Final Report

EU Concerted Action

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

CONTRACT NO: MAS3-CT97-0111

Kiel, the 29th of December 1999

left to right, standing
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(one page summary)

Until recently, the importance of ballast water as a major transfer vector that affect aquatic ecosystem stability and modify biodiversity was not generally recognised, although studies on species transfer via ballast water in maritime countries have increased world-wide. Despite considerable research effort (national and international), there has been virtually no consideration of the effectiveness or standardisation of ballast water sampling methodology in order to monitor effectiveness of control measures. One **key objective** of the Concerted Action was to test monitoring systems for sampling ballast water. Two major **intercalibration workshops** compared sampling techniques. The largely varying conditions onboard ships require to develop a "tool box" rather than singling out one method, thereby combining qualitative and quantitative sample analysis for plankton species composition and abundance. The two intercalibration workshops delivered results allowing better comparisons of ship sampling studies around the world. The **second key issue** was to gain more insight on species composition in ballast water during ship voyages. This was achieved by **ocean-going workshops** (OGWs). The data obtained during five OGWs, using the "tool box" originated from European voyages (three OGWs) and during inter-ocean voyages (two OGWs). In total, approximately 700 samples were collected during more than 100 days at sea. More species and specimens were found in new ballast water, and communities were in general similar to outside seawater where ballasting took place. The highest number of phytoplankton species found was 52, including potentially toxic species. At most, 40 zooplankton taxa were found. Abundance and diversity of phyto- and zooplankton species remained fairly stable for 3-4 days, followed by an exponential decline. In some cases no living zooplankton were found after 9 days, in others about 10% of the taxa survived, remaining viable for 25 days (i.e. voyage Hong Kong – Hamburg). Sampling showed that in calm conditions phytoplankton exhibited a vertical zonation in ballast tanks. During rough weather mixing occurred causing increasing in mortality. For the first time in ballast water studies, traps were used with bait and light as attractants, catching taxa not seen in the net samples before. The effect of mid ocean exchange (MOE), recommended by International Maritime Organization (IMO) as a measure against unintentional introduction via ships, was studied. In many cases the number of taxa increased rather than declined while densities of specimens were diluted.

A **public awareness** was launched, preparing a video, a leaflet, flyers, press releases, newsletter articles of International Aquatic Societies, an Internet homepage (visit the homepage at: http://members.aol.com/sgollasch/sgollasch/index.htm) and several posters. A book on case histories, listing species previously introduced to European waters, was prepared especially to address harbour and regulatory authorities.

Assessment of potential **control measures** (treatment) to reduce risks arising from ballast water releases included the evaluation and development of guidelines for ballast water treatment options.

All participants provided input on references (e.g. grey literature, governmental reports, internal reports from harbour authorities, interim project reports) into a database kept by the co-ordinator. The Concerted Action **reviewed** and considered **shipping studies** both within and outside the EU. This provided a more balanced view of the state of the art and also enabled the Intercalibration workshops to consider and compare sampling methods as used throughout the world. During the CA many of these studies were completed and new ones studies commenced.

It is recommended that the EU takes advantage of the well developed expertise within the network of the CA partners to gain momentum in an area where global solutions are urgently needed.

(Executive Summary can be found in Appendix 9, page 72)

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Preamble

In order to provide full access to all information gathered during the two years activity, this document consists of a series of reports, hierarchically structured to allow in depth in-depth analysis of different elements as required by the reader. Due to the complexity of the subject and the wide-range activities, this report is structured according EU Concerted Action workplan (as submitted in the Technical Annex of the contract) with brief summaries on each objective and the relevant deliverables.
The final report of this Concerted Action is available both as printed hard copy and as CD-ROM using the same structure in both media, while hyperlinks on the CD offer the additional option to crosslink statements in the report to more detailed information. The CD-ROM includes workshop reports from all land-based, ocean-going and intercalibration workshops and the public awareness material, including the posters ready for printing in choice of a formats (letter size or poster size format). Hyperlinks in the final report are printed as blue, underlined characters allowing reader to easily select the relevant documents of interest. Please note, that the hyperlinks will only work if you read the documents from the CD-ROM.

For optimal use of the CD-ROM the minimum requirements of computer software are: Word97, Excel97, Powerpoint95, Acrobat Reader 3.x or newer versions and a computer programme to play video files formatted as *.mov (e.g. Quicktime), software to open *.jpg files and software to open *.htm files. A basic soundcard and speakers would enable you to listen to some spoken messages. This software, e.g. Microsoft Audiorecorder, should be included in your Windows95 package. We hope this CD-ROM will provide easy access, but we would highly appreciate your indication if you have any problem in reading files from the CD-ROM.

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Appendices

Note for the CD-ROM reader: You may need to adjust the page numbers of this table of content. Mark the section by clicking on any line and as result lines become grey shaded. Press F9 & choose “page numbers only”.

Attachments

Reports

Printed copies of all reports are attached to this report. On the CD-ROM all reports can be found as MS Word files in the folder "Meeting reports". The file name includes information on the type of the workshop, its individual number (e.g. LBW1), its number according to the Concerted Action duration (e.g. CA1), place and year when the workshop was held:

Land-based-workshops (=LBW)	**File name**
Jan. 1998; Kiel, Germany	LBW1_CA1_Kiel_98.doc
Mar. 1998; The Hague, The Netherlands	LBW2_CA2_TheHague_98.doc
Sept. 1998; Killaloe, Ireland	LBW3_CA5_Killaloe_98.doc
Apr. 1999; Conwy, Wales	LBW4_CA8_Conwy_99.doc
Sept. 1999; Nida, Lithuania	LBW5_CA12_Nida_99.doc
Dec. 1999; Kiel, Germany	LBW6_CA13_Kiel_99.doc
Ocean-going-workshops (=OGW)	**File name**
July 1998; St. Petersburg (Russia) – Lisbon (Portugal)	OGW1_CA4_Lisbon_98.doc
Oct. 1998; Cork (Ireland) – Sture (Norway)	OGW2_CA6_Cork_98.doc
May 1999; Kaohsiung (Taiwan) – Hamburg (Germany)	OGW3_CA9_Taiwan_99.doc
May 1999; Auckland (New Zealand) – Hamburg	OGW4_CA10_Auckland_99.doc
Sept. 1999; Black Sea	OGW5_CA11_BlackSea_99.doc
Intercalibration workshops (=ICW)	**File name**
June 1998; Helgoland & Kiel, Germany	ICW1_CA3_Helgoland_98.doc
Jan. 1999; Helgoland & Kiel, Germany	ICW2_CA7_Helgoland_99.doc

Books

- Gollasch, S., Minchin, D., Rosenthal, H. and M. Voigt (eds.) (1999): Exotics Across the Ocean. Case Histories book on introduced species. Prepared by all CA partners and guest authors. (on **CD-ROM** version of this report you will find parts of this book in the folder "Case Histories")
- Gollasch, S. & E. Leppäkoski (1999): Initial risk assessment of alien species in Nordic coastal waters. 1-124. In: Gollasch, S. & E. Leppäkoski (eds.) Initial risk assessment of alien species in Nordic coastal waters. Nord 1999: 8. Nordic Council of Ministers, Copenhagen. 244 pp. (on CD-ROM version of this report you will find the report´s title page, preface and table of content in the folder "Nordic Report" as Acrobat Reader file)
- Gollasch (1998): Removal of Barriers to the Effective Implementation of Ballast Water Control and Management Measures in Developing Countries. Background information compiled to support GEF Project, 196pp (**not** included in **printed report**, but on CD-ROM in the folder "GEF Report")

Posters

Coloured print outs in letter size format of all four Concerted Action posters are attached to the printed version of this report. On the CD-ROM you will find the posters as MS Powerpoint files in the folder "Poster":

- Exotics Across the Ocean (file name: 1_Poster_Introduction.ppt)
- Exotics Travelling with Ships (file name: 2_Poster_Survival.ppt)
- Harmonization of European Ballast Water Sampling Methods
  (file name: 3_Poster_Intercal1.ppt
- Are Seas at Risk (file name: 4_Poster_Risk.ppt)

Video

Both videos are attached to the printed report in PAL format. In the folder "Video" on the CD-ROM you will find copies of the videos. Additionally two colour photos of the Chinese Mitten Crab are available in the same folder. **Please note that this material is for your personal use only.**

- Video I: Documentation of the first Intercalibration workshop, carried out in June 1998
- Video II: Migration of juvenile Chinese Mitten Crabs in the German river Elbe. This documentary was produced by the Norddeutscher Rundfunk, Kiel, Germany in close co-operation with S. Gollasch, but the producer holds the copyright. **Unauthorised copying and commercial use of this video or parts of this video is illegal.**

Homepage

The newest version of the Concerted Action homepage is enclosed on the CD-ROM version of this report in the folder "Homepage".

Flyer

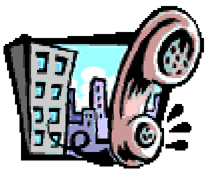
A paper copy of the Concerted Action flyer is included in the printed report and is available as MS Excel file in the folder "Flyer" on the CD-ROM.

Press Releases

Print outs of all four Concerted Action press releases are enclosed in the printed report and are available as MS Word documents in the folder "Press Releases" on the CD-ROM.

Voice Messages

Voice messages are only available if you read the CD-ROM version of this report in areas where you can click on this symbol:



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1 Background information

In recent decades, ballast water discharges from ships into coastal areas have increased throughout the world, mainly occurring in or adjacent to port areas. Discharge volumes vary according to the size of vessel, type of trade and shipping routes, but are relatively high. It is estimated that the ballast water volume discharged annually world-wide exceeds 10 billion tonnes. Further estimates by the EU Concerted Action (CA) indicate that over 4,000 species are in intercontinental transit daily. The probability of successful establishment of self-sustaining populations of non-indigenous species has increased and is expected to increase further with greater volumes of ballast water carried by larger, faster ships with reduced transit times. Ships have been recognized as a major vector for the introduction of non-indigenous and **harmful organisms** and may thereby lead to deleterious effects on other human activities in the coastal zone.

The first accounts of species sampled from ships' ballast water were reported 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 discussed the **risks** associated with transplantation of disease agents, parasites and competitive species to fisheries and aquaculture, including organisms transported in ballast water. He indicated that modern aquaculture development in the coastal zone may be at risk of disease and parasite transfers from ballast water if aquaculture facilities and fishing areas are located in close proximity to shipping routes. The recent world-wide growth of aquaculture along shipping routes and near ports amplifies this risk, possibly rendering strict disease regulations for this industry useless in some areas.

The importance of ballast water introductions as a major vector for affecting aquatic ecosystem stability and modifying biodiversity was not generally appreciated until relatively recently. There has been a subsequent proliferation of studies on species transfer via ballast water in maritime countries across the world. However, despite considerable research effort, at both national and international scales, there has been virtually no consideration of the effectiveness or standardisation of ballast water sampling methodology. One **key objective** was to test monitoring systems for sampling ballast water and this was achieved by two major **intercalibration workshops** which compared scientific sampling techniques. These workshops delivered results allowing better comparison of ship sampling studies around the world. The **second key issues** were the results of the **ocean-going workshops,** documenting the composition of organisms in ballast water during ship voyages. In addition, the effect of mid ocean exchange (MOE), which is recommended as a measure against unintentional introduction via ships, was studied (see below). Another key objective was the **public awareness** issue dealt with by the preparation of a video, a leaflet, flyer, press releas**es**, articl**es** to newsletters of International Aquatic Societies, Internet homepage and poster**s,** and the case histories book listing species previously introduced to European waters.

2 Management of the Concerted Action

2.1 Overall management

The CA was planned for 2 years and commenced towards the end of 1997. The CA brought together not only scientists working on ballast water in Europe, but also those from outside the European Union. While 6 land based workshops took place during two years, ocean-going workshops were also conducted. In addition to the partners from EU member states and the IMO as an intergovernmental organisation, at least 21 countries have participated in one or more of the CA activities. The CA has been an open discussion forum (including ocean-going and intercalibration workshops) where experts from around the world have gathered and co-operated, resulting in improved studies and an improved understanding of the problems related to ballast water sampling and management. Workshops with technical sessions, practical workshops for testing of methodologies including intercalibration exercises, methodological tests onboard ships to evaluate survival capabilities of species in-transit, and preparatory meetings to prepare documents (guidelines, manuscripts, statistical analysis, press releases etc.) were held (Tab. 1). The CA was co-ordinated by the Department of Fishery Biology, Institute of Marine Science, University of Kiel (IfM).

2.2 Workshops

All workshops involved CA Partners and invited experts (Tab. 1). Additionally, non-scientific authorities (e.g. shipping companies, ship owner associations, and port authorities) and institutions from nearby meeting sites were also invited as guests and/ or observers. In several cases workshops were timed and linked to other international and inter-governmental activities related to the subject, such as the meetings of the International Council for the Exploration of the Sea (ICES) Working Group on Introductions and Transfers of Marine Organisms (WGITMO), the ICES/IOC/IMO Study Group on Ballast Water and Sediments (SGBWS) and the Baltic Marine Biologists (BMB) Working Group on Non-indigenous Estuarine and Marine Organisms (NEMOs).

Additionally, CA partners participated actively in many European and overseas conferences and workshops addressing exotic species and ballast water issues on a local, national, regional and intercontinental basis. Thus, the CA incorporated the world-wide expertise into its active work. The world map (Fig. 1) illustrates the origin of the experts and institutions who participated in one or more of the CA workshops. Detailed listings can be found in the relevant meeting reports.

Tab.1 Details of the held workshops during the CA study (LBW = Land-based Workshop, OGW = Ocean-Going Workshop, ICW = Intercalibration Workshop, * = Invited expert participants (for details see report of relevant workshop)). Double-click hyperlink to get to the relevant report or see attachments.

Work-shop	Time	Location	Number of CA participants	Number of invited guests
1. LBW	Jan. 1998	Kiel, Germany	7	
2. LBW	Mar. 1998	The Hague, The Netherlands	10	10
3. ICW	June 1998	Helgoland & Kiel, Germany	4	2
4. OGW	July 1998	St. Petersburg (Russia) – Lisbon (Portugal)	1	2
5. LBW	Sept. 1998	Killaloe, Ireland	9	* 7
6. OGW	Oct. 1998	Cork (Ireland) – Sture (Norway)	3	1
7. ICW	Jan. 1999	Helgoland & Kiel, Germany	6	15
8. LBW	Apr. 1999	Conwy, Wales	10	19
9. OGW	May 1999	Kaohsiung (Taiwan) – Hamburg (Germany)	2	1
10.OGW	May 1999	Auckland (New Zealand) – Hamburg	2	
11. OGW	Sept. 1999	Black Sea	2	
12. LBW	Sept. 1999	Nida, Lithuania	7	2
13. LBW	Dec. 1999	Kiel, Germany	10	* 3

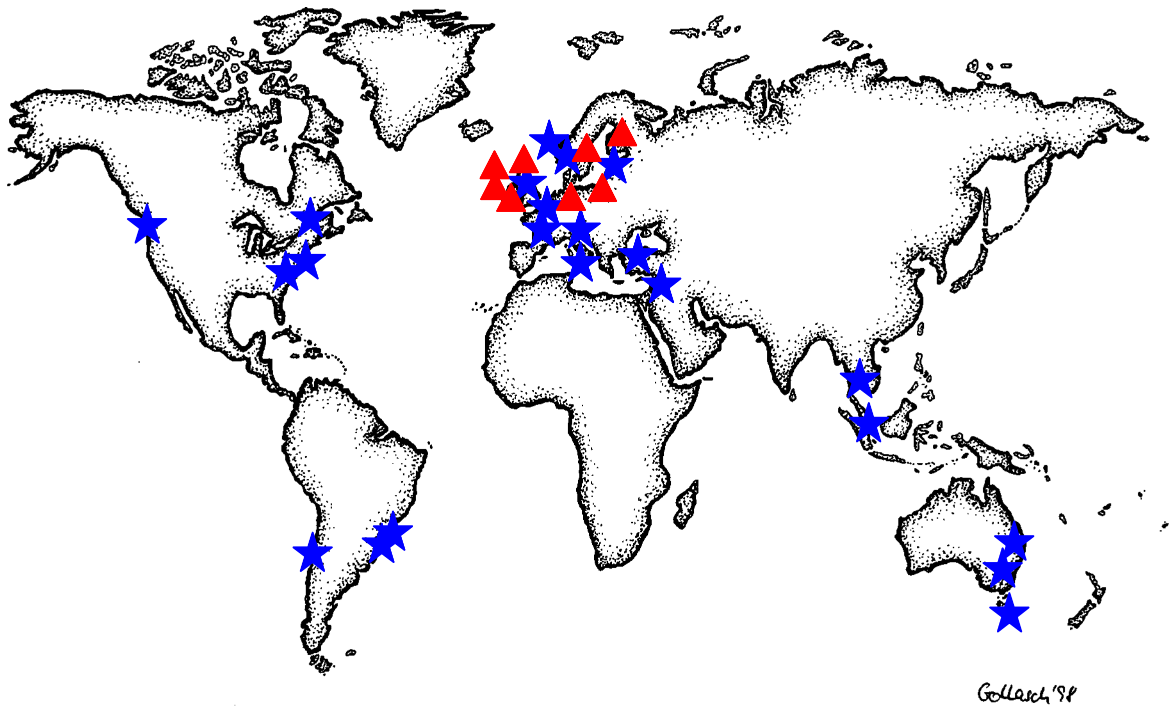


Fig. 1 World-map indicating (using stars) the origin of the invited experts and institutions who participated in CA workshops (listed in alphabetical order): Australia, Brazil, Canada, Chile, Croatia, Estonia, France, Israel, Italy, Netherlands, Norway, Singapore, Thailand, Turkey, UK, and USA. Detailed listings can be found in the relevant meeting reports. The home countries of the CA partners are indicated by using diamonds (listed in alphabetical order): Finland, Germany, Ireland, Lithuania, Scotland, Sweden, UK. (Wales) and IMO (London, UK).

2.2.1 Land-based workshops

The Initial Planning Workshop was held with all partners of the CA at the co-ordinating institute in Kiel, Germany. The second workshop was held in The Hague in late spring 1998, prior to the meeting of the ICES (International Council for the Exploration of the Sea) Working Group on Introductions and Transfers of Marine Organisms and also the meeting of the ICES/IOC/IMO Study Group on Ballast Water and Sediments enabling the participation of several experts outside the EU, such as representatives from non-EU ICES members countries and participants from the BMB (Baltic Marine Biologists) Working Group on Non-indigenous Estuarine and Marine Species as well as experts from IMO (International Maritime Organisation, London).

2.2.2 Intercalibration workshops

These workshops dealt with practical exercises of ballast water sampling techniques, and took place on the island of Helgoland in the German Bight where laboratory facilities were available. Due to limited laboratory space, equipment availability and the wide range of methods and sampling equipment to be tested and compared, the intercalibration exercises were performed in two complementary workshops while also repeating some of the tests under improved operational conditions. The **first workshop** focussed on the European ship sampling techniques whilst the **second workshop** was larger and involved all sampling techniques for ballast water presently in use world-wide. The results of both intercalibration exercises were evaluated for the preparation of guidelines and protocols for sampling. Ballast tanks vary greatly in design and size, and therefore sampling protocols must be structured to recognize these factors as to and how they may influence the representativeness of the sampling method. Handling procedures (sampling methods, logistics on board ships) were documented via video recording which can initially be used as learning tools and to compare methods.

2.2.3 Ocean-going workshops

A total of 5 ocean-going workshops to quantify the survival of organisms in ballast tanks were undertaken. These exercises were carried out after the intercalibration workshops were held in order that participants could use and refine that information on different methodologies during the ocean-going workshops. The cruise observations resulted in additional recommendations for the comparison of different sampling techniques, especially in handling sampling equipment and samples on board ships. The timing was set with some overlap so that seasonal temperature differences were covered. Short-term and long-term workshops were undertaken covering a wide geographic range of different climate zones.

2.2.4 The Final Workshop

The workshop was held again in the co-ordinating institute to prepare the summary report and to formulate recommendations, while also assigning tasks for preparing the scientific data publications in scientific refereed journals.

3. Objectives

According to the Technical Annex submitted to the EU in 1997, the following objectives were fully addressed during the project. These were: 1 Case histories, 2 Intercalibration of ship sampling techniques, 3 Survival of organisms in ballast water during voyages (ocean-going workshops), 4 Assessing potential control measures (treatment) to reduce the risks arising from ballast water releases, 5 Identification of research priorities (including general

recommendations of the CA), 6 Public awareness, 7 European waters as a donor area, and 8 Documentation of European studies on ships and introduced species in the past.
For further information, please consult the CD-ROM and press the relevant hyperlinks at the end of each section (formatted underlined and in blue letters). Linkages refer to summary reports and more detailed reports prepared during the CA.

3.1 Case histories

Responsible persons: All CA partners

Objectives: Studying and comparing **case histories** of species previously introduced through ballast water and/or hull fouling into European waters. Existing literature on non-native species or ballast water research was consulted. During the first CA meeting, a case history format was designed and 11 species were selected for inclusion, ranging from unicellular algae to fish. The case histories provide background information for both the scientific and non-scientific communities. The case history format may serve as a prototype for a European database on harmful invasive species.

Deliverables: Book on selected case histories concerning the following species: **Flora**: *Coscinodiscus wailesii, Gyrodinium aureolum, Sargassum muticum, and Undaria pinnatifida.* **Fauna**: *Balanus improvisus, Crepidula fornicata, Dreissena polymorpha, Ensis americanus, Eriocheir sinensis*, (press the two (!!!) hyperlinks for viewing *.jpg files on the Chinese Mitten Crab – also available in the folder "Video"), *Marenzelleria viridis,* and *Neogobius melanostomus.*

A video on the Chinese Mitten Crab (*.mov) is available in the folder "Video".

For more information (incl. detailed report) click here.

3.2 Intercalibration of ship sampling techniques

Responsible persons: All CA partners and invited guests (see workshop reports)

Objectives: Before the ocean-going workshops commenced, the CA carried out an initial comparison of the ballast water sampling methods used by the partners within the European group during the first intercalibration workshop (summer 1998). To confirm these results and to further refine this initial exercise, a second intercalibration workshop was held in January 1999. At this workshop the ballast water sampling techniques were compared on a **world-wide** basis using commonly employed European and overseas techniques. Both intercalibration workshops consisted of two parts. The first part was a land-based experiment at the marine station on Helgoland (German Bight). The second part, a mini symposium on recent results of shipping studies and other related activities of all participants (see appendices), was held at the Institut für Meereskunde in Kiel, Germany. After the mini symposium, a container ship passing through the Kiel Canal was accompanied by CA partners and invited participants. Various techniques were employed for the sampling of one ballast tank on board the selected ship in order to demonstrate and compare the practical application of the methods *in situ* during the 7 hour ship's passage through the Kiel Canal.
Based on the results from the first intercalibration workshop, the second workshop resulted in a more robust sampling design that permitted the simultaneous and consecutive testing of a variety of ships' ballast water sampling techniques. In particular, the use of a "reference net" along with each sampling method tested and an increased number of replicates improved the quality of the data compared to the initial intercalibration workshop. The exercise demonstrated the high variability between and within methods and the virtual impossibility to obtain a complete representation of the taxa that are present in ballast tanks. The entire CA clearly showed that full recovery of organisms contained in ballast tanks is virtually impossible, but that it is feasible to strive for representative target plankton taxa for ease of

comparison between studies. At best, the outcome of this exercise documents the option to operate with a known level of error between methods, thereby allowing for some reasonable comparability among research teams. This is particularly important when ships are sampled by different teams at each end of their voyage so that results on survival and species composition are more comparable.

Knowing that ballast water tanks vary greatly by size, shape and accessibility and that the sampling method may vary according to the behaviour and the target taxa, a tool box of recommended sampling techniques was the outcome of the two intercalibration workshops.

Deliverables: Reports of the two intercalibration workshops (workshop one June 1998 and workshop two January 1999); a video was produced to document the different ways to sample ships and an overall report summarizing the results and recommendations of both workshops. A manuscript to be submitted to a international peer reviewed scientific journal is presently in preparation.

For more information (including detailed reports) click here.

3.3 Survival of organisms in ballast water tanks during voyages (ocean-going-workshops)

Responsible persons: All participants in ocean-going workshops

Objectives: The purpose of the Ocean Going Workshops (OGW) within the CA was to examine the survival and diversity of organisms in ballast water and to compare different methods of sampling ballast water in order to allow a better comparison and interpretation of results obtained so far by independent studies carried out in the past. In addition, the effect of mid ocean exchange of ballast water (MOE), presently recommended in IMO draft guidelines and unilaterally required in some countries, as a measure against unintentional introduction via ships which are intercontinental transit, was studied.

The data were obtained during five OGW, which were undertaken both in European waters (OGW 1, 2 and 5) and during inter-ocean voyages (OGW 3 and 4) onboard different types ships: research vessels, an oil tanker and container vessels. In total, approximately 700 samples were collected during more than 100 days at sea.

The **first** OGW was undertaken in July-August 1998 onboard a Russian Navy hydrographic ship, "Sibiryakov" (DWT 3442 t, length 86 m, draught 5 m, built in 1990). The cruise was organised by the Russian State Hydrometeorological University (St. Petersburg) within the framework of the IOC-UNESCO sponsored "Year of the Ocean" research and educational program. This voyage covered intercontinental waterways from the Baltic Sea to the Atlantic coast of Europe (Portugal).

The **second** OGW was carried out in October 1998 onboard the Norwegian oil tanker "Nordic Torinita" (DWT 108683 t, length 244 m, draught 15 m, built in 1992) from Cork, Ireland to Sture, Norway, crossing the Irish Sea and the North Sea. Samples were taken in various tanks throughout this short-term voyage.

The **third** OGW was carried out in May-June 1999 onboard the German container vessel "Pusan Senator" (DWT 63654 t, length 294 m, draught 13, built in 1997). The voyage was from Kaohsiung, Taiwan via the South Chinese Sea, Malacca Strait, the Indian Ocean, the Red Sea, the Mediterranean, the Bay of Biscay and the North Sea to Hamburg, Germany. The effect of multiple MOE were studied.

The **fourth** OGW was carried out in May-June 1999 onboard the British container vessel "Mairangi Bay" (GWT 43674 t, length 239 m, built in 1977) from Auckland, New Zealand to Hamburg, Germany via the South Pacific Ocean, Atlantic and the North Sea, being the longest OGW undertaken during the CA.

The **fifth** OGW was carried out in September 1999 onboard the Ukrainian hydrometeorological research vessel "Georgij Ushakov" (DWT 1420 t, length 101 m, draught

5 m, built in 1970) during the IMO Workshop on Ballast Water Management and Control (Odessa-Constanta-Varna-Odessa) in the Black Sea, dealing with another enclosed sea.
Deliverables: Reports from all ocean-going workshops (St. Petersburg – Lisbon – St. Petersburg, Cork – Sture (Norway), Kaohsiung (Taiwan) – Hamburg, Auckland – Hamburg and Odessa – Varna – Constanta – Odessa) and an overall summary report.
A manuscript to be submitted to a international peer reviewed scientific journal is presently in preparation.
For more information (including detailed reports) click here.

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

Responsible persons: S. Gollasch, M. Voigt and M. Nauke
Objectives: Assessing potential control measures in order to reduce the risks arising from ballast water releases. This assessment includes the evaluation and development of guidelines for the methodological approaches for ballast water treatment.
The ballast water management options currently required by many Port States are the "non discharge of ballast water" and the "exchange of ballast water in deep ocean" operations. The shipping industry is co-operating in the preparation of a Convention on Ballast Water Management and requests that standards need to be included in the Convention regarding the safety and environmental efficacy of all ballast water management options. It also seems necessary that an approval mechanism be devised, regarding human health and environmental safety aspects of physical and chemical ballast water treatment options on board ships.
There are currently world-wide industrial and scientific institutions which have recently started to develop treatment techniques for future application on land as well as onboard ships with the aim to minimise the transfer of aquatic organisms and pathogens with ballast water and associated sediment. Whilst the scientific basis of a number of treatment options have been developed and documented, comprehensive testing for the application aboard ships of most chemical and physical treatment options and the efficiency of combined techniques have not been carried out and evaluated. The economic viability and safety measures regarding personnel on board ship and the long term environmental impacts of most treatment options have to be demonstrated through co-operative efforts involving the scientific community and industry.
Deliverables: A consensus report on suggested and/or recommended interim guidelines for ballast water treatment.
For more information click here.

3.5 Identification of research priorities (including general recommendations of the CA)

Responsible persons: All CA partners
Objectives: Development of joint research programmes on methodological and other aspects, for example, distribution mapping (time series) of introduced and invading species, their interaction with native species, the feasibility of target species lists, the development of expert ballast water management systems, the need for treatment research were all separately evaluated. Numerous problems related to sampling techniques and sampling strategies were specifically addressed. Both regular and ocean-going workshops helped to generate many recommendations on how to deal with these problems in future research and how to better advise management towards environmentally sound and effective solutions to the problems. A summary of research needs and priority subjects areas are given together with their justification. These are based on an overall evaluation of world-wide activities in this area.

Deliverables: A list on recommended research priorities. The Nordic Risk Assessment Study was prepared with support from the Nordic Council of Ministers and the BMB NEMOs in conjunction with and as a contribution to the CA. The report was completed in 1998 and is available as a published book via the Nordic Council of Ministers, Copenhagen, Denmark.
Gollasch, S. & E. Leppäkoski (1999): Initial risk assessment of alien species in Nordic coastal waters. 1-124. In: Gollasch, S. & E. Leppäkoski (eds.) Initial risk assessment of alien species in Nordic coastal waters. Nord 1999: 8. Nordic Council of Ministers, Copenhagen. 244 pp.
As members of the CA group, both authors of the report linked the two studies closely together. In chapter 18 (page 103 and following pages) gaps were identified where further research is needed.
For more information click here.

3.6 Public awareness

Responsible persons: S. Gollasch and all CA partners
Objectives: The importance of ballast water as a means for affecting aquatic ecosystem stability and modifying biodiversity was not generally appreciated either by the public at large or by the shipping industry or regulatory authorities except the IMO. Through press releases, flyers and posters to the mass media, the CA created a more realistic focus on the essential environmental concerns that relate to ships' ballast water, sediment and hull fouling. The list of activities (poster presentation, lectures, reporting etc.) of the participants during the CA is impressive and is documented in appendix. Furthermore, the scientific community was informed through general articles, jointly prepared by participating partners, for example through newsletters and annual meetings such as ICES, BMB and other national, regional and overseas events. Scientific results of the intercalibration exercises and other scientific findings are being prepared for publication in peer reviewed scientific journals.
Deliverables: These include: video documentation of the intercalibration experiment and sampling of ships passing through the Kiel Canal. Public awareness material, which was distributed widely, including a leaflet, flyer, press releas**es**, articl**es** to newsletters of International Aquatic Societies, Internet homepage, poster**s,** and the case histories book listing species previously introduced to European waters. A background report for the GEF- Project: Removal of Barriers to the Effective Implementation of Ballast Water Control and Management Measures in Developing Countries developed by S. Gollasch benefited also from the expertise gained during the strategic think tank activities of the first CA workshops in 1998.
For more details click here.

3.7 European waters as a donor area

Responsible persons: All CA partners
Objectives: Within Europe, some port regions may be at greater risk from ballast water introductions in account of the volume of ballast released, local topographic features or aquaculture activities, etc. Conversely, overseas port areas may be at greater risk from the introduction of some European species. European waters may also be a donor area for the transport of organisms even within the same country (e.g. Mediterranean Sea and Atlantic Ocean, North Sea and Baltic Sea). European waters can be a significant donor of species transported by ships elsewhere.
Deliverables:
Europe
A **Nordic Risk Assessment Study**, was launched to evaluate whether aquatic resources in Nordic countries are at risk and vulnerable to invasions by non-indigenous species. Nordic

marine areas are particularly sensitive to the introduction of non-indigenous organisms, many of which have potential to cause, large-scale environmental problems (disruption of biodiversity in particular); and/or whether economic effects, ecosystems and indigenous species were particularly sensitive to the impact of non-indigenous species. A calculation of economic losses due to the impact of non-indigenous species and prerequisites (e.g., salinity and temperature conditions, availability of habitats, turbidity, eutrophication, pollution) were carried out and probabilities of selected harbour areas to act as receivers and / or donors were quantified in relation to survival probabilities of non-native species. Studies of existing vectors in selected, international harbours, including harbour profiles with regard to import / export of ballast water (i.e. a origin / destination profile for imported / exported ballast water) were undertaken together with suggestions of measures and strategies to be employed with a view to tackling the problem and the need for further research, and suggestions concerning monitoring activities. The Nordic Risk Assessment Study was prepared in conjunction with and as a contribution to the CA. The report was completed in 1998 and is available via the Nordic Council of Ministers, Copenhagen, Denmark. Both authors of the report (S. Gollasch and E. Leppäkoski) as members of the CA group linked the two studies closely together. In chapter 15.5 (page 82 and following pages) Nordic waters were considered as donor areas listing probable transport mechanisms and a selected number of species of concern. Further expertise to the Nordic Risk Assessment Study was given by the authors of the port profiles, prepared under the supervision of the CA members E. Leppäkoski, I. Wallentinus, H. Botnen and S. Olenin.

Gollasch, S. & E. Leppäkoski (1999): Initial risk assessment of alien species in Nordic coastal waters. 1-124. In: Gollasch, S. & E. Leppäkoski (eds.) Initial risk assessment of alien species in Nordic coastal waters. Nord 1999: 8. Nordic Council of Ministers, Copenhagen. 244 pp.

Australia

A list of target species representing high risk species, compiled by **Australian** scientists and authorities is in preparation. From a ballast water management perspective, the capacity to rapidly screen ballast water samples and identify target species is crucial. Delaying the unloading of a vessel while testing is undertaken is likely to be costly to the shipper and may cause major scheduling problems for port authorities. Ideally therefore, a testing or screening procedures should be: quantitative; suitable for use by non biologists outside a laboratory setting; and rapid (a turn round time of less than 3 hours). Currently there are no screening or testing procedures available that meet these requirements.

North America

Information on **North American** target species is available at the internet site of The Nature Conservancy entitled "America’s Least Wanted: Alien Species Invasions of U.S. Ecosystems" (http://www.consci.tnc.org/library/pubs/dd/toc.html). Many species end up in the USA as accidental stowaways, having hitched a ride in mail, cargo, ballast water, or even by slithering into aircraft landing gear. With expanding global travel and trade, opportunities for such unwanted guests are only increasing. The Congressional Office of Technology Assessment found that about 15 percent of non-native species do cause severe harm to the US economy or ecology. Safeguarding the United States' natural heritage from harmful non-indigenous species requires work on four fronts: 1. Prevention of Additional Introductions, 2. Early Detection and Eradication of New Pests, 3. Control and Management of Established Problem Species, and 4. Protection and Recovery of Native Species and Ecosystems. The "**Dirty Dozen**" is a gallery representing some of America's least wanted non-indigenous species. Although these 12 intruders differ from each other in many ways, all share a common trait: they spell trouble for the native species and ecosystems. The "Dirty Dozen" were chosen by the nature Conservancy in 1998, for this dubious distinction because they exemplify the worst of a bad lot. The species profiled here depict an array of different organisms (plants and animals), a variety of ecological systems (terrestrial, freshwater, and marine), and a wide geographical range-from Hawaii to Florida, and Maine to California: Zebra Mussel, Purple Loosestrife, Flathead Catfish, Tamarisk, Rosy Wolfsnail, Leafy Spurge, Green Crab, Hydrilla, Balsam Wooly Adelgid, Miconia, Chinese Tallow and Brown Tree Snake. It is important to note that all non-indigenous species are believed to be potentially harmful. Every import should be assumed harmful in the beginning until shown to pose a low risk. Therefore the target list approach of unwanted species needs critical consideration. It was concluded that another list of species listing introduced species with low impacts is needed.

It was concluded by the CA group that these kind of target species lists are only of limited help in order estimate future severe species introductions.

For more details click here.

3.8 Documentation of European studies on ships and introduced species in the past

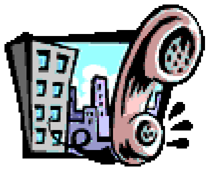
Responsible persons: All CA partners

Objectives: During the CA, all participants provided 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 a database to be kept by the co-ordinator.

Deliverables: List of references, providing full citation and - as far as possible - contact addresses where originals are deposited. Summary of past desk studies and ship sampling programmes carried out in European and non-European countries

For more details click here.

4 Conclusions and recommendations



The CA took advantage of numerous international and inter-governmental activities related to ballast water issues. Thus, virtually all the presently available ballast water expertise from around the world participated in one or more of the activities of the CA and greatly assisted in providing new results, while contributing valuable ideas and priority arguments which helped the CA-partners to formulate the following recommendations:

1) **Recommendation:** Studies should be supported to improve understanding of real survival, viability and behaviour of species in ballast tanks.
2) **Recommendation:** Sampling techniques using nets and pumps need to be improved and diversified.
3) **Recommendation:** A comprehensive re-evaluation of the vast amount of data collected in studies undertaken by CA partners and by associated participants from other counties should be undertaken to gain a further understanding and interpretation of community changes and behaviour of organisms in ballast tanks during voyages. This could be undertaken by a new EU project or CA.
4) **Recommendation:** It is recommended that a land-based (large-mesocosm) project be promoted in order to test and compare environmentally acceptable, cost-effective and save ballast water treatment options in fully controllable systems.
5) **Recommendation:** The initial studies using baited traps and light sticks showed promising results; further studies with improved equipment should be strongly encouraged.
6) **Recommendation:** Ballast water exchange strategies should be developed to designate exchange areas not only based on biological criteria but also according to operational situations (e.g. routing, length of trip, geographical area coverage, ports of call within and outside these areas).
7) **Recommendation:** Better designed and extended mid-ocean exchange methodologies should be developed.
8) **Recommendation:** Modelling and onboard studies on hydrodynamics in ballast tanks should be undertaken to improve the understanding of mixing characteristics and avoidance response of organisms.
9) **Recommendation:** Ship designers and engineers should incorporate the results of studies on hydrodynamics and species' behaviour in order to improve ballast tank design in support of either (a) better water renewal effectiveness during mid-ocean exchange, and (b) more effective mixing while treating ballast water.
10) **Recommendation:** Further studies on standardised methodologies for data analysis of ballast water (considering past, present and new sampling methods as requested under rec. 2 and 5) as well as for assessing the efficacy of onboard treatment options are requested to be further carried out by the membership of the CA for inclusion in legally binding treaties which are currently being prepared.
11) **Recommendation:** The members of the CA should provide guidance to port State authorities for their development of risk assessment systems and this should be done in close co-operation with the IMO/UNDP/GEF project.
12) **Recommendation:** It is required that the public awareness campaign undertaken by the CA be expanded into a project that deals on an European scale with aquatic exotic species in general (e.g. by establishing an online GIS) while also updating and expanding the existing case history studies published by the CA.
13) **Recommendation:** Further studies on exotic species management should include investigations of hull fouling and ballast sediment as well as ballast water.
14) **Recommendation:** Port studies should be initiated to document and evaluate the effects of pollutants, e.g. TBT, on the settlement of exotic species.

As a result, CA-partners and other scientists from EU-member countries have formulated and submitted project proposals to the EU Framework V programme. It is hoped that the recommendations given will assist the EU in making the right decisions related to ballast water management and monitoring. It must be recognized that a sound scientific basis for management is urgently needed, and those developing the know-how appreciate the important regulatory and commercial consequences as a result of the rapidly increasing globalization of economies and the increase in economic, social and environmental processes in the coastal zone.

It is finally recommended that the EU takes advantage of the now well developed expertise within the network of the CA partners in order not to lose the momentum in an area which is now already looking for global solutions.

This contribution may be cited as:
Rosenthal, H.; Gollasch, S. & M. Voigt (eds.) 2000: Final Report of the European Union Concerted Action "Testing Monitoring Systems for Risk Assessment of Harmful Introductions by Ships to European Waters" Contract No. MAS3-CT97-0111, 72 pp (incl. various appendices).

Back to “Objectives”.

Appendix 1
Deliverable 1 Case histories

Studying and comparing case histories of species previously introduced through ballast water and/or hull fouling into European waters. Existing literature on non-native species or ballast water research was consulted. During the first CA meeting a case history format was elaborated and 11 species have been chosen ranging from unicellular algae to fish. The case histories provide background information for both the scientific and non-scientific communities. The case history format may serve as a prototype for a European database on harmful invasive species. The book on selected case histories includes details on the following species: **Flora**: *Coscinodiscus wailesii*, *Gyrodinium aureolum*, *Undaria pinnatifida*, and *Sargassum muticum*. **Fauna**: *Balanus improvisus*, *Crepidula fornicata*, *Dreissena polymorpha*, *Eriocheir sinensis*, *Ensis directus*, *Marenzelleria viridis*, and *Neogobius melanostomus*.

The hyperlinks above refer to more detailed information attached as Word files in the folder “Case Histories”.

Back to relevant section in “Final Report”.

Appendix 2
Deliverable 2 Intercalibration of ship sampling techniques

Before the ocean-going workshops were initiated it was decided to intercalibrate the ballast water sampling methods used by the partners within the European group during the first intercalibration workshop (summer 1998). To confirm the previous results and to refine the initial Helgoland exercise, a second intercalibration workshop was held in January 1999 to compare ballast water sampling techniques on a **world-wide** basis.

The intercalibration workshops consisted of two parts. The first part was a land-based experiment at the marine station on Helgoland (German Bight) and the second part, a mini symposium on recent results of shipping studies and other related activities of all participants (see numerous appendices) was held at the Institut für Meereskunde in Kiel, Germany. After the mini symposium, a container ship passing through the Kiel Canal was accompanied. Various techniques were employed for the sampling of one ballast tank on board the selected ship in order to compare the practicability of the methods *in situ* during the 7 hour ship's passage through the Kiel Canal.

Based on the results of the first intercalibration workshop, the second workshop on Helgoland allowed development of a more detailed and structured sampling design that permitted the simultaneous and consecutive testing of a variety of ships' ballast water sampling techniques. In particular, the use of a "reference net" between the application of each tested sampling method and an increased number of replicates improved the quality of the outcome compared to the previously undertaken intercalibration workshop. Once again, the exercise demonstrated the overall high variability between and within methods and the virtual impossibility to obtain a complete picture of the taxa that are present in ballast tanks. At best, the outcome of this exercise documents the option to operate with a known level of error between methods, thereby allowing some comparability among research teams.

Net design

The variability of results between tested nets is in part due to their individual design. There was consistently a low efficiency in nets having a high canvas area in relation to the filtration area. In addition, the design of the cod-end on some nets potentially reduces their efficiency. Some nets have a sample bottle that can be attached to and removed from an internal fitting in the net. A thicker, stronger layer of net or canvas wrapped around the fitting is usually attached via an external clip. An area between the fitting and the thicker layer of net may trap water and results in organisms not being included in the sample. There is also potential loss of organisms when removing an bottle that is not fitted with filtration panels on its side, which creates water overflow. In addition, ensuring good rinsing of the net into the sample bottle may be problematic and involves emptying the bottle and re-rinsing the net. Cod-ends that are incorporated into the net and allow the water to flow out enable more efficient rinsing and therefore greater efficiency of sampling. Therfore, it is recommended that the cod end of a net should be made of a cup with filtration panels on its side and, if possible, a tap at the base of the cup. If the cod end is metallic no additional weighting is required to sink the net and this will reduce the risk of entanglement in structures in the ships ballast tanks.

Cone-shaped nets were the most effective nets in terms of number of specimens and number of taxa collected. Such nets are recommended in future ballast water studies. Nevertheless the cone-shaped net will not capture all taxa and would still lead to an underestimate of diversity. Paired nets (bongo nets) for sampling were not considered because these are likely to be lost during employment due to snagging. Although the 55 µm cone-shaped net was found to be the most effective, when targeting larger plankton species, a larger mesh-size and larger net diameter is desirable. Larger organisms may also be sampled by the use of different collecting methods, such as light traps or baited traps.

In order to increase the likeliness of catching more taxa methods filtering larger volumes of water should be preferred to methods sampling small amounts of water.

In this study the mesh-size was not the limiting factor in the sampling of the test organisms (*Artemia salina* and oyster larvae). However, mesh size in relation to the taxa to be selected is an important component of design. In the case of general studies phytoplankton nets with mesh sizes of 10 µm would include many harmful algal species including dinoflagellates and cysts of some species. For zooplankton nets a size of 55 µm would allow capture of the youngest stages of molluscs and Crustacea as well as many other taxonomic groups commonly found in ballast water, including larger phytoplankton taxa.
Equipment deployed in ballast tanks may become easily snagged on the structural support frames and ladders. Therefore, nets with a small overall length and diameter of about 25 cm may perform better when attempting to capture a wide range of species.

Pumps
Sampling via sounding pipes can only be undertaken by pumps. Some pump systems are unable to lift water from more than 7 meters depth. Consequently ballast tanks with low water levels or deep location within the ship are unlikely to be sampled at all. The only pump being able to sample deep tanks is the Australian Water pump with a tube. The pump can only be operated if the sounding pipes are straight enabling to lower down the hose. Practicabilities of sampling are greatly impeded by the heavy equipment required to sample. Another restriction is that the Australian pump needs a power supply not available or not permitted to use on board several ships. A good compromise seems to be the German hand-pump, but this pump cannot be operated in depths greater than 9 meters. Further considerations should include requirements of special ships. Petroleum, gas and oil carriers will all have regulations which do not permit electrical or petroleum engines to operate pumps. Some novel techniques, yet to be developed, that have higher efficiencies and are easily carried will be needed.

Recommendations for future intercalibration experiments

- The lack of cultured zooplankton in sufficient number for spiking the test plankton tower enabled a quantitative comparison only. Future workshops should aim to provide the qualitative results from different zooplankton sampling techniques for comparison. It is recommended to use *Artemia salina* and oyster larvae in future tests to compare the results with those from the recent intercalibration workshop while also involving additional species, such as mysids, *Brachionus* sp, fish eggs and fish larvae in order to cover taxa of different sizes and escape responses during sampling.
- In order to minimize the human error in pulling up the nets to the surface it is recommended to use a block and tackle or a similar device to pull up all nets at a known and fixed speed.
- The number of replicates should be increased to a minimum of seven and if possible a larger water body should be sampled. Although the test plankton tower was relatively large, sampling effects (e.g. thinning out effects) occurred with a great number of techniques employed.
- During the phytoplankton trial at the south port of Helgoland there was so much sampling going on in a limited area and at the same time that the whole activity might have influenced the result. It is believed that natural water currents in the harbour were able to renew the water

body that was sampled between each replicate. Sampling of a plankton tower would solve this problems.

- To minimize the unwanted distributional patchiness of organisms in the water body of the plankton tower, an appropriate mixing technique should be guaranteed. The selected technique should be efficient in mixing the entire water column without inducing the destruction of organisms.. It is likely that the mixing rate of 60 L/min was not sufficient in this experiment.
- The test tanks volume was 5.3 m³ and it is recommended to use a larger volume tank for additional experiments. Advantageous was the design of the plankton tower with a funnel shaped bottom. The pump was connected to the very bottom of the funnel and in this way the sedimentation of organisms in the tank was minimized.

Recommendations for ongoing and planned shipping studies

- Ballast water projects currently underway should consider using the recommended methods tested by the CA and if possible should compare these alongside with their own methods and sampling results.
- The techniques used for sampling will vary according to the configuration of the ballast tank being sampled and the size and the design of the ship. The most effective equipment will consist of easily transported components. Unfortunately it is meritable that ballast water sampling by using any of the methods employed will not representatively sample the organisms in the ballast water. An understanding of the behaviour of organisms may depend on the distribution of some organisms, such as algae. Future observations should consider the use of fluorescence standardized against chlorophyll levels at varying depths with each sampled ballast tank.

Recommended phytoplankton sampling gear

The tool box of sampling techniques should include methods that combine qualitative and quantitative sample analysis for phytoplankton composition and abundance. In light of this the overall suitability characteristics of the equipment tested can be summarized as follows:

(a) **Australian pump** operated via **sounding pipes** was the best pump in **qualitative** sampling trial. It was the only sampling technique being able to sample water from the bottom of deep tanks and e.g. double bottom tanks. Restrictions of its use: power supply needed (not always available on board or not permitted to use). Samples need to be concentrated by using a net.

(b) **German pump** operated via **sounding pipes** and **manhole** was the best hand pump operated via sounding pipes of all **qualitative** samples. The pump is light-weight, easy to apply and may sample depths < 9 m. Samples need to be concentrated by using a net.

(c) **Scottish Monopump** operated via **sounding pipes** and **manholes** was the most effective of all methods in **quantitative** sampling trial, but it heavy and cumbersome to employ. The sampling depth is > 9 m.

(d) **German cone-shaped net** (10 µm) operated via **manholes** was the best of all methods in the **qualitative** sampling trial, and

(e) **Ruttner sampler** operated via **manholes** showed similar **quantitative** effectiveness as the Scottish Monopump, but it is able to sample (small amounts of) water from greater depths and is of light-weight. An advantage of using the Ruttner is that the sample is not squeezed through a plankton net or pump resulting in less damaged organisms caught. This might enable easier taxonomic species identification.

It is recommended to use the smallest mesh-size available. It is obvious that larger mesh-sizes will exclude smaller species and therefore will have lower species richness relative to nets

with larger mesh-sizes. Many of the organisms causing harmful algal blooms (target species in ballast water research) are very small.
The type of pump would depend on the access and permission of equipment to use on deck, but access may not be the only aspect to consider, however.

Recommended zooplankton sampling gear
Taken the most common scenarios into account which have been experienced during this study, the following sampling techniques can be recommended for zooplankton recovery in ballast tanks and should become a common option within the "tool box" of sampling methods:
(a) **German cone-shaped net** operated via **manholes** was the most effective of all methods in **quantitative** sampling trial. The relatively short net is unlikely to become stuck in ballast tanks (length <1 m). Easy handling due to valve equipped cod-end with filtering capacity.
(b) **Australian Waterra pump** operated via **sounding pipes** shows similar **quantitative** effectiveness to German cone-shaped net (see above), however power supply is needed to operate the pump and may face difficulties in some instances. It is the only method to sample water from the bottom of deep tanks e.g. double bottom tanks.
(c) **German pump** operated via **sounding pipes** and **manholes** was the best manual pump of all **quantitative** samples. The pump is easy to apply, comparatively light-weight and therefore easy to transport and handle. The maximum sampling depth is 9 m.
(d) **Scottish pump** operated via **sounding pipes** and **manholes** is recommended to use, if required sampling depth is higher than 9 m and the Waterra pump cannot be used due to the lack of power supply, and
(e) **Chinese cone-shaped net** operated via **manholes** was the second effective net method in the **quantitative** sampling trial. The relatively long net may easily become stuck in ballast tanks (length >2 m). Easy handling due to valve equipped cod-end.

The CA Group welcomes any advice or comments that may help develop the standardization of sampling methods further. Other groups involved in ballast water sampling are invited to attend future land-based and ocean-going workshops of the CA to further improve the compatibility of sampling methods.

Press hyperlinks to get access to the attached more detailed report of the
1st Intercalibration Workshop
2nd Intercalibration Workshop
saved in the folder "Meeting reports" as ICW1_CA3_Helgoland_98.doc and ICW2_CA7_Helgoland_99.doc.
A video on the 1st Intercalibration report is available in the folder "Video" (file name: CA_Video_1.mov)

Back to relevant section in "Final Report".

Appendix 3
Deliverable 3 Survival rates of organisms in ballast water tanks during voyages (ocean-going workshops)

The purpose of the Ocean Going Workshops (OGW) within the CA was to examine the survival and diversity of organisms in ballast water and to compare different methods of sampling ballast water. In addition the effect of mid ocean exchange (MOE), which is recommended as a measure against unintentional introduction via ships, was studied.

The data was obtained during five OGW, which were undertaken both in European waters (OGW 1, 2 and 5) and during inter-ocean voyages (OGW 3 and 4) onboard ships of different type: research vessels, an oil tanker and container vessels (Table 1, Figure 1). In total, about 700 samples were collected over more than 100 days at sea (Table 3).

The hyperlinks below connect you to the detailed workshop reports attached (files also available in the folder “Meeting reports” – file names indicated in brackets.

The **first** OGW (OGW1_CA4_Lisbon_98.doc) was undertaken in July-August 1998 onboard a Russian Navy hydrographic ship, "Sibiryakov" (DWT 3442 t, length 86 m, draught 5 m, built in 1990). The cruise was organised by the Russian State Hydrometeorological University (St. Petersburg) within the framework of the IOC-UNESCO sponsored "Year of the Ocean" research and educational program. This voyage covered intercontinental waterways from the Baltic Sea to the Atlantic coast of Europe (Portugal).

The **second** OGW (OGW2_CA6_Cork_98.doc) was carried out in October 1998 onboard the Norwegian oil tanker "Nordic Torinita" (DWT 108683 t, length 244 m, draught 15 m, built in 1992) from Cork, Ireland to Sture, Norway, crossing the Irish Sea and the North Sea.

The **third** OGW (OGW3_CA9_Taiwan_99.doc) was carried out in May-June 1999 onboard the German container vessel "Pusan Senator" (DWT 63654 t, length 294 m, draught 13, built in 1997). The voyage was from Kaohsiung, Taiwan via the South Sea, Malacca Strait, the Indian Ocean, the Red Sea, the Mediterranean, the Bay of Biscay and the North Sea to Hamburg, Germany.

The **fourth** OGW (OGW4_CA10_Auckland_99.doc) was carried out in May-June 1999 onboard the British container vessel "Mairangi Bay" (GWT 43674 t, length 239 m, built in 1977) from Auckland, New Zealand to Hamburg, Germany via the South Pacific Ocean, Atlantic and the North Sea.

The **fifth** OGW (OGW5_CA11_BlackSea_99.doc) was carried out in September 1999 onboard the Ukrainian hydrometeorological research vessel "Georgij Ushakov" (DWT 1420 t, length 101 m, draught 5 m, built in 1970) during the IMO Workshop on Ballast Water Management and Control (Odessa-Constanca-Varna-Odessa) in the Black Sea.

The capacity of the sampled ballast tanks varied in the range from 11 t to 3393 t and the duration of sampling in one ballast water tank ranged from 1 to 17 days. The parameters measured and the methods are listed in Table 2.

Table 1. Ocean going workshops. Origin of ballast water is either from port (no symbol); exchange at sea or in port (*); mid-ocean exchange (**).

Dates	Vessel	Origin of ballast water	Duration of sampling (days)	Number of ballast water tanks sampled
July 22 - August 28, 1998	Sibiryakov	St. Petersburg area, Russia	4	1
		Northern Baltic (*)	11	1
		Strait of Dover (*)	14	1
		Strait of Zund (*)	4	1
Oct 8 - 11, 1998	Nordic Torinita	Cork, Ireland	2,5	3
May 16 - June 28, 1999	Mairangi Bay	Auckland, New Zealand	1	1
		Port Chalmers, New Zealand	14	1
		Santos, Brazil (*)	17	1
		South Pacific (**)	1	1
May 21 - June 14, 1999	Pusan Senator	Kaohsiung, Taiwan	2	1
		Hong Kong (*)	3	1
		Hong Kong (*)	9	1
		Singapore (*)	6	1
		Indian Ocean (**)	15	1
		Indian Ocean (**)	5	1
		Roads of Suez (*)	7	1
		Bay of Biscay (**)	1	1
		Le Havre, France (*)	1	1
		Rotterdam, the Netherlands (*)	2	1
Sept 14 - 17, 1999	Georgij Ushakov	Odessa, Ukraine	2,5	2

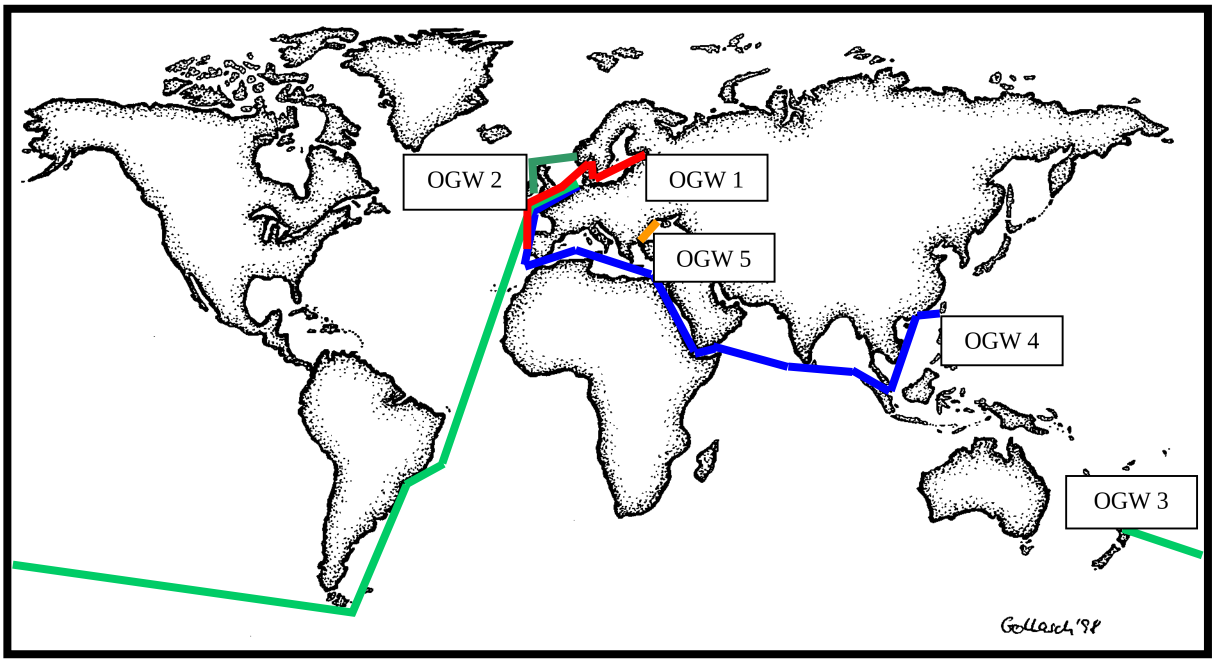


Figure 1. All CA ocean going workshops undertaken in 1998-1999. OGW 1 = St. Petersburg – Lisbon, OGW 2 = Cork – Sture, OGW 3 = Auckland – Santos – Hamburg, OGW 4 = Kaohsiung – Hongkong – Singapore – Hamburg and OGW 5 = Odessa – Varna – Constanta.

Table 2. Parameters measured and sampling methods applied

Parameters	**Methods**	**No. of OGW**
Temperature	Thermometer	1,2,3,4,5
Salinity	Conductivity meter	1,2,3,4,5
Oxygen	Titration (Winkler) method	1,5
pH	Standard pH meter	1,3,5
Nutrients	Spectrophotometer	1
Suspended matter	??	2
Phytoplankton	Hand pump Ruttner water sampler Bucket Integrated hose sampler	1,4 2,3 1,5 4
Zooplankton	Plankton nets Trap Hand pump Bucket	1,2,3,4,5 2,3 1,2,3,4 1,2,3

RESULTS

Abiotic factors

The temperature of ballast water in the tanks was similar to that of the surface seawater. Changes in seawater surface temperature were generally followed by a change in ballast water temperature with a short delay.

Salinity of ballast water remains stable. Measurement of salinity in the ballast tanks following exchange with water of known salinity indicated that there was a residual amount of ballast water in the tanks that was not exchanged.

Oxygen measurements showed a tendency to decline with time, but levels remained well above those required by marine organisms.

The pH varied between 6.18 and 8.09. The changes may have been related to microbial activity and ballast water exchanges, but could not be correlated with any other observations made.

Concentration of nutrients in ballast water was initially similar to that of the seawater pumped into the tanks. There was a steady decline in concentrations of nitrate, nitrite and phosphate. In some cases concentrations fell to below detectable levels after a few days. This may also be related to microbial activity.

The volume of total suspended sediment in the water column largely reflected the wind speed. After 8 hours of subsequent calm weather the majority of suspended material settled out of the water column. Subsequently, any rough weather conditions encountered were sufficient to re-suspend sediment throughout the water column.

Many of the biological samples collected are still being processed (Table 3). However, some preliminary results are available.

Table 3 - Sampling equipment and number of samples collected.

Method	OGW 1	OGW 2	OGW 3	OGW 4	OGW 5	Total	% of total
Ruttner Water Sampler		8	65			73	10,5
Bucket	21	11	11		5	48	6,9
Hand pump/man hole	11	23*	11	56		101	14,6
Hand pump/sounding pipe	36		10			46	6,6
Integrated sampler (hose)				28		28	4,0
Ballast pump				72		72	10,4
20-30 µm n e t		8	65			73	10,5
55 µm net		8	61			69	10,0
55 µm cone net	21	8	65	28	8	130	18,8
62 µm net				28		28	4,0
68 µm net		5				5	0,7
Traps			20			20	2,9
Total	89	71	308	212	13	693	
% of total samples	12,8	10,2	44,4	30,6	1,9		
Duration of OGW (days)	31	4	27	44	4	110	

Phyto- and zooplankton

More species and specimens were found in new ballast water, and communities were in general similar to outside seawater. The highest number of phytoplankton species found was 52, including several potentially toxic species. At most, 40 zooplankton taxa were found in the initial samples. Abundance and diversity of phyto- and zooplankton species is fairly stable for 3-4 days, followed by an exponential decline. In some cases no living zooplankton were found after 9 days, in other cases about 10% of the taxa survived remained viable for 25 days, on the voyage from Hong Kong to Hamburg. Sampling methods showed that in calm conditions phytoplankton exhibited vertical zonation. The layers became disrupted during rough weather and this was then associated with an increase in mortality.

For the first time in ballast water studies, traps using bait and light as attractants were deployed for sampling zooplankton. Taxa not seen in the net samples were identified in trap samples.

Ballast water exchange

There were two mid-ocean exchanges (OGW 3). In one, in the Indian Ocean, the abundance and diversity of zooplankton increased. The other mid-ocean exchange, in the Bay of Biscay, resulted in decreased abundance and diversity. The age of the ballast water was about the same (5-6 days) in both cases.

Some species were found in samples both before and after the supposedly complete exchange of ballast water. The decline of living marine organisms in the ballast water samples taken after the MOE was similar to that described above.

Comparisons of sampling methods

In rough weather and on smaller vessels it is sometimes only possible to take samples through sounding pipes. Comparison of samples taken at the same time from manholes and through sounding pipes showed significant differences for zooplankton. The effectiveness of different net types was also compared and differences were found, which reinforced the information obtained in the Intercalibration workshops, that the most appropriate method will depend on the type of vessel and organisms of most interest and that a toolbox of methods should be available.

CONCLUSIONS

A lot of valuable data have been obtained during the five ocean going workshops. It has not been possible to process all the samples collected and thus to collate and analyse all the data from these workshops. The eventual completion of this task will add to the above information. It is also recommended that the full data sets from these and other similar studies are collated and re-evaluated in the light of the knowledge gained from ocean-going workshops and Intercalibration exercises.

Some conclusions are made, as follows:

1. Mortality of marine organisms in ballast water tanks is variable and some taxa can survive prolonged periods. Some algae, particularly toxic dinoflagellate species, have the ability to form cysts in ballast water sediments, overcoming unfavourable conditions and remaining viable for long periods. Thus, although the risk of introductions from discharge of ballast water may be minimised over longer voyages, it is not removed completely.
2. Although ballast water exchange is the currently recommended management method the results have shown that this will not necessarily reduce the abundance and diversity of marine organisms in ballast tanks. In some cases the same types of organisms are found in greater numbers following exchange, due to either re-suspension of residual water during exchange and/or improvement in water quality with the input of new sea water.

3. Further studies are needed to obtain a better understanding of changes in biota in ballast water tanks with changing conditions (including exchange) over time. These studies should include:

   A The survival and physiological condition of organisms, and the effect of the latter on viability, with changes in abiotic conditions.

   B. Further investigations on effect of exchange on abundance and diversity of organisms under varying conditions of ambient salinity and temperature.

   C. The microbiological activity and chemistry of ballast water.

   D. The deployment of alternative sampling strategies, including traps, and development of new methods.

   E. Studies on the fouling of tank walls, and the role of biofilms in the introduction of exotic species in ships' ballast water.

   F. Further studies on species in ballast water sediments.

   G. Modelling studies of interactions between the numbers and types of different species in ballast water over time and under various conditions, including exchange.

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Appendix 4
Deliverable 4 Assessing potential control measures (treatment) to reduce the risks arising from ballast water releases

In 1997, guidelines for the control and management of ships' ballast water to minimise the transfer of harmful aquatic organisms and pathogens were adopted by IMO Assembly Resolution A.686 (20). That resolution also requested governments to take urgent action in applying the guidelines and to use them as a basis for any provisions they adopt to minimise the risks of transferring species. It further requested IMO to develop legally binding provisions in this regard. An "International Convention for the Control and Management of Ships' Ballast Water" is being developed for adoption by a Diplomatic Conference in 2002.
The Convention will be accompanied with a technical annex ("regulations") including operational requirements and a "ballast water management code" providing details of ballast water management options. The exchange of ballast water in deep ocean areas is the only option practised so far and this has raised general concern in the shipping industry with respect to safety aspects during poor weather etc. Other options identified and considered within the CA Project are set out in the following section.

A. Uptake and treatment technology options

Uptake and treatment technology options can be applied during different stages of ballast water operations as follows:

on or before departure from port of ballast water uptake
on departure or during the voyage between ports
on arrival at ballast discharge port

1. On or before departure from port of ballast water uptake:
   water supply uptake:
   - special shore-based facilities provide treated salt or fresh water

   minimising organisms intake:
   - ships avoid ballasting in global "hot spot" areas
   - ships avoid ballasting in waters with high sediment loads
   - ships avoid ballasting in areas of sewerage discharges or known human disease incidents
   - ships avoid ballasting at night
   - ships are installed with mechanical filtration, hydrocyclones systems.

2. On departure or during the voyage between ports:
   extermination of organisms :
   - altering water salinity e.g. by adding freshwater to saltwater
   - optical: ultraviolet treatment
   - acoustic: ultrasonic treatment

   active disinfection:
   - tank wall antifouling coatings
   - oxidising agents / chemicals
   - biocides

   physical techniques:
   - thermal treatment
   - electrical treatment (including microwave)
   - filtration/ultraviolet/ultrasonic treatment

   technical procedures:
   - exchange of ballast water in deep waters (deballast/reballast)

3. On arrival at ballast discharge port
discharges to shore reception facilities, reception vessels or sewage treatment facilities
sediment removal and disposal ashore
non-release of ballast water

B. The technology and treatment options for onboard applications are briefly described as follows:

Filtration techniques: are widely used in industrial and municipal applications. Filtration systems for use onboard ships are being tested in a number of countries. Periodic cleaning of the filter systems is achieved by automatic backflush systems.

Hydrocyclones: are in use onboard ships for oil/water separation. Specific systems are being developed to separate organisms and particles from ballast water.

Ultraviolet treatment: is a well developed treatment option for destruction of cellular components. Wavelengths of around 200 nm are being used in test systems.

Ultrasonic treatment: causing cavitation in ballast water and resulting in mechanical stresses which disrupt cells.

Tank wall antifoulings: antifouling coatings on walls minimise biofouling by toxicity and ablation.

Chemical treatments: oxidising chemicals such as chlorine, ozone or peroxid formulations are used for waste water treatment, and are being tested for ballast water. Non-oxidising biocides include a wide variety of compounds used by industry e.g. for treating cooling water. Such biocides are often pesticides which may accumulate in the environment, causing a wide range of effects.

Thermal treatment: is commonly used to sterilise water. Temperatures of 40-45 degrees C for a period of 4 to 5 minutes are effective for exterminating some organisms.

Deoxigenation: oxygen can be removed from water by purging with an inert gas or by binding oxygen to chemical additives.

Current situation and future tasks

The ballast water management options currently required by many Port States are the “non discharge of ballast water” and the “exchange of ballast water in deep ocean” operations. The shipping industry is co-operating in the preparation of a Convention on Ballast Water Management and requests that standards be included in the Convention regarding the safety and environmental efficacy of all ballast water management options. It also seems necessary that an approval mechanism be devised, regarding human health and environmental safety aspects of physical and chemical ballast water treatment options on board ships.

There are currently world-wide industrial and scientific institutions which have recently started to develop treatment techniques for future application on land as well as onboard ships with a view to minimising the transfer of aquatic organisms and pathogens with ballast water and associated sediment. Whilst the scientific basis of a number of treatment options have been developed and documented, comprehensive testing for the application aboard ships of most chemical and physical treatment options and the efficiency of combined techniques have not been carried out and evaluated. The economic viability and safety measures regarding personnel on board ship and the long term environmental impacts of most treatment options have to be demonstrated through co-operative efforts involving the scientific community and industry. In this regard, the following questions have to be answered and tasks have to be carried out by the different stakeholders:

the development of ship designs which facilitate the sampling of ballast water and associated sediments, their onboard treatment and ballast water exchange at sea by one of the recognised methods (i.e. by the sequential method of emptying and refilling ballast tanks; by continuous flushing of at least 3 times the volume of the tanks; and by the dilution method through injection of ballast water from deep oceans through a main ballast line and discharge through suction pumps near the tank bottom).
The development of designs have to take account of the current knowledge of the ecology of organisms in ballast water tanks. Furthermore, a hazard rating schedule for chemicals regarding their environmental and human health effects as those recommended by OECD, ASTM, USEPA and used by GESAMP, EU and the UN agencies in the field of labelling dangerous goods should be applied.

pending the outcome of the above, it is still unknown as to whether a complete sterilisation of ballast water will be economically feasible, environmentally safe or otherwise practical. Nevertheless, a system of ballast water management and controls have to be developed with a view to minimising the risks of harmful introductions with ballast water. Such a risk assessment involves the identification of "hot spots" where the uptake of ballast water should be avoided. Risk-based approaches use quantitative risk assessment methodologies to assess the likelihood of introductions of specific target species including the assessment of economic and social implications. However, biologists currently cannot answer many questions regarding the fate of discharged organisms and the likelihood of their establishment. It is not known how many individuals of a given species or their densities, are needed to establish a viable, self-reproducing population at a new site.

taking into account the results and the outcome of developments mentioned above, standards for the safe release of ballast water into the aquatic environment have to be established by national port authorities based on guidelines that are being developed to assist in the effective implementation of provisions that are being prepared for inclusion in globally applicable as well as regional conventions.

The completion of the tasks outlined above is only achievable through co-operative action involving national administrations, port authorities, the shipping industry and scientific institutions. The development of hazard rating procedures and the evaluation of ballast water options need the involvement of a scientific advisory group which should include technical shipping expertise. This way it would be possible to design a „tool box", that accounts for different types of ships as well as for different ballast water operations (e.g. individual ballast water management plans of individual ships) or the specific needs of port and / or flag states in relation to the protection of their marine environments.

Risk assessment methodologies including the identification of target species and so-called "hot spots" and emergency ballast discharge areas are matters for national port authorities who want to protect the sustainability of national resources and legitimate activities in the sea and coastal areas under their jurisdiction.

For developing countries, the establishment of training programmes and convening of workshops is necessary, combined with the establishment of efficient infrastructures in such countries involving existing institutions. Such capacity building shall remove the barriers for effectively implementing regional and globally applicable regulations that are being developed.

C. Tables of candidate requirement options (and their ranking)

Tab. 1 Comparison of physical ballast water treatment options. ( ) = proposed but not tested for ballast water or tests in process. Explanation of symbols:

Efficiency	very good =	👍	sufficient =	✓	low =	👎
risk	low =	⬆	medium =	⬄	high =	⬇
costs compared to IMO A.868(20)	lower =	⇧	similar =	⬄	higher =	⇩
practicability	likely =	☺	questionable =	😐	unlikely =	☹

Method	efficiency	Safety & handling	environ. Risk	costs	practicability
Filtration					
granular (>1µm)	✓	⬄	⬄ to ⬇	⇩	😐 to ☹
micro (0.005-10µm)	✓ to 👎	⬄	⬄ to ⬇	⇩	😐 to ☹
reverse osmosis	👍 to 👎	⬄	⬄ to ⬇	⇩	😐 to ☹
Heat treatment	✓	⬇	⬄	⇩	😐
UV radiation	✓ to 👎	⬇	⬄	⇩	😐 to ☹
Gamma radiation	👎	⬇	⬄	⇩	☹

Tab. 2 Comparison of chemical ballast water treatment options. ( ) = proposed but not tested for ballast water or tests in process. Explanation of symbols see Tab. 1 above.

Method	Conc. ppm	efficiency	Safety & handling	environ. Risk	costs	practicability
Chlorination	100 - 500	✓	⬇	⬇	⇩	☹
Hypochlorite	8.000	✓	⬇	⬇	⇩	☹
Chlorine dioxide	(0.5 - 2)	(👍)	⬇	⬇	⇩	😐
Chloramines	NH_3 : CL 1 : 3/4	(👎)	⬇	⬇	⬄	☹
Ozon	1.000 - 2.000	✓	⬇	⬆	⇩	☹
H_2O_2	1.000 - 2.000	✓ to 👎	⬄ to ⬇	⬆	⇩	😐 to ☹
$DEGA_{xy}$	150 - 500	👍	⬄ to ⬇	⬆	⬄	😐 to ☺
Peracetic acid	100 - 2.000	(✓)	⬇	⬄	⇩	😐 **to** ☺
Glutar-dialdehyde	10 - 50	👎	⬇	⬄ **to** ⬇	⇩	☹
Formaldehyde	10.000	(✓ to 👎)	⬄	⬄	⇩	☹
Isothiazolone	100 - 5.000	(✓)	⬄ **to** ⬇	⬇	⇩	😐 **to** ☹
EDTA	100 - 5.000	(✓)	⬄ **to** ⬇	⬇	⇩	😐 **to** ☹
pH adjustment	pH 2 - 10	✓ to 👎	⬄	⬄	⇩	☹
Deoxygenation		👎	⬄	⬄	⬄	☹
Salinity adjustment		👎	⬆	⬄	⇩	☹
Coagulants		👎	⬆	⬄	⇩	☹

A background report for an GEF/UNDP/IMO Project on ballast water was prepared by S. Gollasch in 1997 and is included in the folder "GEF Project" as Word document.

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Appendix 5
Deliverable 5 Identification of research priorities (including general recommendations of the CA)

Numerous problems related to sampling techniques and sampling strategies were addressed. Both regular and ocean-going workshops helped to generate many ideas on how to deal with the problems in future research and how to better advise management towards environmentally sound and effective solutions to the problems. A summary of the most important research priorities are given as follows:

- **Recommendation:** Studies should be supported to improve understanding of real survival, viability and behaviour of exotic species in ballast tanks.
- **Justification:** Despite all the practical work carried out under this CA, our knowledge on this subject is still fragmentary. Sampling in parallel with different methods used in partner laboratories indicate that present methodologies may not adequately monitor bio-diversity and abundance in ballast tanks since many species may not be caught by the sampling procedures when distributed in areas of the tanks that are inaccessible by equipment in use. There is a need to improve net designs and to develop criteria that may be very different form conventional plankton sampling techniques.
- **Recommendation:** Sampling techniques using nets and pumps need to be improved and diversified.
  Justification: It was evident form the intercalibration exercise and from ocean-going workshops that many species may not be caught by commonly used nets and pumps. Effectiveness differs among various nets and this relates to both taxa and number of specimens. Baited traps and light sticks were used for the first time in ballast water studies and clearly showed that there are - as expected - many other species that escape our common sampling methods.
- **Recommendation:** A comprehensive re-evaluation of the vast amount of data collected in studies undertaken by CA partners and by associated participants from other counties should be undertaken to gain a further understanding and interpretation of community changes and behaviour of organisms in ballast tanks during voyages. This could be undertaken by a new EU project or CA.
- **Justification:** Following the analyses of data collected during ocean-going workshops it was concluded that there is a need to combine and re-analyse all data sets from past studies in light of our findings on the comparability of sampling techniques. This activity could serve as a forum for continued exchange of information and experience.
- **Recommendation:** It is recommended that a land-based (large-mesocosm) project be promoted in order to test and compare environmentally acceptable, cost-effective and save ballast water treatment options in fully controllable systems.
- **Justification:** This should preceded full-scale testing onboard ships as these operations are expensive and may benefit from insights gained in strictly controlled test facilities. The CA partners are fully aware of ongoing full-scale tests undertaken by various countries and industries. However, our results from ocean-going workshops are not only indicating the need for controlling primary inoculation but also secondary ones which may include unexpected sediment movements and the re-distribution of specimens hiding in certain regions of ballast tanks of different construction.
- **Recommendation:** The initial studies using baited traps and light sticks showed promising results; further studies with improved equipment should be strongly encouraged.

- **Justification:** The employment of traps in ballast tanks was undertaken for the first time ever during this CA. While many technical and legal problems hat to be overcome, we are now beginning to refine the sampling methods.
- **Recommendation:** Ballast water exchange strategies should be developed to designate exchange areas not only based on biological criteria but also according to operational situations (e.g. routing, length of trip, geographical area coverage, ports of call within and outside these areas).
- **Justification:** For example, the ocean-going workshop results indicate that traffic within Europe between inshore areas of the Atlantic and adjacent seas while moving to the Baltic, should exchange in the North Sea because the salinity stress is likely to reduce the number of living organisms transported.
- **Recommendation:** Better designed and extended mid-ocean exchange methodologies should be developed.
- **Justification:** Some evidence is accumulating that mid-ocean exchanges do not necessarily achieve objectives under all circumstances. Studies by CA members clearly indicate that (a) number of taxa may increase after mid-ocean exchange, (b) weak and near bottom settling (dying) organisms may be „revived“ by replenishment of the tank water and (c) current tank design permits effective escape and hiding response actions of organisms and prevents their removal, despite the theoretical complete exchange.
- **Recommendation:** Modelling and onboard studies on hydrodynamics in ballast tanks should be undertaken to improve the understanding of mixing characteristics and avoidance response of organisms.
- **Justification:** Organisms respond quickly to micro-turbulence and aggregate in areas with preferred or less stressful hydrodynamic conditions. Most zooplankton and meroplankton taxa will find numerous hiding places so that ballast water exchanges will not permit their removal unless tank design, ballast water intake and outlet arrangements and pumping strategies allow rapid quantitative and effective mixing. The recommended studies will enable to design better and more effective treatment methodologies through adapted ballast water tank design.
- **Recommendation:** Ship designers and engineers should incorporate the results of studies on hydrodynamics and species' behaviour in order to improve ballast tank design in support of either (a) better water renewal effectiveness during mid-ocean exchange, and (b) more effective mixing while treating ballast water.
- **Justification:** The next generations of ships are still designed by engineers that are not sufficiently familiar with aquatic life sciences to understand the importance of tank design for treatment effectiveness. So far, ship designers are concerned with engineering aspects of ship stability and safety. Awareness campaigns and training workshops demonstrating the modelling results arising from studies initiated under recommendations 8 should greatly assist in know how transfer and awareness building on environmental management issues.
- **Recommendation:** Further studies on standardised methodologies for data analysis of ballast water (considering past, present and new sampling methods as requested under rec. 2 and 5) as well as for assessing the efficacy of onboard treatment options are requested to be further carried out by the membership of the CA for inclusion in legally binding treaties which are currently being prepared.
- **Justification:** The members of the CA project comprise most relevant scientific disciplines necessary to evaluate the efficiency of ballast water treatment options as well as sampling and analysis of ballast water organisms. This potential should be utilised effectively so that the developed momentum is not lost.

- **Recommendation:** The member of the CA should provide guidance to port State authorities for their development of risk assessment systems and this should be done in close co-operation with the IMO/UNDP/GEF project.
- **Justification:** The collective expertise and knowledge assembled within the membership of the CA provides an unique opportunity and core for training as well as advisory services for regional and global organisations.
- **Recommendation:** It is required that the public awareness campaign undertaken by the CA be expanded into a project that deals on an European scale with aquatic exotic species in general (e.g. by establishing an online GIS) while also updating and expanding the existing case history studies published by the CA.
- **Justification:** The CA has provided information to the public in the form of posters, public meetings, press releases and a publication involving 11 case histories of harmful species introduced into European waters. There is a need for accurate information on exotic species and their impacts particularly when interest groups become involved and require accurate information that can be made available to all users.
- **Recommendation:** Further studies on exotic species management should include investigations of hull fouling and ballast sediment as well as ballast water.
- **Justification:** Ballast water is not the only means that exotic species become spread. Several studies have shown that sediments harbour living organisms and resting stages of planktonic species. In addition hull fouling will continue to pose a problem of exotic species transport and is likely to become of greater concern following the ban of TBT. Species associated with hull fouling includes some commercial bivalve species, and there may also transport their pests parasites and disease agents and compromise aqua culture and molluscan fisheries elsewhere. Similarly ballast sediments have been shown to certain living organisms and also warrant further investigations.
- **Recommendation:** Port studies should be initiated to document and evaluate the effects of pollutants, such as TBT , on the lack of success of settling of exotic species.
- **Justification:** The unique opportunity to use TBT as a maker of residual water flow from port regions can help to understand to what extend various toxic substances in and around harbours influence invaders success. Since the IMO have recently proposed to ban the use of TBT in ships antifouling paints by the year 2003 the novel approach of using TBT as indicator of residual drift should be utilised as soon as possible. Plumes of TBT diffusion are already known for several ports. Such studies would therefore establish a baseline for future monitoring of exotic species expansion from port areas once TBT is banned. With remidiation of port regions more exotic species are expected to succeed and some of these will have economical and ecological consequences. Therefore, the implications of the anticipated changes (post TBT period) for ballast water and port management must be addressed in the very near future.

Nordic Risk Assessment Study (see *.pdf files (Nordic_Risk_Assessment_Title.pdf and Nordic_Risk_Assessment_Intro.pdf) in folder "Nordic Report")

A Nordic Risk Assessment Study was prepared in conjunction and as a contribution to the CA. The report was completed in 1998 and is available via the Nordic Council of Ministers, Copenhagen, Denmark. Both authors of the report (S. Gollasch and E. Leppäkoski) as members of the CA group linked the two studies closely together. In chapter 18, page 103 (and following pages) gaps were identified where further research is needed:

18. Gaps identified, further research needed

Much remains unknown in terms of the patterns and processes of invasions. Large gaps remain in the knowledge needed to establish risk assessment protocols and effective management plans (Box 17). The following list summarises examples of important research needs and applications.

1 Further studies on the ecology of introduced species

Only a few of the NIS have been studied experimentally or in a wider ecosystem context. The exact impact of NIS on native ecosystems can only be quoted by knowing more details on their requirements and relationships to the native biota.

2 Shipping studies and port profiles

A more intensive biological and ecological study of major ports and the ballast water arriving in the Nordic waters is urgently needed. A regional shipping study would provide basic data for management plans and guidelines to deal with ballast water.

The provided information on the port profiles enabled a first, initial risk assessment for the potential of further species introductions to selected areas in the Nordic coastal waters. Relevant data on additional port areas are essential to assess the risk in more detail.

3 Economic impacts of wood borers and fouling organisms

Impacts of wood-boring organisms (shipworms and isopods) and of fouling organisms (on vessels and submerged installations) are widely unknown and remain largely undocumented and entirely unquantified in Nordic countries.

4 Genetic studies of introduced species

The application of modern molecular genetic techniques has already revealed the cryptic presence of previously unrecognised invaders in the San Francisco Bay area (Cohen & Carlton 1995). European Studies on the polychaete *Marenzelleria* revealed that in fact two, morphologically very similar species *M. viridis* and *M. wireni* did invade. *M. viridis* is predominantly found in the Baltic Sea and *M. wireni* in the North Sea (Bastrop et al. 1997, Bick et al. 1997, Schiedek 1997, Schiedek et al. 1997, Zettler 1997 a, b).

The objective to evaluate "hot spot donor areas" of future species introductions may be determined more precisely by genetic comparison of previously introduced species. In this way the origin (native range or introduction from a habitat formerly invaded) of the introduced species can be proven.

5 Post-invasion control mechanisms

Studies on potential control mechanisms (e.g. biocontrol, physical treatment, eradication) of harmful introduced species are in their initial phase. Currently pilot studies are undertaken in order to control *Carcinus maenas* in Tasmania and *Mnemiopsis leydii* in the Black Sea and for *Caulerpa taxifolia* in the Mediterranean Sea. If it is impossible to eradicate a new invader completely, it might be possible to prevent or slow down its further (secondary) post-invasion spread. Public awareness programmes may assist in slowing down the process of spread of *Caulerpa taxifolia* in the Mediterranean Sea and the Zebra mussel in the North American Great Lakes and in Ireland.

6 Additional risk assessments

Knowing the fact, that each single vessel has the potential to introduce a new species, it is not meaningful to estimate the total amount of ballast water discharges. In order to evaluate the risks in a Nordic perspective, it would be helpful to know all potential source areas of ballast water outside the Nordic area. In combination with additional port profiles of major Nordic harbours a more detailed risk assessment can be carried out in the future.

The establishment of a network of experts, institutions and authorities would support the effectiveness of future risk assessment studies by transferring knowledge between working groups.

There are no specific monitoring programmes for NIS in the Nordic or Baltic Sea area. However, programmes carried out within the HELCOM system, as well as national monitoring programmes for bottom fauna and plankton, do produce overviews on changes in the environment. These programmes could support the control of introduced and/or established NIS. Knowing the areas with alien species enables to develop guidelines on ballast water uptake in order to prevent secondary introductions by ballast water within the Nordic countries.

18.1 Conclusions

No area of the Nordic Seas is not protected for future alien species introductions. The special Baltic Sea conditions as a brackish water body will not prevent the introduction of NIS: there are approx. 90 NIS recorded from the Baltic Sea (incl. Kattegat) of which approx. 70 can be regarded as established parts of the biotic community (Leppäkoski & Olenin in prep.) (consult the database on alien species in the Baltic Sea at http://www.ku.lt/nemo/mainemo.htm). A potential new invader can be any sort of species going into any sort of habitat.

Window of introduction

It is false to say that every species that could have been introduced would be here by now. As example there have been shipping routes from the Caspian and Black Sea region to the North American Great Lakes since many decades before the zebra mussel *Dreissena polymorpha* was finally introduced successfully to this area. It took several decades to "open" the window of introduction, i.e., to catch the right conditions in both donor and recipient areas and a vessel releasing ballast water containing a sufficient number of zebra mussel larvae at the same time.

The chance of an introduced species to become established and the chance for this introduced species to become a serious problem for the environment or economy is small. But, one single introduced species can cause severe harm to the economy and ecosystem the species invaded, as shown by zebra mussel in the North American Great Lakes, the comb jelly in the Black Sea and the green seaweed *Caulerpa taxifolia* in the Mediterranean Sea.

Risk assessment

Our current knowledge indicates that anthropogenically supported invasions in aquatic ecosystems increase on a world-wide basis. Many other aspects of invasions remain nearly unpredictable. Among them, unfortunately, are the most wanted answers to: Which species will invade, when will it invade, where will the species invade and what will be the impact of this new species? Today these questions can be answered only on a theoretical or broad scale. Accordingly an indication of habitats at risk can be given only on a limited base. We know that certain areas such as estuaries and areas with high input of NIS (ports, waterways and shipping routes as well as aquaculture sites) represent high risk areas for further introductions. Taking into account the shipping routes and comparing matching salinity and climate conditions in donor and recipient area first incomplete estimations are possible. Adding the duration of the ships voyage (short term voyage will increase the survival rate of specimens in the ballast tank) the picture comes more clear, but still is far from a prediction and represents a kind of an advanced guess.

Network

The establishment of a network of experts, institutions and authorities would support the effectiveness of future risk assessment studies by transferring knowledge between working groups. In this way an effective warning system in order to document and possibly control/prevent secondary introductions within the Nordic countries may be installed facing different aspects needed to undertake a positively overlapping risk assessment.

Control of occurring introduced species

Future invasions may include large negative financial impacts enforcing the need to take action in order to prevent or at least minimise/control the number of future introductions. Eradication methods of unwanted introduced species are cost intensive and in most cases not highly effective and for species which can propagate vegetatively this may also increase the dispersal. In some cases it is discussed to introduce intentionally a new species (predator, competitor, parasite or disease agent) to eradicate the unwanted invader (bio-control). In some cases this has been successful, but in others the trial failed completely. The bio-control species needs to interact specifically only with the target species. Otherwise one will eradicate native species as well.

On the other hand the application of chemical treatment of the unwanted organisms by adding substances to the water is in use to control the population density of e.g. the sea lamprey (*Petromyzon marinus*) in the North American Great Lakes (Morse 1990).

Both, the bio-control and chemical treatment methods need to be studied intensively in regard to identify a useful species or substance, test the specificity of the treatment (to prevent negative effects on native non-target species), and evaluate the risks of the bio-control species to interact with native species unknown in the area of origin of the bio-control species. Since three years Australian researches are looking for an effective and specific agent to treat the harmful Pacific seastar (*Asterias amurensis*) and the European green crab (*Carcinus maenas*). Promising trials are underway, but still after years of research it is not clear if the bio-control agent will not threaten any native species as well (ICES Report of the Study Group on Marine Biocontrol of Invasive Species 1997, Thresher pers. comm.). Also for the tropical green alga *Caulerpa taxifolia* such tests have been carried out in the laboratory, as well as for purple loose strife and the Eurasian water milfoil (Wallentinus pers. comm.).

In addition, after the hypothetically successful trial, the newly introduced bio-control species needs to be eradicated. Furthermore, not all unwanted species introductions can be managed in this way. Therefore, the money spent to prevent future introductions will pay off in the longer run due to the prevention of costs to manage impacts of uncontrolled introductions.

Ballast water management

Management practices as (e.g. the ballast water exchange in open sea) are the first step to minimise the risk associated with species introductions. Especially in the case of the Baltic Sea and other brackish water areas, such as the Black Sea, river mouths and diluted waters of inner parts of fjords and coastal inlets, the ballast water exchange in highly marine water with oceanic salinity represents a practicable and cost effective method reducing the risk of further species introductions. Some oceanic species might, however, have the capacity to tolerate brackish salinities. On the other hand many ships may not pass such areas en route and a Scottish study (Macdonald 1998) indicated that the number of species may in fact increase on short routes within Europe. To follow the IMO guidelines how to ballast and how to exchange the ballast water will minimise the risk of further introductions without any re-construction of ships.

Strategies to implement the IMO guidelines are needed. Regional authorities shall promote to implement these guidelines as legally binding provisions. It is important to note that the IMO guidelines do not solve a long term solution to the problem of ship mediated species transport; ballast water issues must be given high priority while designing the new generation of ships.

Back to relevant section in “Final Report”.

Appendix 6
Deliverable 6 Public Awareness

The importance of ballast water as a means of human intervention in aquatic ecosystem stability and biodiversity was not generally appreciated. The activities of the CA members solved this lack of information by widely distributing material relevant to the issue inside and outside the scientific community. The public awareness activities included the distribution of:

- several articles, jointly prepared by participating partners, for example through newsletters and annual meetings such as ICES, BMB and others,
- many lectures were given mentioning the CA objectives and initial results
- a **leaflet** (see file CA_introduction.doc in folder "Flyer") and a **flyer** (see file 1_flyer.xls in folder "Flyer") introducing the CA members and study objectives (7 pages),
- **press releases**, in total four press releases have been prepared, (see four files in folder "Press Releases": 1_PressRel_Jan_98.doc, 2_PressRel_Jun_98.doc, 3_PressRel_Oct_98.doc, and 4_PressRel_Dec_99.doc),
- **posters**, in total four poster were prepared. See four files in the folder "Poster": Please note that the hyperlinks are active, but it may take some time to open the files due to the large size (>15 MB). Your computer screen may turn black for some seconds (usually less than 30 seconds), but the poster will show up after the waiting time. After having seen the poster you can come back to this report by using the Escape button on your keyboard: 1_Poster_Introduction.ppt, 2_Poster_Survival.ppt, 3_Poster_Intercal1.ppt, and 4_Poster_Risk.ppt). Keep in mind that all poster are larger than 15 MB and therefore, it may take some time for your computer to open the files.
- an **Internet homepage** entitled „Exotics Across the Ocean" was put on the net in August 1999 (see file index.htm in the folder "Homepage"). So far the total number of visitors was 759 (Dec. 28th 1999) (Fig. 1 & 2 below)
- a **video** to document the intercalibration experiment and sampling of ships passing through the Kiel Canal (see file CA_video_1.mov in folder "Video"), and
- the case histories book listing species previously introduced to European waters (see relevant files in folder "Case Histories").

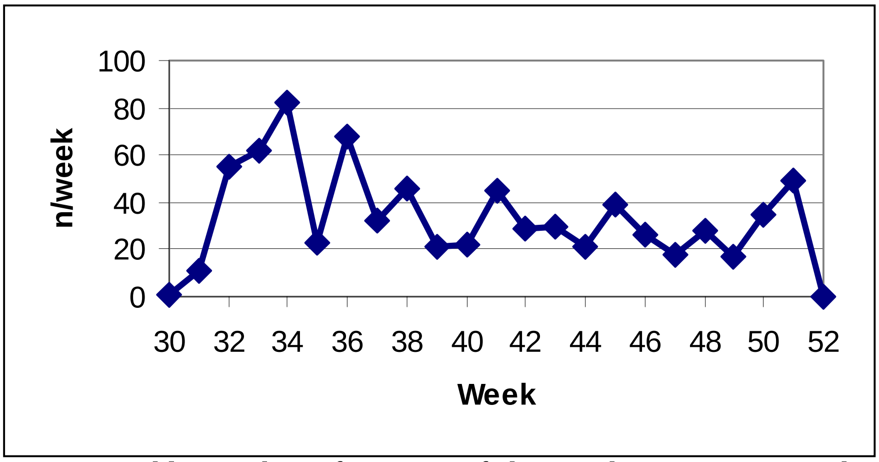

Fig. 1 Weekly number of visitors of the CA homepage since the homepage was put on the Internet in August 1999.

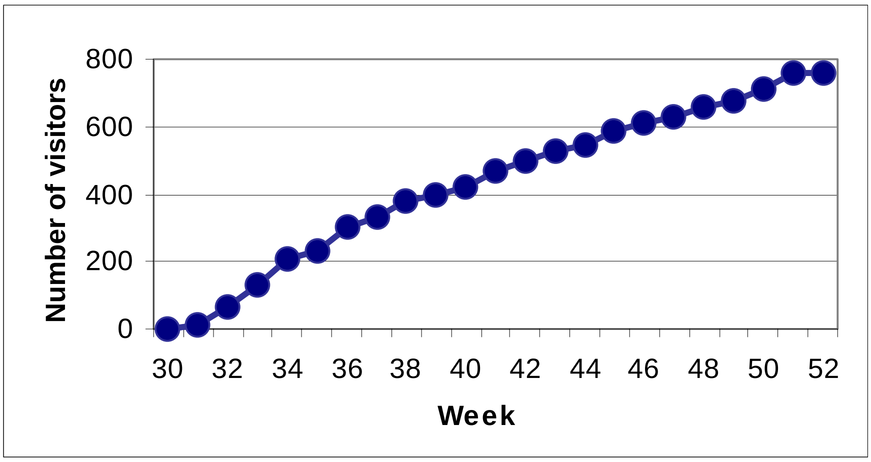

Fig. 2 Cumulative number of visitors on CA homepage since the homepage was put on the Internet in August 1999.

Lectures & poster presentations given by CA partners

February 1998

- 1st Sylt Seminar: Exotics of the North Sea Shore: Properties of Biotic Invaders, List (Sylt), Germany, 20th to 21st February 1998. The Abstract of the CA was presented (S. Gollasch).
- Environmental impacts of shipping. Centre for Maritime Studies, University of Turku, February 12, 1998, Turku, Finland (lecture, E. Leppäkoski)
- Bremerhaven, Germany: Nautical Society: February 25, 1998. Title of presentation "Interactions between Aquaculture and other Resource users: Environmental Issues" (H. Rosenthal)

March 1998

- Lecture at the Umweltbundesamt [Federal Environment Protection Agency], Berlin (Germany): Eintrag nichtheimischer Organismen durch den internationalen Schiffsverkehr und Möglichkeiten der Regelung. Prepared for Umweltbundesamt, Arbeitsgespräch „Die rechtliche Regulierung nichtheimischer Organismen im Vergleich zu genetisch veränderten Organismen“, 05.-06.03.1998, Berlin, Germany. The CA Abstract was presented at the meeting. (S. Gollasch)
- International Council for the Exploration of the Sea/International Oceanographic Commission/International Maritime Organization, Report of the Study Group on Ballast Water and Sediments, meeting in The Hague, 23.-24. March, Current Research Activities, Europe: A Concerted Action Plan, p. 17 (S. Gollasch)
- International Council for the Exploration of the Sea, Report of the Working Group on Introductions and Transfers of Marine Organisms, meeting in The Hague, 25.-27. March, Multinational Activities, CA Study, (S. Gollasch)
- ICES members were introduced to the objectives of the Concerted Action and several joint discussion groups of Concerted Action partners, (S. Gollasch)
- Vancouver, Canada: Canadian Aquaculture Association/ Biotechnology Conference on "Science and Industry". March 7, 1998: Title of presentation: "Science and Aquaculture: Where are we headed?" (H. Rosenthal)
- Invited Department Seminar, University of Dundee, Scotland, Dept. of Biology, 5th of March (E. Macdonald). The Concerted Action was mentioned in respect to ongoing and collaborative activities in the EU.

April 1998

- International Maritime Organization, Marine Environment Protection Committee, meeting 41, April 1998. The Abstract of the Concerted Action was presented to the working group

and is mentioned in the meeting report, London, U.K. (S. Gollasch), MEPC 42/8, page 4, paragraph 15.
- Wilhelmshaven, Germany, Schutzgemeinschaft Deutsche Nordseeküste e.V. Kolloquium: Biodiversität: die Vielfalt des Lebens im Meer bewahren, 29.04.1998, Forschungszentrum Terramare. Objectives of the Concerted Action were mentioned during two lectures:
  -- H. Rosenthal: Umwelt und Aquakultur sowie prinzipielle Überlegungen zur Verwendung von Biodiversitätsindizes
  -- S. Gollasch: Warum war "Holland in Not" ? Auswirkungen eingeschleppter Arten
- World Expo, Lisbon, Swedish Pavilion, June 9th (I. Wallentinus)
- World Expo, Lisbon, Swedish Pavilion, June 30th (I. Wallentinus)
- Concerted Action poster displayed at Department of Fisheries, Institute for Marine Sciences, Kiel (S. Gollasch).

July 1998
- INTECOL, 19.-25.07.1998, Florence, Italy. The Concerted Action poster "Exotics Across the Ocean" (E. Leppäkoski)
- Non-native invertebrates and rates of spread: lessons from the brackish Baltic Sea. INTECOL VII International Congress of Ecology, July 19-25 1998, Florence, Italy (scientific paper presented; E. Leppäkoski, coauthor Concerted Action partner S. Olenin)
- UNDP/IMO/GEF Project: Removal of Barriers to the Effective Implementation of Ballast Water Control and Management Measures in Developing Countries. Meeting of the Steering Committee, Capetown, 29.-30.07.98. The meeting was attended by S. Gollasch. The Concerted Action was presented by poster and handout.
- UNESCO-IOC sponsored cruise devoted to the International Year of the Ocean onboard the Russiona NAVY oceanographic ship "Sibiryakov", July 22nd to August 22nd. Lectures and practical work in ballast water sampling using the Concerted Action equipment (S. Olenin).
- Concerted Action poster displayed at Department of Marine Botany, University of Göteborg, Göteborg, Sweden (I. Wallentinus)

August 1998
- World EXPO, Lisbon, EU-Pavilion. The Concerted Action was mentioned during a lecture on coastal zone management. (H. Rosenthal).
- *27th Limnological Congress held* in Dublin, 9-15 August 1998 (D. Minchin)
- Spillcon '98. Oil Spills: causes and cures. 18-20 August 1998. Cairns Convention Centre, Queensland, Australia. The poster was displayed in the AQIS ballast water booth, by Penny Lockwood & Aaron Gladki (AQIS, Australia).
- Concerted Action poster displayed at Societas Internationalis Limnologiae (SIL) – Society of Limnologists in Dublin, 9th to 15th of August (D. Minchin).
- Concerted Action poster laminated and on display in entrance hall at CEFAS Conwy Laboratory, Conwy, Wales (S. Utting).

September 1998
- Coastal Zone Canada ´98, Victoria, B.C. Canada, August 31st to September 3rd. Lecture (H. Rosenthal): What science needs do CZM (Coastal Zone Management) committees have? The case of aquaculture as an equal rights partner in the use of coastal resources: Conflicts and possible methods of resolution.
- Coastal Zone Canada ´98, Victoria, B.C. Canada, August 31st to September 3rd. Poster presentation (S. Gollasch) "Exotics Across the Ocean, Testing Monitoring Systems for risk assessment of harmful introductions by ships to European waters"
- 33rd European Marine Biology Symposium (EMBS), Wilhelmshaven, Germany, 7th to 11th September 1998. Poster presentation (S. Gollasch) "Exotics Travelling with Ships" and Abstract "Testing Monitoring Systems for risk assessment of harmful introductions by ships to European waters"

- Universidad de Cenception, Facultad de Ciencias Naturales y Oceanographicas, Departamento de Oceanographia, Ciclio de Conferencias. Lecture (H. Rosenthal): “Aquaculture in marine waters and its integration in the context of coastal zone management”. September 15th 1998
- Conference: Climate of the 21st century – Climate change and global warming? Poster presentation: Is there a connection between climate change and the occurrence of exotics? Geomatikum, University of Hamburg, 21st of September 1998 (S. Gollasch)
- Mentioning the work of the Concerted Action during teaching in two Swedish student courses (I. Wallentinus).
- Conference “Marine Environmental Regulation – the Costs to the Shipping Industry” Presentation : Aquatic Organisms in Ships Ballast Water. Scientific Perspectives. London, UK, 23rd to 24th September (E. Macdonald). Activities of the Concerted Action group mentioned during presentation.

October 1998

- Istanbul Üniversitesi su Ürünleri Fakültesi. Istambul Ticaret Odasi Konferans Salonu. October 5th 1998. Lecture (H. Rosenthal): “Trends in modern aquaculture production systems and their environmental implication”.
- ICES Symposium: Marine Benthos Dynamics, Environment and Fisheries Impacts, IMBC, Crete, Greece, 5th to 7th of October 1998, Poster presentation (D. Minchin)
- Concerted Action poster displayed at School of the Ocean Sciences, University of Wales, Bangor (T. McCollin).

November 1998

- International Maritime Organization, Marine Environment Protection Committee, meeting 42, November 1998. The work of the Concerted Action was mentioned during the session of the ballast water working group and during the Plenary session of the Marine Environment Protection Committee, London, U.K. (S. Gollasch)
- The comments of the Concerted Action were mentioned at the meeting of the International Maritime Organization, Marine Environment Protection Committee (MEPC), meeting 42, November 1998. The Concerted Action was mentioned during the session of the ballast water working group and during the Plenary session of the MEPC, London, U.K. (S. Gollasch)
- Marine Transportation and the Marine Environment Workshop. Simon Fraser University, Vancouver, Canada, Nov. 17, EU Concerted Action poster was presented by H. Rosenthal
- Aquaculture and the environment: interaction between coastal resource users and the need for co-management. Ocean limited, Nov. 17-20th, A lecture introducing the objectives of the EU Concerted Action was given by H. Rosenthal
- Testing Monitoring Systems for Risk Assessment of Harmful Introductions by Ships to European Waters. Baltic Sea Science Conference. The Changing Coastal Oceans: From Assessment to Prediction. 27.11.98, Baltic Sea Research Institute Warnemünde, Germany, prepared by S. Gollasch
- Invasion Biology. Lecture give at P. Shirshov Institute of Oceanology, Kaliningrad branch, Kaliningrad, Russia, November 1998. (S. Olenin)

December 1998

- EU Concerted Action on ballast water and EXPO 98 activities. Workshop on Non-native Species in the Baltic and Black Seas. Zoological Institute of the Russian Academy of Sciences, St. Petersburg, Russia, Dec. 1st –4th, prepared by S. Gollasch
- NorFA/BMB course for graduate students on Invasive Ecology. St. Petersburg, Russia, December 1998. (S. Olenin)
- Fachgespräch: Ziele des Naturschutzes und einer nachhaltigen Naturnutzung in Deutschland Küsten und Randmeere. Poster of the Conercerted Action were distributed to

relevant participants from the federal and regional environmental authorities. Nov. 7th (H. Rosenthal)

January 1999

- Survival rates of species in ballast water during international voyages. Results of the first intercalibration workshop on ship sampling techniques and the first ocean-going workshops of the European Concerted Action: "Testing Monitoring Systems for Risk Assessment of Harmful Introductions by Ships to European Waters. Massachusetts Institute of Technology, Cambridge (Boston), USA, 26th of January (S. Gollasch)
- Xenodiversity of the European brackish water seas: the North American contribution. The First National Conference of Marine Bioinvasions. January 25-27, 1999, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA (scientific paper presented; E-Leppäkoski, co-author Concerted Action partner S. Olenin)
- Invasion Biology. Lecture given at Faculty of Natural Sciences, Vilnius University, Lithuania, January 1999. (S. Olenin)

February 1999

- The importance of ship hull fouling as a vector of species introductions into the North Sea. 10th International Congress on Marine Corrosion and Fouling. University of Melbourne, Australia, 8th - 12th February (S. Gollasch)
- Exotics Across the Ocean. European Studies on Ballast Water. Centre of Research on Marine introduced pests (CRIMP), Hobart, Tasmania 16th February (S. Gollasch)
- Exotics Across the Ocean. Brief introduction into the objectives of the European Concerted Action. Australian Quarantine and Inspection Service (AQIS), Sydney, Australia, 25th February (S. Gollasch)
- Possible inoculation mechanisms in port areas by hull fouling organisms, Melbourne, Australia (D. Minchin, S. Gollasch)

March 1999

- Ballast water and hull fouling – problems with exotics in harbours. Asea – EU SimCoast ™ Workshop „Industrial Development“, University of Kiel, Institute of Marine Sciences, Germany, 14th – 21st March 1999 (S. Gollasch)
- Current status on the increasing abundance of the Chinese Mitten Crab *Eriocheir sinensis* H. Milne Edwards, 1854 in German rivers. Chinese Mitten Crab Workshop, Sacramento USA, March 23rd (S. Gollasch).
- Introduced species and ecosystem effects. Lecture during A Conference in Honor of Professor Emeritus Bengt-Owe Jansson. Problems of scale in marine systems. Stockholm Marine Research Centre, Sweden, March 22nd to 23rd (I Wallentinus)
- Impact of exotic species in Ireland, Royal Irish Academy, Dublin, Ireland, Poster seminar, (D. Minchin).
- Sex, Drugs and Ageing bodies. Society of Toxicology, Colraine, North Ireland. Poster seminar. Aspect on TBT and the Environment and future species invasions. (D. Minchin)
- Ballast water surveys at Sture and the Concerted Action ocean-going workshop on the oil carrier Nordic Torinita. Meeting at Det Norske Veritas in Oslo, March 9 (H. Botnen)

April 1999

- An update of the progress of the Concerted Action (CA) was presented at the ICES, WGITMO and ICES/IOC/IMO Meeting in Wales including lectures on the “status quo of the CA, preliminary results of long-term and short-term ocean going workshops, results of first intercalibration workshop on ship sampling techniques, the case history of the Chinese Mitten Crab. The CA posters were presented during coffee breaks (S. Gollasch)
- Regional Conference "Lithuanian Coast: problems and decisions", April, 1999. (S. Olenin)

May 1999

- BSH Symposium für Aktuelle Probleme der Meeresumwelt. Exotics Across the Ocean, Poster presentation, 26th -27th May (S. Gollasch). 30 handouts were distributed.
- Lecture mentioning the work of the Concerted Action during teaching in a Swedish student course, May 25th (I. Wallentinus).

June 1999

- 16th Baltic Marine Biologists Symposium: First “European-wide” Ballast Water Study. Results and future perspectives. 21st – 26th, June, (Key Note lecture S. Gollasch)
- Ballast Water Seminar, Pre-meeting IMO MEPC, 27th June, The Global Consequence of Not Managing Ballast Water. Lecture given jointly by Prof. Dr. J. T. Carlton, USA and S. Gollasch

September 1999

- Lectures mentioning the work of the Concerted Action during teaching in a Swedish student course, September 3rd and 10th (I. Wallentinus).
- Several talks given during scientific workshop on ballast water management and control, Black Sea on M/V Georgyi Ushakov, 14.- 17. September 1999, Gollasch, S. (1999):1. The dimension of the ballast water problem, 2. Exotic species introduced via ships ballast water - background and consequences, 3. Why are exotic species a problem. The case history of the Chinese Mitten Crab introduced to European waters more than 90 years ago and still a problem? 4. Results of new European Concerted Action Study on Species introductions with ships: Documentation of the varying effectiveness of world-wide ballast water sampling techniques, 5. What can be done: Treatment methods of ballast water and 6. Is it only ballast water what introduces unwanted organisms in a broad scale? (S. Gollasch)
- Several talks given during scientific workshop on ballast water management and control, Black Sea on M/V Georgyi Ushakov, 14.- 17. September 1999, (S. Olenin): Invasion biology and the Baltic Sea perspective, historical and future aspects.
- 3rd International Conference on Coastal Shellfish Resource Management, Cork, Ireland (D. Minchin)

October 1999

- A national framework for biological diversity. Dublin, Ireland (D. Minchin).
- The European perspective on the ballast water problem. Pre-ASLO 2000 Workshop scheduled in association with the ASLO 2000 Conference in Copenhagen in June, 2000. Pre-workshop held in Amsterdam, 15th to 17th October 1999. (S. Gollasch).
- Ships and ballast water as a vector for dispersal of organisms. Report on Concerted Action ocean-going workshops. Lecture given at The Naval Collage in Bergen. October 19th and 21st (H. Botnen)

November 1999

- 2º Seminar on the Marine Environment. Ballast Water Management - The State of Art of International Legislation, Environmental Hazards and Procedures. 17th – 18th Nov. 99 Petrobras, Rio de Janeiro, Brazil (S. Gollasch).
- Ballast water– Background information and a vision for the next millennium. Lecture at Fachtagung"Umweltaspekte der Seeschifffahrt" GAUSS Bremen, 25.Nov.99 (S. Gollasch)
- Regional Seminar of the International Agricultural Association of Students (IAAS), Kaunas Agricultural University, Lithuania, November 1999. (S. Olenin)

December 1999

- Alien species in the Baltic Sea - threat or a resource? Annual Symposium of Societas pro Fauna et Flora Fennica December 27, 1999. Helsinki University, Finland (lecture, E. Leppäkoski)

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Publications mentioning the Concerted Action objectives

Rosenthal, H.; Gollasch, S; Laing, I.; Leppäkoski, E.; Macdonald, E.; Minchin, D.; Nauke, M.; Olenin, S.; Utting, S.; Voigt, M. & Wallentinus, I. (1998): Testing Monitoring Systems for Risk Assessment of Harmful Introductions by Ships to European Waters. In: Barthel, K. G.; Barth, H.; Bohle-Carbonell, M.; Fragakis, C; Lipiatou, E; Martin, P.; Ollier, G. & Weydert, M. (eds.): 3rd European Marine Science and Technology Conference, Lisbon, 23-27 May 1998, Project Synopses Vol. II, Strategic Marine Research, 919-928 (EUR 18220 EN).

Gollasch, S. & E. Leppäkoski (1999): Initial risk assessment of alien species in Nordic coastal waters. 1-124. In: Gollasch, S. & E. Leppäkoski (eds.) Initial risk assessment of alien species in Nordic coastal waters. Nord 1999: 8. Nordic Council of Ministers, Copenhagen. 244 pp.

Gollasch, S. (1999) Eintrag nichtheimischer Organismen durch den internationalen Schiffsverkehr und Möglichkeiten der Regelung. Prepared for Umweltbundesamt, Arbeitsgespräch „Die rechtliche Regulierung nichtheimischer Organismen im Vergleich zu genetisch veränderten Organismen, 05.-06.03.1998, Berlin, Germany, UBA Texte 18/99, 74-86

Gollasch, S. (1999): Survival rates of species in ballast water during international voyages. Results of the first intercalibration workshop on ship sampling techniques and the first ocean-going workshops of the European Concerted Action: "Testing Monitoring Systems for Risk Assessment of Harmful Introductions by Ships to European Waters. Massachusetts Institute of Technology, Cambridge (Boston), USA, 26th of January (in prep.)

Gollasch, S. (1999): Ballast water – Background information and a vision for the next millennium. Report of the GAUSS Seminar, Bremen, Nov. 25th, 13 pp.

Olenin, S. Ballast waters of ships and the problem of invasive species. Sea and Environment (Klaipeda), 1999, 1:54-62. (in Lithuanian, with English summary)

Gollasch, S. (1999): First European Ballast Water Study: Results and Perspectives. Key note at the 16th BMB Symposium, Klaipeda, Lithuania, June 24th. (in prep.)

Olenin, S., S. Gollasch, I. Rimkute, S. Jonusas. The potential for transfer of the plankton organisms in the ballast water of ships between the Baltic Sea and open Atlantic coast of Europe. International Review of Hydrobiology (in prep.)

Scientific results of the intercalibration exercises and other scientific findings will soon be published in peer reviewed journals.

Internet homepages referring to the Concerted Action

1999: Removal of Barriers to the Effective Implementation of Ballast Water Control and Management Measures in Developing Countries. Background information compiled to support GEF Project, 196pp. **http://www.imo.org/focus**

1999: Exotics Across the Ocean. Homepage on the EU Concerted Action: “Testing Monitoring Systems for Risk Assessment of Harmful Introductions by Ships to European Waters” **http://members.aol.com/sgollasch/sgollasch/index.htm**

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Feedback on the Concerted Action homepage (in the order as received)**:**

Cláudio Gonçalves Land, PETROBRAS; Rio de Janeiro, Brazil, 10th of August 1999
I visited, quickly, the site of the Concerted Action. I noted several interesting matters and relevant information in the site. Congratulations for this very important initiative / work which help the scientific, technical, environmental and maritime communities to know better about the consequences of the harmful / pathogenic organisms transference through ship ballast water. I have already initiated the dissemination of this site address to some Brazilian persons who are interested in these matters.

Caroline Sutton, CRIMP, Hobart, Tasmania, Australia, 11th of August 1999
Thanks for the email about the web site. It looks great!!

Keith Hayes, CRIMP, Hobart, Tasmania, Australia, 12th of August 1999
Thanks for the email - I liked the webpage - was good and informative - particularly the links to the other sites - although I could not access the UNESCO sites via your web page - not sure whether it is my machine or an error on the page. Also like the ballast water calculation sheet - might be improved by including some text on the results of the German study and the algorithms/assumption used in the spread-sheet? This way users can gauge just how different their situation might be to the one on which the spreadsheets are based.

Vadim Panov, Russian Academy of Sciences, St. Petersberg, Russia, 14th of August 1999
Yesterday I had a look at your web site (I was a visitor number 125!): You did a nice job! Thank you for linking with the GAAS site - we will make appropriate linkage in September (our web manager on vacation).

Debbie Rudnick, Aquatic Ecology Lab, ESPM-Division of Insect Biology, University of California, Berkeley, USA, 17.08.99
I find the site to be very informative and am excited to hear what Europe has been doing on this issue- so far I have mostly researched US efforts for ballast water sampling and treatment.

Janet Cant, Australian Ballast Water Management Program, AQIS, Canberra, Australia 18.08.99
Stephan, I have received your e-mail via John Fleming from the AQIS National Offices, which advised of your new web site. I have opened the site, and have found it most informative. I have sent your email to all the ballast water staff here in Canberra.

M. R. Robertson, FRS, Marine Laboratory, Aberdeen, Scotland, UK, 18.08.99
I like the web site!

Tami Huber, SERC, USA, 23.08.99
I did check out your website, and found it impressive where it is, and anticipate its further development.

Dr. Uwe Lange, FI Senckenberg c/o DESY, Hamburg, Germany, 03.09.99
I like the homepage of your project very much.

Dr Phil Smith, The Limes, Creedy Park, Crediton, Devon, UK 05.09.99
Just visited your page on marine alien introductions - looks good. Keep up the good work!

Nathalie Simard, Habitat Science, Maurice Lamontagne Institute, Canada 04.10.99
Thank you very much about the information on European study, you have a very interesting web site!

Julio Neuling, DIRECTEMAR (Chilean Maritime Authority), Valparaiso, CHILE 10.11.99
Congratulations! for the new Web page of the EU Concerted Action, I think it is a very good contribution to the subject and I believe that it could be a good tribune to make global contacts on this and other matters, sending abstracts of publications, seminaries, congresses, trips, the news, etc., everything at global level.
For example, I think that it could be interesting to have the Wales meeting Final Report available to be downloaded from the Web, or perhaps to create open groups of discussion on certain subjects, with chat and opinion interchanges between all the members included in the list. Even when I recognise that this is high time consuming and I suppose that you really do not have time to dedicate to such matters, perhaps somebody else could do that.

Sara Belson, Maritime Research Centre, Southampton Institute, East Park Terrace, Southampton, UK, 23.11.99
I also wanted to congratulate you on the web site, as I found it very interesting and well designed. I only wish it had been around when I started my research - it would have been a great introduction to the subject, and having all those useful links in one place would have made a literature search much easier!

Concerted Action Poster and Abstract was mailed to

(listed according to the forwarding of the material):

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Appendix 7
Deliverable 7 European waters as donor area

It is important to note that all non-indigenous species are believed to be potentially harmful. Every import should be assumed harmful in the beginning until it is shown to pose a low risk. Therefore the target list approach of unwanted species needs critical consideration. It was concluded that another list of species listing introduced species with low impacts is needed.
It was concluded by the Concerted Action group that these kind of target species lists are only of limited help in order estimate future severe species introductions.

However, a Nordic Risk Assessment Study (see *.pdf files Title and Introduction in folder "Nordic Report") was prepared in conjunction and as a contribution to the CA. The report was completed in 1998 and is available via the Nordic Council of Ministers, Copenhagen, Denmark. Both authors of the report (S. Gollasch and E. Leppäkoski) as members of the CA group linked the two studies closely together. In chapter 15.5, page 82 (and following pages) Nordic waters have been considered as donor areas of species:

15.5. The Nordic countries as donor area of species

The potential export of NIS from the Nordic seas is of equally importance as the introduction organisms into Nordic waters. The survival potential of "exported" organisms will depend among other factors on physical characteristics of donor and recipient habitats, the area of origin and the duration of transit.
Overseas port areas may be at risk from the introduction of some European species. Most of the important harbours in the world are located at river mouths or in estuaries. The salinity of these brackish habitats (salinity ranges from nearly marine to fresh water) are comparable to the Baltic Sea. Therefore, organisms from the Nordic coasts may establish in ports with temperate climate and matching hydroclimate all over the world. In this way the Baltic Sea, as well as the Nordic harbours along the North Sea and the North Atlantic coasts, serve as donor area introducing European species into habitats outside their native range.
Two mechanisms of species export from the Nordic waters are obvious. **Firstly**, species native to the north eastern Atlantic and/or Baltic coasts may be transported and become established in areas outside their native ranges (see list below). **Secondly**, species previously introduced into the Nordic region may be transported to regions outside the Nordic coasts. Genetic studies may reveal the origin of introduced species more clearly; in some cases an introduced species has been introduced to a new habitat not only from its native distribution area but also from areas were it was introduced in former times. As an example, the area of origin of the zebra mussel population, introduced to the North American Great Lakes is unknown. It might have been transported from its native range or from other places, where it was introduced in the past (Baltic Sea, north western Europe). Other examples are the Ponto-Caspian *Cordylophora caspia* and the Chinese mitten crab *Eriocheir sinensis.* Neither is the origin of the introductions of *Codium fragile* ssp. *tomentosoides* to the North American east coast, where it was the first recorded in Long Island Sound in 1957, probably due to accidental introduction by ships, the species then rapidly spread along the east coast (see Carlton and Scanlon 1985 for a review) and finally in 1990s to the Canadian waters.
In the San Francisco Bay 17 out of the 212 NIS aquatic species are of European origin; among them are:

Phytoplankton

Several harmful algae are recorded from the west coast of Sweden which could be liable to be exported to new areas via ships' ballast water. As mentioned above of the resistant resting spores surviving very well in the ships' ballast water tanks. The cyst forming potentially PST producing species *Alexandrium minutum, A. tamarense* and *Gymnodinium catenatum* are all found in the sediment of the Stenungsund area (Persson & Godhe 1997). These cysts might be taken into the ballast water tanks while ballasting in the shallow ports and transported to new areas. Other harmful algae that could be exported from the area are *Prorocentrum lima*, a benthic, DST producing dinoflagellate. It lives as an epiphyte on macroalgae and fouling macroalgae of ships' hull could serve as a vector for the spread of *P. lima*. *Gyrodinium* cf. *aureolum* a known fish killer is as well present along the Swedish west coast and might become established elsewhere via ships' traffic. The species of the potential AST producing genera *Pseudonitzschia* could as well spread further from the Swedish west coast. Several of the harmful microalgae present on the Swedish west coast are not recorded from the Baltic. Some species are true marine species and could not survive in the brackish water of the Baltic, whereas others might survive and become established. The traffic from the ports of Stenungsund to ports in the Baltic are extensive and there are several opportunities for microalgae to be transported into new areas.

***Littorina saxatilis* (Mollusca, Gastropoda)**

The common North Atlantic snail was first recorded in the San Francisco Bay in 1993 and became locally abundant. Further spread of the snail is not excluded (Cohen & Carlton 1995).

***Carcinus maenas* (Decapoda, Brachyura)**

The arrival and establishment in 1989-90 of the European shore crab *Carcinus maenas* in San Francisco Bay signals a new level of a new mode of trophic interference with native food webs. The green crab is a food and habitat generalist, capable to prey on an extraordinarily wide variety of animals and plants, and capable to inhabit marshes, rocky substrates, and fouling communities. European, South African, and recent Californian studies indicate a broad and striking potential for this crab to significantly alter the distribution, density, and abundance of prey species, and thus to profoundly alter community structure in the San Francisco Bay (Cohen & Carlton 1995). This species has also been introduced to the North American east coast around 200 years ago, to Australia in the late 19th century and to South Africa in 1983.

***Botryllus schlosseri* (Tunicata)**

This species was probably introduced by hull fouling of ships. It is native to waters of the north east Atlantic Ocean (Cohen & Carlton 1995).

***Ascidiella aspersa* (Tunicata)**

A. aspersa is a common sea squirt populating the Swedish west coast. It has been a successful invader of the North American east coast where it has spread from Massachusetts to Connecticut since it was introduced in the mid 1980's. The vectors for spreading *A. asper*sa from Europe to America were either larvae being transported in ships' ballast water tanks or adults fouling ships' hull (Carlton 1993).

In the North American Great Lakes approx. 55 % of 139 NIS established are native to Eurasia, including the Eurasian watermilfoil (*Myriophyllum spicatum*), faucet snail (*Bithynia tentaculata*), common carp (*Cyprinus carpio*) and rudd (*Scardinius erythrophthalmus*). More recent introductions are *Bythotrephes cederstroemi* (a spiny water flea), zebra mussel (*Dreissena polymorpha*), ruffe (*Acerina cernua*), and round goby (*Neogobius melanostomus*), some of which have appeared to be highly aggressive invaders causing a heavy impact to the ecology of the lakes (Mills et al. 1993).

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Appendix 8
Deliverable 8 Documentation of European studies on ships and introduced species in the past

Introduction

The Concerted Action reviewed and considered shipping studies both within the EU and within the rest of the international community. This helped to give a more balanced view of the state of the art and also enabled the Intercalibration workshops to consider and compare sampling methods as used throughout the world. Many of these studies were completed, and some new studies commenced during the lifetime of the Concerted Action.
Shipping studies fall into two categories. Firstly, there are practical studies in which samples of ballast water and, where available, sediments, were collected from ships' ballast tanks and the biota identified. These studies attempted to collect samples seasonally from a variety of ship types from a range of destinations. Some of these studies included sampling en-route and the results were applied to the Concerted Action ocean-going workshops. Secondly, there are theoretical studies in which the relationships between documented introductions of exotic organisms were compared with shipping movements to assess the likelihood of ballast water as a vector. Both types of studies included an assessment of the risk of introduction of unwanted exotic organisms. This assessment was sometimes reinforced by collecting information on the scale of ballast water discharge operations in national ports and waters.
The studies discussed are summarised in Table 1 and short description of each study follows. Whilst this list attempts to summarise all the studies that the CA is aware of, it should not be assumed that the list is fully comprehensive.

Table 1 - Summary of shipping and theoretical studies in European and non-European countries.

EUROPEAN STUDIES		**NON EUROPEAN STUDIES**	
Practical	**Theoretical**	**Practical**	**Theoretical**
Belgium	France	Australia	Georgia
Croatia	Ireland	Brazil	South China Seas
England and Wales	Nordic Countries	Canada	
Germany	Sweden	Chile	
Lithuania		Israel	
Netherlands		New Zealand	
Norway		USA	
Scotland			
Sweden			

NB Further information on many of these studies can be found in reports of the ICES/IOC/IMO study group on ballast water and sediments (SGBWS).

SUMMARIES OF SHIPPING STUDIES

SHIPPING STUDIES IN EUROPEAN COUNTRIES

BELGIUM (Free University of Brussels)

An investigation entitled "Study of the Potential Role of Transportation of Ships Ballast Water on the Geographical Extension of Blooms of Toxic Algae" was carried out between 1994 and 1995 at the Free University of Brussels (REFS). A total of 21 genera of planktonic algae were found in ballast water samples from 21 ships. The dominant taxa collected in these samples were dinoflagellates. Large numbers of dinoflagellate resting cysts were found in ballast tank sediments, some of which were thought to be toxic species. The main results of the study were that risks do exist concerning the introduction of non-indigenous toxin-producing phytoplankton species into European waters with ballast water or sediment discharges. It is recommended to implement ballast water management guidelines on an international level.

CROATIA (University of Dubrovnik)

A shipping study is currently being undertaken sampling vessels entering the port of Dubrovnik. The main aim of the project is the determination of the best practicable ballast water treatment method. In order to address the problem, the project will bring together experts from marine biology, chemistry, physics, water treatment, shipping crews and ship construction and ship building parties.

ENGLAND AND WALES (School of Ocean Science, University of Wales, Bangor)

The aims of this programme were to investigate the range of organisms present in ballast water and the variation in ballast water organisms in relation to geographic origin and season. A further objective was to assess the potential risk from the introduction of organisms in ballast water and sediment. Ship sampling was carried out from August 1996 to December 1998. A total of 112 vessels were sampled at 20 ports throughout England and Wales. This resulted in 114 water samples, 89 net samples and 102 sediment samples. The vessels sampled ranged in size from approximately 1200 dwt to 142 000 dwt, and the majority of the ballast water sampled originated from ports in the northern hemisphere.

Dinoflagellate resting cysts were found in 69% of sediment samples, and 49 species were identified, representing 20 genera. More species of cysts were found in sediment that had been directly collected from inside ballast tanks whilst ships were in drydock, than by pumping sediment slurries. Five species of cyst which have not previously been recorded in UK waters were found. A relatively large percentage (25%) of the sediment samples appeared to contain cysts of the dinoflagellate genus *Alexandrium*, some of which are known to be toxic. However, it was noted that further taxonomic and germination studies were necessary to accurately identify these cysts. As observed in the Scottish study, motile phytoplankton were found in all bar one of the water samples and there appeared to be a great deal of cosmopolitanism in the motile phytoplankton. The number of phytoplankton taxa in the water samples varied from five to 60. Zooplankton were observed in 95% of net samples, and copepods were the most commonly found taxa. Many larval stages of benthic organisms were also found. Several of these organisms metamorphosed into adults when cultured in the laboratory, and these included a non-indigenous American crab, *Cancer irroratus*, which grew to the adult stage from a megalopa larva collected from the ballast tank of an oil tanker that had loaded ballast 17 days previously in New York (Hamer *et al*., 1998).

In terms of temporal trends, there was some indication of a seasonal pattern of temperate spring and autumn peaks for both phytoplankton and zooplankton, although higher numbers were recorded in the autumn peak. The length of journey affected the diversity and abundance of both phytoplankton and zooplankton, which were generally reduced with increasing time in transit. There were no clear relationships between salinity and species composition, or port of origin and species composition.

GERMANY (Institut for Meereskunde, Kiel, and University of Hamburg)

The first European shipping study was undertaken in Germany between 1992 and 1996 (Gollasch, 1996). This joint research project between the Institut fur Meereskunde, Kiel and the University of Hamburg was commissioned by the Umweltbundesamt, Berlin (German Environment Protection Agency). This first European study on ballast water sampling, aimed to carry out a thorough taxonomic assessment of planktonic and benthic organisms found in ballast water tanks The main objectives were to determine the variety of species introduced by ships and to evaluate the risks associated with species introductions by shipping. The vessels investigated were selected according to type of vessel and sea areas covered by their voyages. The majority of samples originated from tropical and warm-temperate regions. The abiotic parameters of the ballast water (temperature, salinity, pH value, and oxygen content) were measured aboard immediately after sampling. In the initial phase of the project a questionnaire was mailed to more than 200 scientist in order to collect information on non-indigenous species in German waters and neighbouring countries. The amount of ballast water discharged in German ports and waterways was estimated during the shipping study (based on data from the Verband Deutscher Reeder and records from the crews of sampled) at approximately 10 million tonnes discharged annually, of which approx. 2.2 million tonnes originated outside of Europe (Gollasch 1996, Lenz *et al.*, in prep.).

A total of 211 ships visited resulted in 334 samples (132 ballast water samples, 131 hull samples and 71 samples in the ballast tank sediment). More than 60% of the 404 species that were determined (ranging from microscopic algae to crustaceans, molluscs and fishes) were non-indigenous to German waters of the North Sea and Baltic Sea.

LITHUANIA (University of Klaipeda)

A study has started recently in Klaipeda, the only port in Lithuania.. This involves sampling ballast water and examining hull fouling on ships in dry dock. To date, about 10 ships have been examined and samples are awaiting analysis. *Balanus improvisus* is frequently found on hulls.

THE NETHERLANDS (Aquasense, Amsterdam)

In co-operation with the North-Eastern University, Maryland, USA, a shipping study based at Aquasense (Amsterdam) was carried out, sampling ships in ports of the Chesapeake Bay region and in Rotterdam. Three ships were sampled at both sides of the Atlantic ocean and analysed for phytoplankton and zooplankton content. The sampling design enabled estimation of the number of species and specimens transported to both ports. In addition to other non-indigenous species, there is special focus on toxic phytoplankton species. A standardized sampling protocol for testing of phytoplankton and their cysts was developed by both partners of the co-operation (Tripos 1998). A desk study identifying the need for further research in this field concerning the biological risks for the Dutch coastal waters with respect to ballast water is in preparation. The study was initiated by the Ministry of Transport, Public Works and Water Management, Department North Sea.

NORWAY (UNIFOB, Bergen)

In 1996, a project entitled the Sture Project, funded by Norsk Hydro who operate the Sture Terminal, was launched This project involved sampling the ballast water of ships calling at the Sture oil terminal north west of Bergen on the Norwegian west coast. The aim of the study was to investigate the potential of unintentional introductions of non-indigenous aquatic species to Sture via ships’ ballast. Between April 1996 and September 1997, samples were collected from 30 tankers, all arriving from ports outside Norway. Samples were examined for zooplankton and phytoplankton species composition, and also to measure salinity, oxygen, temperature and for the determination of nutrients content in the ballast water. Oxygen content was high in all tanks sampled, suggesting that there was sufficient oxygen to sustain aquatic life. No samples were collected from ballast tank sediment or from ship hulls. Most ships arriving at Sture depart from harbours in Europe. However, 15 % depart from harbours in North America, and another 5 % depart from harbours in other geographic regions. In total about 360 vessels arrive at Sture each year, and around 14 million tonnes of ballast water are discharged annually.

Live organisms were detected in all but one vessel sampled. The organisms most commonly found were crustaceans, and a diverse range of phytoplankton were found in 29 of the 30 vessels. Bivalve and gastropod larvae occurred in 20-30% of vessels and fish eggs in < 10%. The number of taxonomic groups and stages decreased with increasing voyage length, and this was more pronounced for zooplankton than for phytoplankton.

SCOTLAND (FRS Marine Laboratory, Aberdeen)

Between May 1994 and December 1996, ballast water was sampled from 127 vessels in 10 Scottish ports. Vessels sampled ranged from small cargo vessels of < 1000 dwt to VLCCs of

> 300 000 dwt. Ballast water sampled had been loaded in over 80 different ports representing 25 countries worldwide. Most origins were in northern hemisphere countries, with the southern hemisphere appearing to feature very little in shipping trade in Scotland. The aims were to investigate the planktonic organisms in ballast water and sediment, with special emphasis on harmful and potentially toxic phytoplankton (Macdonald, 1995, Macdonald and Davidson, 1997). This study was funded by the Scottish Office Agriculture, Environment and Fisheries Department, the Marine Safety Agency and Scottish Natural Heritage.

A total of 92 ballast tank sediment samples were collected and examined for dinoflagellate resting cysts. Full cysts were found in 62% of sediment samples. Approximately 29 dinoflagellate species within 12 genera were represented. Cysts of potentially harmful species were found in 17% of sediment samples. Experiments on the hatching success of dinoflagellate cysts from sediment samples were carried out. Cysts were isolated into culture media and 51% of these cysts hatched into motile dinoflagellates, suggesting that many cysts from ballast tanks are indeed viable. A total of 13x ballast water samples were examined for motile phytoplankton, and all but one of these samples contained motile cells. These samples showed considerable cosmopolitanism, and it seemed that salinity regime rather than geographic origin had a greater effect of the species composition. Some potentially toxic phytoplankton species were observed. Five non-indigenous zooplankton species were found in the net samples (Macdonald and Davidson, 1997).

In addition to sampling ballast tanks upon arrival in port, samples were taken from two ships on 13 occasions prior to and following in-transit exchange in the North Sea and Irish Sea. This allowed study on how the diversity and abundance of diatoms and dinoflagellates were affected by in-transit ballast exchange in regional seas. Diatom diversity increased in 69% of cases following exchange and abundance increased in 31% of cases, whilst dinoflagellates diversity increased in 85% of cases and abundance in 62% of cases (Macdonald and Davidson, 1998). The issue of in-transit exchange in regional seas is currently being investigated in more detail by this laboratory.

SWEDEN (Swedish Environmental Protection Agency and University of Gothenburg)

A pilot project entitled "Risks associated with introduction of non-indigenous organisms to Swedish waters by water/sediment in the ballast tanks of ships" was carried out in 1996. The study included sampling of ships' ballast water. The project also included a regional survey of dinoflagellates along the province of Bohuslan on the Swedish west coast. This pilot study focussed on phytoplankton in ballast water. Hatching experiments of phytoplankton cysts from sediments of tanks were carried out in order to support the identification of taxa. In addition to the taxonomic work on ballast water and sediment samples, experiments in culturing the ballast tank species were carried out. Although few living cells were observed in the samples, results from the cultures showed that there were large numbers of live organisms present in the ballast water and tank sediment. It is possible that these species could hatch and survive following their discharge in Swedish waters (Persson, Godhe and Wallentinus pers. comm., Swedish Environmental Protection Agency 1997).

THEORETICAL/DESK STUDIES IN EUROPEAN COUNTRIES

FRANCE (IFREMER-URAPC)

A study on the role and impact of ballast water on aquaculture, with particular emphasis on the potential release of dinoflagellate cysts is planned by Masson & Fouche (Aquaculture Research Laboratory of IFREMER-URAPC, Unite de Recherches Aquacoles Poitou-Charentes).

IRELAND (Fisheries Research Centre, Dublin)

In 1994/95, Cork Harbour was examined to determine if there was a potential risk from introductions by shipping. Since 1955, estimated ballast water discharges in Cork have increased from about 50,000 t to around 400,000 t in the late 1990s. In Cork Harbour, 15 unintentional introductions have been recorded. Eight of these may have been imported on the hulls of ships and two were possibly introduced by ballast water.

In a subsequent study, sampling of ballast water and sediments took place during 1996 on one vessel in Dublin, in addition to activities related to the development of a desk study of port profiles for all 32 Irish ports. These profiles consisted of several topics, including an analysis of current and past shipping traffic patterns, estimates of ballast water releases, tidal amplitude and aquaculture activities. As a result, two regions were considered to have greater risk: The Shannon Estuary and Cork Harbour. Species introductions, by means of ballast water, are likely to gain entry to Ireland from populations that have become established in other European ports.

The importance of hull fouling as a vector for dispersal of exotic species still needs to be given serious consideration and may have an effect as significant as that of ballast water discharges, albeit for different species.

NORDIC COUNTRIES (Nordic Council)

In 1997-99, the Nordic Council of Ministers funded a project “Risk Assessment for Marine Alien Species in the Nordic Area” (Gollasch and Leppekoski, 1999). A semi-quantitative model was developed and applied to five ports in Scandinavia and the Baltic Sea. Individual risk profiles and risk level quantification for these harbours were based on the volume of ballast water released, number of ship arrivals, shipping routes to areas with matching climate and salinity, and duration of voyages. The ports were evaluated as either receiving or donor areas for ballast water mediated non-indigenous species on the basis of number of estuaries, aquaculture sites and ship yards in the area. The salinity gradient, degree of water pollution and number of previous introductions were also taken into consideration.

SWEDEN (Swedish Environmental Protection Agency)

Sweden prepared a questionnaire for countries of the OSPAR Convention Area (i.e. the NE Atlantic including the North Sea) concerning non-indigenous species in the marine environment, to gather relevant national information on non-indigenous species, including, inter alia, information on relevant research activities, strategies for the development of monitoring programmes and sampling techniques (IMPACT 95/14/1). In total, 12 countries replied to the questionnaire. Additional information was provided by the Helsinki Commission covering the Baltic Sea. In total, 102 non-indigenous species have been reported from waters of the North Sea and the Baltic area. Only one country reported that there were no known non-indigenous species occurring in their waters. It is not clear if all of the reported species have become established in the long term. The dominant vectors mentioned for species introductions are shipping (unintentional introductions via ballast water, tank sediments and hull fouling) and aquaculture (intentionally introduced non-native target species and unintentionally introduced non-target species). After an introduction in one country, secondary dispersal (introductions into waters of neighbouring countries) can take place either by natural means as currents or by recreational and commercial coastal ship traffic or with the transfer within Europe of aquaculture species (Jansson 1994; Swedish Environmental Protection Agency, 1997)

In 1997 a risk assessment desk study for the ports in the Stenungssund carried out at the University of Gothenburg. Associated to the project “Risk Assessment of Marine Alien Species in Nordic Waters” (see under Nordic Countries), a desk study entitled "Ballast Water - Transportation Patterns and Volumes" was carried out. The Project objective was described as an inventory of volumes and patterns of ballast water required for assessing the scope and significance from a regional perspective, and to identify risk areas (donor as well as recipient area) for introductions. The desk study documented main transport routes and volumes of ballast water imported to and from Swedish ports.

SHIPPING STUDIES IN NON-EUROPEAN COUNTRIES

AUSTRALIA

There are several well-documented ballast water mediated marine introductions causing problems for aquaculture and fisheries in Australian waters (Hallegraeff and Bolch, 1992; Hutchings *et al.*, 1992). There exists considerable concern that further introductions should be prevented. The Australian Quarantine and Inspection Service (AQIS) have co-ordinated comprehensive sampling programmes and associated research, including studies on behaviour of organisms during ballast water exchange. Ballast water sampling methodologies have been compared. An assessment has been made of the risk of introductions of unwanted marine organisms, including fish and shellfish diseases. AQIS has used the results from these and other studies to develop a Decision Support System for ballast water management of ships entering Australian waters.

BRAZIL

Shipping studies have been restricted to sampling ballast water to verify the effectiveness of the continuous dilution method on certain types of tanker vessels. This is a ballast water management technique intended to become an option in the toolbox of management methods.

CANADA

A three year national ballast water research programme has recently started and will include sampling of ships' ballast water, as well as studies on the physiological status (for assessment of survival and viability) of marine organisms found in the samples. A National Ballast Water Working Group has been formed to co-ordinate research activities and develop management strategies. An earlier study investigated phytoplankton in the ballast water of ships arriving in Canada (Subba Rao *et al*., 1994).

Much research effort on shipping studies has concentrated on the Great Lakes and St. Lawrence Seaway. Locke *et al*., (1991) studied the compliance of ships with the Great Lakes Ballast Water Control Guidelines, and the effectiveness of these Guidelines at reducing freshwater and coastal organisms in ballast water. Whilst compliance and effectiveness were estimated at 95% and 67% respectively, it was concluded that risks of invasions were still present, as some ships did not comply with the Guidelines, and those that did could not guarantee that all freshwater and coastal organisms were eliminated by ballast exchange.

CHILE

Toxicity of ballast water samples was assessed by a bioassay, using a sea urchin as the test organism. Evidence was found for toxicity, but this could not be related to type of ballast tank or age of ballast water (REF).

ISRAEL

Sediment and ballast water were collected from a ballast tank of a container ship travelling from Haifa to Japan. Fifty-seven species of marine organisms were identified. The sample was then treated with water of different salinity, from fresh water to seawater, to simulate ballast exchange in different environments. All sub-samples retained some living protists after 3 months.

NEW ZEALAND

A sampling programme has obtained information from over 150 ballast tanks in 70 ships. About 80% of the samples contained living plankton and sediment-dwelling species. In common with other similar studies, exotic species were identified in the samples and a risk of these species becoming introduced was identified. Mid-ocean exchange apparently led to an increase in phytoplankton abundance and diversity. Other studies have followed the changes in the concentration and growth of organisms during the course of a voyage. New Zealand is following the lead of and working closely with Australian authorities on ballast water management issues.

USA

There have been many shipping studies in the USA, many of which arose from requirements of the National Invasive Species Act of 1996 (NISA) and it's predecessor, the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA) (Carlton and Holohan, 1998). Shipping studies in the USA have been carried out or are planned at the following institutes:

Smithsonian Environmental Research Centre (SERC) in Chesapeake Bay has carried out shipping studies in Chesapeake Bay and Port Valdez, Alaska. These studies have been focussed on a range of organisms including plankton, bacteria and viruses. In addition, SERC is studying the role of domestic shipping in translocation of species within the USA.

Williams College - Mystic Seaport Maritime Studies Program - two shipping studies coordinated here (one in collaboration with SERC) investigated the role of shipping (ballast water and sediments) in the introduction of nonindigenous organisms to coastal waters of the USA (other than the Great Lakes).

Duke University Marine Laboratory, North Carolina has investigated ballast tank contents of ships arriving in the Port of Morehead City, North Carolina.

Battelle Memorial Institute has investigated Gulf of Mexico ports.

University of North Carolina at Wilmington, has proposed to study microbial flora in ballast water

In addition, other studies have also been carried out or are in progress within the USA.

THEORETICAL/DESK STUDIES IN NON-EUROPEAN COUNTRIES

GEORGIA

Treatment facilities for oil contaminated ballast water were built on the shores of the Black Sea in regions of Georgia as early as in the 1960s. This facilities are able to treat up to approx. 6 million cubic meters of ballast water. However, Georgia are concerned about the possible impacts that uncontrolled ballast water discharges may have on the marine ecosystem of the Black Sea if non-indigenous species are introduced.

SOUTH CHINA SEA

A coastal environmental profile has been developed with a view to integrated coastal management. Port studies have included an audit of organisms present. There is some evidence to suggest that toxic algae blooms have increased through shipping activities.

Back to relevant section in "Final Report".

Appendix 9
Executive Summary

EU Concerted Action

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

CONTRACT NO: MAS3-CT97-0111

Summary of Project Objectives and Results

1 Background information

In recent decades, ballast water discharges from ships into coastal areas have increased throughout the world, mainly occurring in or adjacent to port areas. Discharge volumes vary according to the size of vessel, type of trade and shipping routes, but are relatively high. It is estimated that the ballast water volume discharged annually world-wide exceeds 10 billion tonnes. Further estimates by the EU Concerted Action (CA) indicate that over 4,000 species are in intercontinental transit daily. The probability of successful establishment of self-sustaining populations of non-indigenous species has increased and is expected to increase further with greater volumes of ballast water carried by larger, faster ships with reduced transit times. Ships have been recognized as a major vector for the introduction of non-indigenous and **harmful organisms** and may thereby lead to deleterious effects on other human activities in the coastal zone.

The first accounts of species sampled from ships' ballast water were reported 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 discussed the **risks** associated with transplantation of disease agents, parasites and competitive species to fisheries and aquaculture, including organisms transported in ballast water. He indicated that modern aquaculture development in the coastal zone may be at risk of disease and parasite transfers from ballast water if aquaculture facilities and fishing areas are located in close proximity to shipping routes. The recent world-wide growth of aquaculture along shipping routes and near ports amplifies this risk, possibly rendering strict disease regulations for this industry useless in some areas.

The importance of ballast water introductions as a major vector for affecting aquatic ecosystem stability and modifying biodiversity was not generally appreciated until relatively recently. There has been a subsequent proliferation of studies on species transfer via ballast water in maritime countries across the world. However, despite considerable research effort, at both national and international scales, there has been virtually no consideration of the effectiveness or standardisation of ballast water sampling methodology. The **key objective** was to test monitoring systems for sampling ballast water and this was achieved by two major **intercalibration workshops** which compared scientific sampling techniques. These workshops delivered results allowing better comparison of ship sampling studies around the world. The **second key issue** are the results of the **ocean-going workshops** documenting the composition of organisms in ballast water during ship voyages. In addition, the effect of mid ocean exchange (MOE), which is recommended as a measure against unintentional introduction via ships, was studied (see below). Another key objective was the public awareness issue dealt with by the preparation of a video, a leaflet, flyer, press releases, articles to newsletters of International Aquatic Societies, Internet homepage and posters**,** and the case histories book listing species previously introduced to European waters.

2 Objectives

According to the Technical Annex submitted to the EU in 1997, the following objectives were fully addressed during the project.

2.1 Case histories

Objectives: Studying and comparing **case histories** of species previously introduced through ballast water and/or hull fouling into European waters. Existing literature on non-native species or ballast water research was consulted. During the first CA meeting, a case history format was designed and 11 species were selected for inclusion, ranging from unicellular algae to fish. The case histories provide background information for both the scientific and non-scientific communities. The case history format may serve as a prototype for a European database on harmful invasive species.

Deliverables: Book on selected case histories concerning the following species: **Flora**: *Coscinodiscus wailesii, Gyrodinium aureolum, Sargassum muticum, and Undaria pinnatifida.* **Fauna**: *Balanus improvisus, Crepidula fornicata, Dreissena polymorpha, Ensis americanus, Eriocheir sinensis, Marenzelleria viridis,* and *Neogobius melanostomus.*

2.2 Intercalibration of ship sampling techniques

Objectives: Before the ocean-going workshops commenced, the CA carried out an initial comparison of the ballast water sampling methods used by the partners within the European group during the first intercalibration workshop (summer 1998). To confirm these results and to further refine this initial exercise, a second intercalibration workshop was held in January 1999. At this workshop the ballast water sampling techniques were compared on a **world-wide** basis using commonly employed European and overseas techniques.

Based on the results from the first intercalibration workshop, the second workshop resulted in a more robust sampling design that permitted the simultaneous and consecutive testing of a variety of ships' ballast water sampling techniques. In particular, the use of a "reference net" along with each sampling method tested and an increased number of replicates improved the quality of the data compared to the initial intercalibration workshop. The exercise demonstrated the high variability between and within methods and the virtual impossibility to obtain a complete representation of the taxa that are present in ballast tanks. The entire CA clearly showed that full recovery of organisms contained in ballast tanks is virtually impossible, but that it is feasible to strive for representative target plankton taxa for ease of comparison between studies. At best, the outcome of this exercise documents the option to operate with a known level of error between methods, thereby allowing for some reasonable comparability among research teams. This is particularly important when ships are sampled by different teams at each end of their voyage so that results on survival and species composition are more comparable.

Knowing that ballast water tanks vary greatly by size, shape and accessibility and that the sampling method may vary according to the behaviour and the target taxa, a tool box of recommended sampling techniques was the outcome of the two intercalibration workshops.

Recommendations for future intercalibration experiments

- The lack of cultured zooplankton in sufficient number for spiking the test plankton tower enabled a quantitative comparison only. Future workshops should aim to provide the qualitative results from different zooplankton sampling techniques for comparison. It is recommended to use *Artemia salina* and oyster larvae in future tests to compare the results with those from the recent intercalibration workshop while also involving additional species, such as mysids, *Brachionus* sp, fish eggs and fish larvae in order to cover taxa of different sizes and escape responses during sampling.

- In order to minimize the human error in pulling up the nets to the surface it is recommended to use a block and tackle or a similar device to pull up all nets at a known and fixed speed.
- The number of replicates should be increased to a minimum of seven and if possible a larger water body should be sampled. Although the test plankton tower was relatively large, sampling effects (e.g. thinning out effects) occurred with a great number of techniques employed.
- During the phytoplankton trial at the south port of Helgoland there was so much sampling going on in a limited area and at the same time that the whole activity might have influenced the result. It is believed that natural water currents in the harbour were able to renew the water body that was sampled between each replicate. Sampling of a plankton tower would solve this problems.
- To minimize the unwanted distributional patchiness of organisms in the water body of the plankton tower, an appropriate mixing technique should be guaranteed. The selected technique should be efficient in mixing the entire water column without inducing the destruction of organisms.. It is likely that the mixing rate of 60 L/min was not sufficient in this experiment.
- The test tanks volume was 5.3 m³ and it is recommended to use a larger volume tank for additional experiments. Advantageous was the design of the plankton tower with a funnel shaped bottom. The pump was connected to the very bottom of the funnel and in this way the sedimentation of organisms in the tank was minimized.

Recommendations for ongoing and planned shipping studies

- Ballast water projects currently underway should consider using the recommended methods tested by the CA and if possible should compare these alongside with their own methods and sampling results.
- The techniques used for sampling will vary according to the configuration of the ballast tank being sampled and the size and the design of the ship. The most effective equipment will consist of easily transported components. Unfortunately it is meritable that ballast water sampling by using any of the methods employed will not representatively sample the organisms in the ballast water. An understanding of the behaviour of organisms may depend on the distribution of some organisms, such as algae. Future observations should consider the use of fluorescence standardized against chlorophyll levels at varying depths with each sampled ballast tank.

Recommended phytoplankton sampling gear

The tool box of sampling techniques should include methods that combine qualitative and quantitative sample analysis for phytoplankton composition and abundance. In light of this the overall suitability characteristics of the equipment tested can be summarized as follows:

(a) **Australian pump** operated via **sounding pipes** was the best pump in **qualitative** sampling trial. It was the only sampling technique being able to sample water from the bottom of deep tanks and e.g. double bottom tanks. Restrictions of its use: power supply needed (not always available on board or not permitted to use). Samples need to be concentrated by using a net.

(b) **German pump** operated via **sounding pipes** and **manhole** was the best hand pump operated via sounding pipes of all **qualitative** samples. The pump is light-weight, easy to apply and may sample depths < 9 m. Samples need to be concentrated by using a net.

(c) **Scottish Monopump** operated via **sounding pipes** and **manholes** was the most effective of all methods in **quantitative** sampling trial, but it heavy and cumbersome to employ. The sampling depth is > 9 m.

(d) **German cone-shaped net** (10 µm) operated via **manholes** was the best of all methods in the **qualitative** sampling trial, and
(e) **Ruttner sampler** operated via **manholes** showed similar **quantitative** effectiveness as the Scottish Monopump, but it is able to sample (small amounts of) water from greater depths and is of light-weight. An advantage of using the Ruttner is that the sample is not squeezed through a plankton net or pump resulting in less damaged organisms caught. This might enable easier taxonomic species identification.
It is recommended to use the smallest mesh-size available. It is obvious that larger mesh-sizes will exclude smaller species and therefore will have lower species richness relative to nets with larger mesh-sizes. Many of the organisms causing harmful algal blooms (target species in ballast water research) are very small.
The type of pump would depend on the access and permission of equipment to use on deck, but access may not be the only aspect to consider, however.

Recommended zooplankton sampling gear

Taken the most common scenarios into account which have been experienced during this study, the following sampling techniques can be recommended for zooplankton recovery in ballast tanks and should become a common option within the ”tool box” of sampling methods:
(a) **German cone-shaped net** operated via **manholes** was the most effective of all methods in **quantitative** sampling trial. The relatively short net is unlikely to become stuck in ballast tanks (length <1 m). Easy handling due to valve equipped cod-end with filtering capacity.
(b) **Australian Waterra pump** operated via **sounding pipes** shows similar **quantitative** effectiveness to German cone-shaped net (see above), however power supply is needed to operate the pump and may face difficulties in some instances. It is the only method to sample water from the bottom of deep tanks e.g. double bottom tanks.
(c) **German pump** operated via **sounding pipes** and **manholes** was the best manual pump of all **quantitative** samples. The pump is easy to apply, comparatively light-weight and therefore easy to transport and handle. The maximum sampling depth is 9 m.
(d) **Scottish pump** operated via **sounding pipes** and **manholes** is recommended to use, if required sampling depth is higher than 9 m and the Waterra pump cannot be used due to the lack of power supply, and
(e) **Chinese cone-shaped net** operated via **manholes** was the second effective net method in the **quantitative** sampling trial. The relatively long net may easily become stuck in ballast tanks (length >2 m). Easy handling due to valve equipped cod-end.
The CA Group welcomes any advice or comments that may help develop the standardization of sampling methods further. Other groups involved in ballast water sampling are invited to attend future land-based and ocean-going workshops of the CA to further improve the compatibility of sampling methods.

2.3 Survival of organisms in ballast water tanks during voyages (ocean-going-workshops)

Objectives: The purpose of the Ocean Going Workshops (OGW) within the CA was to examine the survival and diversity of organisms in ballast water and to compare different methods of sampling ballast water in order to allow a better comparison and interpretation of results obtained so far by independent studies carried out in the past. In addition, the effect of mid ocean exchange of ballast water (MOE), presently recommended in IMO draft guidelines and unilaterally required in some countries, as a measure against unintentional introduction via ships which are intercontinental transit, was studied.
The data were obtained during five OGW, which were undertaken both in European waters (OGW 1, 2 and 5) and during inter-ocean voyages (OGW 3 and 4). In total, approximately 700 samples were collected during more than 100 days at sea.

The **first** OGW was undertaken in July-August 1998 onboard a Russian Navy hydrographic ship, "Sibiryakov" (DWT 3442 t, length 86 m, draught 5 m, built in 1990). The cruise was organised by the Russian State Hydrometeorological University (St. Petersburg) within the framework of the IOC-UNESCO sponsored "Year of the Ocean" research and educational program. This voyage covered intercontinental waterways from the Baltic Sea to the Atlantic coast of Europe (Portugal).

The **second** OGW was carried out in October 1998 onboard the Norwegian oil tanker "Nordic Torinita" (DWT 108683 t, length 244 m, draught 15 m, built in 1992) from Cork, Ireland to Sture, Norway, crossing the Irish Sea and the North Sea. Samples were taken in various tanks throughout this short-term voyage.

The **third** OGW was carried out in May-June 1999 onboard the German container vessel "Pusan Senator" (DWT 63654 t, length 294 m, draught 13, built in 1997). The voyage was from Kaohsiung, Taiwan via the South Sea, Malacca Strait, the Indian Ocean, the Red Sea, the Mediterranean, the Bay of Biscay and the North Sea to Hamburg, Germany. The effect of multiple MOE were studied.

The **fourth** OGW was carried out in May-June 1999 onboard the British container vessel "Mairangi Bay" (GWT 43674 t, length 239 m, built in 1977) from Auckland, New Zealand to Hamburg, Germany via the South Pacific Ocean, Atlantic and the North Sea, being the longest OGW undertaken during the CA.

The **fifth** OGW was carried out in September 1999 onboard the Ukrainian hydrometeorological research vessel "Georgij Ushakov" (DWT 1420 t, length 101 m, draught 5 m, built in 1970) during the IMO Workshop on Ballast Water Management and Control (Odessa-Constanta-Varna-Odessa) in the Black Sea, dealing with another enclosed sea.

The purpose of the Ocean Going Workshops (OGW) within the CA was to examine the survival and diversity of organisms in ballast water and to compare different methods of sampling ballast water. In addition the effect of mid ocean exchange (MOE), which is recommended as a measure against unintentional introduction via ships, was studied.

RESULTS **Abiotic factors**

The temperature of ballast water in the tanks was similar to that of the surface seawater. Changes in seawater surface temperature were generally followed by a change in ballast water temperature with a short delay. Salinity of ballast water remains stable. Measurement of salinity in the ballast tanks following exchange with water of known salinity indicated that there was a residual amount of ballast water in the tanks that was not exchanged. Oxygen measurements showed a tendency to decline with time, but levels remained well above those required by marine organisms. The pH varied between 6.18 and 8.09. The changes may have been related to microbial activity and ballast water exchanges, but could not be correlated with any other observations made. Concentration of nutrients in ballast water was initially similar to that of the seawater pumped into the tanks. There was a steady decline in concentrations of nitrate, nitrite and phosphate. In some cases concentrations fell to below detectable levels after a few days. This may also be related to microbial activity.

The volume of total suspended sediment in the water column largely reflected the wind speed. After 8 hours of subsequent calm weather the majority of suspended material settled out of the water column. Subsequently, any rough weather conditions encountered were sufficient to re-suspend sediment throughout the water column.

Phyto- and zooplankton

More species and specimens were found in new ballast water, and communities were in general similar to outside seawater. The highest number of phytoplankton species found was 52, including several potentially toxic species. At most, 40 zooplankton taxa were found in the initial samples. Abundance and diversity of phyto- and zooplankton species is fairly stable for 3-4 days, followed by an exponential decline. In some cases no living zooplankton were found after 9 days, in other cases about 10% of the taxa survived remained viable for 25 days, on the voyage from Hong Kong to Hamburg. Sampling methods showed that in calm conditions phytoplankton exhibited vertical zonation. The layers became disrupted during rough weather and this was then associated with an increase in mortality.

For the first time in ballast water studies, traps using bait and light as attractants were deployed for sampling zooplankton. Taxa not seen in the net samples were identified in trap samples.

Ballast water exchange

There were two mid-ocean exchanges (OGW 3). In one, in the Indian Ocean, the abundance and diversity of zooplankton increased. The other mid-ocean exchange, in the Bay of Biscay, resulted in decreased abundance and diversity. The age of the ballast water was about the same (5-6 days) in both cases.

Some species were found in samples both before and after the supposedly complete exchange of ballast water. The decline of living marine organisms in the ballast water samples taken after the MOE was similar to that described above.

Comparisons of sampling methods

In rough weather and on smaller vessels it is sometimes only possible to take samples through sounding pipes. Comparison of samples taken at the same time from manholes and through sounding pipes showed significant differences for zooplankton. The effectiveness of different net types was also compared and differences were found, which reinforced the information obtained in the Intercalibration workshops, that the most appropriate method will depend on the type of vessel and organisms of most interest and that a toolbox of methods should be available.

CONCLUSIONS

A lot of valuable data have been obtained during the five ocean going workshops. It has not been possible to process all the samples collected and thus to collate and analyse all the data from these workshops. The eventual completion of this task will add to the above information. It is also recommended that the full data sets from these and other similar studies are collated and re-evaluated in the light of the knowledge gained from ocean-going workshops and Intercalibration exercises. Some conclusions are made, as follows:

4. Mortality of marine organisms in ballast water tanks is variable and some taxa can survive prolonged periods. Some algae, particularly toxic dinoflagellate species, have the ability to form cysts in ballast water sediments, overcoming unfavourable conditions and remaining viable for long periods. Thus, although the risk of introductions from discharge of ballast water may be minimised over longer voyages, it is not removed completely.
5. Although ballast water exchange is the currently recommended management method the results have shown that this will not necessarily reduce the abundance and diversity of marine organisms in ballast tanks. In some cases the same types of organisms are found in greater numbers following exchange, due to either re-suspension of residual water during exchange and/or improvement in water quality with the input of new sea water.
6. Further studies are needed to obtain a better understanding of changes in biota in ballast water tanks with changing conditions (including exchange) over time. These studies should include:
    A. The survival and physiological condition of organisms, and the effect of the latter on viability, with changes in abiotic conditions.
    B. Further investigations on effect of exchange on abundance and diversity of organisms under varying conditions of ambient salinity and temperature.
    C. The microbiological activity and chemistry of ballast water.
    D. The deployment of alternative sampling strategies, including traps, and development of new methods.
    E. Studies on the fouling of tank walls, and the role of biofilms in the introduction

of exotic species in ships' ballast water.

F. Further studies on species in ballast water sediments.

G. Modelling studies of interactions between the numbers and types of different species in ballast water over time and under various conditions, including exchange.

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

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

The ballast water management options currently required by many Port States are the ”non discharge of ballast water” and the ”exchange of ballast water in deep ocean” operations. The shipping industry is co-operating in the preparation of a Convention on Ballast Water Management and requests that standards need to be included in the Convention regarding the safety and environmental efficacy of all ballast water management options. It also seems necessary that an approval mechanism be devised, regarding human health and environmental safety aspects of physical and chemical ballast water treatment options on board ships.

There are currently world-wide industrial and scientific institutions which have recently started to develop treatment techniques for future application on land as well as onboard ships with the aim to minimise the transfer of aquatic organisms and pathogens with ballast water and associated sediment. Whilst the scientific basis of a number of treatment options have been developed and documented, comprehensive testing for the application aboard ships of most chemical and physical treatment options and the efficiency of combined techniques have not been carried out and evaluated. The economic viability and safety measures regarding personnel on board ship and the long term environmental impacts of most treatment options have to be demonstrated through co-operative efforts involving the scientific community and industry.

In 1997, guidelines for the control and management of ships’ ballast water to minimise the transfer of harmful aquatic organisms and pathogens were adopted by IMO Assembly Resolution A.686 (20). That resolution also requested governments to take urgent action in applying the guidelines and to use them as a basis for any provisions they adopt to minimise the risks of transferring species. It further requested IMO to develop legally binding provisions in this regard. An ”International Convention for the Control and Management of Ships’ Ballast Water” is being developed for adoption by a Diplomatic Conference in 2002.

The Convention will be accompanied with a technical annex (”regulations”) including operational requirements and a ”ballast water management code” providing details of ballast water management options. The exchange of ballast water in deep ocean areas is the only option practised so far and this has raised general concern in the shipping industry with respect to safety aspects during poor weather etc. Other options identified and considered within the CA Project are set out in the following section.

A. Uptake and treatment technology options

Uptake and treatment technology options can be applied during different stages of ballast water operations as follows:

on or before departure from port of ballast water uptake
on departure or during the voyage between ports
on arrival at ballast discharge port

B. The technology and treatment options for onboard applications are briefly described as follows:

Filtration techniques: are widely used in industrial and municipal applications. Filtration systems for use onboard ships are being tested in a number of countries.

Periodic cleaning of the filter systems is achieved by automatic backflush systems.

Hydrocyclones: are in use onboard ships for oil/water separation. Specific systems are being developed to separate organisms and particles from ballast water.

Ultraviolet treatment: is a well developed treatment option for destruction of cellular components. Wavelengths of around 200 nm are being used in test systems.

Ultrasonic treatment: causing cavitation in ballast water and resulting in mechanical stresses which disrupt cells.

Tank wall antifoulings: antifouling coatings on walls minimise biofouling by toxicity and ablation.

Chemical treatments: oxidising chemicals such as chlorine, ozone or peroxid formulations are used for waste water treatment, and are being tested for ballast water. Non-oxidising biocides include a wide variety of compounds used by industry e.g. for treating cooling water. Such biocides are often pesticides which may accumulate in the environment, causing a wide range of effects.

Thermal treatment: is commonly used to sterilise water. Temperatures of 40-45 degrees C for a period of 4 to 5 minutes are effective for exterminating some organisms.

Deoxigenation: oxygen can be removed from water by purging with an inert gas or by binding oxygen to chemical additives.

Current situation and future tasks

The ballast water management options currently required by many Port States are the ”non discharge of ballast water” and the ”exchange of ballast water in deep ocean” operations. The shipping industry is co-operating in the preparation of a Convention on Ballast Water Management and requests that standards be included in the Convention regarding the safety and environmental efficacy of all ballast water management options. It also seems necessary that an approval mechanism be devised, regarding human health and environmental safety aspects of physical and chemical ballast water treatment options on board ships.

There are currently world-wide industrial and scientific institutions which have recently started to develop treatment techniques for future application on land as well as onboard ships with a view to minimising the transfer of aquatic organisms and pathogens with ballast water and associated sediment. Whilst the scientific basis of a number of treatment options have been developed and documented, comprehensive testing for the application aboard ships of most chemical and physical treatment options and the efficiency of combined techniques have not been carried out and evaluated. The economic viability and safety measures regarding personnel on board ship and the long term environmental impacts of most treatment options have to be demonstrated through co-operative efforts involving the scientific community and industry. In this regard, the following questions have to be answered and tasks have to be carried out by the different stakeholders:

> the development of ship designs which facilitate the sampling of ballast water and associated sediments, their onboard treatment and ballast water exchange at sea by one of the recognised methods (i.e. by the sequential method of emptying and refilling ballast tanks; by continuous flushing of at least 3 times the volume of the tanks; and by the dilution method through injection of ballast water from deep oceans through a main ballast line and discharge through suction pumps near the tank bottom).
>
> The development of designs have to take account of the current knowledge of the ecology of organisms in ballast water tanks. Furthermore, a hazard rating schedule for chemicals regarding their environmental and human health effects as those

recommended by OECD, ASTM, USEPA and used by GESAMP, EU and the UN agencies in the field of labelling dangerous goods should be applied.

pending the outcome of the above, it is still unknown as to whether a complete sterilisation of ballast water will be economically feasible, environmentally safe or otherwise practical. Nevertheless, a system of ballast water management and controls have to be developed with a view to minimising the risks of harmful introductions with ballast water. Such a risk assessment involves the identification of ”hot spots” where the uptake of ballast water should be avoided. Risk-based approaches use quantitative risk assessment methodologies to assess the likelihood of introductions of specific target species including the assessment of economic and social implications. However, biologists currently cannot answer many questions regarding the fate of discharged organisms and the likelihood of their establishment. It is not known how many individuals of a given species or their densities, are needed to establish a viable, self-reproducing population at a new site.

taking into account the results and the outcome of developments mentioned above, standards for the safe release of ballast water into the aquatic environment have to be established by national port authorities based on guidelines that are being developed to assist in the effective implementation of provisions that are being prepared for inclusion in globally applicable as well as regional conventions.

The completion of the tasks outlined above is only achievable through co-operative action involving national administrations, port authorities, the shipping industry and scientific institutions. The development of hazard rating procedures and the evaluation of ballast water options need the involvement of a scientific advisory group which should include technical shipping expertise. This way it would be possible to design a “tool box”, that accounts for different types of ships as well as for different ballast water operations (e.g. individual ballast water management plans of individual ships) or the specific needs of port and / or flag states in relation to the protection of their marine environments.

Risk assessment methodologies including the identification of target species and so-called ”hot spots” and emergency ballast discharge areas are matters for national port authorities who want to protect the sustainability of national resources and legitimate activities in the sea and coastal areas under their jurisdiction.

For developing countries, the establishment of training programmes and convening of workshops is necessary, combined with the establishment of efficient infrastructures in such countries involving existing institutions. Such capacity building shall remove the barriers for effectively implementing regional and globally applicable regulations that are being developed.

2.5 Identification of research priorities

Objectives: Development of joint research programmes on methodological and other aspects, for example, distribution mapping (time series) of introduced and invading species, their interaction with native species, the feasibility of target species lists, the development of expert ballast water management systems, the need for treatment research were all separately evaluated. Numerous problems related to sampling techniques and sampling strategies were specifically addressed. Both regular and ocean-going workshops helped to generate many recommendations on how to deal with these problems in future research and how to better advise management towards environmentally sound and effective solutions to the problems. A summary of research needs and priority subjects areas are given together with their justification. These are based on an overall evaluation of world-wide activities in this area.

A Nordic Risk Assessment Study was prepared in conjunction and as a contribution to the CA. The report was completed in 1998 and is available via the Nordic Council of Ministers, Copenhagen, Denmark. Both authors of the report (S. Gollasch and E. Leppäkoski) as members of the CA group linked the two studies closely together. In chapter 18, page 103 (and following pages) gaps were identified where further research is needed:

Gaps identified, further research needed

Much remains unknown in terms of the patterns and processes of invasions. Large gaps remain in the knowledge needed to establish risk assessment protocols and effective management plans. The following list summarises examples of important research needs and applications.

1 Further studies on the ecology of introduced species

Only a few of the NIS have been studied experimentally or in a wider ecosystem context. The exact impact of NIS on native ecosystems can only be quoted by knowing more details on their requirements and relationships to the native biota.

2 Shipping studies and port profiles

A more intensive biological and ecological study of major ports and the ballast water arriving in the Nordic waters is urgently needed. A regional shipping study would provide basic data for management plans and guidelines to deal with ballast water.

The provided information on the port profiles enabled a first, initial risk assessment for the potential of further species introductions to selected areas in the Nordic coastal waters. Relevant data on additional port areas are essential to assess the risk in more detail.

3 Economic impacts of wood borers and fouling organisms

Impacts of wood-boring organisms (shipworms and isopods) and of fouling organisms (on vessels and submerged installations) are widely unknown and remain largely undocumented and entirely unquantified in Nordic countries.

4 Genetic studies of introduced species

The application of modern molecular genetic techniques has already revealed the cryptic presence of previously unrecognised invaders in the San Francisco Bay area (Cohen & Carlton 1995). European Studies on the polychaete *Marenzelleria* revealed that in fact two, morphologically very similar species *M. viridis* and *M. wireni* did invade. *M. viridis* is predominantly found in the Baltic Sea and *M. wireni* in the North Sea.

The objective to evaluate "hot spot donor areas" of future species introductions may be determined more precisely by genetic comparison of previously introduced species. In this way the origin (native range or introduction from a habitat formerly invaded) of the introduced species can be proven.

5 Post-invasion control mechanisms

Studies on potential control mechanisms (e.g. biocontrol, physical treatment, eradication) of harmful introduced species are in their initial phase. Currently pilot studies are undertaken in order to control *Carcinus maenas* in Tasmania and *Mnemiopsis leydii* in the Black Sea and for *Caulerpa taxifolia* in the Mediterranean Sea. If it is impossible to eradicate a new invader completely, it might be possible to prevent or slow down its further (secondary) post-invasion spread. Public awareness programmes may assist in slowing down the process of spread of *Caulerpa taxifolia* in the Mediterranean Sea and the Zebra mussel in the North American Great Lakes and in Ireland.

6 Additional risk assessments

Knowing the fact, that each single vessel has the potential to introduce a new species, it is not meaningful to estimate the total amount of ballast water discharges. In order to evaluate the risks in a Nordic perspective, it would be helpful to know all potential source areas of ballast water outside the Nordic area. In combination with additional port profiles of major Nordic harbours a more detailed risk assessment can be carried out in the future.

The establishment of a network of experts, institutions and authorities would support the effectiveness of future risk assessment studies by transferring knowledge between working groups.

There are no specific monitoring programmes for NIS in the Nordic or Baltic Sea area. However, programmes carried out within the HELCOM system, as well as national monitoring programmes for bottom fauna and plankton, do produce overviews on changes in the environment. These programmes could support the control of introduced and/or established NIS. Knowing the areas with alien species enables to develop guidelines on ballast water uptake in order to prevent secondary introductions by ballast water within the Nordic countries.

Conclusions

- It is false to say that every species that could have been introduced would be here by now. As example there have been shipping routes from the Caspian and Black Sea region to the North American Great Lakes since many decades before the zebra mussel *Dreissena polymorpha* was finally introduced successfully to this area. It took several decades to "open" the window of introduction, i.e., to catch the right conditions in both donor and recipient areas and a vessel releasing ballast water containing a sufficient number of zebra mussel larvae at the same time.
- The chance of an introduced species to become established and the chance for this introduced species to become a serious problem for the environment or economy is small. But, one single introduced species can cause severe harm to the economy and ecosystem the species invaded, as shown by zebra mussel in the North American Great Lakes, the comb jelly in the Black Sea and the green seaweed *Caulerpa taxifolia* in the Mediterranean Sea.
- Our current knowledge indicates that anthropogenically supported invasions in aquatic ecosystems increase on a world-wide basis. Many other aspects of invasions remain nearly unpredictable. Among them, unfortunately, are the most wanted answers to: Which species will invade, when will it invade, where will the species invade and what will be the impact of this new species? Today these questions can be answered only on a theoretical or broad scale. Accordingly an indication of habitats at risk can be given only on a limited base. We know that certain areas such as estuaries and areas with high input of NIS (ports, waterways and shipping routes as well as aquaculture sites) represent high risk areas for further introductions. Taking into account the shipping routes and comparing matching salinity and climate conditions in donor and recipient area first incomplete estimations are possible. Adding the duration of the ships voyage (short term voyage will increase the survival rate of specimens in the ballast tank) the picture comes more clear, but still is far from a prediction and represents a kind of an advanced guess.
- The establishment of a network of experts, institutions and authorities would support the effectiveness of future risk assessment studies by transferring knowledge between working groups. In this way an effective warning system in order to document and possibly control/prevent secondary introductions within the Nordic countries may be installed facing different aspects needed to undertake a positively overlapping risk assessment.
- Management practices as (e.g. the ballast water exchange in open sea) are the first step to minimise the risk associated with species introductions. Especially in the case of the Baltic Sea and other brackish water areas, such as the Black Sea, river mouths and diluted waters of inner parts of fjords and coastal inlets, the ballast water exchange in highly marine water with oceanic salinity represents a practicable and cost effective method reducing the risk of further species introductions. Some oceanic species might, however, have the capacity to tolerate brackish salinities. On the other hand many ships may not pass such areas en route and a Scottish study (Macdonald 1998) indicated that the number of species may in fact increase on short routes within Europe. To follow the IMO guidelines how to ballast and how to exchange the ballast water will minimise the risk of further introductions without any re-construction of ships.

- Strategies to implement the IMO guidelines are needed. Regional authorities shall promote to implement these guidelines as legally binding provisions. It is important to note that the IMO guidelines do not solve a long term solution to the problem of ship mediated species transport; ballast water issues must be given high priority while designing the new generation of ships.

2.6 Public awareness

Objectives: The importance of ballast water as a means for affecting aquatic ecosystem stability and modifying biodiversity was not generally appreciated either by the public at large or by the shipping industry or regulatory authorities except the IMO. Through press releases, flyers and posters to the mass media, the CA created a more realistic focus on the essential environmental concerns that relate to ships' ballast water, sediment and hull fouling. The list of activities (poster presentation, lectures, reporting etc.) of the participants during the CA is impressive and is documented in appendix. Furthermore, the scientific community was informed through general articles, jointly prepared by participating partners, for example through newsletters and annual meetings such as ICES, BMB and other national, regional and overseas events. Scientific results of the intercalibration exercises and other scientific findings are being prepared for publication in peer reviewed scientific journals.
The importance of ballast water as a means of human intervention in aquatic ecosystem stability and biodiversity was not generally appreciated. The activities of the CA members solved this lack of information by widely distributing material relevant to the issue inside and outside the scientific community. The public awareness activities included the distribution of:

- several articles, jointly prepared by participating partners, for example through newsletters and annual meetings such as ICES, BMB and others,
- many lectures were given mentioning the CA objectives and initial results
- a **leaflet** and a **flyer** introducing the CA members and study objectives,
- **press releases**, in total four press releases have been prepared,
- **presentations** (approx. 75) at scientific meetings,
- **posters**, in total four poster were prepared.
- an **Internet homepage** entitled ”Exotics Across the Ocean” was put on the net in August 1999. So far the total number of visitors was 759 (Dec. 28th 1999)
- a **video** to document the intercalibration experiment and sampling of ships passing through the Kiel Canal, and
- the **case histories book** listing species previously introduced to European waters.

2.7 European waters as a donor area

Objectives: Within Europe, some port regions may be at greater risk from ballast water introductions in account of the volume of ballast released, local topographic features or aquaculture activities, etc. Conversely, overseas port areas may be at greater risk from the introduction of some European species. European waters may also be a donor area for the transport of organisms even within the same country (e.g. Mediterranean Sea and Atlantic Ocean, North Sea and Baltic Sea). European waters can be a significant donor of species transported by ships elsewhere.
It is important to note that all non-indigenous species are believed to be potentially harmful. Every import should be assumed harmful in the beginning until it is shown to pose a low risk. Therefore the target list approach of unwanted species needs critical consideration. It was concluded that another list of species listing introduced species with low impacts is needed.
It was concluded by the Concerted Action group that these kind of target species lists are only of limited help in order estimate future severe species introductions.
However, a Nordic Risk Assessment Study was prepared in conjunction and as a contribution to the CA. The report was completed in 1998 and is available via the Nordic Council of

Ministers, Copenhagen, Denmark. Both authors of the report (S. Gollasch and E. Leppäkoski) as members of the CA group linked the two studies closely together. In chapter 15.5, page 82 (and following pages) Nordic waters have been considered as donor areas of species:

Deliverables:

Europe. A **Nordic Risk Assessment Study**, was launched to evaluate whether aquatic resources in Nordic countries are at risk and vulnerable to invasions by non-indigenous species. Nordic marine areas are particularly sensitive to the introduction of non-indigenous organisms, many of which have potential to cause, large-scale environmental problems (disruption of biodiversity in particular); and/or whether economic effects, ecosystems and indigenous species were particularly sensitive to the impact of non-indigenous species. A calculation of economic losses due to the impact of non-indigenous species and prerequisites (e.g., salinity and temperature conditions, availability of habitats, turbidity, eutrophication, pollution) were carried out and probabilities of selected harbour areas to act as receivers and / or donors were quantified in relation to survival probabilities of non-native species. Studies of existing vectors in selected, international harbours, including harbour profiles with regard to import / export of ballast water (i.e. a origin / destination profile for imported / exported ballast water) were undertaken together with suggestions of measures and strategies to be employed with a view to tackling the problem and the need for further research, and suggestions concerning monitoring activities. The Nordic Risk Assessment Study was prepared in conjunction with and as a contribution to the CA. The report was completed in 1998 and is available via the Nordic Council of Ministers, Copenhagen, Denmark. Both authors of the report (S. Gollasch and E. Leppäkoski) as members of the CA group linked the two studies closely together. In chapter 15.5 (page 82 and following pages) Nordic waters were considered as donor areas listing probable transport mechanisms and a selected number of species of concern. Further expertise to the Nordic Risk Assessment Study was given by the authors of the port profiles, prepared under the supervision of the CA members E. Leppäkoski, I. Wallentinus, H. Botnen and S. Olenin.

Gollasch, S. & E. Leppäkoski (1999): Initial risk assessment of alien species in Nordic coastal waters. 1-124. In: Gollasch, S. & E. Leppäkoski (eds.) Initial risk assessment of alien species in Nordic coastal waters. Nord 1999: 8. Nordic Council of Ministers, Copenhagen. 244 pp.

2.8 Documentation of European studies on ships and introduced species in the past

Objectives: During the CA, all participants provided 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 a database to be kept by the co-ordinator.

The Concerted Action reviewed and considered shipping studies both within the EU and within the rest of the international community. This helped to give a more balanced view of the state of the art and also enabled the Intercalibration workshops to consider and compare sampling methods as used throughout the world. Many of these studies were completed, and some new studies commenced during the lifetime of the Concerted Action.

Shipping studies fall into two categories. Firstly, there are practical studies in which samples of ballast water and, where available, sediments, were collected from ships' ballast tanks and the biota identified. These studies attempted to collect samples seasonally from a variety of ship types from a range of destinations. Some of these studies included sampling en-route and the results were applied to the Concerted Action ocean-going workshops. Secondly, there are theoretical studies in which the relationships between documented introductions of exotic organisms were compared with shipping movements to assess the likelihood of ballast water as a vector. Both types of studies included an assessment of the risk of introduction of unwanted exotic organisms. This assessment was sometimes reinforced by collecting information on the scale of ballast water discharge operations in national ports and waters.

The studies discussed are summarised in Table 1 and short description of each study follows. Whilst this list attempts to summarise all the studies that the CA is aware of, it should not be assumed that the list is fully comprehensive.

Table 1 - Summary of shipping and theoretical studies in European and non-European countries.

EUROPEAN STUDIES		**NON EUROPEAN STUDIES**	
Practical	**Theoretical**	**Practical**	**Theoretical**
Belgium	France	Australia	Georgia
Croatia	Ireland	Brazil	South China Seas
England and Wales	Nordic Countries	Canada	
Germany	Sweden	Chile	
Lithuania		Israel	
Netherlands		New Zealand	
Norway		USA	
Scotland			
Sweden			

3 Conclusions and recommendations

The CA took advantage of numerous international and inter-governmental activities related to ballast water issues. Thus, virtually all the presently available ballast water expertise from around the world participated in one or more of the activities of the CA and greatly assisted in providing new results, while contributing valuable ideas and priority arguments which helped the CA-partners to formulate the following recommendations:

Numerous problems related to sampling techniques and sampling strategies were addressed. Both regular and ocean-going workshops helped to generate many ideas on how to deal with the problems in future research and how to better advise management towards environmentally sound and effective solutions to the problems. A summary of the most important research priorities are given as follows:

- **Recommendation:** Studies should be supported to improve understanding of real survival, viability and behaviour of exotic species in ballast tanks.
- **Justification:** Despite all the practical work carried out under this CA, our knowledge on this subject is still fragmentary. Sampling in parallel with different methods used in partner laboratories indicate that present methodologies may not adequately monitor bio-diversity and abundance in ballast tanks since many species may not be caught by the sampling procedures when distributed in areas of the tanks that are inaccessible by equipment in use. There is a need to improve net designs and to develop criteria that may be very different form conventional plankton sampling techniques.
- **Recommendation:** Sampling techniques using nets and pumps need to be improved and diversified.

  Justification: It was evident form the intercalibration exercise and from ocean-going workshops that many species may not be caught by commonly used nets and pumps. Effectiveness differs among various nets and this relates to both taxa and number of specimens. Baited traps and light sticks were used for the first time in ballast water studies and clearly showed that there are - as expected - many other species that escape our common sampling methods.
- **Recommendation:** A comprehensive re-evaluation of the vast amount of data collected in studies undertaken by CA partners and by associated participants from other counties should be undertaken to gain a further understanding and interpretation of community changes and behaviour of organisms in ballast tanks during voyages. This could be undertaken by a new EU project or CA.

- **Justification:** Following the analyses of data collected during ocean-going workshops it was concluded that there is a need to combine and re-analyse all data sets from past studies in light of our findings on the comparability of sampling techniques. This activity could serve as a forum for continued exchange of information and experience.
- **Recommendation:** It is recommended that a land-based (large-mesocosm) project be promoted in order to test and compare environmentally acceptable, cost-effective and save ballast water treatment options in fully controllable systems.
- **Justification:** This should preceded full-scale testing onboard ships as these operations are expensive and may benefit from insights gained in strictly controlled test facilities. The CA partners are fully aware of ongoing full-scale tests undertaken by various countries and industries. However, our results from ocean-going workshops are not only indicating the need for controlling primary inoculation but also secondary ones which may include unexpected sediment movements and the re-distribution of specimens hiding in certain regions of ballast tanks of different construction.
- **Recommendation:** The initial studies using baited traps and light sticks showed promising results; further studies with improved equipment should be strongly encouraged.
- **Justification:** The employment of traps in ballast tanks was undertaken for the first time ever during this CA. While many technical and legal problems hat to be overcome, we are now beginning to refine the sampling methods.
- **Recommendation:** Ballast water exchange strategies should be developed to designate exchange areas not only based on biological criteria but also according to operational situations (e.g. routing, length of trip, geographical area coverage, ports of call within and outside these areas).
- **Justification:** For example, the ocean-going workshop results indicate that traffic within Europe between inshore areas of the Atlantic and adjacent seas while moving to the Baltic, should exchange in the North Sea because the salinity stress is likely to reduce the number of living organisms transported.
- **Recommendation:** Better designed and extended mid-ocean exchange methodologies should be developed.
- **Justification:** Some evidence is accumulating that mid-ocean exchanges do not necessarily achieve objectives under all circumstances. Studies by CA members clearly indicate that (a) number of taxa may increase after mid-ocean exchange, (b) weak and near bottom settling (dying) organisms may be "revived" by replenishment of the tank water and (c) current tank design permits effective escape and hiding response actions of organisms and prevents their removal, despite the theoretical complete exchange.
- **Recommendation:** Modelling and onboard studies on hydrodynamics in ballast tanks should be undertaken to improve the understanding of mixing characteristics and avoidance response of organisms.
- **Justification:** Organisms respond quickly to micro-turbulence and aggregate in areas with preferred or less stressful hydrodynamic conditions. Most zooplankton and meroplankton taxa will find numerous hiding places so that ballast water exchanges will not permit their removal unless tank design, ballast water intake and outlet arrangements and pumping strategies allow rapid quantitative and effective mixing. The recommended studies will enable to design better and more effective treatment methodologies through adapted ballast water tank design.
- **Recommendation:** Ship designers and engineers should incorporate the results of studies on hydrodynamics and species' behaviour in order to improve ballast tank design in support of either (a) better water renewal effectiveness during mid-ocean exchange, and (b) more effective mixing while treating ballast water.

- **Justification:** The next generations of ships are still designed by engineers that are not sufficiently familiar with aquatic life sciences to understand the importance of tank design for treatment effectiveness. So far, ship designers are concerned with engineering aspects of ship stability and safety. Awareness campaigns and training workshops demonstrating the modelling results arising from studies initiated under recommendations 8 should greatly assist in know how transfer and awareness building on environmental management issues.
- **Recommendation:** Further studies on standardised methodologies for data analysis of ballast water (considering past, present and how sampling methods as requested under rec. 2 and 5) as well as for assessing the efficacy of onboard treatment options are requested to be further carried out by the membership of the CA for inclusion in legally binding treaties which are currently being prepared.
- **Justification:** The members of the CA project comprise most relevant scientific disciplines necessary to evaluate the efficiency of ballast water treatment options as well as sampling and analysis of ballast water organisms. This potential should be utilised effectively so that the developed momentum is not lost.
- **Recommendation:** The member of the CA should provide guidance to port State authorities for their development of risk assessment systems and this should be done in close co-operation with the IMO/UNOP GEF project.
- **Justification:** The collective expertise and knowledge assembled within the membership of the CA provides an unique opportunity and core for training as well as advisory services for regional and global organisations.
- **Recommendation:** It is required that the public awareness campaign undertaken by the CA be expanded into a project that deals on an European scale with aquatic exotic species in general (e.g. by establishing an online GIS) while also updating and expanding the existing case history studies published by the CA.
- **Justification:** The CA has provided information to the public in the form of posters, public meetings, press releases and a publication involving 11 case histories of harmful species introduced into European waters. There is a need for accurate information on exotic species and their impacts particularly when interest groups become involved and require accurate information that can be made available to all users.
- **Recommendation:** Further studies on exotic species management should include investigations of hull fouling and ballast sediment as well as ballast water.
- **Justification:** Ballast water is not the only means that exotic species become spread. Several studies have shown that sediments harbour living organisms and resting stages of planktonic species. In addition hull fouling will continue to pose a problem of exotic species transport and is likely to become of greater concern following the ban of TBT. Species associated with hull fouling includes some commercial bivalve species, and there may also transport their pests parasites and disease agents and compromise aqua culture and molluscan fisheries elsewhere. Similarly ballast sediments have been shown to certain living organisms and also warrant further investigations.
- **Recommendation:** Port studies should be initiated to document and evaluate the effects of pollutants, such as TBT , on the lack of success of settling of exotic species.
- **Justification:** The unique opportunity to use TBT as a maker of residual water flow from port regions can help to understand to what extend various toxic substances in and around harbours influence invaders success. Since the IMO have recently proposed to ban the use of TBT in ships antifouling paints by the year 2003 the novel approach of using TBT as indicator of residual drift should be utilised as soon as possible. Plumes of TBT diffusion are already known for several ports. Such studies would therefore establish a baseline for future monitoring of exotic species expansion from port areas once TBT is banned. With remidiation of port regions more exotic species are expected to succeed and some of these

will have economical and ecological consequences. Therefore, the implications of the anticipated changes (post TBT period) for ballast water and port management must be addressed in the very near future.

As a result, CA-partners and other scientists from EU-member countries have formulated and submitted project proposals to the EU Framework V programme. It is hoped that the recommendations given will assist the EU in making the right decisions related to ballast water management and monitoring. It must be recognized that a sound scientific basis for management is urgently needed, and those developing the know-how appreciate the important regulatory and commercial consequences as a result of the rapidly increasing globalization of economies and the increase in economic, social and environmental processes in the coastal zone.

It is finally recommended that the EU takes advantage of the now well developed expertise within the network of the CA partners in order not to lose the momentum in an area which is now already looking for global solutions.

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