REPORT OF THE
ICES/IOC/IMO STUDY GROUP ON BALLAST WATER
AND SEDIMENTS

La Tremblade, France
21 April 1997

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International Council for the Exploration of the Sea
Conseil International pour l’Exploration de la Mer

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SUMMARY

The first meeting of the ICES/IOC/IMO Study Group on Ballast Water and Sediments (SGBWS) met in La Tremblade, France, 21 April 1997, with representatives from Australia, Canada, France, Germany, Ireland, Norway, Sweden, the United Kingdom, and the United States of America. It was concluded at this first meeting that the Study Group provided a unique opportunity to exchange detailed information about research programs, different sampling methods and approaches, similar challenges faced by each research group and means to address these challenges, and to consider focuses for new research directions.

International Coordination and Cooperation

* The Concerted Action Plan: Testing Monitoring Systems for Risk Assessment of Harmful Introductions by Ships to European Waters, funded through the EU, is going forward with Dr H. Rosenthal as Project Coordinator and Dr S. Gollasch as Project Assistant. The project includes participants from Ireland, Lithuania, Finland, Sweden, and the UK.

* Critically important is the coordination and calibration of sampling techniques. In particular, standardization of data sheets, specific sampling techniques (nets, pumps, traps, and other devices), sample analysis methods, and identification procedures were discussed. Australia’s Center for Research on Introduced Marine Pests (CRIMP) is conducting a world-wide survey of ballast sampling methods with a goal of internationally comparative data bases. Relative to increased levels of international cooperation, a prospectus was tabled by the USA for a project entitled INFORMIR (International Network for Marine Invasion Research).

* All research groups noted the extensive taxonomic challenges in analyzing ballast plankton samples, in terms of obtaining identifications of holoplankton (such as copepods) from foreign waters and the even greater difficulties of identifying meroplankton (the larvae of marine invertebrates and fish). The inability to identify the latter, in particular, offered another suite of challenges for risk assessment.

Predicting Invasions and Invasion Success

* Relative to predictive invasion ecology and biology, research programs are addressing the volume of water coming in as potentially related to number of successful invasions, ballast water source regions as potentially related to the diversity and/or number of invasions; survival potential during the transport phase, and post-transport colonization potential (with emphasis placed upon examining the ‘environmental match’ between donor and recipient environments).

Management and Control

* Extensive research is being conducted on the effectiveness of open-ocean exchange of ballast water, which is the ‘number 1’ stop-gap ballast management tool now in global use. Ballast exchange involves deballasting on the high seas and then reballasting with oceanic water (and thus oceanic plankton). IMO issued resolution A774(18) in 1993, calling for open-ocean ballast exchange when safe and practical. This resolution will be revised in fall 1997 with a new section on ship safety and ship stability added. In addition, IMO is planning a new world-wide questionnaire on the current use and practice of ballast exchange.

* Studies on effectiveness of at-sea exchange are focusing on the extent to which both water and sediment may be released during the exchange process; the use of ballast exchange within coastal areas compared to high seas exchange, and understanding exactly what individual vessels are able to accomplish in the exchange process. Studies are also underway on how ballast exchange can be monitored and the costs of monitoring.

* A variety of experimental approaches are being pursued in order to supplement and/or replace open ocean ballast exchange. In particular, sea trials are underway on thermal (heat) treatment in Australia and on microfiltration in the United States.

* Research is proceeding on risk assessments and decision systems relative to ballast management. It was noted that it was critical to include economic models in such assessments. It was further noted that more rapid advances may
be made when the policy-setting and decision-making bodies include joint representation from the shipping industry, from government, and from science.

Other Ship-Associated Vectors

* Other ship-associated vectors play roles in the transport of non-indigenous species. Hull fouling studies are now underway in Australia, Germany, Ireland, and the United States.

* There may be difficulty in distinguishing between the different ship-associated dispersal vectors. This leads to the resulting challenge of which species, and how many, to attribute to ballast water, ships' hull fouling, ships' sea chests, etc. In addition, the same species may be transported by more than one vector—such as both in hull fouling and in ballast water. Risk assessment studies are made the more difficult and complex by not understanding or knowing which vector may be at play or be at risk of bringing in particular species or suites of species.

Recommendations

* The ICES/IOC/IMO Study Group on Ballast Water and Sediments (SGBWS) should meet for a second year, from 30–31 March 1998 in The Hague, The Netherlands, to continue its work on international intercalibration of ballast water and sediment sampling methods, to discuss cooperative research programs and data bases and to discuss the results of on-going research on new ballast management technologies. The SGBWS should also continue to address other ship-mediated vectors in addition to ballast systems.

* The ICES/IOC/IMO Study Group on Ballast Water and Sediments (SGBWS) should stay in communication with and work as closely as possible with the ICES Working Group on Harmful Algal Bloom Dynamics (WGHABD), given the potential importance of ballast water transport in the introduction of phytoplanktonic organisms that can cause toxic and harmful algal blooms.
1 TERMS OF REFERENCE

The first meeting of the ICES/IOC/IMO Study Group on Ballast Water and Sediments (SGBWS) was held in La Tremblade, France, on 21 April 1997, with 19 representatives and additional observers from Australia, Canada, France, Germany, Ireland, Norway, Sweden, the United Kingdom, and the United States of America (see Annex 1 for a complete listing of meeting participants). Co-chairing the meeting were Dr J.T. Carlton (USA) representing ICES, Dr M. Nauke representing IMO, and Dr T. Wyatt representing the IOC/IPHAB. Dr C. Bolch (Australia) also attended and participated in the meeting through IOC support. The Agenda was considered and approved with modifications (Annex 2).

The SGBWS was established by ICES Council Resolution in 1996 (ICES C.Res.1996/3:10) and was given the terms of reference for 1997, to:

a) consider the scientific, sampling, management, and international cooperative issues relevant to ballast water and sediments;

b) summarize information on the dissemination of particular groups of organisms by ballast (human health pathogens, phytoplankton, and other plants and animals);

c) review options for the control of the dissemination of organisms by ballast;

d) evaluate the role of ballast inoculations in the subsequent establishment of invasive species;

e) develop an inventory of databases on, e.g., organisms and invasions, as well as hot spots, relevant to ballast water issues;

f) assess the contributory role of other ship-associated vectors (e.g., hull fouling).

2 CONCERNS AND GOALS OF COOPERATING ORGANIZATIONS AND OTHER INTERESTED PARTIES

The interests of the International Council for the Exploration of the Sea (ICES), the Intergovernmental Oceanographic Commission (IOC), and the International Maritime Organisation (IMO) in ballast water issues specifically, and in introduced (invasive) species in general, were presented and reviewed. These interests and concerns are reflected in the discussions and conclusions provided below. In addition, a representative from the International Chamber of Shipping (ICS) was given the opportunity to present some of the interests in these issues from the point of view of the shipping industry (see Section 3.3.2).

Relative to overall IOC/IPHAB interests, two presentations were made by Dr C. Bolch and Dr T. Wyatt (Annex 3) on the issue of the relationship between the appearance of novel harmful phytoplankton blooms (toxic phytoplankton blooms) and the potential for the transport in ballast water and ballast sediments of the organisms (dinoflagellates and diatoms) that can cause such blooms.

3 CONCLUSIONS AND FINDINGS

The conclusions and major findings of the Study Group meeting are summarized below and refer to the terms of reference (TORs) set by the ICES Council. The use and role of risk assessment are addressed throughout.

3.1 Science of Ballast Water, International Coordination and Databases (TORs ‘a’, ‘b’ and ‘e’)

3.1.1 Overall scientific challenges

Two general categories of scientific matters were touched on during the day’s discussions:

*Recognition of Introduced, Native, and Cryptogenic Species

It was recognized that there is often difficulty in always reliably recognizing which species are introduced. This may lead to the conclusion that many species whose history is poorly known or which are taxonomically difficult must be recognized as cryptogenic—that is, species that are not clearly native or introduced. For example, a great many species of phytoplankton may fall in this category.
Distinguishing Among Dispersal Mechanisms

There is often a difficulty in reliably distinguishing between several different human-mediated dispersal vectors which may have served to bring a non-native species to a new region. This leads to the resulting challenge of determining which species, and how many, to attribute to various mechanisms, such as ballast water, ships' hull fouling, ships' sea chests, and so forth (this leads to categorizing some species as cryptovehicle—that is, species for which the mechanism of dispersal is not known). In addition, the same species may be transported by more than one vector—such as in hull fouling and in ballast water. Derivative challenges are that risk assessment studies are made the more difficult and complex by not understanding or knowing which vector may be at play or be at risk for bringing in a particular species or suite(s) of species.

3.1.2 Sampling Challenges

Current research activities, ballast water research programs, and sampling methods in use in Australia, Canada, France, Germany, Ireland, Norway, Sweden, Scotland (UK), Wales (UK), and the United States were reviewed and presented in detail (Annex 4), permitting a great deal of discussion among research groups.

Highlights of these discussions include the following:

*International Questionnaire: Australia

Australia's Center for Research on Introduced Marine Pests (CRIMP) (Annex 4) is conducting a world-wide survey of ballast sampling methods. The goal of this questionnaire, and of efforts such as INFORMIR (below), are internationally comparative data bases achieved through similar sampling programs and regimes.

*Concerted Action Plan on Ballast Water: Europe

The concerted Action Plan: Testing Monitoring Systems for Risk Assessment of Harmful Introductions by Ships to European Waters, funded through the EU, will be going forward on an initial basis in 1997 and 1998 (Annex 5). The Project Coordinator is Dr H. Rosenthal (Germany) and the Project Assistant is Dr S. Gollasch (Germany). The project includes participants from Ireland, Lithuania, Finland, Sweden, and the UK. Lead invited experts contributing to the work are from Australia, Canada, Israel, Japan, and the USA.

*The Need for International Coordination and Cooperation and Taxonomic Challenges; The INFORMIR Proposal (USA)

There was general agreement that increased levels of international coordination and cooperation are extremely important, given the number of studies and programs now underway, and the probability that more studies will commence in 1997 and 1998.

In particular, there is much interest and support for intra- and inter-ship calibration studies involving a comparison of sampling techniques. In particular, standardization of data sheets, specific sampling techniques (nets, pumps, traps, and other devices), sample analysis methods, and identification procedures were discussed and encouraged. All research groups noted the extensive taxonomic (systematic) challenges that they face, in terms of obtaining professional identifications of holoplankton (such as copepods) from foreign waters, and the even greater difficulties of identifying meroplankton (the larvae of marine invertebrates and fish). The inability to identify the latter, in particular, offered another suite of challenges for risk assessment modelling.

Relative to increased levels of international cooperation, a prospectus was tabled by the USA for a project entitled INFORMIR or International Network for Marine Invasion Research (Annex 6; see also ICES 1997 WGITMO Report).

*Ballast Water Sampling Handbook (USA)

A ballast sampling methods handbook has been submitted to the United States Coast Guard (Carlton et al., 1997). This handbook is a generalized outline of methods rather than offering detailed, step-by-step processing 'recipes', and is designed to emphasize in particular special or unique approaches when sampling ballast systems. It is expected to be released in late 1997 or early 1998.
3.2 Inoculations and Invasions (TOR ‘d’)

There are many on-going studies to assess the biotic diversity of incoming ballast (Annex 4)—these studies range from broad approaches looking at many different taxonomic groups to specific studies targeting certain taxa. There are, however, only a few programs to date that include studies of viruses and bacteria (these are in Australia, Canada, and the United States). In concert with all of these studies is a great deal of interest in the possibility and reality of identifying so-called ‘hot spots’—regions from which high-profile exotic invasions could occur.

Relative to **predictive invasion ecology and biology**, different research programs address the following:

- The volume of water coming in as potentially related to number of successful invasions.
- Ballast water source as potentially related to the diversity and/or number of invasions.
- Survival potential during the transport phase.
- Post-transport colonization potential (emphasis is being placed upon examining the details of the ‘environmental match’ between donor and recipient environments).

It may be noted that for the purposes of risk assessment, the data arising from these ‘inoculations and invasions’-oriented research projects are invaluable, in terms of establishing the biotic diversity of the ballast water and sediments, in terms of recognizing critical donor regions, and in terms of identifying the variables that may lead to successful invasions.

3.3 Management and Control (TOR ‘c’)

Much of the Study Group’s time and focus were placed on considering the ‘state-of-the-art’ in ballast management and control. Of particular interest was recent legislation on ballast water, the new National Invasive Species Act of 1996 [NISA 1996] in the United States (see Annex 4) which provides a three year window-of-opportunity for vessels arriving in US ports to exchange their water on the high seas (given safety considerations). At the end of this period, the US Coast Guard will assess the level of compliance with this regulation, and if levels are found to be insufficient, ballast exchange will become mandatory.

3.3.1 Ballast management: initial pre-ballasting advice

It was noted that IMO has issued information and advice to mariners relative to paying greater attention to exactly *where* and *when* ballast water is taken up, in order to avoid areas known as primary infestations of nuisance species—such as avoiding harmful (toxic) phytoplankton blooms. The United States Coast Guard provides information brochures and videos to encourage ships’ personnel to be aware when ‘red-tide blooms’ (or similar phenomena) are occurring in harbor waters, and not to ballast, or to minimize ballasting operations under such conditions.

3.3.2 Ballast management: ballast exchange research

Much research is being conducted on the effectiveness of open-ocean exchange of ballast water, which is the ‘number 1’ stop-gap ballast management tool now in global use. Ballast exchange involves deballasting on the high seas (in waters with a depth greater than 2000 meters) and then rebballasting with oceanic water (and thus oceanic plankton). The result of this procedure is that neritic (coastal, estuarine) organisms die in the open ocean, and oceanic organisms in high seas ballast die when released in coastal waters, particularly estuaries. Ballast water exchange includes two different techniques: (1) a two-step process of deballasting followed by rebballasting, or (2) ‘pressing up’, that is, filling to the top a ballast tank or ballasted cargo hold and allowing the water to overflow onto the ship’s deck. All ballast systems can be operated using the first approach, but not all ballast systems can be operated using the second technique. Note that in this methodology and terminology, ‘re-ballasting’ is not viewed as being in contrast to high seas exchange, but rather is one method of exchange. It should also be noted that ballast water is held in two distinctly different systems within ships: in ballast tanks and in ballastable cargo holds.

IMO issued resolution A774(18) in 1993, calling for open-ocean ballast exchange when safe and practical. This resolution is due to be revised in fall 1997 with a new section on ship safety and ship stability to be added. In addition, IMO is planning a new world-wide questionnaire on the current use and practice of ballast exchange.

Mr A. Bilney of ICS noted that the shipping industry, while desiring to respond to the issues of ballast water transport of alien species, faces certain constraints and challenges relative to open ocean ballast exchange. These include the issues...
of ship and crew safety, the added costs of exchange (for example, using the ships' pumps twice as often and therefore potentially decreasing their life-time by half), the time element involved in the exchange process, and the impracticalities of having to stop and exchange water in coastal zones prior to coming into port, should the vessel have been unable to do so in the open ocean. A related concern is that because ships’ masters—who are anxious to make port on time—may be required or requested to exchange their water in a 'back-up' zone in a coastal region, potentially leading to a delay of many hours, masters may feel compelled to take certain risks in heavy weather to accomplish open ocean exchange.

Studies on effectiveness of at-sea exchange are focusing on the following arenas, and are variously underway in Australia, Canada, the UK, and the USA:

* The extent to which both water and sediment are released during the exchange process.

* The use of ballast exchange within coastal areas (intra-regional seas) compared to long-distance transoceanic and interoceanic voyages.

Studies on this question are underway in Scotland and the USA. K. Jansson (Sweden) noted that at the 1996 meeting of the IMPACT Working Group of the Oslo and Paris Commissions (OSPAR) the need to identify measures to control intra-regional dispersal of non-native species via shipping was identified.

* Understanding exactly what the individual vessel was able to accomplish in the exchange process. It was noted that ballast exchange is not a simple 'yes' or 'no' procedure, and yet is often treated as such in questionnaires and statistical breakdowns (as in, "70 % of the ships exchanged their water"). In reality, it is not only how many ships exchanged their water, but how much water a given ship was able to exchange. By simply scoring the percentage of ships exchanging, a vessel exchanging only 20 % of its water is scored on an equal basis with a vessel exchanging more than 90 % of its water.

* How can ballast exchange be monitored, what are the costs of monitoring, and what incentives can be used?

Dr. H. Gollamudi (USA) addressed these questions by presenting the results of her recent work (carried out in collaboration with Dr. A. Randall) at Ohio State University on protocols and policies to prevent invasions relative to economic paradigms. Dr. Gollamudi gave the following presentation:

Our current research focuses on theoretical foundations of an effective monitoring scheme for ballast water operations, followed by identifying the important (economic) components necessary for an efficient monitoring scheme, and the possible pitfalls that one should avoid while devising these schemes. The fundamental premise here is to achieve the goal in a cost-effective manner and with minimal disruption to all the concerned parties.

In response to the recent surge of nuisance species, Open Water Exchange (OWE) was set as a voluntary guideline in several ports around the world, and made mandatory for transoceanic ships entering the Great Lakes in the USA. Some of our recent work focuses on policies for preventing unintentional introduction via shipping, by employing economic incentives to devise cost-effective monitoring mechanisms with dual objectives: one, to ensure compliance with OWE in the short run, and two, to encourage ships to adopt and use a preferred ballast water 'cleansing' technology in the long run. A scheme under which monitoring pressure is focused on ships with poor records of previous compliance is developed which has two useful effects: monitoring resources are targeted more efficiently and ships have an incentive to maintain good compliance records. The strategy here is to divide all ships into groups with differential monitoring pressures. Further, certain key investment principles are incorporated into the model which act as incentives for ships to adopt permanent technologies. Operability of this model is tested using Great Lakes data which shows that the concerned authorities can save on monitoring costs by following the proposed model. More on the model is available in a report (An Efficient Mechanism for Monitoring Ships' Ballast Water Clean-up Operations by H. Gollamudi and A. Randall).

Care must be taken to avoid possible negative consequences of a poorly designed monitoring scheme because differential monitoring schemes between regions/countries can disrupt and send wrong signals to the shipping industry. Cautious development of monitoring schemes is needed to avoid excessive fleet specialization and losses to port economies.
3.3.3 Ballast management: other management approaches

Throughout the Study Group meeting and in the national reports, it was noted that a variety of experimental approaches are being pursued in order to supplement and/or replace open ocean ballast exchange. These include research on:

- thermal (heat) treatment in Australia (sea trials have been and are being conducted);
- ozone studies in Australia (a desk study by a Ph.D. student);
- chlorination studies in Australia and Canada (desk and trial applications);
- hydrogen peroxide studies in Australia;
- organic acids (chemical control) (a desk study in Canada);
- centrifugation combined with ultraviolet light (a desk study in Norway);
- filtration (sea trials underway in the United States).

A major research project commenced in April 1997 in the Great Lakes, headed by A. Cangelosi of the Northeast-Midwest Institute and R. Harkins of the Lake Carriers Association, and funded by the Great Lakes Protection Fund, to test the effectiveness of high speed (1500-2000 gallons per minute) microfiltration, using advanced technologies of self-cleaning, back-washing filters, on the removal of organisms and sediments from ballast water being pumped into a vessel (in this way, the resulting filter residue can be returned immediately back to the originating water, alleviating further disposal problems). The smaller mesh size scheduled to be tested initially is 40 \( \mu \text{m} \) (note that, relative to red-tide causing dinoflagellates, for example, the ellipsoid cysts of most \textit{Alexandrium} species are 35 to 40 microns long and the spherical cysts of \textit{Gymnodinium catenatum} are 40 to 60 microns long (G. Hallegaard, pers. comm., 1996)).

3.3.4 Risk assessment and decision systems

Several countries are engaged in detailed research on risk assessments and decision systems relative to ballast water uptake, exchange, and release (Annex 4). It was noted by Australia and the USA that it is very important to incorporate economic models in such assessments. It was further noted that more rapid advances in ballast management may be made when the policy-setting and decision-making bodies include joint representation from the shipping industry, from government, and from science.

3.4 Other Ship-Associated Vectors (TOR 'f')

As noted earlier, other ship-associated vectors can and do play roles in the transport of non-indigenous species (Table 3.4.1). In this regard, a point of particular interest is that the frequency and density of ship hull fouling may be increasing concomitant to the decreased use of certain antifouling paints such as TBT. Hull fouling studies are now underway in Australia, Germany, Ireland, and the USA (see the 1997 WGITMO Report for a presentation by Dr D. Minchin (Ireland) on ship's fouling).

It was noted that WGITMO is now working on a Directory of Vectors that will provide detailed descriptions of each vector along with examples of the types of species that could be or have been known to be transported.
Table 3.4.1. Global human-mediated dispersal mechanisms: vessels (ships, boats). (Modified from Carlton, 1994.)

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<thead>
<tr>
<th>VESSELS (Ships, Boats)</th>
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<tr>
<td><strong>On the outside of the vessel</strong></td>
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<tr>
<td>Fouling Organisms</td>
<td>Attached organisms; associated biota (including benthic species) in fouling community; planktonic and other organisms entrained and entangled in transit. Occur on the hull, rudder, propeller, and anchor, and on other submerged structures on any specialized vessel.</td>
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<tr>
<td>Boring Organisms</td>
<td>Wood borers and associated biota in tunnels and holes. Occur below waterline in wood structures: sheathing, keel, wormshoe, rudder.</td>
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<tr>
<td>Entrained Organisms</td>
<td>Organisms on logs and other floating materials entrained in vessel’s wake.</td>
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<tr>
<td><strong>On the inside of the vessel: accidentally transported</strong></td>
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<tr>
<td>Fouling Organisms</td>
<td>In/on sea chest, seawater pipe systems including intakes, anchor chains.</td>
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<tr>
<td>Planktonic Organisms</td>
<td>In water accidentally taken aboard (bilge water; chain locker water) and in water intentionally taken aboard (potable water, live well water, ballast water, propeller shaft cooling water, engine cooling water, fire control water, and waste (sewage) water).</td>
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<tr>
<td>Benthic Organisms</td>
<td>In sediments in tanks, holds, and chain lockers</td>
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<tr>
<td>Maritime, Marsh, Intertidal, and other Benthic Organisms</td>
<td>In solid ('dry') ballast (rocks, sand, debris, etc.) and in dunnage in holds</td>
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<td><strong>On the inside of the vessel: intentionally transported</strong></td>
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<tr>
<td>Fish and Shellfish</td>
<td>In live holding and bait wells</td>
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<tr>
<td><strong>Aboard the vessel</strong></td>
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<tr>
<td>Planktonic Organisms</td>
<td>In incidental water (in scuppers or other deck basins)</td>
</tr>
<tr>
<td>Benthic Organisms</td>
<td>In nets, traps, trawls, grabs; in scuppers or other deck basins</td>
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<tr>
<td>Fish and shellfish: living organisms for human consumption</td>
<td>In ship’s galley</td>
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<tr>
<td>Aquaria (pets), seashells, curiosities</td>
<td>In company or private possession</td>
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<td><strong>AQUACULTURE, OTHER FISHERIES, AND AQUARIUM INDUSTRIES</strong></td>
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<td>Experimental organisms</td>
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<td>Scientific equipment</td>
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1997 SGBWS Report
3.5 Overall Considerations Relative to the Study Group

The Study Group unanimously concluded that the meeting had provided a unique and welcomed opportunity to exchange detailed information about on-going research programs, different sampling methods and approaches, similar challenges faced by each research group and ways to address these challenges, and focuses for new research directions.

It was also strongly felt that, given the number of research programs now in progress or just commencing, it would be extremely valuable to meet again next year, but for two days, rather than one, in order to provide time for more detailed presentations and more interactive discussions.

Finally, there was a strong consensus that, given the potential importance of ballast water transport in the introduction of phytoplanktonic organisms that can cause toxic and harmful algal blooms, the SGBWS should stay in communication with and work as closely as possible with the ICES/IOC Working Group on Harmful Algal Bloom Dynamics (WGHABD).

3.6 Recommendations

The ICES/IOC/IMO Study Group on Ballast Water and Sediments (SGBWS) should meet for a second year, from 30-31 March 1998 in The Hague, The Netherlands, to continue its work on international intercalibration of ballast water and sediment sampling methods, to discuss cooperative research programs and data bases and to discuss the results of on-going research on new ballast management technologies. The SGBWS should also continue to address other ship-mediated vectors in addition to ballast systems.

The ICES/IOC/IMO Study Group on Ballast Water and Sediments (SGBWS) should stay in communication with and work as closely as possible with the ICES/IOC Working Group on Harmful Algal Bloom Dynamics (WGHABD), given the potential importance of ballast water transport in the introduction of phytoplanktonic organisms that can cause toxic and harmful algal blooms.

Reference

## ANNEX 1

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ANNEX 2

AGENDA

0900 Opening of the Study Group Meeting
  • Welcome to all
  • Welcome by IFREMER Officials
  • Appointment of Rapporteur(s)
  • Introduction of All Participants and Guests
  • Logistical Announcements (P. Goulletquer)
    (meals, telephone, FAX, photocopying, transportation, etc.)

0920 Review of Terms of Reference (above): Achieving the TORs
Review of the Agenda (below): changes, corrections, additions
Statements of Interests in Ballast Water and Goals of Cooperating
Organizations and Other Interested Parties:
  • IOC/IPHAB: Intergovernmental Panel on Harmful Algal Blooms)
    (T. Wyatt for IOC/IPHAB; C. Bolch for IOC)
  • IMO (M. Nauke)
  • ICES WGITMO (J. Carlton)
  • ICES/IOC WGHABD (Harmful Algal Bloom Dynamics) (E. Macdonald)
  • ICS (International Chamber of Shipping) (A. Bilney)

10:30 Coffee break (20 minutes)
10:50 Reports of Ballast Water Research, Studies, and Management
  Australia R. Thresher
  Canada M. Gilbert, M. Campbell
  France P. Goulletquer and others
  Germany S. Gollasch, N. Huelsmann [with B. Gallil, Israel]

11:55 Group Photo
12:00 Lunch
13:30 sharp Reconvene for the Afternoon Session
Reports of Ballast Research and Management (continued)
  Ireland D. Minchin
  Norway A. Jelmert
  Sweden K. Jansson and I. Wallentinus
  UK: England/Wales S. Utting, T. McCollin, J. Hamer
  UK: Scotland E. Macdonald

15:30 Coffee Break (20 minutes)
15:50 Reports of Ballast Research and Management (concluded)
  United States of America J. T. Carlton (and reports from G. Ruiz, 
    A. Cangelosi and R. Gaudiosi, in absentia)
16:10 Presentation: Population Dynamics of Range Extension, 
    Based on the Dinoflagellate Alexandrium (T. Wyatt)
16:25 Presentation: Protocols and Policies to Prevent Invasions: 
    Economic Paradigms (H. Gollamudi and A. Randall)
16:40 Discussion: The contributory role of other ship-associated vectors 
    (e.g., hull fouling, sea chests, etc.)
    Note agenda item WGITMO, 24 April, 1:30 PM: Directory of Vectors

17:00 Short Break
17:10 Discussion
  *Inventory of databases relevant to ballast water issues
  *International Network for Marine Invasion Research (INFORMIR)
    (see handout)
17:30 *Summary of Findings and Recommendations Relative to the TORs
  *Discussion of future joint meetings of the ICES/IOC/IMO Study Group on Ballast Water and Sediments
18:00* Concluding Remarks by ICES, IOC, and IMO Co-Chairs
18:15 Adjournment of SGBWS meeting for 1997

1997 SGBWS Report
ANNEX 3

STATEMENTS ON ISSUES RELATIVE TO HARMFUL ALGAL BLOOMS AND BALLAST WATER TRANSPORT

Ballast Water and Harmful Algal Blooms: Current Research and Future Directions

C.J.S. Bolch
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The potential of ballast water as a vector for dispersal of harmful or nuisance plankton species is not a new idea. This vector was first postulated as early as 1908 by Ostenfeld for the diatom *Odontella sinensis* which was unknown in European waters until 1903.

More recent concerns of ballast water transporting harmful algal bloom (HAB) species arose in the mid 1980s from research on Tasmanian blooms of the toxic dinoflagellate *G. catenatum*. This distinctive PSP producing dinoflagellate, which appeared unexpectedly in southeastern Tasmanian waters during the mid-1980s, had not been previously recorded in southeast-eastern Tasmania despite quite intensive monitoring programs during the 1940s. During the 1980s, this virtually unknown species was responsible for several PSP episodes world-wide—in Mexico, Spain and Portugal, Tasmania, and Japan—presenting a strangely disjunct global distribution and raising suspicions that it may represent a recent introduction. Examination of dated depth cores for the resistant resting stages (cysts) indicated an appearance in southeastern Tasmania during early 1970s, coincident with the start of the bulk woodchip trade from southeastern Tasmania (1971). Work by Hallegraeff and Bolch during 1989–1991 demonstrated the potential of ballast water as a vector for dinoflagellate cysts; viable toxic dinoflagellates cysts could be detected in up to 6% of vessels entering Australian ports, including those of *G. catenatum*.

As of today, the key processes and steps involved in the transport of planktonic dinoflagellates are relatively well understood. Uptake of cells or cysts appears to be primarily from the water column, with little or no mortality, either as resuspended cysts, or more likely as cysts or sexual stages (pre-cyst formation) being formed during the latter stages of blooms. This is supported by several lines of evidence. Firstly, a strong seasonal pattern can be seen in the presence of toxic species in vessels entering Australian waters, coinciding with known bloom periods in northern hemisphere ports. Secondly, samples with high concentrations of cysts are usually dominated by cysts of one species, not usually seen in the coastal and estuarine sediments. Most vegetative cells do not survive intercontinental voyages, however, once encysted survival during the voyage is high, particularly for species with mandatory cyst dormancy periods exceeding the voyage length (10–15 days). Deballasting appears to present little problem, although there is little data available to assess the proportion of material expelled during deballasting, especially the sediments where the cysts generally reside. For all introduced species, it is almost completely unknown what factors influence the establishment of viable reproductive populations, with the exception of broad ecological matching such as temperature and habitat. The potential for inoculation of genetically diverse, reproductively capable populations of dinoflagellates is high. As many as 300 million cysts have been estimated to be present in some ballast tanks, each presenting 4 genetically distinct progeny after germination. Even a small fraction could then present a genetically diverse and viable population. Despite this, successful establishment appears to present the most likely bottleneck for dinoflagellate introductions.

Considerable future research is required to understand and document ballast water transfer of HAB species. Of primary importance is improving the understanding of the taxonomic and global diversity of plankton populations. Are apparently globally distributed, cosmopolitan morphospecies really the same species worldwide? Do they form discreet genetic populations? Do endemic strains exist? The advent of molecular techniques in the field of HAB research is beginning to provide answers to such questions. So far, it seems that there is often a surprising level of genetic diversity underlying morphologically conservative forms. The frequency and likelihood of successful establishment of species in their receiving environments is unknown, although it is currently difficult to see how this could be approached. Little information is available regarding the presence of other HAB organisms in ballast sediment. Diatoms are common and can be readily recovered and cultured from ballast water sediments. It is conceivable that introductions of harmful diatoms such as *Pseudonitzschia* spp. (ASP poisoning) is also of concern, along with other groups with resistant stages such as raphidophytes (*Chathonella* spp., brevetoxins, ichthyotoxins).

Finally, continuing research to reduce the risk of ballast water introductions is critical. Some form of treating ballast water is an attractive proposition, however, chemical treatments are unlikely to be commercially viable due to the large volumes involved. Electric shock treatment, initially proposed by Montani and co-workers as a viable technique, has...
since been shown to kill dinoflagellates as a result of localized generation of free chlorine and heat (Hallegraeff et al. in press), therefore, it seems highly unlikely that this approach could be effective with large volumes of water. Heat treatment, first proposed and examined by Bolch and Hallegraeff, shows continuing promise as a treatment. Initial studies suggested temperatures of 40-45 °C for 30 seconds was sufficient. However, available ship-board heat sources are more amenable to gradual and lengthy periods of elevated temperature. Recent data using culture produced cysts of toxic dinoflagellates indicate that as little as 35-38 °C for 4-5 hours effectively kills cysts and vegetative cells of toxic and non-toxic dinoflagellates. These temperatures and treatment times are expected to be achievable during prolonged (40-50 hours?) flushing of tank contents with engine cooling water. Ship-board trials, using lab-produced cysts are currently underway to assess the efficacy of this method.

**Future Research**

*Understanding and documenting establishment of introduced HAB species*

- Strain and species specific probes (antibody or DNA probes)

*Potential transfer of other toxic and nuisance species*

- Toxic strains of *Pseudonitzschia* spp. (ASP)

*Are introduced HAB species really introduced?*

- Resolution of taxonomic issues
- Understanding global populations of algal species
- Are toxic and non-toxic strains different species?
- Endemic strains of apparently cosmopolitan morphospecies (e.g., Tasmanian *A. tamarense* is non-toxic and distinct from other strains)

*Risk reduction strategies*

- Bloom avoidance- Port information and bloom alert networks
- Expert Decision Systems for port operations
- Ballast water treatment—Heat?
Some Constraints on the Spread of the Dinoflagellate *Alexandrium* by Ballast Water

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International interest in harmful algae has grown steadily since the late 1960s in response to several major events. Amongst these were the appearance of major blooms of the dinoflagellate *Gyrodinium aureolum* in 1966 in European coastal waters, an outbreak of paralytic shellfish poisoning attributed to the dinoflagellate *Alexandrium tamarense* in 1968 on the northeast coast of England, the ‘spread’ of toxic *Alexandrium* into the western Gulf of Maine in 1972, and the discovery of the dinoflagellate *Gymnodinium catenatum* in northwest Spanish waters in 1976. Attempts to account for these kinds of events sometimes imply that a single inoculation is sufficient for an exotic species to establish itself in a new region. Also, the distinction between the normal dynamics of species ranges (the dynamics of colonization and extinction) and the kinds of spreading due to human agencies are not always clearly maintained. In contrast, experience gained from the study of introductions in terrestrial habitats suggests that successful colonization usually depends not only on the existence of suitable life-history stages, but also on propagule pressure.

The ‘tens rule’ says that 10% of invading species become established, and that of this fraction 10% (actually 5% to 20%) become pests. The rule is based on a wide variety of edible crops, pasture plants, angiosperms, pines, insects and birds. A higher ‘success’ rate, up to 30%, has been achieved by insects introduced intentionally for biological control purposes, and there is a positive relation between the numbers per release and the number of releases (propagule pressure) and the success rate.

Although there are no documented instances of the establishment of *Alexandrium* in new areas as a result of ballast water transport, it is an ideal candidate for such spread, since the life cycle includes a highly resistant (diploid) cyst stage which can survive for years, perhaps decades, in unfavourable conditions. A strong case has been made for the transport in ballast water of *Gymnodinium catenatum*, which also produces resistant cysts, from Japan to Tasmania.

But theoretical considerations suggest that propagule pressure is also required for such dinoflagellates to colonize new habitats by this means. These arguments revolve on the need for a minimum inoculation size which is required to initiate blooms of the vegetative (haploid) phase which, in turn, requires some minimum concentration of cysts in the sediments and a minimum bloom concentration for the occurrence of syngamy and reestablishment of the diploid phase; i.e., several thresholds must be crossed for establishment to take place in a new area, whether as a natural range expansion or as an introduction. These thresholds depend on both the biological characteristics of the species (intrinsic growth rates, loss rates due to grazing, etc.) and on the local hydrodynamics (eddy diffusion rates). Details of the argument can be found in Wyatt and Jenkinson (1977: Journal of Plankton Research, 19(5)). Thus, one might, for example, make a rough assessment of the probability of infection of a new area by *Alexandrium* on the basis of the local tidal regime and flushing rate.

In the ballast water context, this means that the spread of *Alexandrium* would be favoured either by regular transport of ballast water from areas rich in cysts (i.e., high release rates and high numbers per release), or by discharges into restricted areas where diffusive losses to the population are low, or a combination of both. If these conditions are not fulfilled, it might still be possible for *Alexandrium* to build up and achieve the critical numbers needed to pass the thresholds, but the time scale of such a build up might be of the order of a decade or longer, and the link with a particular vector would become increasingly obscure.

Some offshore populations of *Alexandrium* appear to be univoltine, and the excystment which precedes vegetative growth is controlled by an endogenous clock. Should the phasing of excystment not coincide with suitable conditions for growth, the introduction will fail, and the cyst inoculum will gradually become exhausted. Other dinoflagellates, including some inshore members of *Alexandrium*, may be more flexible in this respect and, thus, have higher probabilities of becoming established following their introduction to new areas. *G. catenatum* perhaps belongs to this second category. Thus, it is not only the broad outlines of individual life-history strategies that matter, but also the lower order variations between closely related taxa which may be important in determining whether introductions become established and these, in turn, will influence the propagule pressure parameter.
CURRENT RESEARCH ACTIVITIES ON BALLAST WATER AND INTRODUCED MARINE SPECIES
(BY COUNTRY)

AUSTRALIA

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Over 170 introduced marine species are currently known in Australian coastal waters, of which six (one phytoplankter, two algae, and three macro-invertebrates) have been designated ‘pests’ and targeted for control efforts. Three overlapping and linked initiatives have been started by the Australian government to deal with these invasions: (1) an Australian Ballast Water Management Advisory Council (ABWMAC), which formally links shipping and port authorities with government agencies and scientists, and seeks to reduce rates of new invasions and translocations among Australian ports, (2) a national ‘incursion response’ plan, to deal quickly and effectively with new introductions or range extensions, and (3) the CSIRO Centre for Research on Introduced Marine Pests (CRIMP).

ABWMAC has commenced three initiatives: (i) rationalization and integration of federal and state legislative frameworks for the management of ‘ballast water’ introductions, (ii) establishment of a reliable funding source for research on ballast water (and other ship-vectored means of transport) introductions, and (iii) development and implementation of a strategic research plan to assess the scale of the problem and to develop and evaluate management options. The funding issue has recently been resolved by an ABWMAC agreement to establish an annual levy on shipping to generate an annually recurrent pool of $1 million to support research. This levy has been endorsed by the Australian commonwealth government, which is providing interim funds for one year while the legislation for the levy is drafted and enacted.

The ABWMAC research program has as its initial focus the development of a risk assessment-based Decision Support System (DSS) for port managers and shippers that will allow these managers to determine the relative risk of introducing a pest species posed by an incoming vessel and, if necessary, require that vessel to undertake remedial action. The system is designed around an initial list of designated pest species and for implementation domestically. It is expected that once an effective and operational system is in place, it will be offered as a model for international ballast water management. Risk is being determined on the basis of the distribution among ports of known pest species, the degree of environmental matching of the source and receipt ports, likelihood of dispersive stages being entrained into ballast tanks and surviving the voyage given its route, duration and ship’s configuration, and what, if any, remedial action has been undertaken by the ship’s master. A detailed, modular risk analysis framework and model is being developed to integrate this information and deliver an estimated level of risk; the Decision Support System will incorporate a database accessible via a network of computers linking the ports, into which the port manager can enter the details of a particular incoming vessel and thereby engage the risk assessment process. Ship’s masters will also be able to access the DSS, in order to best plan their routes in order to minimize costs of ballast water management. It is expected that following this risk assessment, most vessels and voyages will be deemed of low risk, so that remediation can be directed at those few vessels where it is necessary and likely to be effective.

A range of research projects are underway to develop this Decision Support System and to obtain the information it will need to operate. These projects include surveys of all Australian ports for the designated target species, development of the risk analysis framework (and later the software and hardware needed to run it), evaluation of options available to ship’s masters and port managers for high risk vessels, studies of the survivability of the designated target (and other) species in ballast tanks of different configurations, and development of scientifically robust methods for accurately sampling ballast tanks, as a step towards validating the system once it comes on line. Projects intended to commence shortly include an assessment of the roles of hull fouling and other vectors in domestic translocation of exotic marine species and analysis of the effects of port management practices on likelihood of successful colonisation. In addition, the ABWMAC is supporting work on the potential for heating to kill pest species in ballast tanks, on evaluating the risk of introducing toxigenic strains of cholera to Australia in ballast tanks, and on the development of awareness campaigns for port managers, shippers and the community on ballast water management.

Independently of the ABWMAC, four other projects are underway to develop or evaluate means to ‘sterilize’ ballast tanks. One is examining ozone as a sterilizes, a second is looking at heat sterilization using on-deck facilities, and two others involve proprietary technology, for which details are not available.
The second initiative involves a broad approach by the Australian state and federal governments to develop a plan for rapidly evaluating and, if necessary, dealing with new pest incursions. The ABWMAC, CRIMP, and the Australian federal Department of the Environment are funding a trial program of community involvement in detecting pest incursions. As the next stage in this process, several ministerial councils are involved in a plan to establish a national rapid response capacity, which will be based on state research agencies coordinated by a national consultative council. A general framework for this process has been developed and strategies for its implementation, on an interim trial and permanent basis, are being considered.

Finally, CRIMP is collaborating with the ABWMAC on a number of research initiatives, including ballast tank sampling, port surveys, and development of the risk analysis framework on which the DSS will be based. The Centre has also begun to research options for managing invasive populations of the Japanese kelp (*Undaria pinnatifida*), the northern Pacific seastar (*Asterias amurensis*), and the European crab (*Carcinus maenas*), as well as developing a conceptual framework for integrated pest management in the sea. Techniques being evaluated range from physical removal and herbicidal treatments to classic biological control and application of transgenic technologies. This project is developing in close cooperation with Australian government agencies responsible for the environment and quarantine issues, in the light of legislated stringent requirements regarding biological safety and efficacy. Field trials on physical removal for several species are underway or will be commencing shortly, whereas biological control projects in Australia are still several years away and will proceed only following extensive overseas studies and broad community and government support for these options.

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**CANADA**

From the Canadian WGITMO Members

An on-going research project at the Department of Fisheries and Oceans' Maurice Lamontagne Institute (see below for further details) aims to assess the risks for the introduction of non-indigenous species through ballast water discharges in the St Lawrence River Estuary and the Gulf of St. Lawrence. The evaluation of these risks is important in the light of current Canadian regulations and guidelines which allow ballast water exchanges by foreign ships in the Gulf of St. Lawrence in situations where it is not feasible to exchange ballast water in the Atlantic Ocean.

A Transport Canada/DFO representative is a member of the Steering Committee of the US funded Great Lakes Ballast Technology Demonstration Project. A filtration unit has been installed on a Canadian ship (the *Algo North*) and will be evaluated during the 1997 shipping season. Transport Canada has conducted a ballast water sampling study in the Welland Canal. DFO Science has initiated a study to examine the possibility of using organic acids to treat residual ballast.

**BALLAST MEDIATED INTRODUCTIONS OF NON-INDIGENOUS MARINE ORGANISMS: RISK ASSESSMENT IN THE ESTUARY AND GULF OF ST. LAWRENCE**

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The Estuary and Gulf of St. Lawrence, on the eastern coast of Canada, form the marine part of the Great Lakes - St. Lawrence drainage basin, which provides an important navigational link to the interior of the North American continent. As a result, ports of the Estuary and Gulf, the St. Lawrence River, and the Great Lakes receive 2000 foreign ships per year on average. A part of this foreign maritime traffic is subjected to the Voluntary Guidelines for the Control of Ballast Water Discharges from Ships, which requests ballast water exchanges offshore in the Atlantic Ocean for all foreign ships carrying ballast waters and proceeding up the St. Lawrence Seaway to ports located west of 64° W longitude. Although protective of the freshwaters of the Great Lakes and the St. Lawrence River, these guidelines do not provide means to prevent potential introductions of non-indigenous species through foreign ballast water discharges in the marine environment of the Estuary and Gulf of St. Lawrence.

In 1994, a major study was initiated at the Maurice Lamontagne Institute of the Department of Fisheries and Oceans to assess the overall risks for ballast water mediated introductions of non-indigenous marine species in the Estuary and Gulf of St. Lawrence. This risk assessment is based on: 1) the foreign maritime traffic in the St. Lawrence Seaway; and
2) surveys of ballast water discharges practices and species diversity in ballast tanks of foreign ships bound for ports of the Estuary and Gulf.

The analysis of the foreign maritime traffic in the Estuary and Gulf of St. Lawrence for 1995, based on Transport Canada's ECAREG-VTS database, showed that the Estuary and northwestern Gulf are the most active areas in terms of foreign vessel traffic with a majority of ships being bulk carriers arriving in ballast. The foreign vessel traffic in the Estuary and Gulf do not vary much with seasons except in the southern Gulf where the traffic is reduced during winter and spring, probably due to ice conditions in the area. In 1995, foreign ships originated from 49 countries belonging to 11 FAO areas, but most came from the eastern coast of the United States (FAO areas A and G), the Northeast Atlantic (FAO area B), and the Mediterranean and Black Seas (FAO area C). The majority of foreign ships that are bound for ports in the Estuary and northwestern Gulf originate from countries of the northeast Atlantic.

To determine the extent of ballast water discharges resulting from this foreign maritime traffic in the Estuary and Gulf of St. Lawrence, a survey of ballast water management practices was conducted with officers of 200 foreign vessels bound for ports of the Estuary and northwestern Gulf. Based on the results of this survey, it was estimated that approximately 12.0 million metric tonnes (MT) of ballast waters are discharged annually in the Estuary and Gulf. Of this amount, 9.1 million MT would originate from the Atlantic Ocean as a result of a high level of compliance to the Voluntary Guidelines, while about 1.6 million MT would originate from the last port of call. Over 90% of these waters would be discharged in the Estuary and northwestern Gulf given the high intensity of the foreign vessel traffic in this area.

Finally, ballast waters and sediments of 94 foreign ships were sampled to determine the zooplanktonic species diversity, abundance, and viability in ballast tanks of incoming foreign ships. Results show that at least 106 different taxa were found in ballast waters of the 94 ships sampled, of which 25 species have never been reported in the Estuary and Gulf ecosystem. On an individual ship basis, the density of zooplankton averages 5000 to 8000 ind. m\(^{-3}\) but may vary depending on the season, while the number of species ranges from 11 to 24 on average. The number of taxa and density of zooplankton were positively correlated with the proportion of waters in ballast tanks that originate from the last port of call for ships who reported partial exchanges in the Atlantic Ocean. These results indicate that this practice is effective in reducing risks for the introduction of non-indigenous marine species in the Estuary and Gulf. These relations were also used to show that some foreign ships reporting complete exchanges in the Atlantic Ocean were in fact still carrying ballast waters originating from the last port of call, which results in underestimating the amount of ballast waters of this type that were discharged in the Estuary and Gulf in 1995 (1.6 million MT).

The results presented here are preliminary as our risk assessment for ballast-mediated introductions of marine organisms in the Estuary and Gulf of St. Lawrence is not yet complete and will continue with: 1) the analysis of interannual variations in the foreign maritime traffic, including vessels bound for the St. Lawrence River and the Great Lakes; and 2) data analysis on phytoplankton in ballast waters and on the diversity, abundance, and viability of cysts in ballast sediments. Nonetheless, the results of this study could be used ultimately as a scientific rationale for extending the application of the existing Voluntary Guidelines to all foreign ships entering the Gulf of St. Lawrence. Our preliminary results show that these guidelines, when complied with, are effective in reducing the potential for ballast mediated introductions in the St. Lawrence marine ecosystem.

FRANCE

Daniel Masson and Dominique Fouche described interests at the Aquaculture Research Laboratory of IFREMER-URAPC (Unite de Recherches Aquacoles Poitou-Charentes) in developing a research program on the role of ballast water in potentially releasing dinoflagellate cysts near mariculture sites.

GERMANY

INTRODUCTION OF NON-INDIGENOUS ORGANISMS INTO THE NORTH AND BALTIC SEAS: INVESTIGATIONS ON THE POTENTIAL ECOLOGICAL IMPACT BY INTERNATIONAL SHIPPING

S. Gollasch, J. Lenz, H.-G. Andres, and M. Dammer

During the investigation period from March 1992 through August 1995, 211 vessels were visited for sampling. It was possible to collect samples from 186 ships. A total of 334 samples were taken: 132 ballast water samples, 71 tank
sediment samples, and 131 ship’s hull samples. The vessels investigated were selected according to type of vessel and sea area of origin. The majority of samples originated from tropical and warm-temperate regions. A total of 8219 l ballast water were inspected, corresponding to an average of 62.3 l per sample. The abiotic parameters temperature, salinity, pH value, and oxygen content were measured aboard immediately after sampling. In none of the ballast water samples were abiotic parameters estimated to be lethal.

After opening the tanks, sediment samples were collected by drawing polyethylene bottles through the sediment. A total of 70 l were collected. Hull samples were taken in dockyards by scraping off the fouling organisms. The total areas investigated amounts to 3.93 m², 100 cm² per sample.

Not all samples contained organisms. Organisms were found in 97 ballast water samples (73.5 %), 53 sediment samples (74.6 %) and 129 hull samples (98.5 %). Among the factors determining survival in ballast water tanks, tolerance towards changing environmental conditions seems to be the most important factor as evidenced during a cruise from Singapore to Bremerhaven (Germany). Temperature and oxygen content were found to vary dramatically and, therefore, are important factors influencing the survival of organisms inside the ballast tanks. Fouling organisms have to tolerate a wide range of temperature and salinity changes due to seasonal and geographical differences.

**Flora**

The main phytoplankton groups recorded in ballast water were diatoms (95 species), Chlorophyceae (18 species), and dinoflagellates (8 species). The sediment samples contained diatoms (18 species), dinoflagellates (3 species) and their cysts (16 species) and Chlorophyceae (2 species). In the hull samples investigated for macroalgae by Prof. Dr I Wallentinus (University of Göteborg, Sweden), mainly green algae of the genus Enteromorpha and brown algae of the genus Ectocarpus were recorded. Non-indigenous species were not found. All species recorded are spread over a wide range of geographical areas.

A total of 11 non-indigenous phytoplankton species were recorded, 8 diatom species in ballast water, and 3 dinoflagellates in sediment samples. Among the 11 non-indigenous species were 2 dinoflagellate genera (Alexandrium and Gonyaulax) which are known for toxin production. Therefore, it cannot be ruled out that such species may be transported to German waters via ships’ traffic.

**Fauna**

Copepoda with 52 species (72.2 %) and Rotatoria with 10 species were the dominant groups in ballast water. The maximum number of species per sample was 12. With increasing age of ballast water (time period spent in the tank), the number of species and specimens decreased. Bivalvia (26 species, 23.6 %) and Cirripedia (17 species, 15.5 %) were the most common groups in sediment samples. The highest species number per sample was 25.

Bivalvia (28 species, 25.5 %) as well as Cirripedia (30 species, 27.3 %) also dominated the hull samples. The highest species number per sample was 15.

Regarding types of vessels and tanks, the highest number of species was recorded in car-carriers and aft peak tanks, respectively.

Of the 257 species identified, 150 (58.4 %) were classified as non-indigenous species to German waters. 37 of the non-indigenous species (37.8 %) have been reported in ballast water, 60 in sediment (56.6 %) and 83 hull samples (75.5 %). Most of the hull samples (126 samples) contained non-indigenous species. In addition, in 37 ballast water and 30 sediment samples non-indigenous species were found.

As far as we know, the list of species known to be transported by ships can be extended by adding several species. The list of species in ballast water samples is supplemented by 79 species. All 110 species recorded in sediment samples in this study are not listed in former analyses of tank sediment (mainly botanical results were listed in previous investigations). Among the organisms sampled on the ship’s hull, 57 species were found which have not been listed as fouling organisms.

The potential for the establishment of non-indigenous species was classified into three categories according to how the climatic conditions in the area of origin compared to those in German waters (low, medium, and high risk of introduction). Ballast water is estimated as an important vector for future introduction of non-indigenous species in our
waters, since most of the species with the highest potential for establishment have been recorded here and not in sediment and hull samples.

The extrapolation of the amount of ballast water, discharged in German ports from regions outside of Europe, results in 0.5–2 million tonnes per annum. Not included in this calculation is the volume of ballast water discharged in the outer fringes of the harbour and waterways before docking. In this study, about 1 animal per 1 l ballast water was recorded. This means an introduction of 69 organisms per second or 6 million per day. A maximum of 110,000 unicellular algae were recorded from 1 l of ballast water and 300 empty cysts per ml sediment.

The potential danger of non-indigenous species being introduced into freshwater areas like the harbours of Hamburg and Bremen is less than in estuarine areas or sea ports like Bremerhaven and Cuxhaven, since most ballast water is taken from brackish water and marine seas.

The present study has demonstrated that a high number of organisms are introduced into German coastal waters and port areas by ballast water, tank sediments, and hull fouling. Every vessel from overseas is a potential carrier of organisms in sufficient numbers to establish a seed population in our waters. Since even a single introduced non-indigenous species may cause severe damage, it is necessary to develop preventive measures. Without special treatment of ballast water with a sterilizing effect further introductions of undesirable species will continue. It is recommended to follow the IMO guidelines for ballast water intake and discharges as a first step to reduce the risk of further species introductions.

**PROTIST TRANSPORT VIA BALLAST WATER - BIOLOGICAL CLASSIFICATION OF BALLAST TANKS BY FOOD WEB INTERACTIONS**

Bella S. Galil and Norbert Hälsmann

The following research is *in press* in the European Journal of Protistology.

Ship's ballast water and sediments serve as vectors in the transportation of marine organisms, including toxic dinoflagellates, parasitic labyrinthulids, and other potentially harmful species. These exotic organisms have caused major ecological changes, as well as concern over effects on human health, fishing, and aquaculture. Heterotrophic protists may be inadvertently introduced when their trophic or resting stages are discharged with the ballast water and tank sediments. This survey describes the protist communities present in ballast tanks of cargo vessels arriving in Israeli Mediterranean ports. 362 records of living protozoan species, identified to at least 198 different species belonging to 82 heterotrophic genera, were made in this study. The maximum number of species were found in one ballast tank containing 138 different living species. The tanks examined exhibited a remarkable uniformity of protist communities, enabling us to classify food web interactions, ranging from bacteria-grazing protists, predatory unicells, and more intricate associations including parasites and metazoans.

**THE SIGNIFICANCE OF BALLAST WATER IN THE INTRODUCTION OF EXOTIC MARINE ORGANISMS TO CORK HARBOUR, IRELAND**

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*The following is the abstract from the 1996 Aalborg meeting on the Irish ballast research program to date.*

We have reviewed the occurrence of exotic species within one Irish port and examined the growing importance of ballast water discharges. Twenty-four exotic species known from Cork Harbour have been assigned according to their method of introduction. Six clam and oyster species have been used in aquaculture and unwanted species have been associated with these. At present aquaculture introductions and transfers are governed by a *Code of Practice* and this will reduce the risk posed by unwanted biota in the future. Eight of these introductions took place prior to 1972 and four
of these are likely to have been introduced as fouling on ships. Antifouling applications on ships generally included TBT from 1972 and subsequently its use will have considerably reduced the risk of introduction by fouling organisms. There has been an overall increase in ballast water discharges with estimates of less than 20,000 tonnes in 1955 to almost 200,000 tonnes or more in each year since 1970. The origin of ballast water in 1993 was principally from northern Europe and the UK, Australia, Egypt, and the French and Spanish Mediterranean. There is a significant threat of establishment of non-native species, that survive in ballast water and are established elsewhere in Europe, becoming introduced to Cork Harbour.

**NORWAY**

From the Norwegian WGITMO Member

Laws and regulations: Presently no laws or regulations for addressing the biological problems related to ballast water are operative.

Research activities: ‘The Sture Study’ is a four-plus year study of the ballast water transported into major Norwegian oil/gas harbours. This is some 12 million tonnes of ballast water annually. In this study, quite extensive inventories of flora and fauna were established for the harbour area for several years before the harbour was built. The study also includes several non-harbour localities. The development in floral and faunal communities in the harbour and the reference localities will be compared in the future. Currently, the project is at its peak sampling frequency of ballast water, and the first official reporting is expected 1997/1998 (Helge Botnen, IFM, University of Bergen).

A report on the knowledge base on ballast water and the implications for fisheries and aquaculture in the Nordic Countries (in Norwegian) has been prepared for NFA (the Nordic Working Group for Fisheries Research).

**SWEDEN**

From the Swedish WGITMO Members

The Nordic Council of Ministers is financing a small joint Nordic project on risk assessment of introduced species in Nordic waters (project leader is Professor Erkki Leppäkoski, Abo Academy, Finland). The ballast water sampling project at Göteborg University (the project leader is Professor Inger Wallentinus) will be completed during 1997. The Swedish Environmental Protection Agency (SEPA) is, after one year’s delay (see last year’s report), commissioning a desk study to assess the sources and volumes of ballast water imported to and exported from Swedish waters. The study is to be completed during 1997. A seminar on ballast water risk assessment will be held at the SEPA by Mr Steve Raymaker of the Ports Corporation of Queensland.

**UK: SCOTLAND**

**INVESTIGATIONS INTO HARMFUL PLANKTONIC ORGANISMS IN BALLAST WATER**

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**Objectives**

The main aim of this project is to investigate the transport of potentially harmful phytoplankton organisms and their resting stages to Scottish waters in ships’ ballast water and sediments. The results of a questionnaire study carried out by MLA in 1993/1994 were used to design a field sampling programme, by targeting important ballast water discharge ports. The extent of the problem will be assessed by sampling vessels from a wide range of origins discharging in various Scottish ports. The risk from potentially harmful species detected in ballast will be assessed by comparison with
examples cited in the scientific literature. Laboratory studies will assess the germination potential of resting stages of harmful dinoflagellates. In addition to examining the flora and fauna contained within ballast tanks, selected chemical pollutants (nutrients and heavy metals) are also monitored.

Summary of Progress to Date

To date, 127 sampling visits have been carried out in 10 Scottish ports. These vessels have been discharging ballast originating from 24 countries worldwide, encompassing freshwater, brackish/estuarine, and marine waters. In addition to ballast loaded in port, vessels have been sampled which have loaded their ballast at sea and some vessels sampled have exchanged their ballast at sea. The SOAEFD programme has, therefore, covered many ballast management scenarios allowing assessment of risk from different management options.

Full resting stages (cysts) of dinoflagellates have been found in over 60% of ships where sediment from ballast tanks was collected, and cysts of potentially harmful species (i.e., those associated with shellfish toxicity) have been found in 17% of the samples. Additionally, diatoms belonging to the toxic genus Pseudonitzschia, the causative organism in ASP, have been commonly found in ballast water samples.

Zooplankton samples are currently being examined, and non-indigenous species have been found. It should be noted that water and zooplankton net samples are chemically preserved and, therefore, viability of the organisms cannot be tested. However, ballast tank sediments are unpreserved and experiments on the hatching success of dinoflagellate cysts from sediment samples are being carried out. Salinity, rather than water temperature, has been found to act as a good measure of 'match' between origin and discharge port, allowing limited assessment of survival upon discharge. Elevated levels of eight heavy metals have been detected in ballast tank sediments, suggesting that discharge of sediments may result in localized heavy metal pollution within discharge areas.

A dedicated computer database has been developed and is now fully in use at SOAEFD to store and efficiently manage all data generated from both the SOAEFD and MAFF ballast water research.

Policy Issues

Experience elsewhere (e.g., Australia and the Great Lakes of North America) has linked detrimental effects on indigenous species and commercial fisheries to the accidental introduction of aquatic species in ballast water. The marine environment can be affected by ballast water in two ways—economically important fisheries may be affected, or ecological consequences may occur as a result of competition from introduced species replacing native ones. In recent years, The Scottish Office has been required to develop a management plan for ballast water discharges to protect the marine environment. The current research will assess whether such harmful introductions are likely to occur in Scottish waters by studying the composition of ballast tank flora and fauna and comparing the conditions in uptake/discharge ports which will help assess whether an organism may survive in the new environment. Additionally, the study of samples taken from vessels which have exchanged their ballast whilst on passage (sampling before and after exchange) will help advise on ballast water management policy which currently frequently recommends exchanging ballast water en route.

The research to date now enables SOAEFD to issue preliminary advice on possible ballast water discharge management strategies. This advice is often requested by Government Departments dealing with coastal planning applications, and with port/harbour authorities who are reviewing or designing ballast water management and treatment options. One area which should be clarified from the current work is that mid-water ballast exchange may be unsuitable for European and near-continental voyages, as the exchange does not take place in true oceanic water, thereby reducing the effectiveness of the procedure. The results will also show that resting cysts of toxic dinoflagellates are a problem which should be addressed in future ballast water treatment options, and that marine environment managers should be aware of the problem of secondary transport within the UK in addition to introductions from abroad. On a more ecological theme, the type of information generated in this work will be important when considering biodiversity issues and the risk to native species from non-indigenous 'invaders'.

Future research requirements

The work carried out to date suggests that open-water exchange of ballast water may be unsuitable as a management option in certain cases, particularly when voyages are between European countries, as this restricts the exchange to non-oceanic waters and may not reduce the risk of species introductions. This issue should be studied in more depth. Other
treatment options such as heat treatment and chlorination should also be studied in order to assess their potential for ballast water management strategies.

It is also important that more effort is directed at studying the survival of organisms whilst on passage, as this affects the likelihood of survival in the discharge environment. The current work also demonstrates that potentially toxic diatom and dinoflagellate genera are transported in ballast tanks. These organisms can have serious economic consequences on shellfisheries and mariculture activities. Many of these genera cannot be resolved to the species level by light microscopy and require further, detailed study by transmission and scanning electron micrography. In addition, genetic studies on ballast water material will help elucidate the genetic (and thereby perhaps geographic) origin of some introduced strains of organisms. This may be useful in determining where introduced species originate from and, in the case of toxic dinoflagellates, may provide valuable information regarding the relative toxicity of different strains.

MARINE ORGANISMS TRANSPORTED IN SHIP'S BALLAST

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This research is being undertaken on behalf of the Ministry of Agriculture, Fisheries and Food (MAFF) and involves investigating the number and types of marine organisms carried in ship's ballast into ports around England and Wales. MAFF, which is responsible for the protection of the marine environment and fisheries interests, needs this information to develop its policy on the discharge of ballast water and sediments into the coastal waters of England and Wales. The project is closely related to that which has been carried out in Scotland at the Marine Laboratory in Aberdeen. The sampling technique is very similar in order that we can utilize a common database to collate and compare the results.

The research will involve taking samples of ballast water from various types of vessels in a number of different ports around the coast of England and Wales. If a ballast tank hatch can be opened then samples are taken with a 65 micron mesh for zooplankton counts and identification. An integrated sample is taken with a hose and samples are taken for phytoplankton counts and identification, bioassays, and future chemical analysis (if the bioassays indicate that water quality is poor). Another sample is pumped up from as close to the bottom of the tank as possible in order to collect sediment, which is examined for dinoflagellate cysts.

The sampling programme has only just started and several trips have been made in order to carry out the necessary safety inductions at a number of ports. Fifteen ports have been selected for sampling, of which eleven have been visited so far, with plans to visit more in the future. So far 26 ships, ranging from small coasters to oil tankers, have been sampled. It has only been possible to take samples via a hatch in six cases, otherwise a sounding pipe is used or, in some cases, the ballast water is collected in a bucket as it is pumped out.

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(Portions of the following material were provided earlier as the United States response to ballast water questions posed by the ICES/IJC Working Group on Harmful Algal Bloom Dynamics (WGHABD) for their meeting in Saint Pardoux La Croisille, France, in April 1997)

New Book on Ballast Water/Sediment Management Released by National Research Council

1997 SGBWS Report
The National Academy of Sciences' National Research Council released a hardback book in October 1996 entitled, *Stemming the Tide: Controlling Introductions of Non-indigenous Species by Ships' Ballast Water*. As noted in WGITMO reports, this book is the result of work carried out by a NRC ballast committee (composed of maritime (shipping) experts and biological scientists) for two years. The book is available through the National Academy of Sciences Press in Washington, D.C.

**Ballast Water Research Program in Chesapeake Bay**

The most extensive surveys now looking at the transport of marine and estuarine organisms via shipping are being conducted under the auspices of the ballast water research program at the Smithsonian Environmental Research Center (SERC) in Edgewater, Maryland, on the shores of the Chesapeake Bay, headed by Drs G. Ruiz and A. Hines. In the Chesapeake Bay, international vessels are being sampled at the ports of Norfolk (lower bay = marine waters) and Baltimore (upper bay = oligohaline to freshwater), which serve as two distinct receiving environments. In addition, experimental studies are being conducted on other vessels, including one at-length experimental voyage conducted in 1996 between Israel and Chesapeake Bay. In June 1997, SERC and other cooperating scientists commenced sampling the ballast water of vessels which enter Prince William Sound in Alaska.

**Recent United States Ballast Water Legislation**

The new National Invasive Species Act of 1996 [NISA 1996] authorized, among many other things, ballast water discharge surveys and ecological surveys of selected U.S. harbors such as San Francisco Bay, the Gulf of Mexico, and Honolulu Harbor. There are no routine monitoring programs in the US which focus on the arrival of marine organisms in ballast water or sediments coming into US waters. The new law requires the United States Coast Guard to regularly sample vessels to determine if and to what extent ballast exchange has occurred. This requirement reflects a US decision to seek protection from all types of foreign organisms, rather than from a limited set of specific taxa.

NISA 1996 provides a three year window-of-opportunity for vessels arriving in US ports to exchange their water on the high seas (given safety considerations). At this end of this period, the US Coast Guard will assess the level of compliance with this regulation, and if levels are found to be insufficient, ballast exchange will become mandatory. More details are presented below under the heading of 'Ballast Exchange Studies and Monitoring'.

**Experimental Filtration Project**

A major research project commenced in April 1997 in the Great Lakes. Further details are provided in the main text of the Study Group report.

**Ballast Exchange Studies and Monitoring**

Ballast exchange studies are now being conducted under the SERC program noted above, but published results are not yet available. These studies consist of completed research programs on a voyage from the eastern Mediterranean to Chesapeake Bay, and on-going research programs on coastal voyages along the Atlantic coast of the US, using tracer particle and tracer dye techniques.

Preliminary considerations based on earlier studies in Oregon conducted by J.T. Carlton, J. Geller, and D.A. Carlton, and previous studies at SERC led by L.D. Smith, indicate that studies of the effectiveness of mid-water (also known as 'open ocean' or 'high seas') exchange should address considerations such as the following:

1) Ballast water exchange must be defined by a measure of thoroughness, as opposed to simply a 'yes' or 'no' phenomenon. Multiple exchanges of water are required to increase the probability that the total volume of original water will be replaced. That is, the question before such studies is not the 'effectiveness of any ballast exchange', but the 'effectiveness of a thorough ballast exchange'. Internationally-accepted definitions of 'thorough ballast exchange' are not yet available, but will likely consist of a minimum number of 'purges' (exchanges of water), in part depending upon the technique being used (that is, whether water is being pumped out and brought back in again by pumping or gravitation, or whether water is being overflowed from the tank by 'pressing up'). Without a standard definition of ballast exchange, vessels exchanging anywhere between 10 % and 99 % of their water can be scored as 'exchanged', diluting the significance of the resulting statistics.

2) Studies of the effectiveness of ballast water exchange should also consider parameters that may affect the sufficiency of the exchange of sediments at the bottom of ballast tanks or at the bottom of ballasted cargo holds.
The efficiency of sediment exchange depends on many parameters, including (a) exactly where the sediments are located in the tanks or holds (noting that these structures are physically complex and offer many baffles, bulkheads, plates, cul de sacs, and other positions where water movement may have differential scouring effects), (b) the amount of sediments in the tanks, (c) the nature of the sediments in the tank (how well bound together they are, including biological interactions (mounds of sediments bound together by polychaete tube worms, and highly resistant to disturbance from water flow, have been found in ballast tanks)), (d) the velocity of water motion created in the exchange process, resulting transitory boundary layer effects, and (e) the overall motion of the vessel in the water at the time of exchange. At-sea conditions will cause widely varying spatial and temporal scales of motion within tanks and holds, leading to variable mixing within the ballast systems, and variable resuspension of settled materials.

3) Of the tens of thousands of vessels at sea, there are scores of varieties of ballast systems, ballast volumes, ship ages, voyage lengths, and so forth, making a simple global characterization of ‘mid-water exchange aboard a ship at sea’ difficult.

In response to these caveats, the United States has taken the position of encouraging *all* vessels to exchange ballast water that *can safely do so*. Whether or not ballast exchange has occurred will be gauged operationally. In the Laurentian (US/Canadian) Great Lakes, where a ballast water management program has been underway for six years, the Coast Guard uses salinity as a measure of whether enough water has been exchanged to meet the ballast exchange requirement. The US Coast Guard is currently researching methods to similarly assess whether sufficient exchange has occurred in vessels arriving to and from saltwater ports.

More importantly, the Coast Guard regards ballast exchange as an extremely important interim measure in reducing the risk of the transport of marine, estuarine, and freshwater organisms by ballast water globally, but encourages the development and ultimate substitution of technological management approaches (such as filtration, heating, and so forth). Thus, the National Invasive Species Act of 1996 requires, in general, that all vessels that have operated outside of the EEZ and entering US ports undertake a monitored program of ballast water management. While ballast exchange is the available technique, alternative methods can be submitted to the Coast Guard for approval and then substituted for it. This program will be voluntary and closely monitored for three years by the U.S. Coast Guard. If compliance is found to be insufficient, ballast management will become mandatory.
Introduction to the
Concerted Action Plan:

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

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Overall objectives

The intensity of shipping and the structure of the fleet have undergone major changes over the past decade. In conjunction with this development, dredging of harbours and river estuaries has also changed the hydrodynamics and altered environmental conditions in coastal habitats, possibly leading to increased opportunity for survival of exotic species. Risk assessment must consider criteria for quantifying survival probabilities in order to define appropriate management strategies to prevent introductions or to minimize risk of introductions. These may have to be adjusted regionally, depending on habitat, type of traffic, interrelationships with other coastal resource users as well as economic considerations. Risks from transfers of harmful species by aquaculture are now considerably reduced because deliberate introductions of useful species should follow the 1994 ICES Code of Practice. This leaves shipping as the main vector for future introductions.

The efficient biocidal organotin anti-fouling paints used by shipping have also considerably reduced the number of fouling organisms on the hulls of present day trading ships. Should alternative anti-fouling paints and techniques be used then these will need to be equally as effective as organotin applications. The major problem in transmission of harmful aquatic organisms, therefore, resides with the continued transfer of ballast water in modern shipping, in particular bulk carriers and container ships of different design and dimension. The overall objective of the Concerted Action will include the following aspects:

- evaluation of the various sampling methods presently used for ballast water studies in selected EU member countries
- validation of the reliability of sampling methodologies (through intercalibration workshops, also onboard ocean-going ships) to assess in-transit survival capabilities
- development of intercalibrated monitoring systems for use by EU countries and by inter-governmental bodies such as ICES, BMB (Baltic Marine Biologists), IOC and IMO.

Additionally, the Concerted Action will consider case histories (e.g. inventories of various types of transmissions) and their major pathways in order to assist in understanding the requirements for the development of adequate mitigation (treatment) techniques while at the same time creating awareness about the dimension and nature of the problem within the science community, the regulatory and inter-governmental bodies as well as in the shipping industry and the public.

State of the art relative to the objectives

During the last decades ballast water discharges have increased throughout the world in most of the major ports. Discharge volumes are considerable in some cases and the probability of successful establishment of self-sustaining populations of alien species is expected to increase with greater volumes of ballast water and reduced ship transit times. Ships have been recognized as a major vector for the introduction of non-indigenous and harmful organisms. The first reports appeared by Medcof (1975) followed by Carlton (1985, 1987), Hallegraeff & Bolch (1991) and Subba Rao et al. (1994). Rosenthal (1976) reviewed the state of knowledge and the risks associated with transplantation to fisheries and aquaculture, including ballast water, particularly indicating that modern aquaculture development in the coastal zone is at high risk of disease transfer from ballast water when the culture facilities and areas of fishing are located near shipping routes. The recent world-wide growth of aquaculture along such infrastructure elements amplifies this risk, possibly rendering tight disease regulations for this industry useless in many areas. A annotated bibliography on transplantation and transfer of aquatic organisms through various means (including ballast water) is presently under preparation, covering about 11,000 entries (Rosenthal, 1996, final draft).

Carlton (1985) has given a review of ballast water as a mechanism for the dispersal of organisms which can be considered as comprehensive up to that time. Recent invasions and population explosion of alien species in various parts of the world are causing ecological and economical damages (Carlton & Geller 1993, Hedgpeth 1993, Gollasch & Mecke 1996). It is believed that more than 3,000 species are transported by ships each day (Carlton et al. 1995).

Some of the outstanding documented examples leading to disastrous ecological consequences are listed here:
- Anguillicola crassus: expanding its range rapidly throughout Europe and increasing in prevalence up to 100% in riverine and lake systems in many areas (Kennedy & Fitch (1990), Kaie, (1988), Koops & Hartmann (1986), Williams & Sindermann (1991)) with drastic effects on fish health and condition.
- Caulerpa taxifolia: accidentally released into the Mediterranean Sea and subsequently transmitted via ships throughout the region (Boudouresque, Meinesz, Verlaque, Knoepffier-Peguy, (1992)).
- D. polymorpha: accidentally introduced by ballast water into the Great Lakes with epizootic dimensions of ecological impact (over 350 publications at Coordinators desk).
- Eriocheir sinensis: affecting fisheries harvest in areas with mass occurrences and causing damages to dikes (burrowing activity) (Panning & Peters (1932), Leppäkoski (1991)).
- Marenzelleria viridis: leading to strong competition with native species Nereis diversicolor (Essink & Kleef, 1988, 1993). Locally, this species exploded to biomasses up to 97% of the total macrobenthic community.
- Mnemiopsis leidyi: Assumed to have been transferred in ballast water of bulk carriers trading between North America and the Black Sea (Harbison, 1993); range extension into the Mediterranean Sea already occurring (Kideys & Niermann (1993)).
- Vibrio cholerae O1, serotype Inaba, biotype El Tor, was recovered from nonpotable (ballast, bilge, & sewage) water from 5 ships (McCarthy & Khambaty (1994)) and Epstein (1995) pointed to the role that algal blooms play in spreading human cholera strains.
- Marine aquaculture (in particular the shellfish industry) is threatened by the world-wide transport of toxic phytoplankton species in ballast water, especially cyst-forming dinoflagellates (e.g. Alexandrium catenella, A. tamarensis, Gymnodinium catenatum), which are able to survive long periods of unfavourable conditions (e.g. in ballast water tanks) (Hallegraeff (1995), Hallegraeff et al. 1990, Hallegraeff & Bolch, 1991), Nehring (1995).

A joint research project between the Institut für Meereskunde, Kiel and the Universität Hamburg commissioned by the Umweltbundesamt, Berlin (German Environment Protection Agency) was launched in 1992 to investigate species introductions by international ships traffic. More than 400 species ranging from microalgae to 20 cm long fishes were collected from ballast tanks and ship hulls. The number of introduced species with discharged ballast water in German ports was estimated to average daily around 2.7 million specimens which is equivalent to approx. 88 individuals released per sec. throughout the year (Gollasch 1996).

Increasing toxic algal blooms of non-indigenous species in Australian waters have been associated with ballast water releases of Asiatic origin. Australian scientists have since intensified their ballast water studies (Hallegraeff & Bolch 1991, 1992). The USA and Canada tried to deal with the problem by developing voluntary guidelines for offshore ballast water exchange in response to the tremendous impact of recently witnessed epidemic spread of introduced species in the Great Lakes area, such as Zebra mussels (Dreissena polymorpha, Roberts, 1990), Ruffe (Gymnocephalus cernuus, Great Lakes Maritime Industry, 1993), and water flea (Bythotrephes cederstroemi, Bur, et al. 1986). In addition, IMO (International Maritime Organization) was sensitized in this matter and considered ballast water problems on its agenda as an official issue, trying to develop tentatively regulations for ballast water management in international ship traffic. Initial guidelines for preventing the transfer of harmful species by ships' ballast water releases and sediment discharges were adopted by the IMO (1993).

Investigations from AQIS (1993) have shown, however, that often, because of the diverse shapes and sizes of ballast tanks, up to 5% of the original ballast water volume remains in a tank after "complete" emptying, containing up to 25% of the entire organismic ballast water load. Therefore, the proposed IMO offshore exchange method has to be taken as an initial attempt but not as a solution. Further studies on potential survival capacity of aliens and on the development of appropriate treatment methodologies are needed.

**Work Content**

Experts from EU countries will be brought together through a series of workshops held at sites of relevance to the subject. Various methods will be studied how qualitatively and quantitatively the rate of exotic species in ballast water may be examined. The sediment accumulating in ballast tanks and fouling biota on ship hulls will also be examined. Treatment measures for the control of exotics will be discussed. Assessment of potential risk of hazardous introductions and their control is an international and interdisciplinary problem.
- Studying and comparing case histories of species transmission through ballast water with the aim to identify potentially harmful invaders to EU waters. This should lead to the development of accounts of species likely to become established in European waters together with their consequences for the environment, aquaculture and fisheries, and human health.

- Develop a standard sampling methodology for collecting and analysing ballast water from ships for European workers, based on methods used elsewhere and our own peculiar needs. The sampling method may vary according to the behaviour and the taxa of species considered to be harmful to Europe. A simple and time-effective technique is also necessary because manpower availability to carry out such studies will always be limited. It may be necessary to consider different techniques according to the local conditions of each port, country or region. Protocols need to be developed to address these issues.

- Develop a methodology to study in-transit survival of organisms. This may involve the development of a network for sampling ballast water and measuring abiotic factors world-wide. Very few studies have been published (the first one carried out in Europe is just in preparation) and there is an urgent requirement to derive a database on the survival potential of commonly encountered ballast water sediment species.

- Assessing potential control measures in order to reduce the risks arising from ballast water releases. This assessment to include the evaluation and development of guidelines for the methodological approaches for ballast water treatment.

- Developing a joint research programme on methods of distributional mapping (time series) of introduced and invading species and their interaction with native species. An attempt will be made to list exotic species for each participating country.

- Public awareness. The importance of ballast water as a means of human intervention in aquatic ecosystem stability and biodiversity is not generally appreciated. Through press releases we intend to create a more realistic focus on the essential environmental concerns that relate to ships' ballast water and sediment and hull fouling while highlighting some potential preventive measures in order to minimize risks to changes or loss of biodiversity from transmitted species. Media broadcasts often overstate the effects of unwanted introductions.

- European waters as donor area. Within Europe, some port regions will have a greater risk from ballast water introductions in account of the volume of ballast release, to topographic features or aquaculture activities, etc. Conversely, overseas port areas may be at greater risk from the introduction of some European species. The importance of donor areas will be addressed.

- Documentation of European studies on introduced species in the past.

Project Milestones

The proposed programme will include a number of workshops and intercalibration exercises which are outlined under Work Content (item A2). The management structure of the Concerted Action is built around this Work Content while the logistics are presented in form of a Table and a Flow-Chart.

Case histories

In order to familiarize all Concerted Action partners it is intended to collect information on recent case histories, including experiences with voluntary guidelines in use for different geographic regions world-wide. Existing literature reviews on non-native species or ballast water research will be consulted. These case history studies will provide a platform for identifying and compiling a "hotlist" of species relevant to each region of the Concerted Action Participants.

Methods of study and standardization

Ballast water tanks vary greatly by size, shape and accessibility. Investigators presently use their own methodology of studying the species composition contained in ballast water tanks. However, the results obtained are not comparable. It is therefore important to develop a common sampling plan. The intercalibration exercises within the workshops will aid in the development of a methodology so that - for example - investigations undertaken at two destinations on the same ship can be compared. Such a methodology is necessary for assessing the effectiveness of (a) suggested treatment procedures and (b) current guidelines (i.e. IMO).

It is clear that there is a need for a common approach by maritime nations world-wide since the shipping industry is inter-regional and inter-continental. Experts in this field from North-America, Australia and Asia will be invited to participate in these exercises on harmonization, standardization and intercalibration of sampling methodology. Existing databases containing data on non-native species or ballast water research should be evaluated as to the format of reporting with the aim to combine national data generated by all participants into a common database.
The survival of organisms in ballast water and ballast tank sediment will depend on the type of ship, type of ballast tank, the translocation distance, temperature changes while in transit, physical characteristics of donor and recipient habitats, the area of origin and the duration in transit. It is therefore important to gain an understanding of the effects of these external factors on the survival potential of aquatic species.

Certain factors will be studied which are related to type of ship and type of ballast tank which affect survival and invasion probability of exotics.

Assessing potential control measures (treatment) to reduce the risks arising from ballast water releases

Several tests and programmes on the development of treatment techniques are presently in progress both in research institutions and industry. The experiences gained will be assessed in workshops involving the shipping industry, shipyards, governmental agencies (involved in the formulation of policy and regulations), harbour authorities who have to implement effective control measures, and the scientific community studying the feasibility and effectiveness of proposed technologies.

Identification of research priorities. The results of the studies obtained under items 3.1-3.4 should enable an assessment of the main research priorities for the future. Some indications as to what they may be deduced from:

(a) methods of distributional mapping of introduced species from existing databases and literature surveys. To identify the modes of introduction, their range extension over time, and their eventual establishment in the recipient area or region.

(b) investigations on factors leading to success or failure of an exotic species.

Public awareness. The intention is to prepare, jointly, press releases on the activity of the participants during the Concerted Action. Furthermore, the scientific community will be informed through general articles, jointly prepared by participating partners, for example through Newsletters and Annual meetings such as ICES, EIFAC, European Aquaculture Society (EAS), European Association of Fish Pathologists (EAFP), World Aquaculture Society (WAS) and others. It is intended to publish the scientific results of the intercalibration exercises and other scientific findings in peer reviewed journals.

European waters as a donor area

European waters are a donor area for the transport of organisms even within the same states (e.g. Mediterranean Sea and Atlantic Ocean, North Sea and Baltic Sea). Exotic species may be imported by ballast water, tank sediment and ships' hulls to Europe, but also European waters can also be a significant donor of species transported by ships elsewhere. The focus will concentrate on European species that have been successful and those which may be potentially harmful elsewhere. In many cases the ballast water originates from already stressed or ecologically disturbed areas (e.g. harbours, canals and highly industrialized or urbanized coasts) where opportunistic organisms resistant to environmental perturbation exist.

Documentation of European studies. During the Concerted Action, all participants will provide as far as possible continuous input of references (in particular on grey literature: e.g. governmental reports, internal reports from harbour authorities, interim project reports, etc) into the database to be kept by the co-ordinator.

Benefits

The ICES Working Group (WG) on Introductions has repeatedly outlined the risks associated with ballast water transfers and during the 1995 Statutory Meeting of the Council strong recommendations were given on methodological studies and management guidelines for ballast water. The ICES WG in its 1996 WG Report strongly suggests close cooperation between ICES, IMO and IOC to review progress on the scientific studies related to ballast water and on technical management, addressing also sampling methods and sharing of data bases. The Concerted Action will be one means to provide the results for this continuing review exercise, in particular in relation to standardization of sampling strategies and monitoring.
Economic and social impacts
The present proposal is along the lines recommended by ICES and EIFAC and is extremely relevant to IMO and HELCOM. IMO has already recommended voluntary guidelines and so have the USA and Canada for the St Lawrence Seaway. OSPARCOM has recently requested to prepare an inventory to assess the scope of the problem with regard to exotic species. The proposed concerted action is meant to provide a forum to guide interested researchers, regulatory authorities and the shipping industry towards an interdisciplinary study which helps in the understanding of the management implications of this development. It is anticipated that the outcome of the Concerted Action will lead to a proposal for research, in conjunction with the industry, to develop management tools, including ballast water treatment and regulatory measures associated with these technologies.

Concerted Action Management Structure
The Concerted Action is planned for 2 years commencing in the beginning of 1998. It will include workshops with technical sessions, practical workshops for testing of methodologies including intercalibration exercises, methodological tests onboard ships to evaluate survival capabilities of in-transit species, and preparatory meetings to prepare documents (guidelines, manuscripts, statistical analysis, press releases etc.). The proposed programme will be co-ordinated from the Department of Fishery Biology, Institute of Marine Science, University of Kiel (IMF). Technical workshops and practical testing workshops are presented separately while the flow-chart provides an overview of the logistical interlinking between the three types of activities (Planning workshop, technical sessions, sea-going workshops).

Proposed meeting sites: Kiel (Germany), Dublin (Ireland), Klaipeda (Lithuania), Göteborg, (Sweden) and Rotterdam (The Netherlands)

Sea-going workshops,
- Intercontinental sea traffic: 4 sea-going workshops on board vessels with teams of at least 2 laboratories participating each time, covering 3 types of ships and/or ballast tanks, according to the major routings (2 North America - Europe; 1 Near East - Europe; 1 Far East - Europe)
- Regional and closed-sea transportation: 2 inter-regional sea-going workshops (within Europe, mainly the Baltic); smaller ships, different operational strategies

Co-operation with shipping industry, regional/local authorities
The coordinator will seek permits (agreements) with respective shipping companies to assure the timely commencement of the intercalibration workshop sampling aboard commercial vessels.

Experience has shown that the co-operation of major shipping companies with Concerted Action participants was smooth and easy. However, exact scheduling can only be carried out on relatively short notice as time tables and routings of ships of these companies have always to respond quickly to changing demands. Several partners already have established ongoing contacts with shipping companies which signaled very positive responses to our requests for participation and co-operation. Therefore, we can assure timely arrangements once this Concerted Action is underway. Examples of companies already contacted include: Delta Marine Ltd, Finland (Consulting Company with multiple contacts to routing of shipping businesses since 1984); Blohm & Voss, Shipyards Hamburg; Bremer-Vulkan, Shipyards Bremen; Llyod-Werft, Shipyards Bremerhaven; Verband Deutscher Reeder, Hamburg; Bundesamt für Seeschifffahrt und Hydrography, Hamburg; Germanische Lloyd Hamburg; Hapag-Lloyd, Hamburg; Deutsche See-Reederei Rostock, Deutsche-Afrika-Flotten, Hamburg). Furthermore, contacts with Dutch shipping companies in Rotterdam have been established and will be revived upon start of the Concerted Action.

There are also contacts to a forward thinking Scottish shipping company who currently practices ballast water exchange in order to minimize environmental damage from their shipping operations. Representatives from the Swedish ship owners association, responsible for research and development can probably be involved to give advice on logistics for ballast water treatment options from their point of view.
PROPOSED INTERNATIONAL NETWORK FOR MARINE INVASION RESEARCH (INFORMIR)

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Over the past decade, the extent and impact of non-indigenous species (NIS) invasions have received increasing attention throughout the world. For marine (including estuarine) habitats, this has resulted in a series of parallel studies in many different countries that examine patterns, mechanisms, and consequences of NIS invasions. This convergence in research programs and priorities is most evident in the area of ballast water ecology and management, but it is also occurring in many other areas (e.g., NIS inventories, impact studies, and so forth).

The information now emerging from these parallel research programs begins to provide exciting comparison across a 'global network' of sites. Importantly, it is only through such a comparative approach that we can derive generalities from individual studies, measuring significant patterns of variation among regions, and testing predictions about invasion processes on various spatial scales. Development of effective management strategies to reduce the risks and impacts of NIS depends on understanding both these generalities and sources of variation (that is, those factors that influence the success and impact of invasions).

The organisation of a coordinated effort is well underway for ballast water research, facilitated strongly by international groups such as ICES and IMO. As a result of frequent meetings about ballast water issues within and among countries, research is increasingly being developed and compared internationally around the world. Although there is still much that could be done to enhance comparative ballast water research through a global network, efforts are already underway to describe and develop standard approaches that promote such comparisons.

In contrast, coordinated research on patterns and impacts of NIS in marine and estuarine habitats lags far behind. There are few data available to compare directly the abundance, distribution, or ecological effects of NIS among communities within a country or among countries. This results both from the relatively few studies (until recently) in this area and from the lack of standardisation. With the apparent increase of research programs to develop NIS inventories and measure various attributes of invasions around the world, we believe there is a strong benefit to establish an 'International Network for Marine Invasion Research' (INFORMIR) that can be used to coordinate comparative and collaborative invasion research in this area especially.

The proposal is thus to establish the 'International Network for Marine Invasion Research' (INFORMIR) to help coordinate and develop standard approaches to measure patterns and impacts of NIS invasions in marine and estuarine habitats. The goal of the network is not to constrain or limit ways in which people study invasion process, but instead to help promote opportunities for comparative and collaborative research among groups who wish to pursue broad-scale comparisons on invasions throughout the world.

Although its exact nature and function are still evolving, primary ‘Network’ goals include (but are not limited to):

* development of standard measures of NIS invasion patterns and impacts that can be included in research programs to allow direct comparisons among studies around the world;

* creation of a forum for regular interaction to discuss results and ideas, foster collaboration, as well as develop novel coordinated approaches to extend the scope and interpretation of invasion research;

* development of funding strategies to implement coordinated international measures of invasion processes across a global network.

At this time, we wish to gauge the level of interest among our colleagues to participate in this ‘International Network’. We have received strong interest from invasion research programs in Australia, New Zealand, and the Baltic countries and will soon attempt to implement some aspects of this program. Any research groups interested in participating and having comments on this proposed Network are invited to contact Dr Ruiz or Dr Carlton.
ANNEX 7

BIBLIOGRAPHY


The ICES/IOC/IMO Study Group on Ballast Water and Sediments (Co-Chairmen: a representative from ICES; a representative from IOC; and a representative from IMO) recommends that it meet from 30-31 March 1998 in The Hague, The Netherlands to:

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

b) discuss cooperative research programmes and databases;

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

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

e) work closely with WGHABD to monitor the introduction, via ballast water transport, of phytoplankton organisms that can cause toxic and harmful algal blooms.