assessment process and are predicated upon a set of social and ecological criteria. The RA framework is capable of evaluating additional species as required. The RA framework can identify risk scenarios, estimate the probability that vessels become infected with target species under each of these scenarios, and estimate the probability that a target species will survive when discharged into a recipient environment. The framework can be used to allocate vessel sampling (management) resources, to conduct cost-benefit analyses for ballast water management strategies, and to allow the shipping industry to pro-actively alter its operations in or between contaminated ports to minimize risks.

The framework will not identify potential pest species from the thousands of potential introductions, will not identify the targeted species, nor will it identify the acceptable levels of risk. The framework will also not prevent all introductions from occurring.

The species-specific approach has been adopted by Australia because it allows a suitably quantitative assessment of risk. The selection of target species will necessarily be a crucial component of the success of such a system. These targets may be selected on the basis of several criteria such as:

- species that are known ballast water introductions in other parts of the world and whose populations have attained 'pest' status;
- species which are morphologically or taxonomically representative of a wider set of species;
- species which are demonstrably tolerant of a ballast treatment technology including ballast water exchange at sea, heat treatment, etc. These species will provide an estimate of success from the basis of the precautionary principle.

The obvious alternative to a species-specific approach is that proposed in the 1996 WGITMO report, i.e., the environmental matching assessment between recipient and donor ports. Environmental matching alone will not provide a progressive assessment and will necessarily become more conservative with additional information from successful incursions. The environmental match between port regions will not necessarily represent the biological capabilities of the species. In contrast, a species-specific approach will become less conservative as more information becomes available.

5 APPLICATION OF MOLECULAR TECHNIQUES TO THE RESOLUTION OF BALLAST WATER DISPERSAL VERSUS NATURAL DISTRIBUTIONS OF PHYTOPLANKTON

Dr C.J.S. Bolch of the School of Plant Science, University of Tasmania, and SGBWS Co-Chairman, presented a summary of his work on tracing global dispersal of phytoplankton using molecular genetics, using the example of the toxic dinoflagellate *Gymnodinium catenatum.* A summary of his presentation follows:

Understanding the sequence of global dispersal and introduction of organisms is essential to constructing and testing introduction hypotheses. Understanding is gained by a form of detective work, where multiple lines of evidence (e.g., historical distributions, taxonomic, morphological, genetic, potential vectors) are carefully considered in order to arrive at the most plausible explanation. An equivalent process is that of epidemiology—tracing and controlling epidemic infectious diseases. However, most epidemic diseases involve single, clonal bacterial or protozoan strains, allowing almost certain symptomatic, morphological, biochemical, or more recently, molecular genetic, matching of various

isolates. Unlike most infectious diseases, many introduced populations are genetically variable, sexually reproducing populations, and genetic matching of introduced and potential donor populations is not as simple as it may seem.

Recent molecular genetic studies of the toxic dinoflagellate *Gymnodinium catenatum*, thought to have been introduced to southeastern Tasmanian waters during the 1970s, provide an example of genetic matching of such sexual populations. *G. catenatum* reproduces primarily by vegetative (clonal) reproduction, however, it also undergoes periodic sexual reproduction via a long-lived resting cyst. Recent studies have shown *G. catenatum* to be genetically conservative, exhibiting no variation in ribosomal RNA gene sequences or allozymes between strains from different global populations.

Examination of 21 Australian, three Spanish, two Portuguese, and four Japanese strains using RAPD-PCR showed that *G. catenatum* displays considerable RAPD-diversity, with all strains representing unique genotypes. There were no clear, fixed differences in RAPD-genotypes between the global groups, however, multidimensional scaling analysis (MDS) of the RAPD-fingerprint patterns showed clear separation of strains into three non-overlapping clusters: Australia, Japan and Spain/Portugal. Analysis of average RAPD-distances between the three populations showed that Australian strains were almost equally related to the Spanish/Portuguese population and the Japanese population. Due to the limited availability of strains from other global populations, the potential source population for Tasmania's introduced *G. catenatum* remains equivocal.

However, two strains from the recently discovered (1996) Port Lincoln, South Australia, population cluster within the Tasmanian group, support the notion that the recent appearance of *G. catenatum* on mainland Australia may have arisen by secondary relocation of Tasmanian populations via a shipping vector. Within Tasmanian strains, geographic and temporal clustering of strains was evident, suggesting that the Tasmanian population is divided into sub-populations, with very limited genetic exchange between blooms in neighbouring estuaries.

Despite the small number of Japanese, Portuguese and Spanish strains examined during this study, statistically significant differences were found between population clusters. The prospects of tracing the global dispersal of this enigmatic species, therefore, are most likely to be assisted by obtaining strains from other global populations (e.g., Uruguay, Venezuela, Mexico, Korea, China, Morocco, etc.) rather than increased numbers of strains from the three geographic groups examined here.

6 CONCLUSIONS AND FINDINGS

The following is a summary of the major conclusions and findings, as agreed by meeting participants. These conclusions and findings are based upon the reports (Annexes 3 to 6) that were reviewed in detail at the meeting, and on substantive and extended discussions arising from these reports:

6.1 Scale and Scope of Ballast Water Movement

- Huge volumes of ballast water are moved around the world, and the amount is likely to increase with increasing global commerce. Extensive data sets on ballast water volumes, and the life in ballast water and sediments, are now being developed for many regions of the world that are beginning to fill in this global picture.
- An important—indeed critical—consideration is the standardization of these data sets so that they may be compared and cross-analysed.
- It is important to obtain data on both imported *and* exported ballast water, to capture a picture of a port system as both a receiver *and* a donor area.

6.2 Sampling the Biota in Ballast Water and Ballast Sediments

* There are two general questions associated with the sampling of ballast water and sediments in order to determine their biotic content:

1) What do various methods of sampling (nets, pumps, etc.) yield in the way of specific types and densities of organisms?

2) What specific methods should be used to sample target organisms?

Relative to these approaches, it is also important to distinguish between sampling programmes that focus on scientific research (academic questions) and sampling programmes that focus on management and compliance monitoring.

Relative to each approach, biotic categories and habitats in ballast include:

a) viruses;
b) bacteria and other microbial populations (including those that might form surface biofilms);
c) phytoplankton and zooplankton;
d) larger mobile organisms such as fish, shrimp, and crabs;
e) the benthic biota in sediments;
f) the fouling organisms that may be attached to ballast tank walls.

Each category represents a different potential sampling challenge.

Global intercalibration of sampling techniques is to be emphasized and encouraged, as well as encouraging global performance standards.

6.3 Understanding the Complexity of the Ballast Environment

The ballast tank (and ballasted cargo hold) environment is a complex one: physical and chemical parameters can change over time and geography, in different types of vessels, between different tanks on any one vessel, and within a single tank. Sampling these variables can represent the same challenges as in sampling the biota. *Understanding these variables is fundamental to understanding how the ballast environment promotes or depresses biological transfer.*

Other variables that contribute to the complexities of understanding ballast processes are water age, trophodynamics (energy flow, predator-prey interactions, prey availability for visual predators in a dark environment, etc.) within the system and what resources organisms 'board' the ship with, for example, energy reserves.

Numerous important research questions remain:

- How do these complexities eventually relate to the scale of inoculation of non-indigenous species?
- Why do some populations of organisms increase and others decrease in ballast systems?
- With a more sophisticated understanding of ballast dynamics, could we manipulate those factors that depress biotic success?

6.4 Ballast Management: The Ballasting and Deballasting Process

Micromanagement strategies, techniques, and approaches of ballast water uptake should receive more research effort, specifically relative to minimizing the uptake of organisms within donor regions. These approaches include, but are not limited to, the following, each of which should receive the benefit of detailed feasibility and practicability studies:

1) Spatial strategies, for example:

- moving the ship to a higher salinity portion of an estuary to minimize the uptake of larvae of oligohaline or freshwater species (such as the zebra mussel *Dreissena*);
- moving the ship away from sewage outfall sites that favour sewage-tolerant species;
- moving the ship away from active harmful algal blooms;
- avoiding regions where dredging operations are in progress.

2) Temporal strategies, for example:

- avoiding or reducing ballasting when larvae or propagules of targetted nuisance species are abundant in the water column (such as is now done with the fish ruffe (*Gymnocephalus cernuus*) management in the Great Lakes, or with Amur Seastar (*Asterias amurensis*) management with vessels travelling from Tasmania to New Zealand).

Similar micromanagement strategies should be more thoroughly explored relative to where ballast is released within an estuary or harbour, if it was not successfully exchanged in the open ocean. For example, every effort should be made to minimize or prohibit release where the released organisms could easily colonize mariculture or aquaculture activities.

6.5 Ballast Management: The Exchange Process

Ballast exchange is a dynamic and complex process: it is important to understand which tanks or holds were exchanged, how much water was exchanged, when the water was exchanged, where it was exchanged, etc., in order to begin to assess the effectiveness of the exchange process.

In addition, it will be increasingly critical to be able to measure the precise nature (extent) and the results of ballast exchange—by using electrical measurement meters ('black boxes'), by examining the ship's logs for the history of pumping activity, by a ballast exchange form, by development of a multivariate probe to distinguish oceanic from coastal water, by direct sampling of the biota, etc.

What organisms *escape* the exchange process will also be critical to an understanding of ballast exchange—how many coastal organisms remain due to partial exchange, the remaining sediment biota, the remaining attached organisms, and so forth. For marine protists, there is new evidence that full exposure for a length of time to freshwater (see Annex 3, the report by Hulsmann and Galil) does not result in full mortality. It was noted that research on the quantity and quality of these post-exchange taxa is urgent, relative to decisions that are being made now by managers concerning the amount and types of exchange being required.

In certain regions, residual water aboard ships declaring 'no ballast on board' (NOBOB) may be resuspended in ballasting operations at a first-arrival port and then pumped out at a second-arrival port (as in the Great Lakes), which can lead to species invasions.

Of particular and ongoing concern are *coast-wise (coastal) voyages*, and the methods that may be available to minimize transfers between port systems within a nation and between adjacent nations sharing a similar hydrographic-biogeographic region. Ballast exchange may have little or limited applicability in these situations, when vessels travel in the near-coastal zone. An important element for consideration here is that coast-wise voyages may play a role in the secondary dispersal (transfer) of species from the first inoculated harbour or bay to other coastal estuaries.

Of further concern is the science and management of designating so-called 'back-up' or 'alternative' ballast exchange zones or sites, being regions, if such exist, on or near the coastline where ships may deballast or exchange (deballast and reballast) their water if they have been unable to do so on the high seas.

6.6 Ballast Management: Other Strategies and Approaches

Studies are under way examining alternative ballast management strategies, including filtration, heat, UV, ozone, vortex separators, freshwater addition, and so forth. Some of these approaches appear to hold considerable promise, but *most such studies have commenced only in the 1990s and thus much additional work remains to be done.*

6.7 Risk Assessment, Decision Support Systems, and Target Species

There is broad interest in attempting to focus on *specific shipping routes, ship types, donor regions, and species of concern* relative to narrowing the spotlight of ballast management. Numerous variables have been identified and are now under study that will make modelling these approaches relative to overall hazard and risk assessment studies. Discussions on the concepts of 'mismatch' (incompatible regions) and on regions of relatively lower resistance or susceptibility to invasions focused on the variables and complexities associated with these concepts, and on being able to apply them to actual management practices.

A particular interest was voiced in a greater understanding of *donor regions* as an important aspect of risk assessment. It was noted that obtaining such information must be a two-way process: donor ports should attempt to provide information on species of concern that departing vessels may ballast up, whereas receiving ports should also seek such information from the donor ports. *Updated information* is critical through continuing port surveys, since the non-native biota of many ports and harbours is under constant change, due to plankton blooms, new invasions, water quality changes, and other factors.

There is an increasing number of nuisance, noxious, pest species world-wide that are serious emerging problems for global marine resources, especially for fisheries and mariculture. Research on the historical and modern distributions of many of these pest species is critical. An example is the situation with the so-called 'phantom' fish-killing dinoflagellate *Pfiesteria* spp. on the Atlantic coast of the United States, a species thought to be eminently transportable by ballast water. Whether it is native or introduced to these waters remains to be determined (J. Carlton and G. Ruiz, in prep.).

6.8 Non-Ballast Water Ship-Mediated Mechanisms

It is becoming clear that increasing attention needs to be paid to *fouling communities on ships' hulls and in sea chests*, in terms of the modern-day diversity and biomasses being transported. It is important to understand these communities both as a vector in-and-of-itself in the transport of non-native species, and also to more clearly determine whether a new introduction has necessarily arrived only by ballast water, or whether the species could have arrived in ship's fouling as well.

The decreased use of TBT-based paints, and the perhaps concomitant decrease in tin (heavy metal) contamination in some harbours, may make some regions now more susceptible to invasions.

Removal of hull fouling by mechanical cleaners while vessels are berthed in the dock may be one means whereby a new inoculation of an exotic species may take place. If this type of cleaning takes place over anoxic zones, the development of an inoculum may however be considerably reduced.

The movement of heavily-fouled vessels and other marine platforms is of growing concern. Examples include exploratory platforms, the movement of dry docks, and the movement of vessels that have been anchored for long periods of time in one region to another region.

6.9 International Cooperation and International Education

Continued international cooperation, through joint multinational research projects, is fundamental to grasping the global scale of ballast-mediated movement of non-indigenous species and to understanding the latest and newest concepts and views on ballast management. It was noted that in the one year since the first meeting of this Study Group in April 1997, the number of participants has more than doubled and the number of countries represented has tripled, while the amount of new data has increased considerably as well.

Dissemination of information on the science, policy, and management strategies of ballast water and sediments should be as broad as possible, and particular efforts should be made to keep the public, the political world, and the shipping community abreast of this rapidly expanding and changing field. In particular, dissemination of information on ballast water through maritime trade journals was encouraged.

7 RECOMMENDATIONS

There was very strong and unanimous consensus by the Study Group that one more meeting, at a minimum, would be of extraordinary value. The participants felt that significant new levels of cooperation, understanding, and intercalibration of research had been achieved both among ICES Member Countries and on a global level (further noting that a great deal of the ballast water arriving in ICES Member Countries originates outside the ICES arena).

It was thus recommended that the ICES/IMO/IOC SGBWS convene again at the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) in Conwy, Wales, from 12–13 April 1999 to:

a) continue its global assessment and review of the status of ballast water biological and ecological research, through the participation of representatives from ICES Member Countries and of invited scientists from all major ballast water research groups in the world;

b) continue its evaluation of the development of ballast water control technologies;

c) continue its review of the relationship between ballast water movement and the invasion of exotic marine organisms, including updates on the latest ballast-mediated invasions globally, particularly relative to those species that are now invasive in other regions of the world and that are ballast-transportable—but have not yet arrived—in ICES Member Countries.

ANNEX 1

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ANNEX 2

AGENDA

Monday, March 23, 1998

9:00 Opening of the Meeting

•Welcoming Remarks (Co-Chairmen J. Carlton, C. Bolch, M. Nauke)

•Introduction of All Participants and Guests

•Logistical Announcements (Bas de Groot) (telephone, Fax, photocopying, etc.)

9:20 Review of Terms of Reference (above)

Review of the Agenda (below): changes, corrections, additions

9:30 Jane Grooss

UNESCO/IOC Concerns: Ballast Water and Sediments

9:40 Manfred Nauke

IMO: Update on Current Activities on Ballast Water

9:50 Harald Rosenthal

Overview of the EU Concerted Action Ballast Programme

10:10 Allegra Cangelosi

USA National Invasive Species Act 1996 and Ballast Water Management

10:30 Coffee break

11:15 Whitman Miller

The USA National Ballast Water Clearinghouse

11:40 Penny Lockwood

Ballast water management and the Australian Quarantine & Inspection Service

12:10 – 2:00 Lunch

2:00 Chad Hewitt

The role of risk assessment in ballast water management

3:00 Christopher Bolch

Ballast water and harmful algal blooms: Current research and future directions, including recent work on molecular genetic data of global *Gymnodinium catenatum* (dinoflagellate) populations

3:30 Elspeth MacDonald

Cysts in ballast: hatching in germination experiments

3:35 Coffee Break

4:15 Norbert Huelsmann and Bella Galil

Net slime molds as a major component of ballast sediment: Cause for global increase of wasting disease?

4:30 Chad Hewitt

Australia: Ballast water research in Australia (CSIRO/CRIMP)

4:45 Michel Gilbert

Canada: Overview of the potential for ballast water-mediated introductions of marine organisms in the Estuary and Gulf of St. Lawrence, in Eastern Canada

5:00 Adjournment of Day 1 of Study Group

Tuesday, March 24, 1998

9:00 Opening of Day 2 of Study Group

9:00 Anya Shotadze

Georgia: Ballast water and Black Sea Concerns: Ballast control in the Port of Batumi, Georgia

9:10 Dan Minchin

Ireland: The Port of Limerick as a High Risk Donor Area via Ballast Water Transport

9:30 Saskia van Gool

Netherlands: Netherlands Ballast Concerns: Overview of Available Data and Estimation of Possible Risks

9:50 Cameron Hay

New Zealand: Operational research on ballast water and invasive marine species in the Antipodes

10:30 Coffee Break

11:00 Julie Hall

New Zealand: Update on National Institute of Water & Atmospheric Research on Ballast Water

11:30 Helge Botnen

Norway: Update on Norwegian Shipping Study and Ballast Water Concerns

12:00 - 1:30 Lunch

1:30 Tracy McCollin and Ian Lucas

UK Wales: Ballast water research in Wales

1:50 James Carlton

USA: Overview of Ballast Research in the USA

2:00 Whitman Miller

USA: Ballast research at the Smithsonian Environmental Research Center (SERC)

2:50 Joel Kopp

USA: Aquatic nuisance species and ballast water investigations in Prince William Sound

3:10 Allegra Cangelosi

Ballast water management: filtration experiments aboard the Algonorth in the Laurentian Great Lakes

3:45 Coffee Break

4:15 Geoff Rigby

Ballast water heat treatment: a summary of Australian research

4:45 Darren Oemcke

Ozone and UV radiation: prospects for ballast water treatment

5:10 Anders Jelmert

A pilot study on the removal of inert particles, bacteria, algae and zooplankton, by an in-line vortex separator and subsequent UV-irradiation

5:35 Bella Galil and Norbert Huelsmann

Effects of freshwater flushing on ballast protist biota

6:00 * Summary of Findings and Recommendations

* Future meetings

* Concluding Remarks by ICES, IOC, and IMO Co-Chairs

6:30 Adjournment of Study Group

ANNEX 3

CURRENT RESEARCH ACTIVITIES ON BALLAST WATER AND SEDIMENTS: STUDIES ON BALLAST WATER BIOLOGY AND GENERAL APPROACHES

(By Country)

AUSTRALIA

The Status of Australian Ballast Water Research

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The Centre for Research on Introduced Marine Pests (CRIMP) has undertaken strategic research in coordination with the Australian Quarantine and Inspection Service (AQIS) and the Australian Ballast Water Management Advisory Council (ABWMAC) a series of Ballast Water and other shipping related vectors (e.g., hull fouling, sea chests) studies. These projects include: Ballast Water Sampling Methodologies; Survival of Target Organisms in Ballast Water Transit; Detection of *Vibrio cholerae* in Ballast Water; and Ballast Water Heat Treatment.

Ballast Water Sampling Methodologies

The initial aim of the Sampling Project was to identify and review existing ballast water sampling methodologies through questionnaires and correspondence with international ballast water sampling groups and subsequently an on-board evaluation of sampling efficacy of a targeted list of sampling techniques. Thirteen ballast water sampling groups were contacted and 9 protocols identified. These protocols included plankton net, a variety of pump types, and whole water sampling. On-board testing of 10 vessels identified the following results:

1) no single sampling method can physically be used on all vessel types;
2) total plankton density and species richness significantly differed between sampling techniques;
3) relative abundances between species differ between sampling techniques
4) vertical stratification exists within ballast tanks which may significantly alter the sampling results.

Survival of Target Organisms in Ballast Water Transit

The second project concerning the survival of target organisms in ballast water feeds directly into the Ballast Water Risk Assessment Project. The project progressed through on-board sampling of ballast water from the Port of Hobart to assess the ability of the Northern Pacific seastar, *Asterias amurensis*, to survive the domestic voyages to other ports within Australia. Both beginning/end of voyage sampling and multiple sampling on-board have demonstrated significant (negative exponential) survival in the ballast tanks.

Detection of *Vibrio cholerae* in Ballast Water

The aim is to evaluate current techniques for detecting toxicogenic *Vibrio cholerae* in ballast water entering Australia. The principle project coordinator is Dr Trish Desmarchelier the CSIRO Division of Food Science and Technology. The sampling protocols and evaluation techniques follow those of Dr Rita Colwell. Currently we have sampled low risk vessels and detected non-toxicogenic *Vibrio* entering Australia. Additional vessels from high risk regions and ports are currently being targeted for assessment.

Ballast Water Heat Treatment

Dr Geoff Rigby of BHP Transport and Research is the Principle Investigator for this project whose aim was to evaluate the efficacy of a heat treatment/flushing technique as an optional treatment method. This research was undertaken on the *MV Iron Whyalla*, a bulk iron-ore carrier, between Port Kembla, New South Wales, and Port Hedland, Western Australia. Caroline Sutton of CRIMP examined the zooplankton during the voyage to determine the mortality effects.

Australia Ballast Water Management

Penny Lockwood
Ballast Water and Introduced Marine Pests Section
Australian Quarantine and Inspection Service
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The Australian Quarantine and Inspection Service (AQIS) is the lead Australian government agency for minimising the risks of introduction into Australian coastal waters of harmful marine pests and disease pathogens. To ensure an effective, nationally consistent and cost efficient approach to this issue in relation to ballast water and hull fouling management, AQIS has developed a national ballast water strategy. The strategy is a framework for policy development, operational procedures and research priorities, and in line with these priorities, and on advice from an Australian Ballast Water Management Advisory Council and its Research Advisory Group, a $1 million per annum Strategic Ballast Water Research and Development Program was developed in 1996. A key element of the R & D Program is the development of a 'target species' risk assessment based decision support system to more effectively manage ballast water translocations. Research projects are focused around inputs to this system, such as target species survivability, port biological baseline surveys and effective ballast water sampling methods. Ballast water treatment methods are also being examined in Australia, and a ballast water exchange verification black box tool is currently being trialed in Western Australia.

As the national regulatory authority for ballast water management, AQIS will introduce improved ballast water management measures in April 1998, including mandatory reporting on a ship's compliance with Australia's ballast water management requirements, mandatory access to a ballast water sampling point, a maritime industry awareness program and a comprehensive training program for AQIS field staff. These measures will coincide with the introduction of the revised IMO ballast water management guidelines adopted under IMO Resolution 868(20). There will also be increased visual inspections of ships' hulls for unacceptably high levels of fouling, and promotion of quality assurance compliance agreements with reputable shipping operators.

CANADA

Overview of the Potential for Ballast Water-Mediated Introductions of Non-indigenous Marine Species in the Estuary and Gulf of St. Lawrence, Eastern Canada

Michel Gilbert, Michel Harvey, and Myriam Bourgeois
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An ongoing research project at the Maurice Lamontagne Institute of the Canadian Department of Fisheries and Oceans aims at assessing the potential for ballast water-mediated introductions of non-indigenous marine species in the Estuary and Gulf of St. Lawrence. This assessment is based upon the foreign maritime traffic and its associated ballast water discharges, the species richness in ballast waters of incoming foreign ships, and the local environmental conditions to which inoculated species are exposed relative to donor areas. Results obtained to date show that a non-negligible number of non native species are inoculated in the Estuary and Gulf ecosystem with the ca. 1,600,000 metric tonnes of ballast waters originating from various parts of the world that are discharged annually by foreign ships. However, the potential for the successful introduction of these species appears to be reduced by offshore ballast water exchanges in compliance with the existing Voluntary Guidelines for the control of ballast water discharges from ships, and by the cold environmental conditions prevailing throughout the year in most areas of the Estuary and Gulf relative to major donor areas of the Northeast Atlantic, the east coast of the United States, and the Mediterranean Sea. Nevertheless, a greater potential for ballast water-mediated introductions exists in the southern Gulf of St. Lawrence because of relatively warmer conditions than in other areas of the Estuary and Gulf and given that the current ballast water exchange guidelines do not apply to foreign ships entering ports of this area. This assessment will be completed by conducting a sampling survey of international ports in the Estuary and Gulf of St. Lawrence to determine the extent of ballast water-mediated introductions, if any, of non native species in these areas. This question needs to be addressed since there is yet no evidence or reports on the occurrence of non native species resulting from ballast water discharges in the Estuary and Gulf.

EUROPE: A CONCERTED ACTION PLAN

Testing Monitoring Systems for Risk Assessment of Harmful Introductions by Ships to European Waters

Harald Rosenthal and Stephan Gollasch, Ian Laing, Erkki Leppäkoski, Elspeth Macdonald, Dan Minchin, Manfred Nauke, Sergej Olenin, Sue Utting, Matthias Voigt, Inger Wallentinus
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Six European countries (Finland, Germany, Ireland, Sweden, United Kingdom (England and Scotland), Lithuania) and several experts from elsewhere (North America, some Mediterranean countries, Australia and Asia) are involved in the Concerted Action Plan recently funded by the EU. The IMO (International Maritime Organization) is also a partner in this study. The EU project is linked with the ICES WGITMO and ICES/IOC/IMO SGBWS for the duration of the project. The study is being coordinated by Germany.

Various methods will be examined as to how representative qualitative and quantitative sampling of species in ballast water can be obtained. Treatment measures for the control of exotic species will be evaluated. There will be an examination of potential risks from harmful introductions and their management by means interdisciplinary approaches. The subject areas of the EU Concerted Action include: (a) determination of the state of the art of ballast water studies, (b) evaluation of sampling method, (c) validation of sampling method (through intercalibration workshops), and assessment of in-transit survival, (d) development of a set of intercalibrated monitoring systems for use by EU countries and by inter-governmental agencies such as ICES, BMB (Baltic Marine Biologists), IOC and IMO. In addition, case histories of selected harmful species associated with ballast water movements to aid in management are being prepared. Information about ballast water as a vector for exotic species movements using multimedia is being used to provide informed advice on the current status of activities

The Concerted Action invites open discussion and opportunities for joint studies by means of land based or sea going workshops. We welcome those who would like to become involved who have interests in this area and are prepared to contribute. For further information, please contact: sgollasch@aol.com

GEORGIA

Ballast-Related Issues in the Black Sea: An Overview

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We monitor the condition of the sea environment and manage the preservation of its ecological equilibrium, preventing pollution, salinisation, and alien biological introductions. Most alien biological introductions result from ballast discharge and sediment from vessels after ocean crossings. The delay and shortage of information about such kinds of introductions do not mean they are not important. Introductions are important even where the ballast waters are discharged in small quantities, because of the impact of certain organisms on the local environment.

The existing ports and those under reconstruction will be important centers for the transit of oil products from Kazakhstan and Azerbaijan. Most vessels arriving in Georgian ports discharge ballast and then load oil. At the present time, Chevron Oil Company has a planned transit of petrol products in quantities up to 5 million tonnes, and this will correspond to 2 million tonnes of discharged ballast in or near the Port of Batumi. Most organisms will die because environmental conditions are radically different, but some survive and take up their habitat in the Black Sea.

According to the Convention on the Protection of the Black Sea, emptying segregated ballast is allowed. But different countries of the region enforce the Convention differently. For example, vessels with a destination to Odessa must change segregated ballast immediately upon entry into the Black Sea area. This must then be recorded in the ship logbook. This is not a viable solution, since ballast waters are emptied upon arrival in the Black Sea.

In Georgia, a widely distributed species emptied with ballast is the predatory mollusc Japanese snail (*Rapana*). It was first found in the Black Sea in 1947 near Novorossisk. Japanese snails feeds on molluscs such as oysters, clams and mussels. On the coast of Georgia, their invasion decreased the numbers of molluscs which clean the sea. In recent years Japanese snails have been harvested for their tasty meat and exported from Georgia. This snail is harvested with the help of dragging equipment, similar to trawling equipment which destroys sea bed environments.

Besides this Japanese snail, another alien to the Black Sea is the so-called 'Dutch crab' (*Rhithropanopeus harrisii tridentata*), the sand mussel (*Mya arenaria*), blue crab (*Callinectes sapidus*), and comb jellyfish (*Mnemiopsis leidyi*) whose quantities now outnumber even the Black Sea jellyfish, *Aurelia aurita*.

The predatory American comb jellyfish began to consume large quantities of zooplankton, and fish larva and roe. This has provoked a catastrophic reduction, reflected in recent Georgian harvests of anchovy and other fish in the Black Sea. In addition to this jellyfish, reductions are due to overfishing of anchovy and other species by Georgian, Russian, Ukrainian, Bulgarian and Turkish fleets. It is urgent to forbid fishing by trawl in the Black Sea. Controls for trawling should be systematic. To improve the fishery situation in the Black Sea, it would be necessary, according to decisions made at meetings in Istanbul (17 September 1996) and in the Commission which met in Constantsa, Romania, to invite specialists to evaluate the situation.

Cleaning facilities were built on the shores of the Black Sea in regions of Georgia in the 1960s, for the reception of ballast waters. This infrastructure could accommodate and clean polluted water from tankers up to approximately 6 million cubic meters. Six reservoirs of 10,000 cubic meters each were built.

The disintegration of the Soviet Union led to the partial disuse of these structures for reception and cleaning ballast waters. The unique plant existing now treats dirty ballast, bilge and sludge by sedimentation, which is-ironically-subsequently discharged at sea. The water discharged in this way contains up to 10 or 20 mg/litre of oil, which is in violation of international norms.

Now with the construction of the Supsa Port, Caspian oil will transit through Georgia, and Kazakh oil also will transit (through the port of Batumi). That will mean a radical increase in ballast discharges near Georgian shores. The level of pollution of all seas and oceans has sharply increased during the last decade. Chemical products and pathogens are threatening the marine ecosystems, and the Black Sea is no exception. Increased ballast will also mean the invasions by many exotic species before the end of the 20 th century. In conclusion, there is no doubt that good environmental conditions of the Black Sea and its coastal region will be the basis of future economic and social development. Good control is a priority issue for natural protection and public health for all the Black Sea region. It is urgent to end uncontrolled spontaneous discharges of all types of pollutants.

GERMANY

Net Slime Molds as a Major Component of Ballast Sediment: Cause for Global Increase of Wasting Disease?

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The members of the genus *Labyrinthula* (Heterokonta, Protista) form 'slimy' (= protoplasmic) nets that cover the benthic substrates and organisms living there up to a depth of 25 m. A greater number of species show the ability to penetrate plant or fungal cell walls and to act as pathogens for several marine plants (referred as 'wasting disease' in seagrass beds, especially of *Zostera* and *Thalassia*). There are indications that every plant species is susceptible to another parasite. Under these circumstances, the question arises whether the potential introduction of *Labyrinthula* species via ballast water and sediments may be correlated with the global increase of wasting disease.

The microscopic analysis of ballast samples revealed that strains of different *Labyrinthula* species are a major component of tank internal communities. They are present in about 22 % of all tanks (n = 52), and in about 52 % of all sampled ballast sediments (n = 21), each with one species in 7 cases and each with two species in 4 cases. The tank-internal biotic and abiotic conditions may favor the surviving or maintaining of *Labyrinthula* strains, as the percentage of successful isolation from natural benthic habitats in the Wadden Sea and Baltic Sea remains relatively low: between 18 and 27 %, respectively. Altogether 15 strains could be detected and recorded up to-date; ten of them could be isolated and are still in culture. The comparison of these cultivable strains showed that 9 of them belong to different

species; only in one case the same species could be isolated from two different tanks (but with nearly the same ballasting history).

For identification of labyrinthulid strains on the species level, uncovering the details of the corresponding life cycles and the elaboration of fine structural characters are extremely time-consuming prerequisites. One character, however, can be used to determine very easily the conspecificity of questionable strains—when cells or plasmodia fuse with each other to form larger communities.

Corresponding tests between the 14 ballast-borne strains and 33 isolates from more natural habitats in the Mediterranean, Red Sea, North Atlantic, North Sea and Baltic Sea showed that in three cases such identities could be already revealed: *Labyrinthula* ballasted along extra-European waterways were identified as strains occurring 'already' in European ports, namely in Bremerhaven (Germany), Naples (Italy) and Valentia (Ireland).

The international marine traffic and the ballast technology therefore must be considered as an important vector for *Labyrinthula* spreading. Potential filtration techniques to prevent the uptake of unwanted organisms should focus on the fact that the size of gametes of *Labyrinthula* is mainly below 5 μm.

NETHERLANDS

Ballast Water Research in the Netherlands

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In the Netherlands, there is no good insight relative to the risks for Dutch waters of introduction of non-native species via ballast water. We therefore set up a research project which is split up in two phases.

Phase One is a desk study where we tried to obtain information on:

- the amounts of ballast water coming in and going out of the Netherlands;
- the risk of having non-native species coming in via ballast water;
- the possible consequences of introduction.

The desk study provides information on what information we need in the second phase of the study, where we will have the possibility for measurements.

Some results of Phase One are as follows:

- the amount of ballast water coming into the Netherlands is higher than we thought—about 7,500,000 tonnes a year;
- the amount of ballast water taken up in the Netherlands is about 70,000,000 tonnes a year;
- at least 41 non native species have entered Dutch waters according to an OSPAR list.

If it is assumed that about half of the introductions come from ballast water, we do have introduction of species via ballast water in the Netherlands. It is however very difficult to assess the risk of impact from introduction of species via ballast water. We have to look very carefully how to perform the second phase of the study in order to achieve the answers we need to make a good assessment of the risks for Dutch water of the introduction of species via ballast water.

NEW ZEALAND

Ballast Water: What Lives, What Dies, What Grows?

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A significant number of studies have been conducted to establish the concentrations of organisms that exist in ship ballast water tanks at the beginning and end of a voyage. Few studies however have followed the changes in the concentration and growth of organisms over the period of a voyage. In this study, samples were collected daily from three ballast water tanks during a trans-Tasman voyage on the cargo ship *Tasman Enterprise* after ballast water was taken on board in Tasmania.

Each sample was processed to allow later analysis of bacterial, microzooplankton and mesozooplankton numbers, bacterial production, size fractionated chlorophyll *a* and nutrients. The nutrient concentrations in the water did not alter over the period of the voyage, however, there were significant differences in the NO_3 concentrations between the tanks which were all filled at the same time. Chlorophyll *a* decreased rapidly over the five-day voyage; this was accompanied by a change in the community structure of the phytoplankton population, with the smaller size fractions surviving longer. Both the microzooplankton and mesozooplankton populations decreased over the period of the voyage. In contrast, the bacterial population showed significant increases in both numbers and production between days 2 and 3 of the voyage. The data suggest that there was significant microbial activity in the tanks during the voyage.

Techniques for sampling mesozooplankton and for the assessment of water exchange efficiency were also examined during the voyage. For the mesozooplankton sampling, both net tow and foot valve pump samples were collected for the evaluation of mesozooplankton numbers. There were significant differences in both the species collected and the numbers of organisms collected between the two methods. The results suggest that avoidance may be a serious problem with foot valve pump for some organisms. To assess the efficiency of ballast water exchange, Rhodamine dye was added to two tanks. Results of these experiments showed an exchange efficiency of approximately 95 %, however there were serious problems with mixing of the dye in the tanks even after 24 hours.

Shipping, Ballast Water and Biosecurity—A New Zealand Perspective

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Hayward (1997, *Tane,* 36: 197–223) records 61 macroscopic non-native species established on New Zealand seashores. Most arrived via fouling and/or the discharge of water ballast. Recent arrivals from Asia coincided with shifting emphasis in trade from the UK to Asia after the late 1960s. Four Asian bivalves, and the kelp *Undaria* and *Spartina* (from Europe and USA) have had significant ecological and economic impacts.

Government funding of operational research on ballast water began in 1995 with a two-year contract to *Cawthron* who sampled 70 ships and over 150 ballast tanks. A fast, reliable and unobtrusive way of sampling all tank types on more than 95 % of the vessels (60 % being container ships) was via sounding pipes through a hose fitted with a foot valve and connected to an electrical inertia pump. Comparative sampling through manholes with van Dorn samplers and plankton nets (20 μm) confirmed stratification of some species in the larger tanks. Thus, some species were under-represented when sampling solely from the pipes. This must be weighed against the convenience of sampling via pipes, and with regard to the purpose of taking the samples. It also highlights the need for intercalibration of sampling methods. About 80 % of the tanks had live plankton and sediment-dwelling species. Phytoplankton diversity and abundance were higher in tanks where water had reportedly been changed in mid-ocean.

A NZ government contract focusing on identifying existing and potential methods for testing the efficacy of mid-ocean exchanges, and that might characterise oceanic and coastal water, was recently awarded (February 1998) to a coalition between *Cawthron* and *Battelle Ocean Sciences* in Massachusetts. Other related government-funded programmes at *Cawthron* are (1) on ballast water treatment experiments; (2) preparing a new ballast water reporting form closely based on the IMO form, and (3) on the establishment, spread, impacts and management of marine invaders.

NORWAY

The Ballast Water Study at Sture, Norway

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The ballast water study at Sture, northwest of Bergen on the Norwegian west coast, was initiated by Norsk Hydro, the operator of the Sture oil terminal, and researchers at SAM during 1994 and 1995. Between 22 April 1996 and 27 September 1997, ballast water samples were collected from 30 oil tankers, all arriving from harbours outside Norway.

The aim of the study was to investigate the potential of unintentional introductions of non-indigenous aquatic species via ballast water to Sture. The oil terminal at Sture was constructed in a previously undeveloped area, and was ready for operations in December 1988. Since then, shipping traffic to the terminal has steadily increased and now about 370 vessels arrive annually, discharging about 14 million tonnes of ballast water. Most of the traffic comes from harbours in Europe, although about 15 % of the traffic comes from other areas, particularly North America.

Sampling was undertaken on a representative number of vessels coming from each geographic region, during spring, summer and fall. One ballast water tank from each vessel was sampled for temperature, salinity, oxygen, phosphate, nitrogen, phytoplankton and zooplankton. Phytoplankton samples were collected by Ruttner water sampler, whereas zooplankton were collected by dip net. Due to staircases and other types of obstructions in the tanks the length of the dip net haul varies between vessels. Thus the zooplankton data are of a qualitative nature.

Most vessels had saline ballast water, but vessels arriving from the Baltic Sea (Finland and Sweden), Antwerp (Belgium), Thames (London, UK), and Philadelphia (Marcus Hook, USA) had low salinity or freshwater ballast. Vessels arriving from harbours in densely populated areas or near river deltas contained more phosphate and nitrogen than vessels arriving from other areas. The oxygen content was high in all tanks, indicating sufficient oxygen supply for aquatic life.

Live organisms were identified in all vessels but one that arrived from St. Croix in the Virgin Islands on 20 April 1997. The ballast water was rusty red, a condition not observed in any other vessel. The most common taxonomic group was crustaceans and diverse phytoplankton that occurred in 29 of the vessels. Diatoms, dinoflagellates and ciliates were also common, whereas bivalve and gastropod larvae occurred in 20–30 % of the vessels, and fish eggs in less than 10 % of the vessels.

The number of taxonomic groups and stages was lower in ballast water after long voyages than after short voyages. This reduction was more pronounced in the zooplankton than in the phytoplankton. Despite the observed reduction and the fact that most traffic comes from European waters, this investigation shows that non-indigenous species from remote areas can be carried in ballast water to Sture.

This investigation was funded by Norsk Hydro and Directorate for Nature Management. For further information contact helge.botnen@ifm.uib.no

SWEDEN

Swedish Ballast Water Study

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The Swedish EPA has completed a desk study, based on questionnaires to ports, shipowners and ships, on volumes and sources of ballast water (export and import) to Swedish waters (including freshwater).

About 23 million m^3 of ballast water and sediments is discharged per year into coastal and inland waters from 22,000 calls of ships from international ports to Sweden. The largest quantities (80 %) are imported from the Baltic and North Sea. Less than 10 % arrives from outside Europe. The largest quantities exported are to other Swedish water areas or to the southeastern Baltic Sea.

A substantial 'pool' of introduced species is already present in Europe, and, additionally, the risks of intra-regional transfer of organisms associated with the possible mixing of ballast water within ports with large transit traffic must not be neglected. From a Swedish perspective, the results underline the importance of identifying measures to be taken regionally, in the Baltic Sea Area and in Europe, in addition to management practices such as the ballast water exchange spelled out in the IMO Guidelines. The development of safe, practicable, cost effective and environmentally acceptable treatment methods for ballast water is urgently needed.

For some results, see the brochure 'Ballast Water Management in Swedish Waters'.

UK: ENGLAND AND WALES

Marine Organisms Transported in Ships' Ballast

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The research is being carried out on behalf of the Ministry of Agriculture, Fisheries and Food (MAFF) and involves investigating the number and types of marine organisms carried in ships' ballast and associated sediment into ports around England and Wales. MAFF is responsible for the marine environment and fisheries interests and needs this information in order to develop its policy on the discharge of ballast water and sediments into coastal waters around England and Wales. This project is closely related to research that has been carried out in Scotland and our methods are based on those developed at the Marine Laboratory in Aberdeen.

This is a three-year project of which two years have been completed. The research involves taking samples of ballast and the associated sediment from vessels that are coming into a number of different ports around England and Wales. Ten ports are visited on a regular basis and a wide variety of vessels have been sampled, ranging from small coasters to oil and chemical tankers. The most common origin of ballast is North Europe, but samples from America, Canada, Japan and the Mediterranean have also been collected.

So far, 81 vessels have been sampled. Samples are taken via a deck hatch in the ideal situation. Net samples are taken for zooplankton counts and identification, and an integrated sample is taken with a hose and samples are taken for phytoplankton counts and identification, salinity analysis and future chemical analysis. A sediment sample is taken by pumping up from as close to the bottom of the tank as possible; this sample is examined for dinoflagellate cysts. It is not always possible to sample via a deck hatch (22 times) and it is more usual to sample via a sounding pipe (36 times); other methods also have to be used depending on the design of the ship and the situation.

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The US representatives distributed a spiral-bound volume (204 pages) entitled, 'USA Ballast Book 1998–1999: Ballast Research in the United States of America'. The contents of this volume are as follows:

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Aquatic Nuisance Species: U. S. Coast Guard Briefing Paper *United States Coast Guard Headquarters*

NISA 1996: National Invasive Species Act of 1996 *(Public Law 104-332)*

NANPCA 1990: Nonindigenous Aquatic Nuisance Prevention and Control Act *(Public Law 101-646)*

Ballast Water Reporting Form and Instructions *United States Coast Guard*

Ballast Water Management: Preventing and Controlling the Spread of Aquatic Nuisance Species *United States Coast Guard*

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Aquatic Nuisance Species Task Force

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Lake Superior Ports and Alpena, Michigan,1998 *Lake Carriers Association et al.*

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West Coast Ballast Management Education Program

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APPENDIX I

Executive Summary:

J. T. Carlton, D. M. Reid, and H. van Leeuwen. 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. The National Sea Grant College Program/Connecticut Sea Grant Project R/ES-6. Department of Transportation, United States Coast Guard, Washington, D.C. and Groton, Connecticut. Report Number CG-D-11-95. Government Accession Number AD-A294809. 213 pages and Appendices A-I (122 pages).

APPENDIX II

Executive Summary:

D. M. Reid and J. T. Carlton. 1997. **Shipping Study I-A** A Study of the Introduction of Aquatic Nuisance Species by Vessels Entering the Great Lakes and Canadian Waters Adjacent to the United States. National Biological Invasions Shipping Study (NABISS). The National Sea Grant College Program/Connecticut Sea Grant Project R/ES-6. Prepared for U.S. Coast Guard Research and Center, Groton CT and United States Coast Guard Marine Safety and Environmental Protection, Washington, D.C. Report No. CG-D-17-97, Government Accession No. AD-A325351, xii + 86 pp. (Final Report, March 1997).

APPENDIX III

Executive Summary:

L. D. Smith, M. J. Wonham, L. D. McCann, D. M. Reid,G. M. Ruiz, and J. T. Carlton. 1996. **Shipping Study II.** Biological Invasions by Nonindigenous Species in United States Waters: Quantifying the Role of Ballast Water and Sediments, Parts I and II. The National Sea Grant College Program/Connecticut Sea Grant Project R/ES-6. Prepared for

U.S. Coast Guard Research and Development Center, Groton CT and United States Coast Guard Marine Safety and Environmental Protection, Washington, D.C. Report No. CG-D-02-97, Government Accession No. AD-A321543, xxv + 97 pp. + Appendices A-M. (Final Report July 1996).

UNITED STATES: ATLANTIC COAST

Ballast Research at SERC (USA): Current Research and Future Directions

Gregory M. Ruiz and Anson H. Hines
Smithsonian Environmental Research Center

Please see Annex 6.

The Relative Importance of Ballast Water from Domestic Ship Traffic in Translocation of Nonindigenous Species among U.S. Ports

Gregory M. Ruiz and Anson H. Hines
Smithsonian Environmental Research Center

L. David Smith
Nahant Marine Center, Northeastern University

James T. Carlton
Maritime Studies Program, Williams College

The overall goal of this research is to measure the patterns of delivery and viability of species transferred among U.S. ports in the ballast water of domestic ship traffic. We propose to measure directly the volume of ballast water delivered to selected Atlantic ports from other domestic ports, the abundance and diversity of organisms associated with that ballast water, and the survival of these organisms during transit and upon arrival. Our approach combines four different elements: (a) analyzing ship traffic and ballast water delivery patterns for vessels arriving from domestic versus foreign ports to three different port systems in the U.S.; (b) sampling and analysis of organisms delivered in ballast water among domestic ports; + measuring the survivorship of organisms during transfer and upon release with ballast water from domestic voyages; (d) comparing the relative contributions of ballast water and biota from ships of foreign versus domestic origin to U.S. ports.

There are virtually no data available to evaluate the role of ballast water in transferring species among domestic ports, yet this appears to be one of the largest vectors for transfer of established coastal species within the U.S. The proposed research will assess (a) the significance of domestic ballast water in transferring nonindigenous species among U.S. ports and (b) the risk of invasion by organisms associated with domestic ballast water. Our results will contribute key information about the need to consider management strategies that prevent or reduce the spread of nonindigenous species introductions from this vector.

In the National Invasive Species Act of 1996, the U.S. Congress, ballast water is singled out as a major cause of biological invasions and as needing close management scrutiny by the U.S. Coast Guard. However, all of the current attention on ballast water as a vector for coastal invasions focuses on foreign shipping traffic, composed only of ships arriving from foreign (non-U.S.) last ports of call to a U.S. port. Ballast water transported by domestic shipping traffic from one U.S. port into another U.S. port is not considered and has not been studied, with the exception of the preliminary work in progress by this research team. Domestic ballast water may be an important mechanism for dispersing NIS throughout many U.S. bays and estuaries for at least 3 main reasons. First, ballast water transported from a U.S. last port of call may have actually originated from a foreign port in a ship that picks up partial loads in each of several U.S. ports before transiting back to a foreign port. Thus, even ships defined as domestic traffic may be carrying large quantities of foreign ballast and NIS. Second, many U.S. ports serving as sources of truly domestic ballast water are themselves extensively invaded by NIS which have arrived by foreign ballast (e.g., San Francisco Bay; Cohen & Carlton, 1995). Thus, domestic ballast serves to facilitate dispersion in a "leap-frog" fashion. Third, domestic shipping traffic often transports large quantities of ballast water long distances coast-wise along U.S. shores around many biogeographic barriers and across current systems. Thus, domestic ballast serves to disperse species from one biogeographic province to another.

The purpose of this project is to evaluate the role of domestic ballast water as a source of biological introductions in coastal ecosystems. We have extensive background knowledge and data for foreign ballast water delivered to the Chesapeake Bay ports of Baltimore and Norfolk, which in combination receive by far the largest volume of foreign ballast of any port system on the east coast and second in the U.S. only to the port system of New Orleans/Baton Rouge. We will use this background to assess the relative importance of domestic versus foreign ballast water in the Chesapeake. By comparing the delivery patterns and biological characteristics of domestic ballast water arriving to Chesapeake Bay from more northern ports (Massachusetts) and more southern ports (Florida), we will test for effects of distance, season, and climate of source ports upon survival of plankton.

This research is funded by the National Sea Grant Program (1997–1999).

UNITED STATES OF AMERICA: ALASKA

Ballast Water Introductions in Alaska

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Abstract

The Prince William Sound Regional Citizens' Advisory Council is managing a cooperative investigation, conducted by the Smithsonian Environmental Research Center, of the risk of invasion by oil tanker ballast water of Prince William Sound, Alaska. An initial pilot study conducted last year examined both the oily and clean ballast of arriving tankers, finding the oily ballast to be relatively free of planktonic life and the clean ballast to have a rich and abundant collection of plankton, some of which are nonindigenous to the area. An expanded study is underway to further analyze the risk posed by the discharge of this plankton and to determine what invasions have already occurred in the sound. Approximately 600 tanker voyages bring 20 million metric tonnes of clean ballast annually to the area.

Slide Presentation:

The Regional Citizens' Advisory Council, or RCAC as it is better known, is an oil transportation oversight council mandated by the U.S. Congress in the Oil Pollution Act of 1990 as a result of the Exxon Valdez oil spill in Prince William Sound in 1989. The RCAC represents 18 communities and organizations that were impacted by that oil spill. The RCAC is funded by the company that operates the 800-mile trans-Alaska pipeline and the marine oil loading terminal in Valdez; the mission is to promote the environmentally safe operation of that terminal and the associated tankers. It is curious that a group whose existence sprang out of North America's largest oil spill is today so involved in the issue of biological invasions. While RCAC is still very much concerned with proper oil spill prevention and response, we are currently investing far more money in the research of nonindigenous species than we are in the research of oil spills.

There are two very good reasons for this new focus. First, although we have learned a good deal about how 260,000 barrels of oil from a grounded tanker affects Prince William Sound, we know very little about how billions of barrels of plankton-rich ballast water discharged over 20 years affects the sound. Secondly, whereas the impacts of an oil spill are mitigated over time, the impact of a successful invasion tends to intensify over time, making biological invasions potentially a more serious threat to the integrity of this high-latitude ecosystem than another catastrophic oil spill.

(Slide A) Prince William Sound is a large archipelago - roughly 15,000 square kilometers in area - located in southcentral Alaska at the northern tip of the Pacific Ocean. The sound is vital ecologically for the array of marine life it supports as well as economically for the industries that rely on those resources, and because through its waters pass 20 % of the United States' domestically produced oil. In the northeast corner of Prince William Sound is Port Valdez (Slide B), a roughly 20 km long fjord with depths of up to 240 m and surrounded by 1,500-meter mountains. Valdez is a small community of roughly 4,500 permanent residents situated on the northeast shore of Port Valdez, and the Valdez Marine Terminal is located on the southeast shore.

(Slide C) A relatively small fleet of oil tankers have made more than 15,000 voyages to this terminal since it began operations 20 years ago, and they are currently arriving at the rate of roughly 600 tankers per year. Shipping, especially this tanker traffic, appears to currently be the major mechanism of transfer of NIS into Alaskan waters. Although we are evaluating other vectors and other types of shipping, most of our work to date focuses on tankers.

(Slide D) These tankers bring with them as much as 40 million metric tons of ballast water per year into the waters of Port Valdez and Prince William Sound. Although proportions and volumes vary widely between ships, roughly half of that total arrives as segregated ballast water, which is carried in ballast tanks and discharged directly into Prince William Sound and Port Valdez. The other half is unsegregated ballast carried in cargo tanks and therefore must be pumped ashore to a ballast water treatment facility to clean it of oil before it is discharged into the Port.

(Slide E) This volume of segregated ballast discharge ranks Port Valdez third in the United States in terms of ballast water received behind Chesapeake Bay and the New Orleans/Mississippi Delta area and well above areas such as San Francisco Bay.

(Slide F) The vast majority of these tankers arrive from domestic ports on the U.S. west coast and from Hawaii, and thus are not required to exchange their ballast, and the balance of the voyages come primarily from ports in the Far East.

(Slide G) Relative to the volumes of ballast from the various donor ports, the large proportion of ballast from west coast ports represents short voyage durations, from as little as three days from Puget Sound to between 7 and 10 days from southern California. So the average age of the vast majority of the arriving ballast is only five or six days.

Given these traffic patterns and volumes of ballast water, and the number of invasions occurring around the world, the RCAC, with funding assistance from the U. S. Fish and Wildlife Service, set out to study the risk of invasion facing Prince William Sound. The first phase of this project was a pilot study completed last year, and the second phase is an expanded study currently ongoing. This work is being conducted by a team of investigators led by Dr Tuck Hines and Dr Greg Ruiz of the Smithsonian Environmental Research Center in Maryland.

(Slide H) The major field component of the pilot study consisted of the sampling of ballast water of arriving tankers for a two-week period in late May and early June of 1997. Using an 80-micron mesh net, we sampled both the oily and segregated ballast of 14 tankers. For the segregated ballast tanks, we pulled the net vertically through the height of the water column to obtain a representative sample.

(Slide I) We sampled the oily ballast in various stages of the shoreside treatment process by pouring an equivalent volume of water through the net to collect our samples. What we found was that the oily ballast water contained very little, if any, viable plankton, which would seem to all but eliminate that medium as a potential vector for introductions.

(Slide J) However, in the segregated ballast water was a rich, diverse, abundant medley of coastal plankton, (Slide K) including polychaetes, (Slide L) barnacles, (Slide M) and copepods. The plankton samples included four species of copepods which we could positively identify as nonindigenous - they are known to be introduced into San Francisco Bay. While we have no evidence that these species have become established in Alaska, it is now clear that NIS of highly invaded source ports are being transported alive and in good condition to Port Valdez.

(Slide N) Most of the main taxonomic categories of the plankton had high prevalence in the tankers, with several categories occurring in all or nearly all samples, (Slide O) and densities of the major taxonomic categories of the plankton were very high, as seen on this logarithmic scale.

(Slide P) By multiplying these densities times the amount of ballast water in the tankers, it is clear that very large numbers of planktonic organisms are being released by these ships on each voyage: 244 million organisms per ship on average.

(Slide Q) We were able to conduct two ballast exchange experiments in this pilot study thanks to the cooperation of SeaRiver Maritime, using the flow-through method, which you see being conducted here. One experiment conducted a 150 % exchange by volume, and the second used a 300 % exchange by volume.

(Slide R) Both experiments showed that exchange is effective at reducing various plankton groups by between 70 and 90 %. However, although these were very limited experiments with small sample sizes of 1 ship per treatment, there was no indication that the higher percentage of exchange is more effective.

(Slide S) For coastal plankton taxa, the exchange was very effective in reducing organisms, although total numbers of organisms remained high as oceanic plankton replaced coastal plankton.

(Slide T) Still, the process is not 100 % efficient. Because of the huge volume of water in the tankers, even the small amount of residual coastal plankton in the tanks amounts to large numbers of coastal plankton being transferred in exchanged tanks.

(Slide U) We compared the physical characteristics of the arriving ballast water to the receiving waters of Port Valdez. Both temperature and salinity are quite similar to that of the water beside the tanker at surface and at 10 m depth, well within the tolerances of most of the species in the source ports.

(Slide V) Low risk factor . . .

(Slide W) High risk factors . . .

(Slide X) Unknown risk factors . . .

(Slide Y) Relative to the second phase of this project. We are currently engaged in an expanded, two year project that features a high degree of cooperation and participation by an array of private and public entities.

(Slide Z) Some of the elements of this expanded phase include extended sampling of tanker ballast in order to document seasonal variability in the plankton, expanded ballast exchange experiments to measure the effectiveness of flow-through and empty-refill methods, survivability studies to see what organisms found in the ballast water can actually survive and grow in Prince William Sound-like conditions, and analysis of samples collected in Prince William Sound to learn what may have already invaded this northern estuary.

As this study unfolds over the next two years, we hope to collect the necessary information for a detailed analysis of the risks, mechanisms, and patterns of species introductions for Prince William Sound.

There are several unique aspects of this investigation. First, and perhaps most importantly, it is a citizen-led effort. Although various government, scientific and industrial organizations are involved in differing capacities, this investigation originates solely from the concern of local citizens and is led by those citizens in the form of the Regional Citizens' Advisory Council.

Second, this investigation is not being undertaken in response to a known invasion. Although our work in the summer of 1998 may reveal the presence of invaders in Prince William Sound, this study began not as a reactionary effort to an already-established nuisance, but a proactive effort to try to learn about and prevent invasions before they actually occur.

Third, there is a very high level of cooperation on this investigation between industry, citizens and government. Oil shippers are allowing free and unfettered access to their tankers for the sampling of ballast tanks and hulls, industrial and scientific organizations are contributing funding, and government agencies - still grappling with this relatively new issue - are closely following the project in order to learn all they can. In addition, all of these entities are participating on a working group to help oversee and direct this project. We are all working together to find answers to questions of mutual concern: What is arriving in the ballast water? What is already here? What is the potential impact? And what can be done about it?

Lastly, the pilot study, while limited in scope, nevertheless takes some important new steps from a scientific standpoint. It is, for instance, one of only a very few studies of invasions in cold-water, high-latitude ecosystems and the first ever for Alaska. It is the first detailed analysis of plankton in the ballast water of oil tankers, as well as for domestic U. S. ballast water of any kind. It is the first identification of nonindigenous species of plankton being transported from a west coast source port to an Alaskan receiving port, and it is the first detailed characterization of plankton in non-segregated ballast water as it passes through a shoreside treatment facility. And the report contains the first synthesis of species introductions for the west coast of North America since 1979.

Highlights of the pilot study report have been included in the U. S. Ballast Water Book.

UNITED STATES: HAWAII

Ballast Water Sampling Research: Hawaii (USA)

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The goal of this project (combined support from the David and Lucile Packard Foundation and the Dingell-Johnson Program) is to focus on commercial and military vessel traffic as a vector for transporting nonindigenous marine organisms to the Hawaiian Islands. Ballast water will be sampled quantitatively from vessels arriving from domestic and foreign ports in South Oahu, Hawaii, focusing on the Port of Honolulu. The condition of the live plankton communities in ballast water will be determined and then quantitatively counted after fixation. Along with the plankton communities, the ballast samples will be assayed for bacteria, ciliate protozoans, and chlorophyll. Data will be collected extensively on hull fouling organisms and ballast sediments from a variety of vessels. Certain ships will be targeted where the entire biotic community represented (i.e., ballast water, fouling organisms, and ballast sediments) can be assessed.

Researchers will participate in cruises on board vessels to conduct experiments on plankton survival during voyages and the efficiency of ballast exchange on removal of organisms from ballast water. While the sampling program progresses, information on vessel traffic patterns will be collected and these data will be combined with existing knowledge at Bishop Museum on the movement of aquatic species around the Pacific region.

UNITED STATES: NORTH CAROLINA

Synthesizing Science and Policy to Reduce the Probability of Marine Biological Invasions Due to Ballast Water Discharge in the Port of Morehead City, North Carolina, USA

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The spread of exotic species is cited repeatedly as one of the greatest threats to marine systems today. During the last several decades, the number of documented cases of established nonindigenous aquatic species has burgeoned around the world. This may be due to the increasing number and efficiency of human vectors that transport non-native species. An overall expansion of the global shipping industry, combined with the use of larger ships, has made ballast water one of the most efficient movers of entire planktonic communities on the planet. This study provides a preliminary biological profile and potential policy alternatives for the management of ballast water discharged from ships in the Port of Morehead City (N 34° 43', W 76° 42'), North Carolina, USA.

The Port of Morehead City is particularly vulnerable to successful invasions of exotic organisms for several reasons. First, the port is one of the deepest on the eastern seaboard (45 foot (13.7 m) maximum draft), providing ships with less reason to release ballast water until they are safely berthed in the estuarine port environment, increasing the survival rate of organisms. Second, the top two exports by volume out of Morehead City (woodchips and phosphate) are shipped in bulk carriers that typically arrive without import cargo, thereby discharging more ballast water and accompanying biota than other types of ships. Since 1985, Morehead City has been the number one exporter of woodchips on the US east coast and projects to double exports to a million metric tonnes by the year 1999. Third, the waters associated with the Port of Morehead City are fed by the Newport River Estuary System, cited for increased human disturbance which is theorized to have increased the invasibility of ecosystems in other parts of the world. Finally, these waters are contained within the North Carolina's unique cusp of barrier islands, reducing the potential 'flushing out' of exotics during daily tidal cycles. These factors culminate in a dynamic environment that is unstable and potentially vulnerable to colonization by nonnative species. At any particular point in time, water conditions may turn hospitable to the invasion of a nonindigenous species introduced via ballast water.

In an effort to ascertain the taxonomic composition of ballast water released into the Port of Morehead City, 22 ships (4 tankers, 8 bulkers, 5 container ships and 5 refrigerated ships (reefers) were boarded during the period from May to July 1997. Samples of ballast water were collected from nine ships that were releasing water from Japan (3 woodchip bulkers), Spain (1 phosphate bulker), Dominican Republic/ Florida (1 container ship), Belgium/ Mid-Atlantic (1 reefer), and New Orleans, Louisiana (1 phosphate bulker). Two of the 9 ships sampled (2 tankers) were importing cargo and had just taken on ballast water in preparation to depart, providing an opportunity to access the types of organisms successfully taken in through ballast pumps and exported from Morehead City waters to other discharge locations. Of the ships boarded, the average amount of ballast water onboard was 7,129 metric tonnes (almost 2 million gallons). For comparison, the woodchip and phosphate ships boarded contained approximately 20,000 metric tonnes of ballast water. When these bulk carriers are excluded, the average amount of ballast water held in these ships dropped down to 2,190 metric tonnes. From this small sampling, bulk carrier ships appear to carry approximately ten times the amount of ballast water as other ships entering the Port of Morehead City.

The ballast water samples each consisted of a 10 liter volume of 'whole' (i.e., unfiltered) water collected with a Niskin bottle at the greatest depth achievable in the holding tank. The samples were filtered with sieves of 333, 62 and 35 micron mesh. The portion of organisms greater than 333 microns (predominantly zooplankton) were immediately preserved. The organisms left on the 62 and 35 micron filters and in the remaining filtrate were cultured using phytoplankton media in 35 psu GF/F filtered Gulf Stream water at 23 degrees Celsius for 21 days. After each filtration, the organisms were divided into four flasks, each receiving a distinct treatment: two received 1 ml of an open-ocean nutrient medium, with one of these placed in low light (25–28 $mmol*1/s*1/m^{-2}$ per mA) and the second in high light (66 $mmol*1/s*1/m^{-2}$ per mA). The two remaining samples were dosed with 1 ml of a coastal water nutrient medium; one flask cultured in low light and the other in high light conditions. Each week during the 21-day culture period, the live biota were observed and identified.

From the nine ships sampled, the water temperature of the ballast water *in situ* ranged from 24 to 33 degrees Celsius, and the salinity of the ballast water ranged from 0 psu water from New Orleans, LA to 38 psu water from the Dominican Republic/Florida. The approximate number of days that the ballast water had been in the tanks prior to sampling ranged from 0 (water from Morehead City) to 40 days (water from Japan). To date, hundreds of species have been observed viable in the ballast water samples collected and cultured during the study.

Recognizing the species richness of live biota observed in the ballast water of ships in Morehead City, proactive public policy in the form of ballast water management to reduce the probability of biological invasion is warranted. Due to a lack of regulatory authority at a local and state level, it is not possible for the Port of Morehead City or the North Carolina government to implement a mandatory ballast water control strategy until the world does via an international mandate. Yet, three actions towards ballast water management can be realistically recommended for implementation on the local level at this time in the Port of Morehead City: 1) submit comments and suggestions to the federal level (e.g., Aquatic Nuisance Species Task Force), 2) rigorously implement and report ballast water surveys, and 3) encourage and educate visiting captains to follow the International Maritime Organization's present voluntary guidelines for mid-ocean ballast exchange prior to entrance into the Port of Morehead City, North Carolina.

Financial support for this research project was provided to Heather P. Walton by a 1997–1998 Sea Grant/National Fish and Wildlife Foundation Fellowship for Nonindigenous Species Research and Outreach.

Molecular strategies to characterize microbial diversity and pathogens in marine ballast water

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Biological invasions are a significant threat to nearshore coastal and estuarine ecosystems. Most recent research is focused on highly visible invasions of large invertebrate species, yet microbes pose a potentially greater hazard to ecosystem function and human health. This research will characterize the microbial flora of ballast water. Genes specific to toxigenic strains of *Vibrio* will also be amplified to test for the presence of these strains in ballast water. Individual invertebrate plankton will be assayed as substratum for bacteria using the same molecular strategy. Total DNA is

isolated from ballast water and a portion of the bacterial 16 rRNA amplified, cloned, and sequenced. Analysis of sequence variation will reveal the phylogenetic diversity of bacteria in these samples. We are targeting endotoxin genes from *Vibrio cholera* and *V. vulnificus* to test for their presence. DNA will be isolated from individuals and pools of copepods, bivalve larvae, and decapod larvae to test for microbial diversity on these substrates, again using 16S rDNA amplification. This research (1997–1999) is funded by the National Sea Grant Program.

ANNEX 4

CURRENT RESEARCH ACTIVITIES ON BALLAST WATER AND SEDIMENTS: STUDIES ON BALLAST WATER CONTROL TECHNOLOGIES

(By Country)

AUSTRALIA

Potential Roles for Ozone and Ultraviolet Irradiation in Ballast Water Treatment

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Ultraviolet irradiation and ozonation were tested for their efficacy against spores of the bacterium *Bacillus subtilis* and the dinoflagellate algae *Amphidinium* sp., and vegetative cells of *Gymnodinium catenatum*. Hypnocysts of *G. catenatum* are yet to be tested. Samples from the ballast tanks of vessels entering a number of North Queensland ports were sampled and tested for chemical and physical characteristics which will affect disinfection technologies. Results from the experiments, literature review and sampling program indicate that ozone will not be effective for the removal of algal hypnocysts, but may have application for some species, including algae, bacteria, viruses and protozoa with treatment during transit. Ozonation during ballasting will be effective for a smaller range of species.

Ultraviolet irradiation may be effective for ballast water treatment in combination with filtration or in combination with heat treatment. A synergism between UV and dark storage is effective for the removal of the dinoflagellates tested to date, and a synergism between UV, dark storage and heat may be effective to speed up the effect of heat treatment on dinoflagellate algae. The need for prefiltration in UV treatment will depend on the target species.

Ballast Water Heating as a Treatment Option to Minimise the Risks of Marine Organism Introductions

Geoff Rigby
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36 Creswell Ave., Charlestown, NSW Australia

Caroline Sutton
CSIRO Centre for Research on Introduced Marine Pests
Hobart, Tasmania, Australia

Gustaaf Hallegraeff
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Hobart, Tasmania, Australia

The potential for inactivating toxic dinoflagellate cysts and killing other marine organisms in ships' ballast water by heating has attracted recent interest as an environmentally responsible and potentially cost effective treatment option for minimising the risks associated with the international translocation and subsequent establishment of these organisms.

In order to test the practicality and effectiveness of this treatment option, a shipboard trial on the BHP-owned bulk carrier *Iron Whyalla* (supported by AQIS as part of the Strategic Ballast Water Research Program) was undertaken to confirm the practicality and earlier heating predictions, assess the behaviour of the phytoplankton and zooplankton present during the heating process and to assess the suitability of this option for future ballast water control. This trial took place in April 1997 during a ten-day voyage from Port Kembla in New South Wales to Port Hedland in Western Australia.

Observation of heated water samples showed that none of the zooplankton (mainly chaetognaths and copepods) and only very limited original phytoplankton (mainly dinoflagellates) survived the heat treatment. In fact, the original organisms were essentially reduced to flocculent amorphous detritus. Subsequent culturing efforts on the heated ballast tank samples only produced growth of some small (5 micrometers) diatoms and colourless ciliates which are considered likely to be of little consequence. Although no toxic dinoflagellate cysts were present in the tanks, based on earlier laboratory experiments, it is probable that these would have been effectively killed by the temperatures achieved during the heating trial, since essentially all of the water reached these conditions. This approach to ballast water management is environmentally very attractive since it does not necessitate the use of chemicals or biocides that could themselves be harmful to the environment. This technique is safe since the tanks are always full of water, cost effective since it makes

use of waste heat normally discarded, and is likely to be practical for use by a range of ships on international voyages. In addition to the effects of heating, this approach has the added benefit of removing a substantial amount (> 90 %) of the original plankton by the flushing action of the hot water.

ISRAEL

The Effects of Freshwater Flushing on Protist Ballast Biota

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Free University, Berlin, Germany

Mid-ocean ballast exchange is a widely-proposed measure that is thought to significantly the reduce risk of invasions by physical displacement and by biocidal effects. An uncommon circumstance allowed examination of changes in the protist ballast community under unusual physical parameters that may hint at the efficacy of exchange for protists. Sediment and water were collected from a ballast tank of a container ship travelling an established route from its home port, Haifa, to the northwestern Atlantic, through the Panama Canal to China and Japan. That tank was filled with freshwater in the Canal, then nearly emptied. The salinity of the remaining ballast water was 2 psu. The sample yielded 57 species, comprising of 13 zooflagellates, 29 rhizopods and 15 ciliates, including 'typical' marine rhizopods such as *Platyamoeba marchelonii, Labyrinthula* sp., *Pontifex maximus* and *Thecamoeba orbis*, and the ciliate *Condylostoma arenarium.*

The sample was then divided into three groups, half of each receiving additional water of different salinity: fresh water, brackish and sea water. Three months later, fresh, brackish, sea water and original salinity samples retained living protists. It seems that some previously unsuspected marine protists are physiologically capable of surviving over four weeks in fresh water, and then return, hale and healthy, to sea water. To reduce the risk of potential migrations, we thus suggest further tests of the effectiveness of mid-ocean exchange for a broad range of taxa, lest we leave open a 'window of opportunity' for stowaways.

NORWAY

Preliminary Results from a Pilot Study on Treatment for Ballast Water with Vortex Separation and UV-Irradiation

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A pilot study on treatment of ballast water with vortex separation and UV-irradiation was conducted. Experimental conditions were as follows: Flow: 55 m^3, applied UV-dose: 92 mWs/cm^2. Experimental organisms used were the brine shrimp *Artemia* sp., both nauplii (instar I& II) as well as cysts, the prymnesid algae *Isochrysis galbana* (var. *thahitis*) and *Pavlova* sp., and two strains of bacteria. The *Artemia* was counted by binocular microscope, the algae were counted and sized in a Coulter Counter 'Multisizer' (a nanoplankton-chamber) and were grown in MPN cultures following exposure to assess viability. The bacteria were counted by plating on MBA, Marine Broth Agar.

As expected (due to small size and/or little difference in specific gravity, compared to sea water), the separation of biota in the hydrocyclone was not very effective. However, a substantial fraction of *Artemia* (60 %) and *Pavlova* (50 %) had disappeared when the samples had passed the vortex, probably due to shearing forces in the hydrocyclone. No viable *Artemia* nauplii were found two days after the treatment. Two days following exposure, 100 % of the *Isochrysis* and 59 % of the remaining *Pavlova* were rendered immobilised. Hatching success for *Artemia*-cysts, and viability data for the algae and the bacteria, will be available later .

UNITED STATES: GREAT LAKES

The Algonorth Experiment: Ballast Water Technology Demonstration Project

Allegra Cangelosi
Northeast Midwest Institute

Richard W. Harkins
Lake Carriers Association

Design of the Great Lakes Ballast Technology Demonstration Project

M. Parsons, A. Cangelosi, R.W. Harkins, T.P. Mackey, D.J. Munro

Please see Annex 6.

ANNEX 5

CURRENT RESEARCH ACTIVITIES ON BALLAST WATER AND SEDIMENTS: EDUCATION PROGRAMS

UNITED STATES: CALIFORNIA

West Coast Ballast Management Education Program

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San Bruno, CA 94066

This project, running from March 1998 to February 2000, and funded by the National Sea Grant College Program and CALFED Bay-Delta Program, will provide an outreach program to educate the shipping industry, government agencies, and the general public about ANS and ballast management issues relevant to the United States West Coast and Pacific Region.

The three overall objectives of the project are as follows:

1) to provide education on aquatic nuisance species (ANS) and ballast management issues for the maritime industry, resource agencies, and the general public, and to demonstrate the key role of preventing introductions of exotic species (and the difficulties and costs associated with post-invasion control);
2) to educate the maritime industry about ballast management practices and technologies, and to facilitate communication and cooperation between the maritime industry, regulators, and researchers concerned with ballast water management; and
3) to facilitate industry interest and participation in the development of ballast management techniques or technologies to provide an alternative to open ocean exchange.

The project will comprise five major components:

1) A general education publication on West Coast ANS and ballast management issues. The publication will be provided to a variety of audiences including the West Coast and Pacific Region shipping industry, the general public, and natural resource professionals. The brochure will be utilized for uses ranging from general education to assisting natural resource professionals with identification of exotics.
2) A series of eight video-conferenced educational forums to increase industry awareness and knowledge of ballast management issues. Forums will be one-half day events where individuals involved with the ANS research and the development of ballast management or ballast technology approaches will be invited to provide a presentation to representatives of the shipping industry. Locations of the forums will be rotated between major West Coast ports in California, Oregon, Washington, Alaska, and Hawaii, and video-conferencing will be provided to allow for real-time participation by industry members who are unable to attend the meeting on-site.
3) The first biannual newsletter and website focused on ballast management and West Coast ANS issues. The newsletter will provide summary proceedings from the project forums, as well as current information on nationwide ballast technology and management research, and West Coast ANS issues. The project web site will contain the newsletter, a current article bibliography, announcements, and linkages to other web sites. Additional general outreach will be pursued through providing articles and announcements to existing ANS and maritime publications and websites.
4) The formation of an industry working group which will provide a basis for initiation and funding of future West coast ballast management demonstration projects.
5) Evaluations conducted for all project activities, and a final report which will summarize the response of project audiences to outreach methodologies, and discuss future needs for ballast water technical assistance and outreach.

UNITED STATES: MASSACHUSETTS

Outreach and Education on Marine Bioinvasions

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Massachusetts Institute of Technology
Sea Grant College Program
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This project will initiate a variety of outreach activities that disseminate reliable scientific information on the types, nature and effects of marine-introduced species to a broad-based audience. A strong focus will be on compiling information on ballast water research and management and making information available to the public through electronic media (web page), written materials, conferences and other communication routes. A National Conference on Marine Bioinvasions, focusing on ballast water research and management and other scientific issues relating to introduction of species into coastal and marine ecosystems will be convened January 3-6,1999 (tentative dates). The project period is September 1, 1997–August 31, 1999; funding sources include National Sea Grant Office, Department of Commerce and National Oceanic Atmospheric Administration grant # NG46RG434.

ANNEX 6

CURRENT RESEARCH ACTIVITIES ON BALLAST WATER AND SEDIMENTS

PART 1: Ballast Research at the Smithsonian Environmental Research Center

SMITHSONIAN ENVIRONMENTAL RESEARCH CENTER
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Marine Invasions Research at SERC (USA): Current Research and Future Directions

Gregory M. Ruiz & Anson H. Hines
(November 1997)

A. Background & Goals

Over the past 7 years, we have developed a collaborative research program at the Smithsonian Environmental Research Center (SERC) to address a broad range of issues in marine and estuarine invasion biology. The overall goal of our program is to:
(1) **measure patterns of nonindigenous species transfer, invasion, and impact**;
(2) **test specific and general mechanisms that underlie these patterns**;
(3) **assess the efficacy of management strategies** to limit the spread and impact of nonindigenous species.

Although our research is focused on nonindigenous species (NIS) invasions, we are also interested in the unique opportunities that invasions offer to understand fundamental processes in population, community, and evolutionary ecology (e.g., patterns of dispersal, dynamics and genetics of small populations, ecological and evolutionary responses of invading and resident populations to species interactions, effects of species insertions on community structure).

SERC is located on Chesapeake Bay, near the middle of the U.S. Atlantic coast, and we have focused much of our attention to date on the Chesapeake as a model system to examine patterns and mechanisms of invasion. A core group of approximately 15 researchers is based in the region, and we have many collaborators outside of the region who participate in the Chesapeake-based research.

Our program also includes research at an increasing number of sites outside of the Chesapeake Bay region to measure variation among sites and test for generalities in invasion processes. Within the U.S., we have research projects in Alaska, California, Florida, and Massachusetts primarily, and this work often involves collaboration with scientists based outside of the Chesapeake region. We also have developed collaborative overseas research in Australia, Israel, Italy, Netherlands, and New Zealand.

B. Current Research

We have implemented a variety of research projects over the past 7 years that examine patterns of NIS transfer, invasion, and impact, and that begin to assess the effect of some control measures. Our invasion biology program is divided into 4 topic areas, and the last three of these focus intensively on ballast water (Fig. 1). We have established two primary bases of operation for this ballast water research, one on each the east coast (Chesapeake Bay, Maryland) and the west coast (Prince William Sound, Alaska) of the U.S., and we are measuring the volume, content, and management of ballast water of vessels arriving from both domestic and foreign sources (Fig. 2-3). This research has examined primarily macroplankton (i.e., organisms > 80 microns), and we have initiated a parallel component to examine similar attributes of microbial communities in ballast water. Although we have now accrued a large descriptive data base on ballast water communities, we have also conducted a series of experiments to measure the efficacy of ballast water exchange, effects of voyage conditions on survivorship, and capacity of organisms to invade upon release (Fig. 4).

Our research to date is summarized below:

Ballast Water Management and Delivery Patterns

- Characterized the cumulative volume, source regions, and ballast exchange rates for commercial vessels arriving to Chesapeake Bay (1993-1997)
- Characterized the cumulative volume, source regions, and ballast management practices for U.S. Navy vessels arriving to Chesapeake Bay (1995-1997)
- Initiating program with U.S. Coast Guard to measure frequency of ballast water exchange on commercial vessels arriving from overseas to ports throughout the U.S. (1997-2001)

Ballast Water Content

- Measured physical attributes and biological (esp. plankton) content of ballast water of approximately 150 commercial ships arriving to Chesapeake Bay (1993-1997)
- Measured physical attributes and biological (esp. plankton) content of ballast water of approximately 30 U.S. Navy vessels arriving to Chesapeake Bay (1995-1997)
- Measured microbial (esp. bacterial and viral) attributes of ballast water for a subset of these same vessels (1996-1997)
- Initiating program to measure content of ballast water of oil tankers arriving to Port Valdez, Alaska from domestic and foreign sources (1997-1999)
- Initiating program to measure density and dynamics of microbial organisms, especially *Vibrio* bacteria, arriving to Chesapeake Bay from foreign sources (1997-1999)
- Initiating program to measure the relative importance of domestic ballast water as a transfer mechanism of nonindigenous species to Chesapeake Bay (1997-1999)

Survival Patterns of Organisms in Ballast Tanks (Transit Success)

- Measured survival of organisms, comparing initial versus final densities, in ballast water on commercial and military vessels (n=15) arriving to Chesapeake Bay from Germany, Israel, Italy, Netherlands, Spain and from domestic ports (1995-1997)
- Initiating measurements of survival during transit for organisms in ballast tanks of vessels arriving to Alaska (1997-1999)

Condition of Organisms arriving in Ballast Water

- Tested ability of organisms arriving in ballast water from foreign ports to survive and reproduce in laboratory conditions (temperature and salinity) that mimic local field conditions of Chesapeake Bay (1994-1997)
- Initiating measurements of viability and tolerance of organisms exposed to local field conditions upon arrival to Port Valdez, Alaska in ballast water of oil tankers (1997-1999)

Efficacy of Ballast Water Exchange

- Tested the efficiency of ballast water exchange in removing entrained plankton and introduced tracers from ballast tanks on commercial and military vessels arriving to Chesapeake Bay (n=6) (1996-1997)
- Initiating tests to measure the efficiency of ballast water exchange (especially variation in exchange effort) in removing plankton and tracers from ballast water or oil tankers arriving to Port Valdez, Alaska (1997-1999)

Patterns of NIS Invasion

- Documenting the history and mechanisms of NIS invasion for the Chesapeake Bay to include all major taxonomic groups that includes creation of detailed relational database on the biology, distribution, ecology, and impact of each species (see attached) (1995-1997)
- Documenting the history and mechanisms of NIS invasion for the Indian River Lagoon (Florida) that includes these same elements (1996-1997)
- Measuring current distribution of NIS and rate of new NIS arrivals across environmental gradients in Chesapeake Bay (1994-1997)
- Measuring rates of geographic spread and population dynamics for selected NIS in Chesapeake Bay and California (1994-1997)
- Initiating comparisons of temporal and spatial patterns of invasion in Alaska, California, and Florida to test specific hypotheses about associations with various factors (e.g., transfer patterns, environmental conditions, etc.) (1996-1999)

Effects of NIS Invasions

- Quantifying ecological effects of selected NIS invasions on resident populations and communities in the U.S. (Chesapeake Bay, California, Massachusetts) and Australia; selected NIS to date include species of crabs, bivalves, hydroids, barnacles, and bacteria (1994-1997)

- Testing predictability and variability of invasion effects among multiple communities; current focus has been measuring impact(s) and population characteristics of a single invader in California, Massachusetts, and Australia (1995-1998).
- Testing the effects of *Vibrio* bacteria on the survival and demography of planktonic organisms

C. Future Directions

Although a large component of our research will continue to examine the invasion processes discussed above, this research is increasingly done in a comparative and collaborative context to measure (in parallel) patterns of NIS transfer, invasion, and impact among sites. We have already initiated this on a limited scale that includes both national and international sites to measure variation in invasion processes on various spatial scales. It is our view that only this broad and coordinated approach will sufficiently describe key patterns, effects, and mechanisms of invasion that extend beyond single estuaries or regions.

To achieve this comparative perspective on invasion processes, two elements of our program will play an especially critical role, and we describe these below.

National Ballast Information Clearinghouse

One key element in this programmatic approach is the development of the National Ballast Information Clearinghouse at SERC as part of the National Invasive Species Act of 1996 (NISA) . NISA requests that all ships arriving to U.S. ports from overseas follow voluntary guidelines for ballast water exchange to minimize the transfer of nonindigenous species. The Clearinghouse was established to track the effectiveness of these NISA guidelines in (a) increasing the rate of ballast water exchange, (b) changing overall the rate and patterns of ballast water delivery, and (c) reducing the rate of ballast-mediated invasions.

At present, the Clearinghouse is implementing a nationwide program with U.S. Coast Guard to measure ballast management practices and delivery patterns of all vessels that arrive to the U.S. from foreign ports. The Clearinghouse is responsible for the management and timely statistical analysis of the extensive data collected under this program, and is assisting in the development and implementation of appropriate data collection techniques and selective "ground-truthing". This program will result in a comprehensive biennial report to the U.S. Congress on ballast water management and delivery patterns.

Additional goals of the Clearinghouse include a similar synthesis and analysis of national data on invasion patterns. These data will be used to (a) assess the effectiveness of NISA in reducing invasion rates and (b) create a national resource center (i.e., *Information*

Clearinghouse) and database for current, comprehensive information on both ballast water and marine invasions (see Fig. 5 for description of overall goals of the Clearinghouse).

The combined synthesis of data on ballast water exchange and delivery patterns with data on invasion rates is necessary to assess the effectiveness of management practices in reducing invasions, as relevant to NISA goals. These data will also address broader issues on spatial variation in both ballast water supply and ballast-mediated invasion across the U.S., allowing us to compare general patterns of invasion as a function of ballast water supply, latitude or coastal region, and various environmental characteristics.

Marine and Estuarine Nonindigenous Species Database

Another key element in our approach includes use of a relational database on nonindigenous species that provides a powerful framework for standardized and formal comparisons that we plan to use for regional-, national-, and international-scale analyses of invasion patterns by taxonomic group, organism traits, environmental characteristics, etc.

We have developed and maintained at SERC a relational database for each nonindigenous species of Chesapeake Bay that includes extensive details of taxonomy, distribution, life history, reproductive and population biology, environmental tolerances, habitat distribution and ecology by life-stage, and documented economic and ecological impacts.

We have recently begun to expand this to include similar records for all nonindigenous marine and estuarine species in the Indian River (Florida) and Prince William Sound (Alaska).

Our long-term goal is to expand this database to include nonindigneous marine species from many additional sites in the U.S. and overseas through collaboration with other research groups. We have already begun this process for a number of national and international sites, using our format as a standard approach. Through this work, we are establishing a formal network of sites to document both the patterns of invasion and the attributes and impacts on nonindigenous species among regions.

Figure 1. Primary research areas of the Biological Invasions Program at the Smithsonian Environmental Research Center.

Figure 2. Location of SERC's Ballast Water research projects (Valdez, Alaska and Chesapeake Bay). Shown are foreign and domestic ballast water source regions for each location.

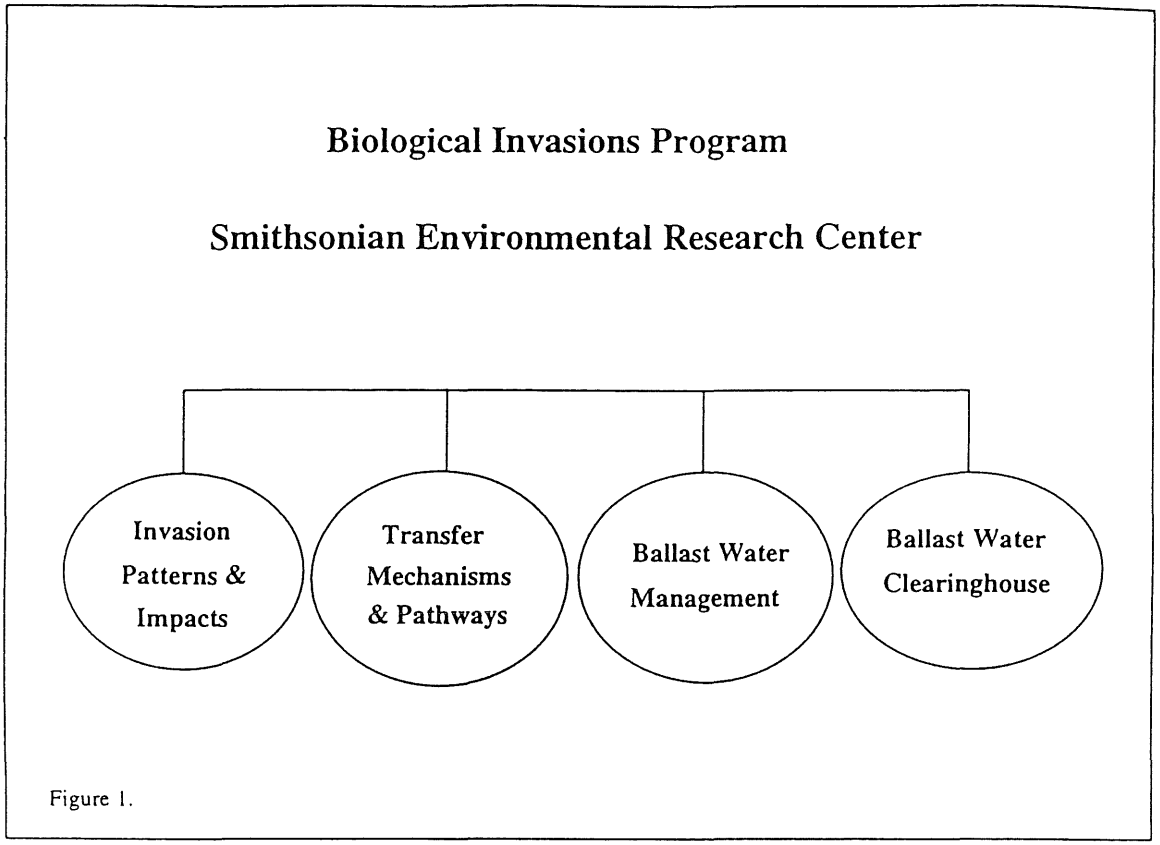


Figure 1.

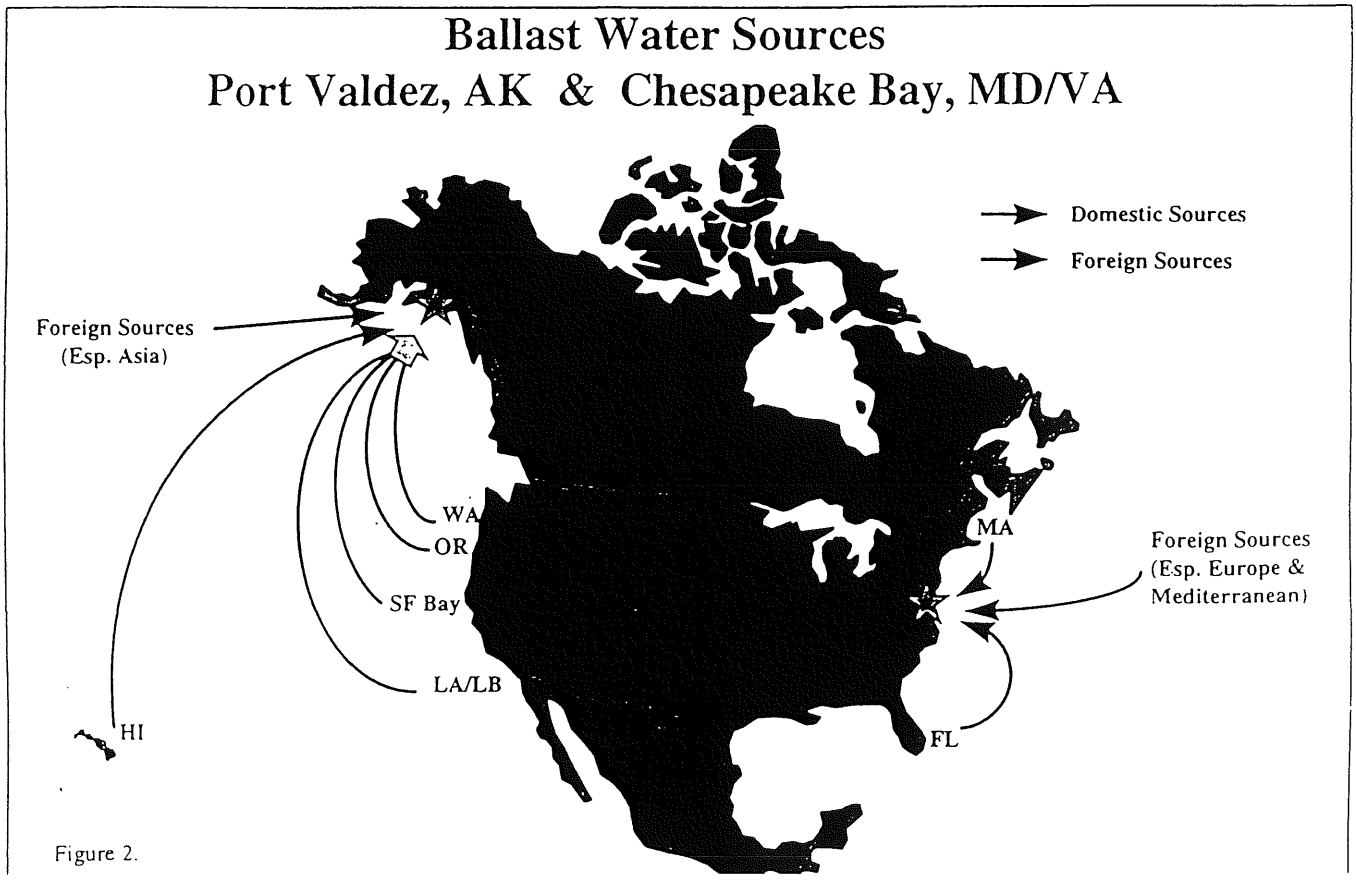


Figure 2.

Figure 3. Primary ballast water characteristics currently under study at SERC. Macroplankton communities are being measured on commercial and military vessels arriving from foreign and domestic ports. Microbial communities are being measured on commercial vessels arriving primarily from foreign ports.

Figure 4. SERC's research on ballast water management including both descriptive and experimental studies (as shown) examining effects of management practices.

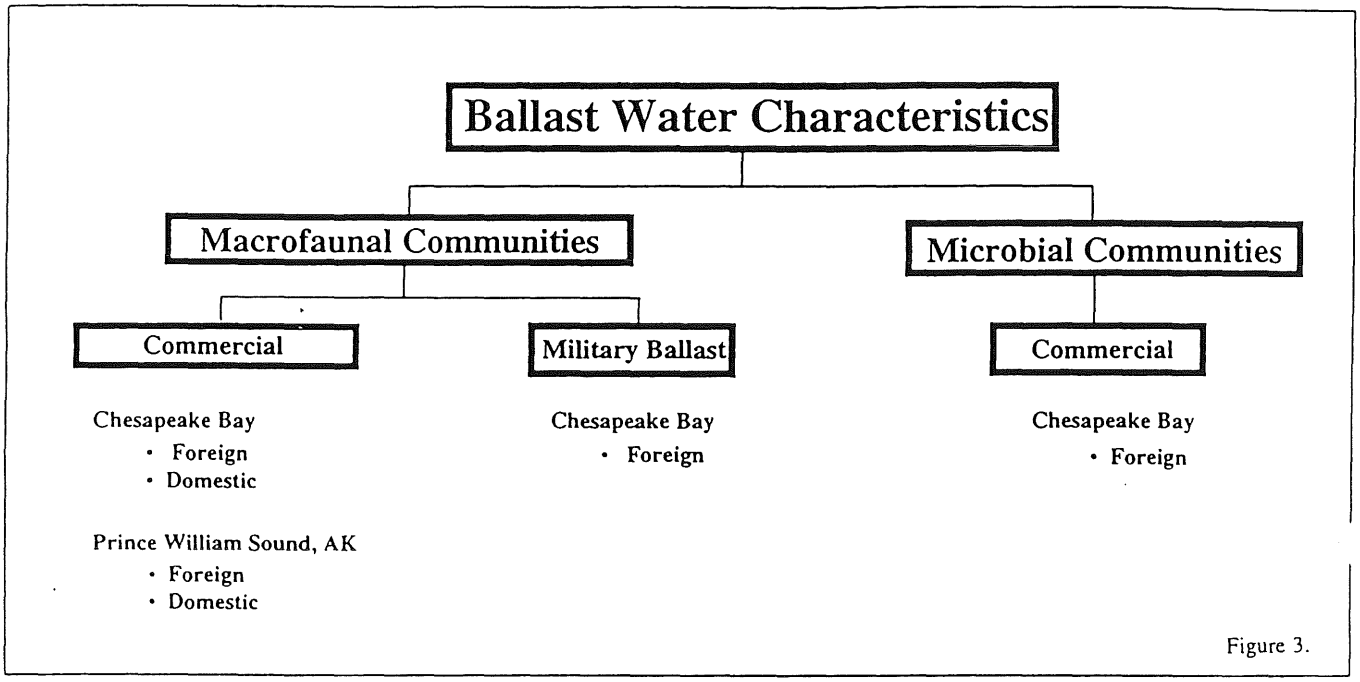


Figure 3.

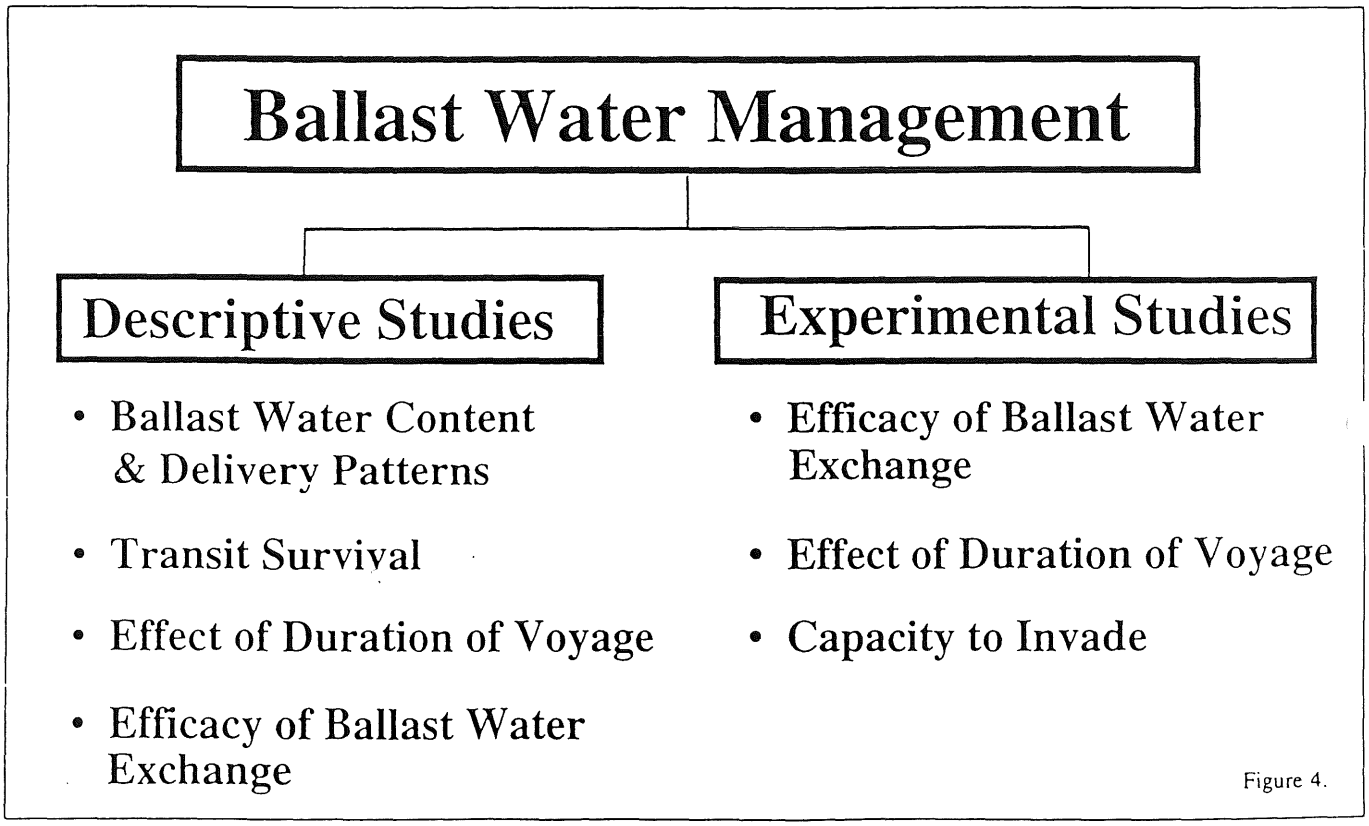
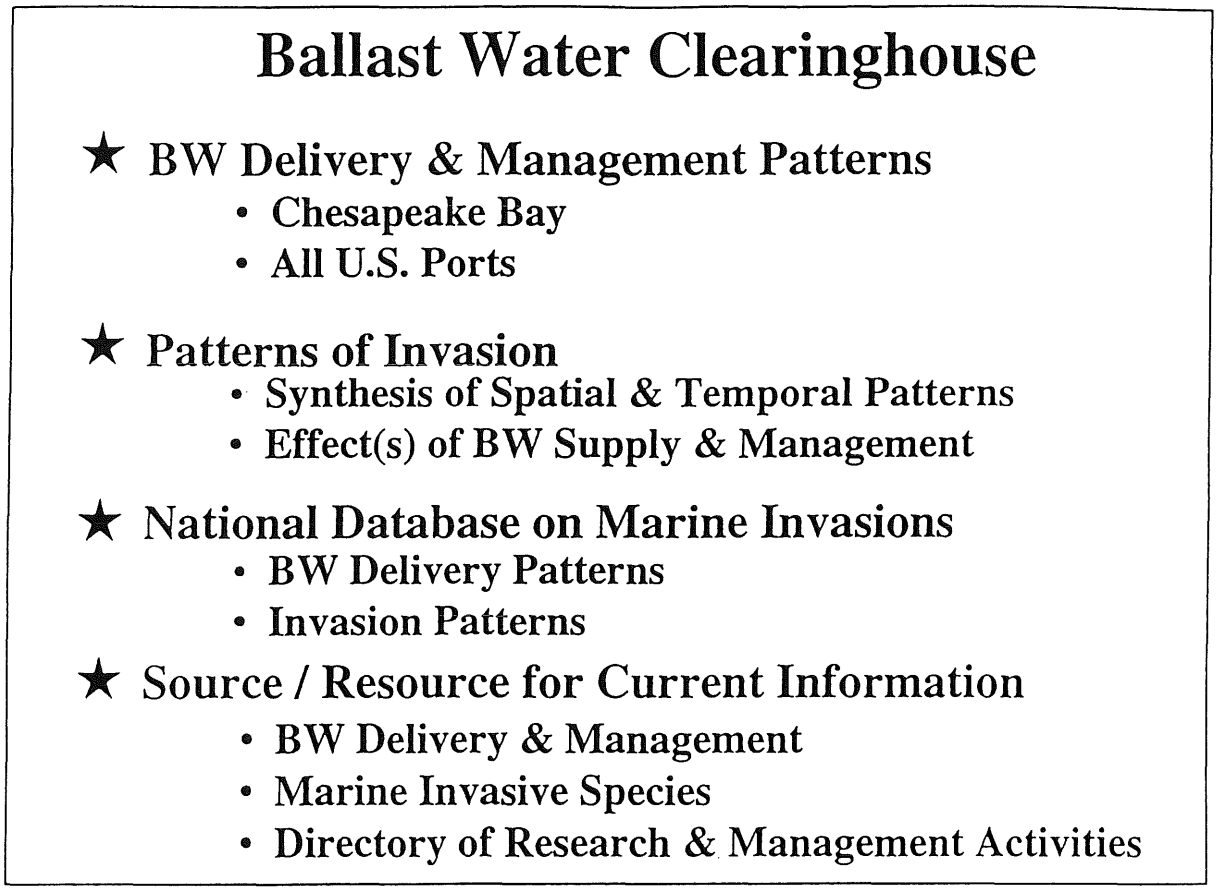


Figure 4.

Figure 5. Goals of the National Ballast Water Clearing House based at SERC.



C. SERC Invasion Research Group

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William Walton (University of Maryland)

Contributors (Taxonomy):
Individual scientists (too numerous to list) from around the world have also made substantive contributions to our program through providing insight into the systematics of many species.

D. SERC Invasion Biology Projects

We have indicated below the major invasion projects for which we have received funding. These are divided into three categories, and we have indicated project title, funding agency, duration, and principal investigators for each project.

Ballast Water Transfer and Management

- "Patterns of ballast water delivery and management for vessels arriving to U.S. ports from foreign ports", U.S. Coast Guard, 1997-1998. Pis: Gregory M. Ruiz & Anson H. Hines.
- "Measuring the transfer, dynamics, and risk of invasion for microbial communities associated with ballast water of ships", Maryland Sea Grant, 1998-2000. PIs: Gregory Ruiz, Fred Dobbs, Anwar Huq, Anson Hines.
- "The relative importance of ballast water from domestic ship traffic in translocation of nonindigenous species among U.S. ports", National Sea Grant Program, 1997-1999. PIs: Gregory Ruiz, Anson Hines, L. David Smith, and James Carlton.
- "Biological invasions of cold-water coastal ecosystems: Ballast-mediated introductions in Port Valdez / Prince William Sound, Alaska", National Sea Grant Program, 1997-1999. PIs: Anson Hines, Nora Foster, John Chapman, Gregory Ruiz, James Carlton, Howard Feder, and Gayle Hansen (includes matching funds as grant to Smithsonian Institution from U.S. Fish & Wildlife Service and Regional Citizens Advisory Council).
- "Ballast water management patterns of ships arriving to U.S. ports from foreign ports. Phase I: Design of data collection and management", U.S. Coast Guard, 1997. PIs: Gregory Ruiz and Anson Hines.
- "Nonindigenous species of Prince William Sound: Pilot study", Prince William Sound Regional Citizens' Advisory Council, 1997. PIs: Gregory Ruiz, Anson Hines, John Chapman, and Gayle Hansen.
- "Susceptibility of Chesapeake Bay to invasion of non-indigenous species associated with ballast water" (Renewal), Maryland Sea Grant Program, 1996-1998. PIs: Gregory Ruiz, Anson Hines, Wayne Coats, James Carlton, and David Smith.
- "Transport and introduction of non-indigenous species to Chesapeake Bay by U.S. Navy vessels", Department of Defense Legacy Program, 1994-1997. PIs: Gregory Ruiz, Anson Hines, James Carlton, and David Smith.
- "Susceptibility of Chesapeake Bay to invasion of non-indigenous species associated with ballast water", Maryland Sea Grant Program, 1994-1996. PIs: Gregory Ruiz, Anson Hines, Wayne Coats, James Carlton, and William Jaeckle.
- "Understanding ballast-mediated invasions: the effects of ballast water transport and prolonged darkness on survival and development of exotic invertebrates", Smithsonian Institution, Scholarly Studies Program, 1994-1996. PIs: Gregory Ruiz, David Smith, Anson Hines, and James Carlton.
- "Changes in ballast water plankton assemblages during transoceanic voyages", NATO Collaborative Research Program, 1994-1996. PIs: Gregory Ruiz, David Smith, Anson Hines, and James Carlton.

- "Ballast Water Escort Study", U.S. Fish and Wildlife Service, 1995. PIs: Gregory Ruiz (with Marjorie Wonham and William Walton.
- "Ballast Water Escort Study", Compton Foundation, 1995. PIs: Gregory Ruiz (with Marjorie Wonham and William Walton.

Invasion Patterns

- "Biological Invasions of Chesapeake Bay", U.S. Fish and Wildlife Service, 1994-1997. PIs: Gregory Ruiz, Richard Everett, Anson Hines, and James Carlton.
- "Indian River Lagoon species inventory: On-line access", Atherton Seidell Program, Smithsonian Institution, 1997-1998. Pis: Anson Hines, Gregory Ruiz, Joseph Dineen, and Mary Rice.
- "Indian River Lagoon species inventory", St. Johns Water Management District (Florida), 1997-1998. Pis: Anson Hines, Gregory Ruiz, Joseph Dineen, and Mary Rice.
- "Exotic introduction or native species? The parasitic copepod *Mytilicola porrectus* in shellfish of the Chesapeake Bay", Dept. of Commerce, NOAA, 1991-1992. PI: Gregory Ruiz.

Invasion Impacts

- "Potential impacts of a nonindigenous crab on selected west coast commercial invertebrates", National Sea Grant Program, 1997-1999. PIs: David Armstrong, Greg Jensen, Edwin Grosholz, and Gregory Ruiz.
- "Quantifying the range expansion and ecological impact of the nonindigenous European green crab in western North America", Sea Grant / NOAA Partnership Program, 1998-1999. Pis: Edwin Grosholz, Gregory Ruiz, Jane Caffrey, Steve Rumrill, and Andre DeVogelaere.
- "Ecological and evolutionary consequences of the recent introduction of green crabs to the Pacific coast of North America", National Science Foundation, Conservation Biology, 1994-1996. PIs: Edwin Grosholz, Gregory Ruiz, and Dennis Hedgecock.
- "Impact of the recently introduced green crab on invertebrate and shorebird populations in Bodega Harbor", National Science Foundation, Biological Oceanography, 1993-1994. PIs: Edwin Grosholz and Gregory Ruiz.
- "Invasion of California estuaries by the non-indigenous green crab *Carcinus maenas*: Assessment of its impact and geographic spread", California Sea Grant Program, 1993-1994. PIs: Armand Kuris and Kevin Lafferty.

E. Reports & Publications

Although we have produced some reports and papers from our invasion research to date, the analyses of many projects are just now being completed. Below is a list of reports and publications that are now available or will emerge soon. In addition, we have attached the Executive Summary from 4 of the studies completed to date.

Completed Products

- Ruiz, G.M., J.T. Carlton, E.D. Grosholz, and A.H. Hines. Global invasions of marine and estuarine habitats by non-indigenous species: Mechanisms, extent, and consequences. Am. Zool. 37:619-630.
- Ruiz, G.M. and A.H. Hines. 1997. Patterns of nonindigenous species transfer and invasion in Prince William Sound, Alaska: Pilot Study. Technical report submitted to the Prince William Sound Advisory Council, 80pp.
- Geller, J.B., E. Walton, E.D. Grosholz, and G.M. Ruiz. Cryptic invasion of *Carcinus* based upon molecular phylogeography. Molecular Ecology 6:901-906.
- Grosholz, E.D. and G.M. Ruiz. 1996. Predicting the impact of introduced species: lessons from the multiple invasions of the European green crab. Biol. Conserv. 78:59-66.
- Smith, L.D., M.J. Wonham, L.D. McCann, D.M. Reid, G.M. Ruiz, and J.T. Carlton. 1996. Biological invasions by nonindigenous species in United States waters: Quantifying the role of ballast water and sediments. Technical report submitted to U.S. Coast Guard and U.S. Dept. of Transportation.
- Wonham, M.J., W.C. Walton, A.M. Frese, and G.M. Ruiz. 1996. Transoceanic transport of ballast water: Biological and physical dynamics of ballasted communities and the effectiveness of mid-ocean exchange. Technical report submitted to U.S. Fish & Wildlife Foundation and the Compton Foundation.
- Ruiz, G.M., L.D. Smith, A.H. Hines, J.T. Carlton, and D.W. Coats. 1996. Ballast water and non-indigenous species in U.S. coastal waters. Review submitted to ICES for distribution at annual meeting in Aalborg, Denmark.
- Grosholz, E.D. and G.M. Ruiz. 1995. The spread and potential impact of the recently introduced European green crab, *Carcinus maenas*, in central California. Mar. Biol. 122:239-247.
- Grosholz, E.D. and G.M. Ruiz. 1995. The influence of spatial distribution and genetic variation on castration of the xanthid crab *Rhithropanopeus harrisii* (Gould) by an introduced parasite. J. Exp. Mar. Biol. Ecol. 187:129-145.

Pending Products for 1998

- Hines, A.H., F. Alvarez, and S.A. Reed. 1998. Introduced and native populations of a marine parasitic castrator: variation in prevalence of the rhizocephalan *Loxothylacus panopaei* in xanthid crabs. Bull. Mar. Sci. 61:xx-xx.

- Ruiz, G.M., P.F. Fofonoff, A.H. Hines, and E.D. Grosholz. Nonindigenous species as stressors in estuarine and marine communities: Assessing invasion impacts and interactions. Limnol. Oceanogr. (in revision).
- Ruiz, G.M., F.C. Dobbs, T.K. Rawlings, A. Huq, and R. R. Colwell. Global dispersal of viruses and bacteria in marine environments. In review.
- Grosholz, E.D., G.M. Ruiz, C.A. Dean, K.A. Shirley, J.L. Maron, and P.G. Connors. The direct and indirect effects of a nonindigenous marine predator on multiple trophic levels. In review.
- Ruiz, G.M., A.H. Hines, J.T. Carlton, and L.D. Smith. Patterns of transfer and introduction of non-indigenous species to Chesapeake Bay by U.S. Navy vessels. Technical report to U.S. Department of Defense. Expected March 1998.
- Ruiz, G.M., P.F. Fofonoff, A.H. Hines, A.F. VonHolle, L.D. McCann, and J.T. Carlton. 1997. Analysis of nonindigenous species invasions of the Chesapeake Bay (USA). Technical report to U.S. Fish & Wildlife Service. Expected December 1998.
- Ruiz, G.M., L.S. Godwin, J. Toft, L.D. McCann, A.H. Hines, and L.D. Smith. Efficacy of ballast water exchange in reducing the transfer of nonindigenous marine species among isolated geographic regions. In preparation.
- Ruiz, G.M., R. Brock, and L.S. Godwin. Geographic spread and physiological tolerance of the nonindigenous Asian crab *Hemigrapsus sanguineus* along the mid-Atlantic coast of eastern North America. In preparation
- McCann, L., J.T. Carlton, G.M. Ruiz, and A.H. Hines. Invasion of Chesapeake Bay and other North American estuaries by the IndoPacific polychaete *Ficopomatus enigmaticus*. In preparation.

Transoceanic transport of ballast water: biological and physical dynamics of ballasted communities and the effectiveness of mid-ocean exchange 1996

Prepared for: U.S. Fish and Wildlife Service and the Compton Foundation

Presented by: Marjorie J. Wonham, William C. Walton, Annette M. Frese, and Gregory M. Ruiz

Executive Summary

The extent and cumulative impact of nonindigenous species invasions in our freshwater and marine (including estuarine) habitats is a significant force of global change:

** Invasions have resulted in fundamental changes to the structure, dynamics, and function of these ecosystems.

** Invasions have caused significant economic losses due to effects on fisheries, industry, and recreation.

** New invasions and their effects continue to accrue, and the rate of recent invasions appears to be increasing.

Today, ballast water transport by commercial vessels is recognized as the largest single source of nonindigenous speciesdelivered to coastal marine and freshwater habitats. This transfer mechanism is active throughout the world and likely responsible for many, if not most, recent marine invasions.

The risk of ballast-mediated invasions is determined in part by the survival of organisms during transit from one port to the next. Although it is clear that significant mortality occurs in transit which may create a barrier to invasion for some organisms, the underlying mechanisms for this mortality are unresolved.

One preventive measure that is thought to significantly reduce risk of invasions is mid-ocean ballast exchange. This involves flushing ballast tanks that contain foreign coastal water with oceanic water during a ship's transoceanic voyage. To date, measures of exchange efficiency are encouraging but are limited to only a few taxonomic groups, in a few vessels and tank types, under unusual conditions.

To address these two aspects of ballast water transport and control, we (1) measured changes in the ballast community and selected physical/chemical parameters of water in multiple ballast tanks and (2) tested the efficiency of open-ocean exchange in 3 separate ballast tanks during a transoceanic voyage.

We accompanied the M/V *Leon*, a commercial coal carrying vessel, on a transatlantic voyage from Hadera, Israel to Baltimore, Maryland in June 1995. Ballast water was taken on in Israel (31 May to 5 June) and released in Maryland (22-23 June). Three paired (port and starboard) deck tanks and one cargo hold were used for our study. We measured changes in the species composition and abundance of plankton, temperature, salinity, and dissolved oxygen (DO) of water through repeated sampling of these ballast tanks during the voyage. Exchange of the ballast water began approximately 400 miles west of Gibraltar (day 6 of the voyage), . Water in one tank from each deck tank pair was exchanged with oceanic water, and the other tanks served as a control.

In addition to measuring changes in the ballast tanks, we performed two experiments to test the effects of ballast exchange on survival. In one experiment, organisms were removed from the deck tanks and placed into replicate enclosures in each exchanged and

control tanks. Concurrent with the enclosure experiment, in the laboratory, organisms were collected from the cargo hold and maintained in replicate dishes that contained either exchanged or original ballast water. We measured survivorship in each experiment.

We also performed a laboratory experiment to measure the survival of organisms exposed to Baltimore water upon arrival. Selected organsims were exposed to either Baltimore water or the original ballast water, maintained in the laboratory, and survivorship was measured on successive days.

Initial zooplankton and phytoplankton densities were very high (103-104/m3) in the cargo hold and deck tanks and declined exponentially through time. Interestingly, densities declined most rapidly in the deck tanks, and differential survivorship among taxa changed the composition of the arriving community. Despite extreme mortality that exceeded 90%, more than 1.5 million organisms arrived in Baltimore.

The relatively high mortality rates did not correspond to changes in the physical or chemical environment. Temperature, salinity, and DO were stable throughout the voyage for both the cargo hold and deck tanks. We hypothesize that food limitation was the primary factor responsible for the high mortality rates observed in all tanks.

The ballast water exchange was highly efficient, replacing > 99% of the original ballast water (based upon salinity differences between Israeli and mid-ocean sources). It is important to note hat this efficiency was achieved through sequential release and replacement of original water, and we expect lower efficiencies when flushing (displacing water through pumping) is the mode of exchange.

Although the density of organisms was insufficient to measure the effects of exchange on removal, laboratory experiments demonstrated that exchanged water had no biocidal effect. Not surprisingly, these data suggest that for residual organisms (i.e., those that remain in tanks following exchange) which are from a high salinity port, mid-ocean salinities offer no barrier to transit success. The enclosure experiment was inconclusive, due to mortality in both exchange and control tanks.

Of the > 1.5 million Israeli organisms that were delivered to Baltimore in with this ballast water, it is unlikely that any of these survived. When exposed to the low salinity Baltimore water, all organisms died within 24 hours, although most survived in control (i.e., ballast tank) water. In this case, the extreme difference of salinity between source and recipient waters was an effective barrier to possible colonization.

We conclude that the dramatic declines in plankton density and diversity over this voyage can not be attributed to changes in the physical or chemical paramaters studied. Instead, we posit that food limitation may be primarily responsible for these declines, and this hypothesis deserves further study as a mechanism that determines the arriving community. Exchange was highly effective at removing the original ballast water, but in this case was not an effective biocide to the residual organisms. Notably, from a

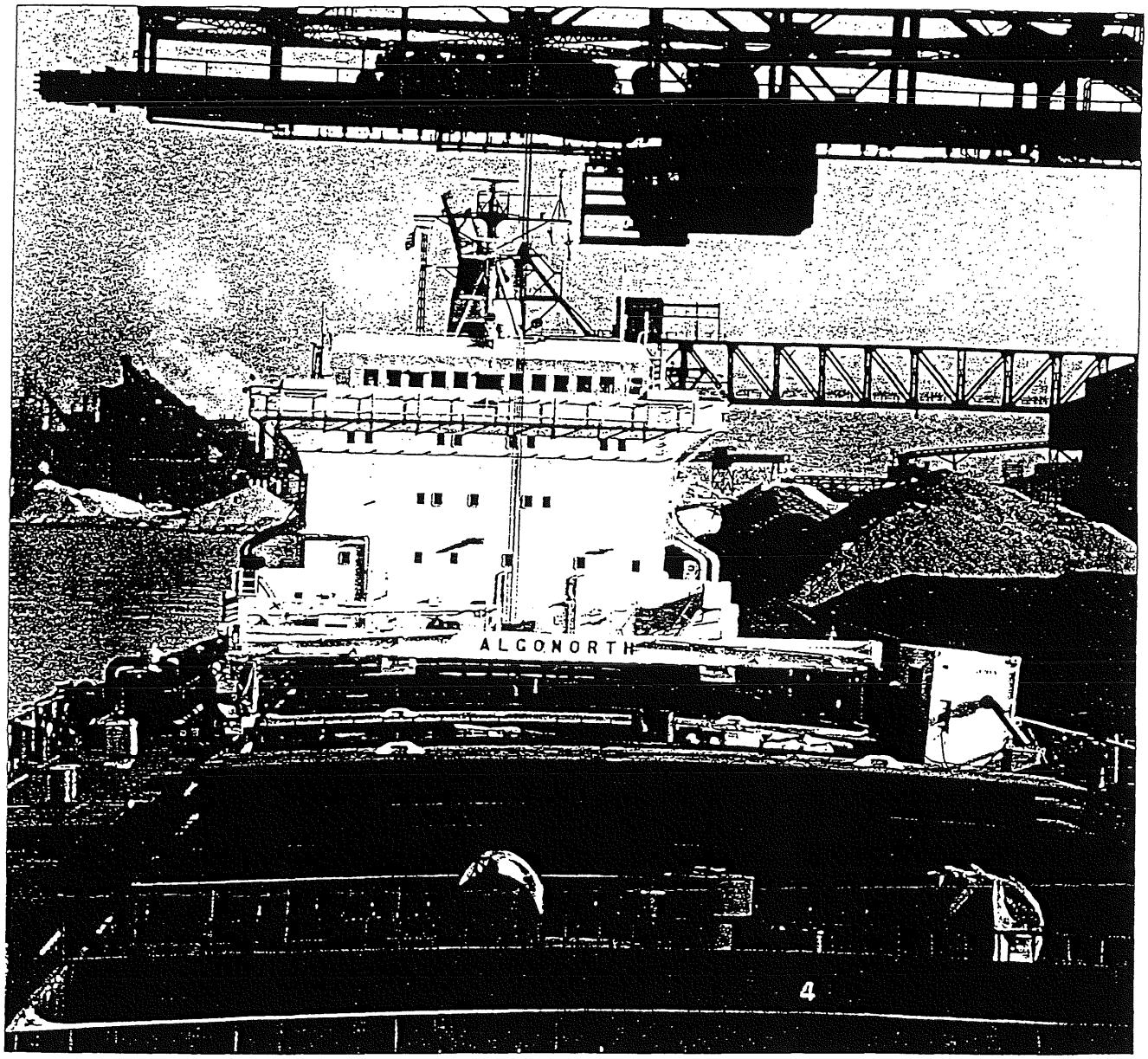
management perspective, the cargo hold, which can not be exchanged at sea, seemed to provide more favorable transit conditions than the deck tanks. Finally, organisms which arrived in Baltimore were viable and therefore candidates for successful invasions; the relatively low salinity of Baltimore harbor, however, appears to have provided an effective barrier to invasion by these particular high-salinity organisms.

Based on the conclusions of this study, we recommend (1) additional studies of this nature to test the generality of our conclusions and, in particular, the food limitation hypothesis, (2) examination of the ballasting process itself as the determinant of the initial conditions and community composition of ballast tanks and therefore a potential management "window", (3) further tests of the effectiveness of mid-ocean exchange across a broad range of shipping conditions, and (4) to prevent future invasions and to more effectively control those which do occur, the establishment of a comprehensive research program for marine invasions focused on a) the factors which allow or prevent successful establishment and spread of exotic marine species and b) the predictability of the effects of these invasions upon native communities. Research of this nature will guide improved management of ballast-water as a vector of exotic species and, more broadly, the prevention & control of nonindigenous species in coastal habitats.

PART 2: The Algonorth Experiment in the Great Lakes

The Algonorth experiment

A groundbreaking project in the Great Lakes will test one potential technology to control the spread of unwanted organisms



For all appearances, the container-sized unit situated on the port side of Algoma Central Marine's bulk carrier *Algonorth* looks like nothing more than a piece of deck cargo with some attached plumbing.

This "deck cargo," however, represents not only a $1.3 million investment in the environmental health of the Great Lakes, but also one of the most ambitious projects yet undertaken to study a ballast water treatment technology.

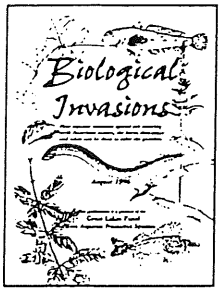
When *Algonorth* steams from her winter lay-up berth in Thunder Bay this spring, a first-of-its-kind experiment will get underway to measure the effectiveness of filtration as a means to control the spread of unwanted organisms through commercial vessels' ballast water.

"In terms of a single, dedicated project, this is bigger than any other similar project in the world," said Richard W. Harkins, Vice President of Operations for the Lake Carriers' Association (LCA)

Exotic Species

An issue that touches all members of the Great Lakes-St. Lawrence Seaway community

Learn more about nonindigenous species; the effects they have on native ecosystems; and federal, regional, state/provincial and local efforts to prevent new introductions to the Great Lakes, the Seaway and inland waterways. For a free copy of the *Biological Invasions* brochure and a complete list of publications available from the Commission, contact us at the address below. Or visit the Commission online at **http://www.glc.org.**



Great Lakes Commission

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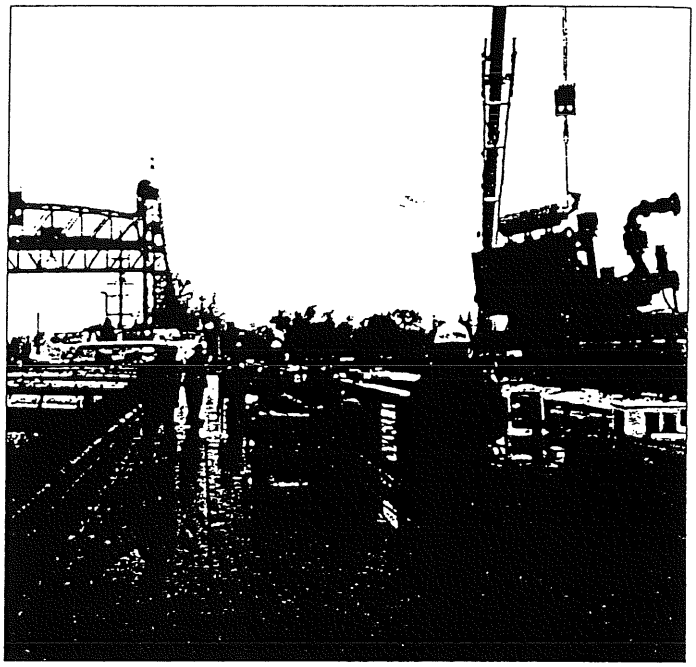
which represents the U.S. flag commercial fleet in the Great Lakes.

"The British have been conducting some experiments with ultraviolet treatment and the Australians have studied the effects of heat. But this is the only actual shipboard application of a technology currently being carried out," Harkins said.

The LCA and the Northeast Midwest Institute, a non-profit organization involved in economic and environmental issues affecting an 18-state tier of northern states from Minnesota to



The diesel pump was hoisted aboard the **Algonorth** *while the ship transitted the Welland Canal in November, 1996.*

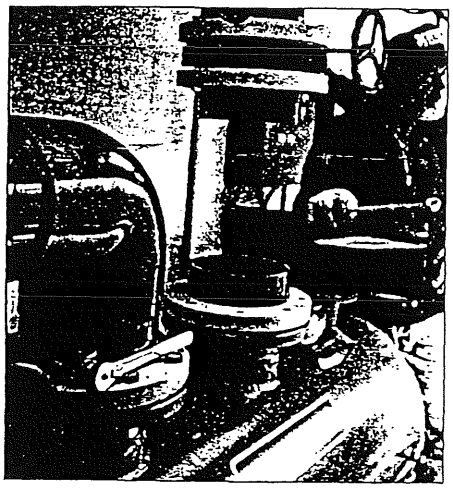
The filtration unit, with testing lab and peripheral equipment, was installed on the Algonorth in late 1996 and, following some shakedown trips, was further refined during the vessel's winter lay-up. Testing in earnest is to begin with the ship's resumption of operations in the spring of 1997.

Maine, are conducting the project with support from a $1 million grant from the Great Lakes Protection Fund. The fund was created in 1989 by the governors of seven Great Lakes states.

When the grant—the largest ever awarded by the Great Lakes Protection Fund for a single project—was announced in July, 1996, Wisconsin Govenor Tommy Thompson said, "We are resolved to keep the Great Lakes open to world commerce, but closed to biological invaders."

The platform for the project, *Algonorth*, is being provided by its owners, Algoma Central Marine.

Environmental and economic threats posed by non-indigenous species to the Great Lakes, such as zebra mussels, the round goby and European ruffe, are well documented. There is also broad consensus that most of these species have been introduced to the Lakes through the ballast water of salt water vessels. Since not much can be done to control the invaders already established in the Lakes, policy makers are focusing attention on how to prevent further infestation.



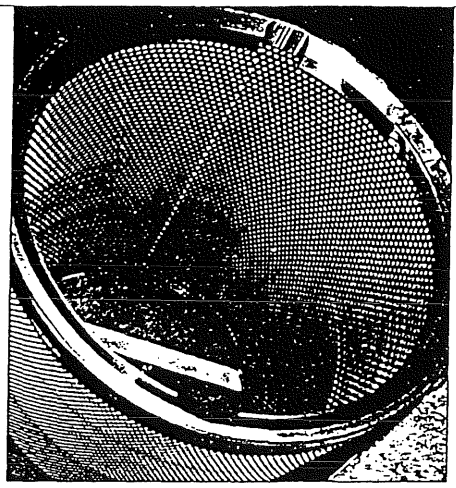
Piping for one of the two filters was assembled at Hyde Products in Cleveland.

The current state-of-the-art is a ballast exchange protocol in which vessels inbound for the Great Lakes purge their ballast tanks—and theoretically any near-coastal organisms within—in mid-ocean. The advantages of this practice are that it involves no capitol investment and is thus relatively inexpensive. Also, it can generally be carried out in transit without disrupting a vessel's schedule.

There are, however, some drawbacks to ballast exchange. It sometimes cannot be carried out safely in adverse weather conditions and some types of vessel designs do not lend themselves well to such a practice. There can also be vessel loading concerns when vessels are fully loaded with cargo, reporting no ballast on board (NOBOB) and thus have no ballast to exchange.

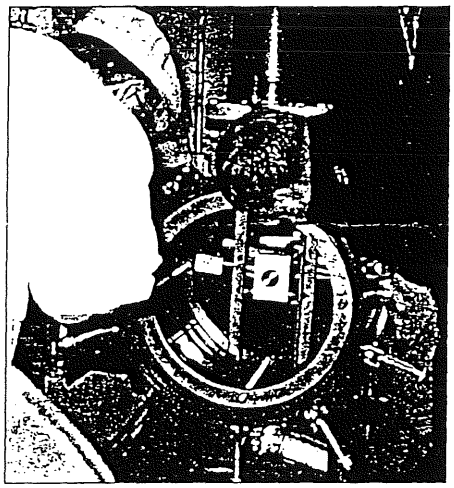
In terms of effectiveness, ballast exchange has been shown to be ineffective for coastwise transit. It is not feasible for NOBOB vessels and, even when ballast exchange is made, it is not effective if the purge is not totally complete.

Finally, there are accountability issues. It is difficult to tell if ballast exchange has occurred in saltwater-to-saltwater voyages and hard to assure that ballast tanks have been completely purged.



The stainless steel filter element weighs 92 pounds.

This project focuses initially on one technology: filtration. Filtration is considered a primary treatment method and is not necessarily meant as a stand-alone system.

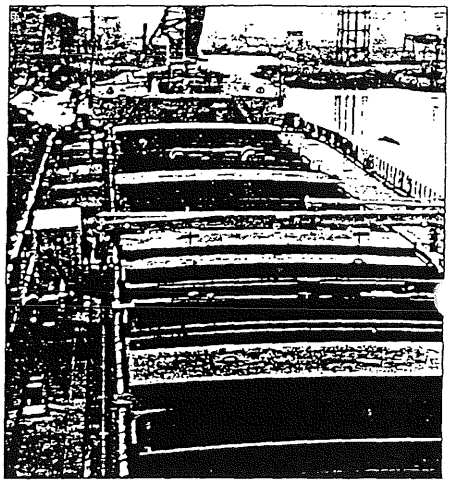


Rear Admiral Gerald Woolever, Commander of the U.S. Coast Guard's Ninth District, inspects the filter's internals.

Despite these problems, it is clear that the use of ballast exchange where possible will significantly reduce the rate of new introductions and can serve as an important stop gap as further research and development is conducted.

A number of recent studies and policy directives call for development of technological alternatives to better prevent ballast-mediated introductions of exotic species.

This was the mandate for the Great Lakes Ballast Technology Demonstration Project initiated in 1996. The object was to test one or more potential technologies aboard an operating commercial vessel, and, in the process, forge a cooperative partnership between an industry group—the Lake Carriers Association—and a non-profit group concerned with resource protection, the Northeast Midwest Institute.



Looking forward from the pilothouse, the filter container is on the left, the diesel pump and related piping on the right.

This project is designed to be widely applicable. While the Great Lakes will serve as the laboratory for the project, a Great Lakes-only solution is not the objective. Ballast water transmission of unwanted organisms has emerged as a concern in coastal regions throughout the world and several of those regions have already expressed interest in the Great Lakes project.

It is also understood that no one technology will serve the needs of all the types of vessels and voyages employed in the maritime trades. In fact, on any given vessel there may be more than one technology needed to address all the varieties of organisms present in ballast water; what will likely be needed is a "tool box" of technologies.

Three phase project. The Great Lakes project consists of three phases. Phase 1 involved preliminary research, scoping,

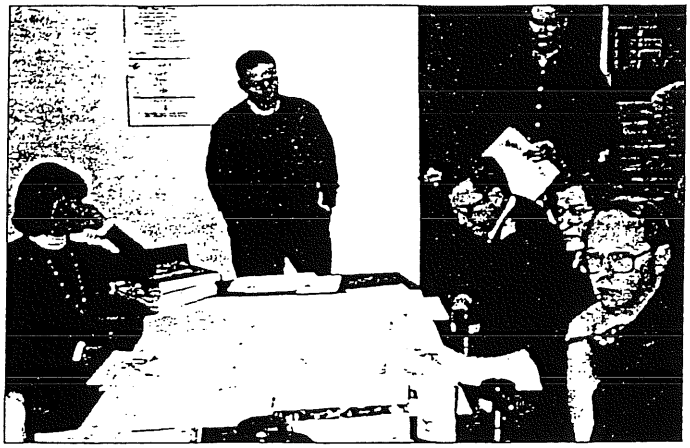
experimental protocol development and documentation of projects funded by U.S. and Canadian federal agencies.

Phase Two is the installation and implementation of the *Algonorth* experiment funded by the Great Lakes Protection Fund. The filtration unit, with testing lab and peripheral equipment, was installed on the *Algonorth* in late 1996 and, following some shakedown trips, was further refined during the vessel's winter lay-up. Testing in earnest is to begin with the ship's resumption of operations in the spring of 1997.

Phase 3 will be directed at refinement of the technologies demonstrated and will be funded the State of Minnesota.

A steering committee has been formed with broad participation from U.S. and Canadian federal agencies, the states, the commercial maritime industry and interested parties from other parts of the country including the West Coast and the Gulf of Mexico.

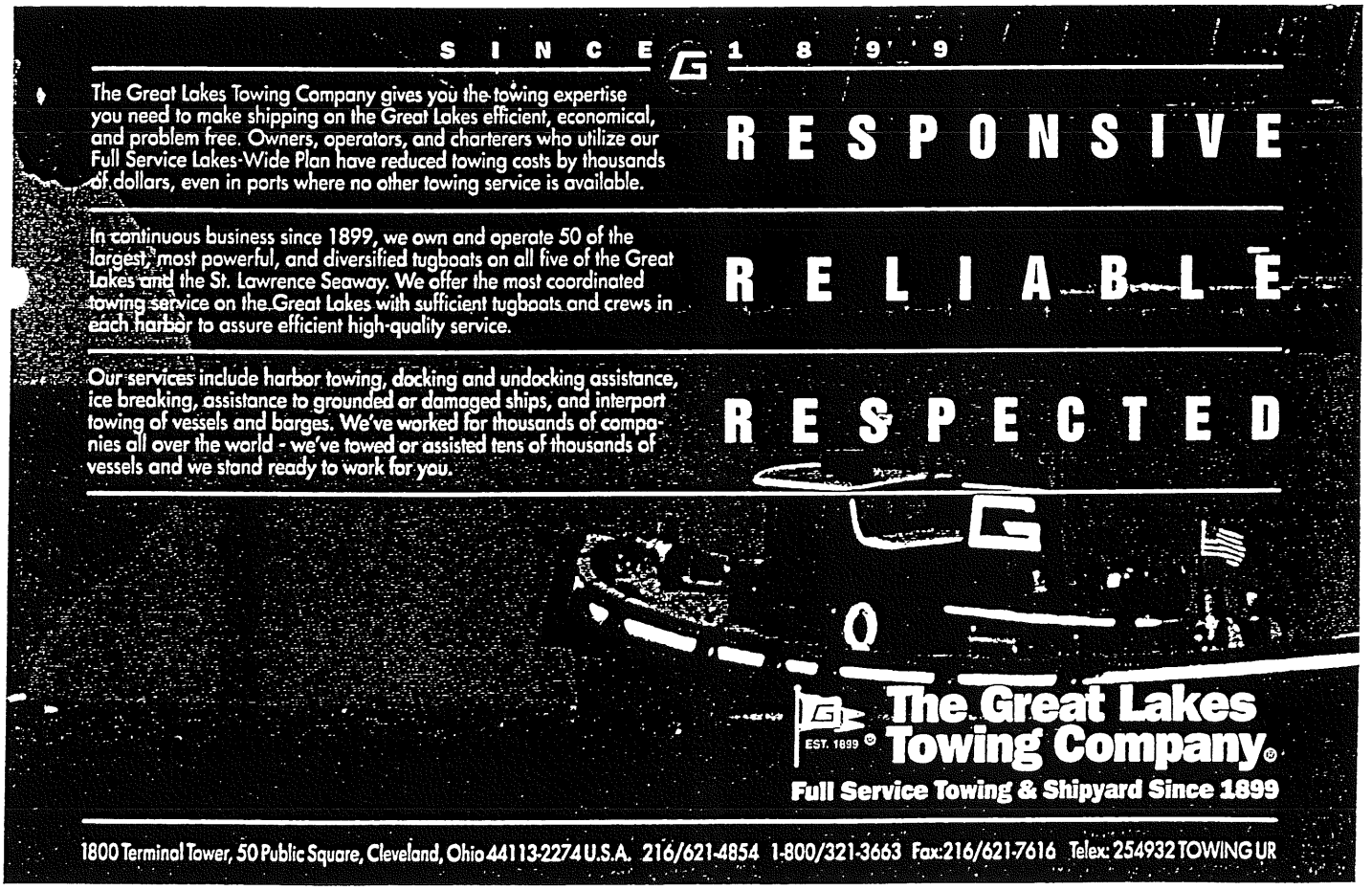
Institutions participating in the project include the U.S. and Canadian Coast Guards, U.S. Fish and Wildlife Service, U.S. EPA, NOAA, Canadian Shipping Federation, Great Lakes Fishery Commission, St. Lawrence Seaway Development Corporation, the Department of Naval Architecture and Marine Engineering and CILER at the University of Michigan, Ontario Hydro Technologies, Hyde Products Inc., Williams College-Mystic Seaport, and the Great Lakes Commission which is serving as the fiscal agent for the project.



Going over engineering drawings for the project are, from left to right, Allegra Cangelosi of the Northeast Midwest Institute, LCA's Rick Harkins, Eric Reeves, USCG, Grad Petrich of Hyde Products, LCDR Chae Giacomo, USCG and Prof. Mike Parsons, University of Michigan.

> It is also understood that no one technology will serve the needs of all the types of vessels and voyages employed in the maritime trades.

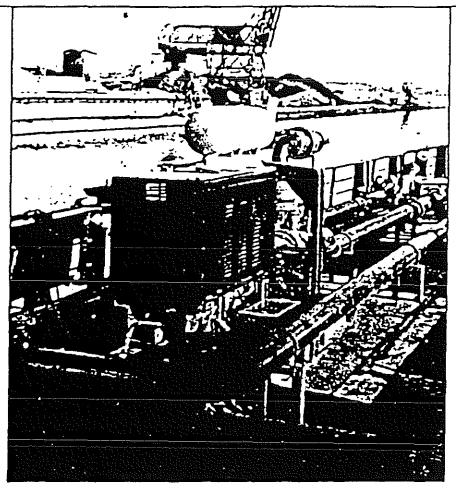
This project focuses initially on one technology: filtration. Filtration is considered a primary treatment method and is not necessarily meant as a stand-alone system. To address pathogens, for instance, it would have to be coupled with another technology. But in a recent study by the U.S. National Research Council's Marine Board, filtration was identified as one of the top three "most



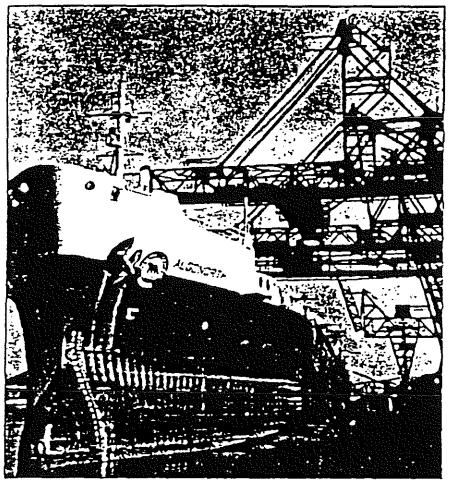
promising" technologies for ballast water treatment.

Filtration offers several advantages:

- It would enhance a number of secondary treatment options such as ultraviolet light, chemicals and heat.
- It is a prevention measure and as such is carried out at the port where ballast is taken on, with backwash returned to the port before the vessel departs.
- It addresses problems associated with NOBOB vessels preventing the uptake of sediments and organisms that become the residuals in ballast tanks.
- It addresses safety concerns associated with ballast exchange since the system would be run at the port of call, not the high seas.
- It addresses effectiveness issues associated with coastwise trade and incomplete purges.
- It addresses accountability problems of ballast exchange.

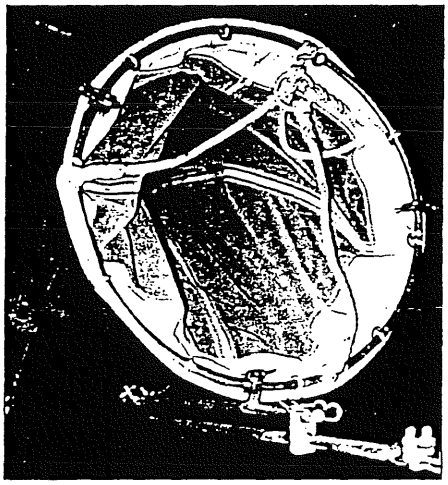


A close-up view of the diesel pump and piping.



Algonorth *unloads iron ore mined in Labrador at Inland Steel in Indiana Harbor.*

> It is also understood that no one technology will serve the needs of all the types of vessels and voyages employed in the maritime trades.



A plankton net on a trolly system is used to retrieve samples from the #3 upper wing ballast tank.

Algonorth perfect for experiment. The platform for the Great Lakes project—*Algonorth*—is ideally suited for a ballast water experiment as its working routine takes it through many marine environments, hauling grain from Lake Superior out to salt water in the Gulf of St. Lawrence, iron ore back into the southern Lakes, and in ballast back to the northern Lakes to start the cycle again.

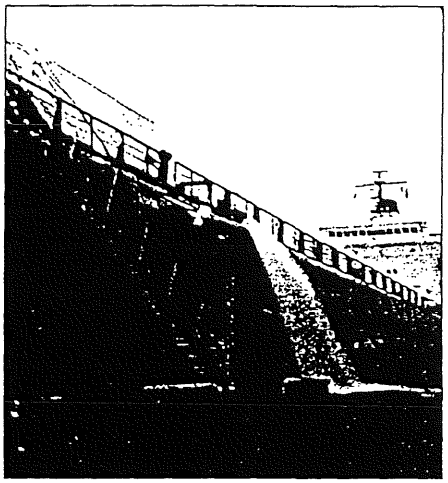
Algonorth's design is also conducive. The filtration unit will treat ballast water held in its No. 3 upper wing tank which has a capacity of about 60,000 gallons, can be segregated from other ballast compartments and can be accessed through manholes on the deck.

The deck-mounted filtration unit incorporates multi-level filtering technology designed by Ontario Hydro and is serviced by a diesel-powered feed pump with a 1,500 gallon-per-minute capability.

The project involves both biological and mechanical testing protocols. Biological tests will sample for zooplankton, phytoplankton, bacteria and water chemistry. The mechanical protocols will measure such factors as the filters' efficiency over time and frequency of backwash required. Both types of tests will be conducted in both fresh and salt water environments, in each of the three seasons of the year the vessel operates and using up to five different filtration levels.

While this project will tell us much about the potential effectiveness and practicality of filtration as a ballast water treatment option, it is not meant to be an ultimatum on the subject.

Neither is it a prototype test. The equipment placed temporarily aboard *Algonorth* is not an attempt to design and install a system as it might be installed in a vessel under normal operating circumstances. Because of the unique engineering aspects of the apparatus (it had to be removable, invisible with respect to the ship's operations, independent of the ship's systems, and pose no safety hazards), there is no way to derive real cost information from this experiment.



The diesel pump, which has the capacity to pump 1,500 gallons per minute, is tested at Indiana Harbor.

Although it will be several months before preliminary testing results are available, this project has already yielded benefits. Its use of a working Great Lakes vessel has increased the awareness and acceptance level of industry for ballast technologies.

Now, hopefully the solid data to be produced aboard *Algonorth* will contribute to a set of technological tools that can be used to better control the introduction of invasive species in the Great Lakes and elsewhere. Allegra Cangelosi ■

Allegra Cangelosi is a senior policy analyst for the Northeast Midwest Institute and project head for the Great Lakes Ballast Technology Demonstration Project

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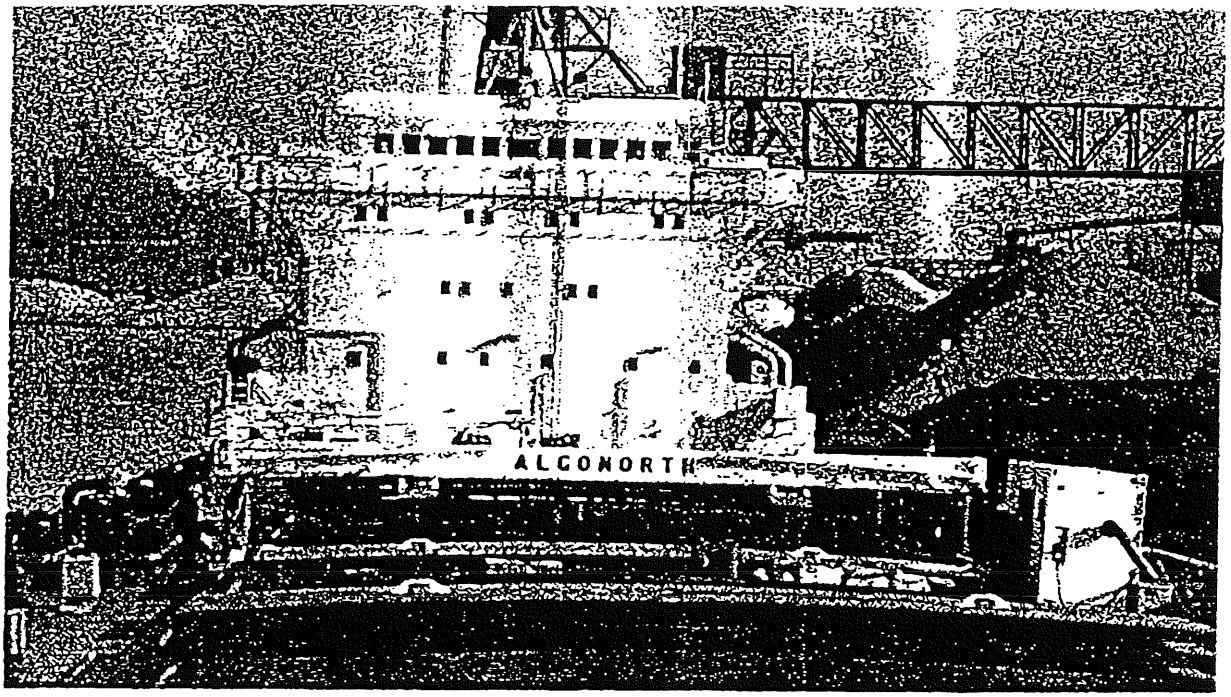
Advance copy of paper to be presented at the Annual Meeting, October 16-18, 1997, Westin Hotel and Ottawa Conference Centre, Ottawa

Design of the Great Lakes Ballast Technology Demonstration Project

Michael G. Parsons, Fellow, University of Michigan, Ann Arbor, Michigan
Allegra Cangelosi, Visitor, Northeast-Midwest Institute, Washington, DC
Richard W. Harkins, Member, Lake Carriers' Association, Cleveland, Ohio
Thomas P. Mackey, Life Member, Hyde Products, Inc., Cleveland, Ohio
David J. Munro, Member, Algoma Central Marine, St. Catharines, Ontario



ABSTRACT

The introduction of nonindigenous aquatic species into the Great Lakes is briefly reviewed. An estimate of the introduction and distribution of ballast water in the Great Lakes by overseas vessels during the 1995 shipping season follows. Recent studies of potential management practices and technologies for nonindigenous aquatic species introduction prevention are also briefly reviewed. With this background, the design of the ballast water filtration demonstration system and its installation onboard the St. Lawrence Seaway-sized bulk carrier M/V Algonorth *is then described. This modularized, temporary system uses two automatic backwashing filters in series to filter the ballast water prior to its introduction into a 200 m^3 upper wing ballast tank prepared to serve as the filtration test tank. The filtered ballast water in the test tank will be compared to that in an identical upper wing non-filtration control tank. This system was fabricated and installed in the final two months of 1996 without taking the vessel out of normal service. Following initial testing during late 1996, the system was completed during the winter layup period. It is being utilized for the Phase II test program during the 1997 shipping season.*

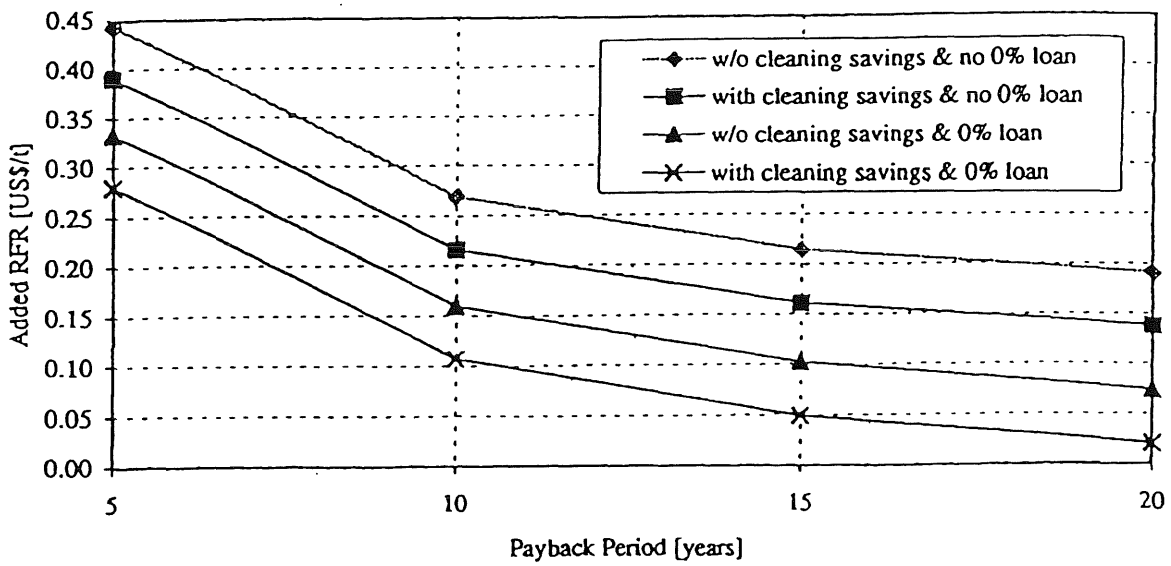


Figure 6. Added Required Freight Rate Required by Ballast Filtration

the added Required Freight Rate for a 20 year payback period representative of new construction is estimated to be only $0.02/t. This represents a 0.2% increase in the average Required Freight Rate for a new vessel built for *M/V Algonorth*'s Seaway trade.

CONCLUSIONS

The Great Lakes Ballast Technology Demonstration Project Phase I team developed the ballast filtration installation design which was installed onboard the *M/V Algonorth* for evaluation and testing during the 1997 shipping season. It was manufactured and installed on the *M/V Algonorth* during the final two months of 1996. The filter module, filter supply/tank discharge pump, and the prefabricated ballast tank manhole extension trunks were landed on the vessel during a transit of the Welland Canal on November 30, 1996. Shakedown operation of the initial configuration was completed in Indiana Harbor on December 13, 1996. The installation was completed during the winter layup period in Thunder Bay, ONT. The installation will be utilized for biological and mechanical effectiveness testing during the 1997 shipping season. The manufacture, installation, and demonstration testing was funded by the Great Lakes Protection Fund as Phase II of the overall project. With shipowner concurrence, the installation will be available for further ballast technology investigations.

REFERENCES

AUSTRALIAN QUARANTINE INSPECTION SERVICE (AQIS) (1993a). *Ballast Water Treatment for the Removal of Marine Organisms*, Report No. 1, June, 1993.

AUSTRALIAN QUARANTINE INSPECTION SERVICE (AQIS) (1993b). *Shipping Ballast Water Trials on the Bulk Carrier M. V. "Iron Whyalla."* Report No. 2, September, 1993.

BOYLSTON, J. W. (1996) "Ballast Water Management for the Control of Nonindigenous Species," *Trans.* SNAME, 104: 17-1 - 17-25.

CANGELOSI, A., and R. W. HARKINS (1996) Individual Demonstration Budget #1 for the Ballast Technology Demonstration Project: "The Effectiveness of Filtration at Minimizing the Uptake and Transfer of Viable Organisms in Ballast Water of a Comunercial Vessel," October 18, 1996.

CANGELOSI, A., and D. REID (1997) "Biological Operations Manual: Great Lakes Ballast Technology Demonstration Project - Vessel Algonorth Filter Effectiveness Study." April 7, 1997.

CARLTON, J. T., D. M. REID, and H. VAN LEEUVEN (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 the Analysis of Control Options*,

Washington, DC: U. S. Coast Guard Report No. CG-D-11-9.

FARLEY, R. B. (1996) *Analysis of Overseas Vessel Transits into the Great Lakes and Resultant Distribution of Ballast Water*, Ann Arbor, MI: University of Michigan, Department of Naval Architecture and Marine Engineering, Report No. 331, October, 1996.

LAKE CARRIERS' ASSOCIATION (1996) *1995 Annual Report of Lakes Carriers' Association*, Cleveland, OH: Lake Carriers' Association.

MILLS, E. L., J. H. LEACH, J. T. CARLTON and C. L. SECOR (1993) "Exotic Species in the Great Lakes: a History of Biotic Crises and Anthropogenic Introductions," *Journal of Great Lakes Research*, 19: 1-54.

NATIONAL RESEARCH COUNCIL COMMITTEE ON SHIPS' BALLAST OPERATIONS (NRC) (1996) *Stemming the Tide: Controlling Introductions of Nonindigenous Species by Ships' Ballast Water*, Washington, D.C.: National Academy Press.

PARSONS, M. G., R. MOLL, T. P. MACKEY, and R. B. FARLEY (1997) Great Lakes Ballast Demonstration Project - Phase I Final Report, Ann Arbor, MI: Cooperative Institute for Limnology and Ecosystem Research (CILER), May, 1997.

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*, prepared for the Canadian Coast Guard, March 31, 1992.

RIGBY, G., and A. TAYLOR (1993) "Shipping Ballast Water - Heating as a Means of Destroying Potentially Harmful Marine Organisms," Melborne, Australia: BHP Research Note BHPR/ENV/TN/93/005, June, 1993.

SUSSMAN, G. (1978) *The St. Lawrence Seaway*, Montreal, Quebec: C. D. Howe Research Institute (Canada); Washington, D.C.: National Planning Association (U.S.A.).

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Chris Goddard, Executive Secretary
Great Lakes Fishery Commission

Steven Hall, Executive Director
Association of California Water Agencies

Rick Harkins (Committee Co-chair)
Vice President for Operations
Lake Carriers' Association

Paul Horvatin, Senior Science Advisor
Great Lakes National Program Office
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The Shipping Federation of Canada

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St. Lawrence Seaway Development Corp.

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Great Lakes Ballast Technology Demonstration Project
Individual Demonstration Budget #2
"Pathogens in Ballast Water and Treatment by Filtration"
June 9, 1997

Introduction:

To be effective, ballast water treatment must address all organisms which threaten the physical, chemical and biological integrity of receiving natural systems, such as the Great Lakes. It also must protect the public health. Harmful organisms may range in size from adult fish to microscopic bacteria, and even viruses. Ballast water is a known vector for human cholera to Mobile Bay (McCarthy and Khambaty 1994), and Vibrio sp. in the Chesapeake Bay (Ruiz, 1997). It is a suspected vector for transfers of fish and shellfish pathogens (Mills et al. 1993). Cursory research conducted by Transport Canada found indications of several pathogens, and ambiguous findings related to human cholera (Aquatic Sciences Inc. 1996).

Filtration, currently under investigation through the Great Lakes Ballast Technology Demonstration Project, may or may not be adequate as a stand-alone ballast treatment method, depending upon its effectiveness against these pathogenic organisms. Little is known regarding a) the types of harmful microorganisms transported by ballast water into the Great Lakes, and b) whether filtration could be effective at reducing the numbers of microorganisms which enter a ship's ballast system. Without answers to these questions, the need for secondary treatment, and the type of secondary which may be needed, cannot be adequately gauged.

The Great Lakes Ballast Technology Demonstration Project proposal to the Great lakes Protection Fund committed the project team to study microbial communities, but did not describe the method in detail pending further investigation. This proposal contains a strategy for addressing the lines of inquiry outlined above. Specifically, it describes a short-term project which would:

1. Survey transoceanic vessels for pathogenic organisms in their ballast water and sediments; and

2. Test the effectiveness of filtration at removing non-pathogenic surrogates from ballast water.

To the greatest extent possible, this project will be carried out in cooperation and collaboration with other similar projects targeting other regions of the country. These project include investigations by the Smithsonian Environmental Research Laboratory targeting the Chesapeake Bay and Prince William Sound. It will also be carried out in cooperation with the Centers of Disease Control in Atlanta, the United States Coast Guard, and Transport Canada. The Steering Committee of the Great Lakes Ballast Technology Demonstration Projectwill oversee this portion of the project, as well as portions already underway.

Project Plan:

Objective 1: Survey of Transoceanic Vessels for Pathogenic Organisms in Ballast Water.

The survey of transoceanic vessels for pathogenic organisms will involve two steps. Step 1 will be the refinement of sample collection and analysis techniques. Step 2 will be the collection and analysis of samples of ballast water and sediment from vessels entering the Great Lakes in a loaded condition (NOBOB), and vessels in ballast that enter a harbor in which there is not yet a ballast exchange requirement (e.g. Chesapeake Bay).

Gaining a representative ballast water sample is a major challenge given the size, structure, and complexity of ballast tanks and the difficulty of obtaining physical access to the tanks. In addition, the foreign registry of most of these vessels, and the United States/Canada border can raise legal and logistical problems in boarding vessels. In close cooperation with the Great Lakes Ballast Technology Demonstration Project, sample collection methods will be "ground-truthed" using the ALGONORTH in the first step of the survey. Samples will be collected from a variety of access points, such as the ship sounding tubes, upper ballast tanks and lower ballast tanks, and compared for results. These samples will be analyzed for endemic Great Lakes microbial organisms, such as non-pathogenic species of Psuedomonas. A sample collection method which is logistically feasible and renders comprehensive findings will be selected for use in the ballast survey.

Effective laboratory analysis of ballast water samples also requires careful attention. A representative set of pathogenic microorganisms which survive in water will be targeted for analysis in the ballast water survey. These include Cryptosporidium, Salmonella, Shigella, pathogenic strains of E. coli, Vibrio cholerae (the causative agent of human cholera), Clostridium perfringens (a standard indicator of human sewage contamination in coastal waters), Enteroviruses, Rotaviruses, and Hepatitis A virus. These organisms represent a spectrum of protozoan parasites, bacterial pathogens, and viruses which pose a potential for impact on human health.

The focus of the laboratory analysis will be to use advanced molecular techniques for direct detection of these organisms. These techniques target molecules specific for each pathogen and have important advantages over traditional methods which rely on cultivating the organisms prior to identification (Knight et al. 1991). Because it will be difficult to employ sterile techniques necessary for conventional culture of the microorganisms while aboard a working vessel. molecular-based methods for direct detection offer a more accurate analytic approach. Furthermore, many of the above-named pathogens are difficult or impossible to culture because they are able to enter a dormant state and molecular methods offer the only reliable method of detecting these organisms.

Techniques which target the nucleic acids (DNA and RNA) of specific pathogens include the use of gene-specific nucleic acid probes (gene probes) and primer-specific amplification of nucleic acids by the polymerase chain reaction (PCR). Gene probes and/or PCR primers have been developed for specific detection of each of the proposed target organisms and many are in use in the laboratories of the proposed collaborating laboratories. Immunoassays, which use antibodies to target pathogen-specific proteins, will also be used for detection of Cryptosporidium cysts and Vibrio cholerae.

Although molecular techniques for direct detection of microorganisms are widely used in environmental samples (Bogert and Knight 1995, DeLong et al. 1989, Morè et al. 1994, Saylor and Layton 1990), they have been rarely employed on ballast water and sediments. It will be necessary, therefore, to do some testing of these techniques prior to deployment in a survey context. In addition to making an

effective survey of ballast-mediated pathogens into the Great Lakes possible, refinement of these methods, both in field and in laboratory, will be a major contribution to ballast management efforts worldwide.

The second step in the survey will be to board a selection of transoceanic vessels entering the Great Lakes and collect the samples, and send them out for laboratory analysis. The primary target of the survey will be vessels reporting NOBOB, or "no ballast on board" (i.e. vessels fully loaded with cargo). Vessels which enter the lakes in ballast will have undertaken high-seas ballast exchange by law, reducing the probability that these vessels are carrying significant quantities of foreign organisms. NOBOB vessels, on the other hand, cannot undertake ballast exchange in the high seas, and the sediments in the ballast tanks are regarded as a continuing vector of exotic organisms of all kinds. To gain a sense for what mircororganisms might be in the water column of a ballasted vessel, samples will be collected from ships entering the Chesapeake Bay where ballast exchange is not yet a requirement.

The survey will target a selection of vessels over a set period of time this shipping season. Access to the vessels will be arranged through the U.S. and Canadian Coast Guards. Samples will be collected and analyzed based upon the procedures defined in the first step described above. In order to determine if the populations of target organisms in the transoceanic vessels differ from those found in the ballast sediment of domestic vessels, parallel analyses of sediment samples collected from the ballast of vessels which do not leave the Great Lakes region will also be analyzed. Samples will also be collected from bays and harbors in the region to help establish background levels of these organisms in the environment.

Objective 2: Test the Effectiveness of Filtration at Removing Non-pathogenic Surrogates from Ballast Water

In this experiment the efficacy of filtration for removal of microorganisms from ballast water will be tested using the ALGONORTH experimental platform. To approaches may be employed. The most desirable would be to test before and after levels of endemic, nonpathogenic organisms in the water column. If these do not exist in adequate quanitites, stock levels of these organisms would have to be injected into the system inlet in known quantities. To assure ship, crew and environmental safety, only non-pathogenic surrogate microorganisms will be utilized to evaluate the filter. Using the ALGONORTH experimental platform, these non-pathogenic microorganisms will be introduced into the filter stream in the sea-to-sea and/or matched tank experimental formats. Filter mesh sizes in the range of 40 to 250 micrometers will be tested for microorganisms filtration efficiency. Molecular detection methods similar to those described under Objective 1 will be used to enumerate nonpathogenic surrogate microorganisms in pre- and post-filtered water.

Although the mesh sizes which are practical for filtration of large amounts of water are larger than the size of bacteria and viruses, many water-borne microorganisms, including most bacterial pathogens, are found associated with much larger organisms, such as copepods, or attached to particles and sediment. It expected that such large-pore filters will retain pathogenic microorganisms attached to particles and larger organisms but this has not been tested in a ballast water filtration system. Data from this set of experiments will be important in decisions regarding the need for possible post-filtration treatment of pathogen-contaminated ballast water.

It is important to note that the safety of the crew and vessel, and environmental protection, will be the highest priority throughout this experiment, and that only organisms which pose virtually no human health or environmental risks will be employed as surrogates. Thus, no special handling or tank cleaning will be required of the crew for this experiment.

Project Outcome:

This project will provide information which is both of interest to the broader scientific community, and vital to industry and the resource management community. With respect to scientific concerns, ballast water and sediments have been tested for the presence of fecal indicator microorganisms and selected pathogens in the past, but a such comprehensive survey of water-borne pathogens has not yet been undertaken. For example, the study by Susan McCarthy at the FDA, which reported in 1994 that Vibrio cholerae was being transported in ballast of vessels coming from South America, was targeted to the question of whether or not shipping from South American ports could serve as a potential vector for spread of the Peruvian cholera epidemic. Our proposed study asks a much broader question. Do transoceanic vessels carry the potential for transporting water-borne pathogens in general? Our plan to look at protozoan, bacterial and viral pathogens is more comprehensive than any published study and will enable us to determine whether the previous reports of pathogens in ballast water can be viewed as "special cases" or sporadic, "isolated incidents" or if they are just the tip of the iceberg, in terms of pathogenic potential of ballast water and sediment.

This study also will provide us with new information about appropriate methodology for sampling and analyzing ballast water and sediment. This is the most comprehensive application of molecular detection techniques for direct detection of pathogens in an environmental setting. On the methodology side, the study will inform both scientists and resource managers in several ways, particularly:

- *What is needed to get good, representative samples from ballast tanks.* This information undoubtedly will be of interest to those wishing to develop sound surveillance methodology in the future.

- *Which pathogens are most prevalent and which can be expected to occur sporadically.* This knowledge will also contribute to the design of future surveillance and treatment regimens.

- *The advantages and limitations of molecular detection techniques.* The study will differentiate which techniques work best in the ballast water/sediment environment. It also will inform the scientific community and resource managers of how well these techniques will be accepted as detection tools in the ballast water application.

On the policy side, this project will supply critical preliminary information in gauging the importance of treating ballast water for pathogenic organisms, and the potential of filtration to reduce risk. This information is critical to the design of effective ballast treatment. The project will screen ballast water entering the lakes for the presence or absence of a representative set of organisms of concern. Rough quantification, and comparison of concentrations of pathogenic organisms in foreign vessels to those of domestic vessels will help in distinguishing levels of concern. However, this information alone is not adequate to determine the extent of any public health risk which ballast water may impose. Eventually a more quantitative analysis and risk assessment will be required to make any linkage between the presence of organisms and their potential hazard to human health. That is, some of these organisms may already be present in the Great Lakes, or not present a public health risk in the context of the Great Lakes for other reasons. Other organisms may be completely foreign to our system or present in greater quantities than normally found in the Great Lakes. Further research on the likelihood of bioconcentration of these pathogens in the Great Lakes will be critical to risk assessment.

Dissemination Strategy:

The findings from this project will be disseminated in the form of scientific papers, and a report for lay consumption. Careful attention will be directed to the release of the information to assure that as constructive an outcome as possible will ensue from it. In particular, efforts will be made to match findings with policy proposals which are acceptable to industry and the environmental community. The papers and reports will be disseminated widely including to international policy fora such as the International Maritime Organization.

Project Team:

Allegra Cangelosi, Ecosystem Project Director for the Northeast-Midwest Institute, and Co-Principal Investigator of the Great Lakes Ballast Technology Demonstration Project, will oversee the project, particularly the refinement of the sample collection methodology, and filtration effectiveness tests. She also will assure compatibility and cooperation with the on-going filtration technology demonstrations aboard the ALGONORTH.

Richard Harkins, Vice President of the Lake Carriers' Association, and Co-Principal Investigator of the Great Lakes Ballast Technology Demonstration Project, will contribute engineering expertise to the filtration effectiveness experiment, and oversee industry-project relationships.

Ivor Knight, Professor of Biology, James Madison University, will be the project Principal Investigator. Dr. Knight will design the overall set of experiments, establish a network of molecular detection laboratories, including his own, for sample analysis, and arrange for personnel, as needed for sample collection and analysis.

Analytic Resources:

Several laboratories have expressed an interest in participating in a cooperative process of sample analysis. These laboratories and contact persons include The University of Maryland Center for Marine Biotechnology, Drs. Rita Colwell and Anwar Huq; Northwestern University, Drs. David Stahl, Barbara MacGregor and Gina Berardesco; The University of Arizona, Drs. Kelly Reynolds and Ian Pepper; The Seattle Biomedical Research Institute, Dr. Jerry Cangelosi; The University of North Carolina at Wilmington, Dr. Jonathan Geller.

Other Potential Collaborators:

Christopher Wiley, Transport Canada
Jim Carlton, Williams College - Mystic Seaport
Larry Green US Coast Guard
Greg Ruiz, Smithsonian Environmental Research Laboratory
Joy Wells, Centers for Disease Control

References:

Aquatic Sciences Inc. (August 1996) Examination of aquatic nuisance species introductions to the Great Lakes through commercial shipping ballast water and assessment of control options phase I & phase II. Ontario, Canada.

Bogert, A.P. and Knight, I.T. (1995) Detection of enterotoxigenic E. coli in ground water using DNA hybridization and PCR. American Society of Microbiology General Meeting, Washington, DC.

DeLong, E.F., Wickham, G.S., and Pace, N.R. 1989. Phylogenetic stains: Ribosomal RNA-based probes for the identification of single cells. Science 243, 1360-1363.

McCarthy, S.A., and F.M. Khambaty. 1994. International dissemination of epidemic Vibrio cholerae by cargo ship ballast and other nonpotable waters. Applied and Environmental Microbiology 60:2597-2601.

Mills, E.L., J.H. Lach, C.L. Secor, and J.T. Carlton. 1993. Exotic species in the Great Lakes: A history of biotic crises and anthropogenic introductions. Journal of Great Lakes Research 19:1-54.

Moré, M.I., Herrick, J.B., Silva, C., Ghiorse, W.C., and Madsen, E.L. 1994. Quantitative cell lysis of indigenous microorganisms and rapid extraction of microbial DNA from sediment. Applied Environmental Microbiology 60, 1572-1580.

Knight, I.T., Holben, W.E., Tiedje, J.M., and Colwell, R.R. 1991. Nucleic acid hybridization techniques for detection, identification and enumeration of microorganisms in the environment. in Microbial ecology: Principles, methods and application to environmental biotechnology, (eds. M. Levin, R.J. Seidler, and M. Rogul), McGraw-Hill, Inc., New York, pp. 65-91.

Ruiz, Gregory, 1997. Personal Communication.

Sayler, G.S., and A.C. Layton. 1990. Environmental application of nucleic acid hybridization. Annu. Rev. Microbiol. 44, 625-648.

Sample handling and processing in the field
(See appended "Sample Processing Procedures")

Collaborating Institutions:

UNCW - University of North Carolina at Wilmington, Dr. John Geller
UAZ - University of Arizona, Drs. Kelly Reynolds, Ian Pepper and Charles Gerba
UMD -University of Maryland, Drs. Anwar Huq and Rita Colwell
JMU - James Madison University, Dr. Ivor Knight

A. High Volume Samples

Samples will be filtered through a series of four sterile filters.

1) 200 uM plankton mesh
2) 64 uM plankton mesh
3) Spiral wound protozoan filter
4) Positively-charged viral filter

Plankton mesh retentates will be split for molecular analysis of plankton-associated *Vibro* species (UNCW) and direct immunofluorescent detection of plankton-associated *V. cholerae* and pathogenic *E. coli* (UMD). Initial preparation of these samples will be carried out in the field, stored, and then shipped to the collaborating labs.

Spiral wound protozoan filters will be stored at 4 C and shipped to UAZ for detection of *Cryptosporidium*.

Elution of viruses from the viral filter will be carried out in the field and frozen eluates shipped to UAZ for detection of Hepatitis A and members of the enterovirus group.

Viruses will also be eluted from residual sediment in the high-volume sample bottles and frozen eluates sent to UAZ for viral detection.

B. Low volume samples

One liter of each sample is packaged and shipped on ice for overnight delivery to each of two laboratories for live analysis of bacterial pathogens and indicator organisms. JMU will culture the samples for enumeration of *Clostridium perfringens*, fecal coliforms and fecal *Streptococci*. UMD will culture the samples for identification of pathogenic *E. coli, Vibrio cholerae, Helicobacter pylori* and *Campylobacter* spp.

Two one-liter volumes will be pumped through high-capacity 0.22 uM pore filters for extraction of total nucleic acids (DNA and RNA). A stabilizing buffer will be added to the filter in the field and then frozen for transport to JMU where DNA and RNA will be extracted and purified for detection of bacterial pathogens using DNA amplification by polymerase chain reaction and hybridization with pathogen-specific nucleic acid probes.

One liter will be pumped through a high-capacity 0.22 uM pore filter to concentrate bacteria for direct viable counting (DVC) technique. Initial preparation of the samples for DVC will be conducted in the field and fixed samples will be shipped to UMD for fluorescent antibody detection of *V. cholerae* and pathogenic *E. coli*.

Ten mL of each sample will be fixed with formaldehyde for determination of total bacteria using acridine orange direct counting (UMD).

Table 2. Ballast water sample analysis currently underway at collaborating laboratories.

I. Indicator Groups

Enumeration of Fecal Coliforms - Wiggins/Knight (JMU)
Enumeration of Fecal Streptococci - Wiggins/Knight (JMU)

II. Bacteria

A. Culture

Clostridium perfringens - Knight (JMU)
Vibrio cholerae - Huq/Colwell (COMB)
E. coli O157:H7 - Huq/Colwell (COMB)
Salmonella typhi - Huq/Colwell (COMB)
Helicobacter pylori - Huq/Colwell (COMB)
Campylobacter spp Huq/Colwell (COMB)

B. Direct Microscopy (Huq/Colwell (COMB))

FA-DVC for *V. cholerae* and *E. coli* O157:H7 in both whole water and plankton samples
Total bacteria using AODC
Total viable bacteria using DVC and ATP measurements

C. Nucleic Acid detection using PCR and probes (Knight - JMU)

Vibrio cholerae
Enterotoxigenic *E. coli*
Salmonella spp.

III. Protozoan and viral pathogens (Reynolds/Pepper/Gerba - U.Arizona)

Cryptosporidium
Hepatitis A
Enteroviruses

IV. Plankton-Association (Geller- UNC Wilmington)

Vibrio spp
Shigella spp

ANNEX 7

RECOMMENDATIONS

There was very strong and unanimous consensus by the Study Group that one more meeting, at a minimum, would be of extraordinary value. The participants felt that significant new levels of cooperation, understanding, and intercalibration of research had been achieved both among ICES Member Countries and on a global level (further noting that a great deal of the ballast water arriving in ICES Member Countries originates outside the ICES arena).

It was thus recommended that the ICES/IMO/IOC SGBWS convene again at the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) in Conwy, Wales, from 12–13 April 1999 to:

a) continue its global assessment and review of the status of ballast water biological and ecological research, through the participation of representatives from ICES Member Countries and of invited scientists from all major ballast water research groups in the world;

b) continue its evaluation of the development of ballast water control technologies;

c) continue its review of the relationship between ballast water movement and the invasion of exotic marine organisms, including updates on the latest ballast-mediated invasions globally, particularly relative to those species that are now invasive in other regions of the world and that are ballast-transportable—but have not yet arrived—in ICES Member Countries.