Removal of Barriers to the Effective Implementation of Ballast Water Control and Management Measures in Developing Countries

prepared by

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This report presents the results of a desk study carried out in November 1997 in order to support the joint GEF/IMO/UNDP project, initiated by the IMO, entitled: „Removal of Barriers to the Effective Implementation of Ballast Water Control and Management Measures in Developing Countries“ with background information. Due to the limited time available to collect these information the compiled lists claim not to be complete but shall give an overview relevant to the subject.

Abbreviations used:

(see also in the world wide web at: http://www.icc.ie/info/net/acronyms/index.htm)

ABWMAC Australian Ballast Water Management Advisory Council
ACME Advisory Committee on the Marine Environment (ICES)
ANS Aquatic Nuisance Species
APHIS Animal and Plant Health Inspection Service (USA)
AQIS Australian Quarantine and Inspection Service
ASMO Assessment and Monitoring Committee
BALLERINA Baltic Sea Region On-Line Environmental Information Resources for Internet Access
BIONET Biodiversity Action Network
BMB Baltic Marine Biologists
DWT Dead Weight Tonnage
CBD Convention on Biological Diversity
CBIN Canadian Biodiversity Information Network
CFR Code of Federal Regulations (USA)
CIEL Centre for International Environmental Law
CIESM Commission Internationale pour l`Exploration Scientifique de la Mer Mediterranée
CITES Convention in Trade on Endangered Species
CRIMP Centre for Research on Introduced Marine Pests (Australia)
CSIRO Commonwealth Scientific and Industrial Research Organization (Australia)
CSA Canadian Shipping Act
EC Environment Committee
EEZ Exclusive Economic Zone
EIFAC European Inland Fisheries Advisory Commission (of the FAO)
ETI Expert Centre for Taxonomic Identification (UNESCO)
FAO Food and Agriculture Organization of the United Nations
FWS Fish and Wildlife Service (USA)
GEF Global Environment Facility
GESAMP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (IMO/FAO/UNESCO-IOC/WMO/IAEA/UN/UNEP)
HAB harmful algal bloom
HEAR Hawaiian Ecosystem at Risk
HELCOM Helsinki Commission (Baltic Marine Environment Protection Commission)
HNIS Harmful Non-Indigenous Species
IAEA International Atomic Energy Agency
IBIN Indigenous Peoples Biodiversity Information Network
ICES International Council for the Exploration of the Sea
ICLARM International Centre for Living Aquatic Resources Management
ICS International Chamber of Shipping
IFREMER Institut Francais de Recherche pour l'Exploration de la Mer
IHS Import Health Standard (New Zealand)
INTERTANKO International Association of Independent Tanker Owners
IPHAB Intergovernmental Panel on Harmful Algal Blooms (IOC)
IMO International Maritime Organization

IOC Intergovernmental Oceanographic Commission
IUCN The World Conservation Union
ISSG Invasive Species Specialist Group (IUCN)
JAMP Joint Assessment and Monitoring Programme
LEML Laboratoire Environment Marine Littoral (Nice)
MARPOL 73/78 International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto
MC Marine Committee
MEPC Marine Environment Protection Committee (of IMO)
NAS Non-Indigenous Aquatic Species (USA)
NEMO Non-Indigenous Estuarine and Marine Organisms (BMB Working Group)
NISA National Invasive Species Act (USA)
NOAA National Oceanic and Atmospheric Administration (USA)
OSPAR Oslo and Paris Conventions for the Prevention of Marine Pollution
RAG Research Advisory Group (Australia)
SCOR Scientific Committee on Oceanic Research
SERC Smithsonian Environmental Research Centre (USA)
SGMBIS Study Group on Marine Biocontrol of Invasive Species (ICES)
SGBWS Study Group on Ballast Water and Sediments (ICES/IOC/IMO)
SOLAS International Convention for the Safety of Life at Sea, 1974
UN United Nations
UNCED United Nations Conference on Environment and Development
UNCLOS United Nations Convention on the Law of the Sea
UNDP United Nations Development Programme
UNEP United Nations Environment Programme
UNESCO United Nations Educational, Scientific and Cultural Organization
USCG United States Coast Guard
USDA United States Department of Agriculture
VPC Vancouver Port Corporation (Canada)
WCMC World Conservation Monitoring Centre
WGITMO Working Group on Introductions and Transfers of Marine Organisms (ICES)
WHO World Health Organization
WMO World Meteorological Organization

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1 Introduction

The unintentional introduction of non-indigenous organisms has resulted in the establishment of many species outside their native ranges with the potential to threat native environments and economies.

It is assumed that the main vector concerning transportation of organisms is, beside the introduction of species for aquaculture purposes, the unintentional transport with ships. Since the introduction of steel hulled vessels in the late 19. century ballast water discharges have increased considerably throughout the world and the probability of successful establishment of self-sustaining populations of non-indigenous species increased with greater volumes of ballast water as well as with reduced ship travel times. The first suggestion of an unwanted species introduction with ships was made by Ostenfeld (1908) after a mass occurrence of the Asian phytoplankton algae *Odontella* (*Bidulpphia*) *sinensis* in the North Sea in 1903. Several decades later a survey was carried out by German scientists sampling the Suez Canal flora and fauna. At that time some ships used ocean water for cleaning purposes pumped on board via segregated pipework. One of the plankton scientists realised that this cleaning water contained organisms and sampled it for his plankton study. This was the preferred way of sampling because the ship was able to continue its voyage without a stop for sampling. But the scientists on board did not realise that in the same way as for cleaning purposes water was pumped on board to fill the ballast tanks and that species may survive this pumping activity as well. The first shipping studies including sampling of ships' ballast water appeared 70 years later by Medcof (1975) followed by those of Carlton (1985, 1987), Hallegraeff & Bolch (1991) and Subba Rao et al. (1994). Rosenthal (1980) reviewed the state of knowledge and the risks associated with the transplantation of non-indigenous species to fisheries and aquaculture, including ballast water as vector. The study concluded that modern aquaculture development in the coastal zone was at high risk of disease transfer from ballast water in cases where aquaculture facilities and areas of fishing were located near shipping routes. The recent world-wide growth of aquaculture along such infrastructure elements amplifies this risk, possibly rendering disease regulations for this industry useless in many areas. An annotated bibliography on transplantation and transfer of aquatic organisms through various means (including ballast water) is presently under preparation, covering more than 10,000 literature entries (Rosenthal, 1996, final draft).

As example we note that with the import of the Pacific Oyster several non-target species have probably been introduced. Some of them are harmful, such as parasites and competitors with native species. More than 100 species have been documented as being transported with living oysters in the packing material or settling on the oyster shell. These may even include disease agents and parasites located in the tissues of the oysters (Bonnot 1935, Korringa 1951, Edwards 1976, Farnham 1980, 1994, Carlton 1992, Sindermann 1992, Minchin et al. 1993).

After having been made aware of the problems, the International Council for the Exploration of the Sea (ICES) established a working group in the end of the 1970s (Working Group on Introductions and Transfers of Marine Organisms (WGITMO)) in order to evaluate quarantine measures dealing with living imports of species for aquaculture and accordingly developed an ICES Code of Practice (Carlton 1992, Sindermann 1992). The ICES WGITMO further emphasised the need to follow the IMO Assembly resolution A.774 (18): "Guidelines for the Control and Management of Ship’s Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens" (see below) during preparation of this report resolution A 774 (18) is being replaced by IMO resolution A 868 (20). In addition to the WGITMO ICES, IOC and IMO established in 1997 a joint Study Group on Ballast Water and Sediments (SGBWS). At its first meeting the study group concluded that this provided an unique opportunity to exchange information on research activities, sampling methods, management and control options and to consider directions for new research activities.

Other regional bodies particularly relevant in this field are a working group of the Baltic Marine Biologists (BMB) on Non-Indigenous Estuarine and Marine Organisms (NEMOs), an adhoc group established in 1994 with a term of reference covering 4 to 5 years.

Non-indigenous species are not only introduced with ballast water and associated sediments, but also as fouling organisms on the ship´s hull. However, efficient biocidal anti-fouling paints currently used considerably reduce the number of fouling organisms on ship´s hulls. Accordingly the major problem in transmission of harmful aquatic organisms, therefore, resides with the continued transfer of ballast water of ships, in particular bulk carriers and container ships of different design and dimensions.

It has been estimated that the major cargo vessels of the world (total number 70,000 [Stewart 1991]) are transferring 10 billion tonnes of ballast water globally per year indicating a global concern for this problem. Ballast water may be taken in from eutrophicated coastal areas containing hundreds of species which may survive voyages of several months duration. It has been demonstrated that in average 3,000 (Carlton & Geller 1993) to 4,000 species (Gollasch 1996) are transported daily by ships of these species only 500 are known today (Carlton et al. 1995). Species discharged with ballast water into the next port of call may threaten native populations, fishing industries and public health.

The likelihood of an introduced species to settle in new regions and to create problems depends on a number of factors, primarily related to the biological characteristics of the species and the environmental conditions in which the species has been introduced. Additional factors are climate, number of introduced species (size of founder population), native competitors and the availability of food. Species are more likely to establish in environments that are similar to those environment of their origin. Therefore, if the port of loading and port of discharge are ecologically comparable the risk of a species introduction is relatively high.

Observations have demonstrated that organisms need not to be harmful pests to cause severe damages. Some invaders affected native flora and fauna by competing for food, habitat and other resourses. The ecological worst case is the replacement of a native species caused by the exotic invader. This can effect not "only" one single newly extinct species but also any other organism dependent on it as a food source or habitat. As a result the food web structure may intensively change after the introduction of one single species.

Carlton (1985) has given a thorough review of the role of ballast water as a mechanism for the dispersal of organisms. Recent invasions and population explosion of non-indigenous species in various parts of the world that are causing ecological and economical damages are described by Carlton & Geller (1993), Hedgpeth (1993) and Gollasch & Mecke (1996).

As early as 1994, it was recommended during a Conference and Workshop on Non-Indigenous Estuarine and Marine Organisms in Seattle, Washington, USA, that educational programmes should be developed to increase overall awareness, list pathways of introductions of species and educate the general public on reporting procedures for new sightings of non-indigenous species (Brown 1994).

It is the aim of this report to summarise ongoing research and to lists national and international regulations on non-indigenous species and / or ballast water. In addition recommendations in the effective implementation of guidelines is given.

1.1 What is ballast water

Ballast water has been used since the late 1870s in cases where ships are not fully loaded in order to submerge the propeller and rudder in the water, to operate effectively and to control the trim and increase the stability. Ballast water is usually carried in segregated ballast water tanks or in emptied cargo holds. Ballast water (not bilge water) is marine or fresh water taken on board in ports, waterways and the open ocean (Carlton 1985, 1987, 1994). With the intake of ballast water organisms in the water are pumped on board into the ballast tanks. Sediments suspended in the water may settle to the bottoms of ballast water tanks or cargo holds containing water ballast. Ships are carrying ballast water in a wide variety of shape of ballast tanks and cargo holds. Vessels almost always carry ballast water when they are not carrying cargo. Loaded ships contain ballast water as well, even if they are loaded to the maximum, ballast water is carried (Carlton 1994). Depending on the construction of ballast water tanks and pipework several tonnes of residual water can remain in maximum emptied ballast tanks.

Depending on the economy of a country it is importing cargo (no or less ballast water necessary to be transported in fully loaded vessels) or exporting goods. Countries characterised by an surplus in exporting cargo usually will record empty vessels calling for their ports in order to load a maximum of cargo for their voyage. These vessels will carry high amounts of ballast water, especially if bulk carriers or oil tankers were employed, what has to be discharged in the ports and waterways.

1.2 Ballast tank configurations

The design of ballast tanks of vessels, the pipework and ballast pumps is varying throughout the different types of ships. Modern oil tankers are equipped with a double hull structure used as ballast water tank. On bulk carriers we mostly find double bottom, wing, fore peak and aft peak tanks. In addition to the segregated ballast tanks cargo holds were filled with ballast water during voyages without carrying cargo. Bulk carrier may carry up to 100,000 tonnes of ballast water, in cases where they do not carry cargo.

Container vessels are usually equipped with segregated ballast tanks water. Container vessels carry a maximum of about 15,000 tonnes compared with bulk carriers this is a low amount. Even less ballast water is transported in cruise liners or ferries.

Most of the ballast tanks are designed with horizontal and vertical frames (double bottom tanks) and additional ceilings (fore peak, aft peak and side tanks) in order to strengthening the construction. The size of the ballast tanks varies due to the size of the vessel and type of tanks. Each ballast tank of a container vessel may contain 500 tonnes of water or more. Side tanks may have a height of more than 15 meters, a length of 10 meters and a depth range of 2 to 3 meters. This size corresponds with a swimming pool of olympic size, installed vertically along the ships hull.

Each ballast tank is connected with the ballast water pump by separated pipework. Most vessels are equipped with at least two ballast water pumps to ensure that ballast water operations are carried out even if one ballast pump is out of order. In addition to the pump pipework most of the tanks are provided with an airpipe and sounding pipes, with outlets on the upper deck. The airpipes allow air in the ballast tank to be expelled from the tank during filling processes. Sounding pipes were used in former times to measure the water level in the ballast tanks. Today many ships are equipped with electrical measurements documenting the amount of ballast water in the tanks.

The ballast water intake is often located in sea chests, with an initial coarse grit for preventing the entry of large floating objects as plastics and timber. The intaken ballast water will pass a second filter with openings of 1 to 2 centimetres.

1.3 Need for ballast water management

Since it is well known that eradication of an introduced species which established in a new marine environment will be either very expensive or even impossible. Efforts to prevent or minimize introductions should be given high priority.

Ballast water that is discharged when a ship arrives in most cases has been taken on board in fare away areas. During the intake of the ballast water, organisms and sediment as well as contaminants may have also been taken on board, especially if the area of intake is shallow. If the ballast water is discharged, parts of the sediment and organisms, which survived the voyage also will be discharged. It is impossible to predict the effects which introductions will cause to the ecology (e.g. competition to and replacement of native species) and economy (e.g. harmful organisms threatening aquaculture sites, damaging port installations, causing diseases, reducing the aquaculture production).

The great number of non-native species introduced in several regions all over the world called for the need to develop treatment options in order to minimize the amount of introduced species. The impact of each introduced species is unpredictable because of the extremely high number of connected parameters (Courteney & Taylor 1986). A species showing no negative impact in its area of origin may cause serious damages to economy and ecology to any new locality where it has been intentionally or unintentionally introduced. Negative effects could be e.g. the limitation of food sources for native species during mass occurrences of the introduced species, unwanted introduction of parasites and disease agents, extinction of native species (worst case if these are commercially harvested) (Rosenthal 1980, Williams & Sindermann 1991, Kern 1994, Grosholz & Ruiz 1995, Holmes & Minchin 1995).

Desk studies revealed that 53 non-indigenous species of macro fauna and flora in British waters (England, Scotland and Wales), 24 exotic organisms in Cork Harbour (Ireland) more than 100 in German waters (North Sea and the Baltic) and about 70 non-native species have been found along the Swedish coasts. At least half of the species quantity is believed to have been introduced with shipping. In Cork harbour, 8 of the 24 species were introduced prior to 1972 and 4 of these are believed to be introduced via ship hull fouling. Antifouling paints of ships generally contain tri-butyl-tinn (TBT) from 1972 onwards and its use has considerably reduced the risk of introduction of fouling organisms. The increase of ballast water discharges in Cork harbour is estimated from less than 20,000 tonnes in 1955 to almost 200,000 tonnes per year since 1970s. The study revealed that the majority of species introduced in Ireland and the British Isles are invertebrates (crustaceans, molluscs and polychaete worms) and algae. The effects of the exotic species on the British marine environment are in general not as harmful as reported from elsewhere in the world. Some of the non-native species are economically important and have been introduced for aquaculture purposes. But some other species, pests and parasites which adversely affect native species by competing for food and space and replace native species in the worst case, have been introduced unintentionally (Farnham 1980, Leppäkoski 1984, 1994, Knudsen 1989, Utting & Spencer 1992, Jansson 1994, Gollasch 1996, Gollasch & Mecke 1996, Eno 1996, Eno et al 1997, Minchin 1997).

More than 145 species are known to have been introduced and established in the Mediterranean Sea. Nearly half of the total number of these non-indigenous species are believed to be introduced by shipping (Ben-Tuvia 1953, Rubinoff 1968, Ben-Eliahu 1972, Walford & Wicklung 1973, Krapp & Sconfietti 1983, Zibrowius 1991, Boudouresque 1994, Galil 1994). The number of non-indigenous species in the eastern Mediterranean Sea is assumed to be higher than 300. Most of these species were actively migrated into the Mediterranean Sea via the Suez Canal. In total more than 450 non-indigenous species can be found in the Mediterranean Sea (Galil pers. comm.).

Investigations by Hallegraeff and Bolch between 1989 - 1991 showed that viable toxic dinoflagellate cysts were found in up to 6 % of the vessels entering Australian ports. The List of organisms reported to have survived ship voyages in the ballast water of vessels is being extended after each sampling programme world-wide. Until today about 500 different species are known to have been transported with ballast water (Howarth 1981, Kelly 1992, Locke et al. 1991, Müller 1995, Müller & Reynolds 1995, Gollasch 1996, Gollasch & Dammer 1996, Carlton 1985, 1987, Carlton & Geller 1993, Carlton et al. 1994).

The area which is supposed to be the habitat with the highest numbers of non-native species in the world is located at the west coast of the USA, the San Francisco Bay. In total 212 exotic species were found in the San Francisco Bay until today (Carlton 1994, 1995, Cohen & Carlton 1995). In the Hudson estuary 120 non-indigenous species were found (Swanson 1995), 97 non-native species were found in the Chesapeake Bay (Ruiz pers. comm.) and 139 non-indigenous aquatic species have been recorded from the Great Lakes (Mills et al. 1990). The total number of aquatic non-indigenous North American species was estimated the higher than 250 (Carl & Guiget 1957, Bousfield & Carlton 1967, Carlton 1985, 1987, Mooney et al. 1986, Smith & Kerr 1992, Mills et al. 1993, Grosholz & Ruiz 1995, Smith 1995). In total 74 of the listed species are believed to be introduced by ballast water of ships (Carlton et al. 1995).

In Australia vessels calling for ports come from more than 300 ports of 53 counties around the world introducing approx. 121 million tons of ballast water each year (Jones 1991, MEPC35/INF.19). In addition, over 4,000 vessels per year move more than 34 million tonnes of ballast water between Australian ports during domestic voyages.

In total 172 marine pests had been introduced into Australia's marine environment (Hoese 1973, Paxton & Hoese 1985, Hutchings et al. 1986, Hutchings 1992, Hallegraeff & Bolch 1991, 1992, Rigby et al. 1993), mostly through ballast water (Thresher pers. comm.) These include molluscs, crustaceans, polychaete worms, seaweeds and toxic phytoplankton species. The species established themselves and some of them even found excellent conditions. Phytoplankton bloomed and entered the food chain via shellfish feeding. The toxins of some phytoplankton species are known as Paralytic Shellfish Poisoning (PSP), which may paralyse or even kill humans who consume affected shellfish. Recent cases of damage resulted in the need to close down all harvesting of shellfish on the River Huon river estuary in Tasmania, in Port Phillippe Bay, Victoria and in Port Jackson, New South Wales, following a bloom of introduced toxic phytoplankton algae (dinoflagellates) in 1993 (Jones 1991, AQIS 1994).

The exact number of non-indigenous species in South African waters is not known due to the lack of appropriate studies. Until today different crustaceans, molluscs and phytoplankton species are known to occur (Jackson in prep.)

The number of species carried in ballast water is another indicator for the need of treatment. Several studies showed that more than 50.000 zooplankton specimens may be found in one cubic meter of ballast water. Usual densities of species are around 10.000 specimens per cubic meter of ballast water. Calculations revealed that a total of several 10.000s or even millions of organisms were transported in the ballast water of a single ship (Locke et al. 1991. 1993, Gollasch 1996, Kabler 1996). The German shipping study revealed that in average each vessel calling for a German port contained in its ballast water, tank sediment and on the ships hull in total more than 4 million specimens of macrofauna (ballast water 300,000 specimen from up to 12 different species in one sample, tank sediment 2 million specimens, hull fouling 1,8 million specimens) (Gollasch 1996).

The number of phytoplankton species is even several times higher. Lenz et al. (in prep) listed up to 110 million phytoplankton specimen in 1 m³ in ballast water and maximal 150 cysts in 1 cm³ of ballast tank sediments. A Canadian study showed that more than 10 million phytoplankton cells were collected in 1 m³ (Subba Rao et al. 1994) and the content of viable cysts of the dinoflagellate *Alexandrium tamarense* in one ballast tank was estimated to be more than 300 million cysts (Hallegraeff & Bolch 1992). Even up to 22,500 phytoplankton cysts per cm³ were found in tank sediments during Australian studies. Cysts of some phytoplankton species may remain viable under unfavourable conditions for 10 to 20 years (Hallegraeff & Bolch 1992).

The existing potential risk of negative impact of harmful phytoplankton species on marine aquaculture was indicated. In 1988, the total world aquaculture production was estimated at 14 million tons (FAO 1990). Therefore operational and procedural practices dealing with ballast water are necessary to prevent unwanted impacts (Subba Rao et al. 1994). The treatment of ballast water is necessary in the light of increasing risks involved with ballast water releases. Firstly, shipping activities have increased over the past decades with corresponding increases of amounts of transported ballast water. Secondly, the duration of ship voyages has decreased due to technical improvements resulting in faster ships. Reduced duration of species in a ballast tank increases the survival rate. Thirdly, the amount of exotic marine organisms in ballast water seem to be increasing. As example dinoflagellate blooms appear increasing world-wide probably due to changing eutrophic conditions and climate changes. Therefore the probability of an uptake of these species in ballast water is increased. Fourthly, the increase in aquaculture world-wide increases the potential of the unintentional spread of diseases and parasites which after their establishment in new areas may be distributed further as e.g. larvae in the ballast water of ships (Jones 1991).

Therefore the uncontrolled discharge of untreated ballast water is a major international problem. It is up to governments, environmental agencies and the shipping as well as the fishing industries to make commitments with a view to identifying a solution to this very complex problem. The presence of human disease agents as e.g. Cholera bacteria in ballast underlines the need for ballast water treatment (see below).

Ignoring the problems that may be caused by introduced species with ballast water could be analogue to an ecological roulette (Carlton & Geller 1993, Hedgpeth 1993). We cannot estimate any probability (as in a roulette game) due to the great number of parameters involved. In the same way as the ecology, major problems may occur impacting local aquaculture business or other economically important activities.

1.4 Inventory of world-wide activities

Scientific studies that have previously been carried out demonstrate that a large number of organisms are introduced in coastal waters and port areas around the world with ballast water, tank sediments, and hull fouling. Every vessel from overseas is a potential carrier of organisms in sufficient numbers to establish a new population. Since even a single introduced non-indigenous species may cause severe damage, it is necessary to develop preventive measures. Without special treatment of ballast water further introductions of undesirable species will continue.

1.4.1 European activities

1.4.1.1 Belgium

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 by A. Vanden Broeck (Université Libre de Bruxelles). In ballast water samples of 21 ships in total 21 genera of plankton algae have been found. The dominant species collected in the ballast water were dinoflagellates. In the tank sediments very large numbers of their cysts were extracted. Some of the determined genera included toxic species. The main result of the study was that a risk exists 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.

1.4.1.2 Croatia

A shipping study is currently undertaken sampling vessels entering the port of Dubrovnik. Main aim of the project will be the determination of the best practicable ballast water treatment method. In order to solve the problem the project will bring together experts from marine biology, chemistry, physics, water treatment, shipping crews and ship construction and ship building parties. Preliminary results of this study are scheduled for late 1998 (Lovrik pers. comm.).

1.4.1.3 Germany

A joint research project between the Institut für Meereskunde, Kiel and the Universität Hamburg commissioned by the Umweltbundesamt, Berlin (German Environment Protection Agency), was launched in 1992 to investigate species introductions by international ships traffic. This first European study on ballast water sampling, aimed at a thorough taxonomic assessment of planktonic and benthic organisms found in ballast water tanks. In addition tank sediment andthe ship hulls were sampled. During the investigation period from 1992 - 1995 the German shipping study (completed in 1996) revealed samples from 186 ships. The scientific project was financed by the Umweltbundesamt, Berlin. A total of 334 samples were taken from the ballast water, tank sediments and ships` hulls. 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 ships resulting in 10 million tonnes of annually discharged ballast water of which approx. 2,2 million tonnes are characterised by an origin outside of Europe (Gollasch 1996, Lenz et al. in prep.).

In co-operation with the Smithsonian Environmental Research Centre (SERC), Edgewater, Maryland (USA) several vessels were sampled in the USA before their departure, after their arrival in German ports and vice versa. This sampling design made an estimation of the survival rate of species during inter-oceanic voyages possible. The results clearly demonstrated that either the number of species or the number of specimens in ballast water dramatically decreased with the time spent in the ballast tank. In addition a visit of the German sampling team at SERC offered the opportunity to harmonize sampling methods.

Routine monitoring programmes in the North Sea area for water qualities, along the coasts of the German Federal States of Niedersachsen and Schleswig-Holstein, include a warning system for harmful algal blooms. In addition a long term monitoring study, established in 1962, close to the island of Helgoland (sampling site located at Helgoland Roads) includes the occurrence of non-indigenous plankton species. The sampling and taxonomical work is distributed through by the Biologische Anstalt Helgoland.

A documentation on introduced non-indigenous species in coastal and marine waters during a future monitoring programme is being discussed within the programme (Bund-Länder-Meßprogramm / BLMP).

Reise (1991) estimated that the number of non-indigenous species in the German Wadden Sea may be summarised to 5 % to 10 %. Another study of the macrozoobenthos species occurring in German waterways and canals indicates 31 non-indigenous species. The number non-indigenous taxa sampled varied between 6 % to 30 % of all collected fauna. The number of non-indigenous species in northern canals was higher than in other German regions (Tittizer 1996) due to the stronger influence of important international ports in this area.

Several studies on the introduced polychaete *Marenzelleria viridis* carried out at the University of Rostock and Warnemünde focussed the taxonomy, ecology and development of the species (Bick, Kinzelbach, Zettler pers. comm.).

1.4.1.4 Finland

A co-operational Nordic educational programme brought together experts and students from several countries at the Abo Akademi, University, Finland in 1997. This post-graduate course sponsored by the Nordic Academy for Advanced Study (NorFA) was entitled as „Ecology of Marine Invasions and Introductions“. Focused subjects included: non-indigenous species in the Baltic and other marine or brackish environments, characteristics of invaders (their biology, ecology, invasion history), vectors, relation to native species, habitat modification ability, interspecific and ecosystem impacts, linkages with biodiversity issues, world-wide case studies on ecological and economic impacts of marine introductions, marine biocontrol of introduced species, global issues relative to ballast water: history, science and policy, treatment techniques to reduce the risks arising from ballast water releases, international treaties and instruments to control introductions of non-indigenous species and regional conventions and agreements.

A Nordic Risk Assessment Study, was launched to evaluate as to whether resources were at risk and vulnerable to invasions of non-indigenous species, nordic marine areas were particularly sensitive to the introduction of non-indigenous organisms, organisms or categories of them were particularly potent to cause, large-scale environmental problems (biodiversity in particular) and / or as to 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) will be carried out and probabilities of harbour areas to act as receivers and / or donors will be 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) are being 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 final report will indicate shipping traffic patterns and ballast water dumping in some harbours in the Nordic countries. The harbours selected are Klaipeda (Lithuania), Turku (Finland), Stenungsund (Göteborg, Sweden) and the oil terminal Sture in western Norway. In addition, the physical environment in these harbours was documented (water depth, sediment types, temperature and salinity, and nutrients). These "harbour profiles" indicate risks of introducing unwanted species by ballast water imports.

The results of the project may be used to fulfil commitments within several international conventions / organizations such as HELCOM, OSPARCOM and ICES. A report (in English) from the project, scheduled to be published in late spring of 1998, could be of use for national authorities and international bodies, in contributing to the assessment of the scope of the problem in Nordic marine areas.

Other objectives are:

a) Review of some existing risk assessment (RA) methods applicable to introductions of non-indigenous species, including ecological RA models and models applied to ballast water introductions.

b) Application of such a model to one or more key / target species. A semi-quantitative model (low - medium - high risk) will be identified and applied to a vector of introduction and a target organism. Relevant parameters should be described, and data needs and availability identified. A tentative list of parameters for ballast water introductions could include, but not be limited to; vessel ballasting characteristics, ballast water treatment applied (if any), characteristics of donor and receiving ports or geographical areas, voyage route and duration, relevant biological information for the key / target species. Information on the key / target species could include, but not be limited to; environmental requirements such as temperature, salinity, and light / energy requirements during different stages of the life cycle (including resting stages), habitat requirements, known biotic interactions

In addition another study will focus the assess if the possibility and probability that (toxic strains of) Vibrio cholerae: could become established in Nordic waters, and if so, could be introduced to Nordic waters by way of ballast water, and if so identify the most likely routes and suggest steps for further action, including legislative and / or treatment options. Assess to what extent the findings on cholera are applicable to other potentially disease-causing micro-organisms that could be transported in ballast water.
Project description:
a) Through literature review assess effect of temperature, salinity, association with copepod and phytoplankton hosts and viruses on the probability of establishment of (toxic strains of) cholera in Nordic waters. Identify historical data, if any, on previous occurrences.
b) Identify possible sources of cholera, and whether there are any direct or indirect links to between Nordic countries / Europe and these sources through shipping.
c) Describe existing techniques / methodologies to monitor and treat (toxic strains of) cholera in ballast water. Identify the existing legislative and administrative framework that could be applied to prevention of cholera infestations through ballast water, and assess whether this provides sufficient means of protection, or if additional (treatment, legislative and or administrative) measures are necessary.

1.4.1.5 France

French scientists are carrying out monitoring programmes on the macroalgae *Caulerpa taxifolia*, *Sargassum muticum* and the Gastropoda *Crepidula fornicata* and the possibly latest macrofauna invader in European waters *Hemigrapsus penicillatus,* a decapod, first recorded at the French coast in 1994 (Meinesz et al. 1997, Noël et al. 1997). The research projects on *Caulerpa taxifolia* and *Crepidula fornicata* focus on the treatment of these unwanted species. Especially the commercial impact of *C. fornicata* in reducing the harvests of aquaculture mussel farms emphasises the need for a treatment on this species (M. Blanchard, IFREMER).

In the case of *Sargassum muticum* the ecological parameters and methods of spread are investigated (T. Belcher, IFREMER)

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

1.4.1.6 Ireland

In 1994 / 95 a port area was examined to determine whether there was a potential risk from ship introductions. The chosen port was Cork Harbour on the south east coast of Ireland. Since 1955 estimated ballast water discharges have generally increased from about 50,000 tonnes to about 400,000 tonnes. In the port 15 un-intentionally introductions are recorded, eight of these may have been imported on the hulls of ships and two were possibly introduced by ballast water. Some cryptogenic species such as the dinoflagellate *Alexandrium tamarense* could have been transferred by ballast water to Cork Harbour from elsewhere. These are presently known to rarely cause toxic phytoplankton blooms in Belfast Lough and Cork Harbour. A desk study involving all 32 Irish ports determined which of these had the greatest relative risk for further un-intentional species introductions. Two port regions, Cork Harbour and the Shannon Estuary appeared to have the greatest risk. The Shannon Estuary is perhaps vulnerable to Baltic species introductions. It was clear that most of the shipping was with European ports and that introductions to Ireland were most likely to be from other areas within Europe where exotic species had already become established. A detailed study of Bantry Bay, a small port on the south west coast, then proceeded to take into account trends in shipping over a number of years, residual flow within the bay and other oceanographic features and how this might influence the risk of species introductions. This port region has had relatively little traffic until the last 100 years when it was a major naval base, more recently most of the shipping consists of fishing vessels, bulk carriers carrying aggregates and oil tankers. This is a bay in which there is also extensive aquaculture and there are concerns by those involved in this industry over possible introductions that may compromize their activities.

More recently, in 1997, at Limerick dock, in the Shannon Estuary, the Zebra Mussel *Dreissena polymorpha* was found and it is thought to have been present there in 1994 or before. The species extends into the freshwater regions of the lower Shannon about 70 km upstream of the dock region. The species has become invasive and already is causing problems for some water abstractors and boat users. There are two possible means by which this species became introduced. Firstly, in ballast water to the Shannon Estuary of vessels carrying timber from the Baltic Sea, these vessels can carry ballast trim, or secondly as fouling organisms on hulls of boats imported on trailers from Britain or both. Zebra Mussels were found on one canal boat imported in 1997.

In an Irish study sampling of ballast water and sediments took place on one vessel in 1996 in Dublin in addition to activities related to the development of port profiles. These profiles consist of an analysis of current and past shipping traffic patterns. Calculations of estimates of ballast water releases were also made. The profiles further took into account a series of factors considered to enhance relative risk such as tidal amplitude and aquaculture activities. As a result of this study two regions were considered to have greater risk: The Shannon Estuary and Cork Harbour. Nevertheless the overall risk to Irish ports, because of the relatively small amounts of ballast releases, was considered to be less than that for other European ports. 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 200,000 tonnes of ballast water discharged annually in Cork harbour are originating from the United Kingdom, Australia, Egypt, French and Spanish Mediterranean regions.
The importance of hull fouling as a vector for dispersal of exotic species still needs to be given serious consideration and may have an affect as significant that related to ballast water discharges, albeit for different suites of species

Special attention was drawn to molluscan parasitology after the unintentional introduction of a bivalve parasite with live oyster imports, probably from France (Minchin, pers. comm.).

1.4.1.7 Norway

In 1996 a project entitled The Sture Project, an one and a half year investigation, was launched including sampling of ballast water of ships calling for the oil terminal Sture north west of Bergen at the Norwegian west coast; the first phase of the study was finished in September 1997. Samples from 30 vessels were collected, including salinity, oxygen,

temperature, zooplankton and phytoplankton, as well as samples for the determination of nutrients content in the ballast water. No samples have been 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 about 14 million m³ of ballast water are released during a year.
In addition, sampling of the water and sediments of waters adjacent to the terminal area shall monitor non-indigenous species that may have been introduced. Monitoring data of benthic and littoral flora and fauna are available from the area before the terminal was opened. Therefore it may be possible to compare the abundance of species before and after the opening of the terminal. The first official report is expected in 1998 (Botnen pers. comm.).

The Kamtschatka King Crab (*Paralithoides camtschatica*) introduced in Russian waters of the Barents Sea with the purpose of future harvests is now occasionally found in Norwegian waters. Records were made by fishermen mostly close to the northern coasts of Norway. A monitoring programme on this species focuses the range of expansion and distribution in Norwegian waters. The range has expanded to Porsangen in northern Norway and additional findings were documented in a distance of more than 1,000 km, close to Tromsö and Vestfjorden. One crab was found at the west coast of Norway indicating a range expansion of the species. Most of the findings by fishermen were not confirmed by scientists and therefore have to be quoted with care. Research on the environmental impact of the crab will be carried out at the Norwegian Institute of Fisheries and Aquaculture, Tromsö (J. Sundet) and the Institute of Marine Research, Bergen (K. Jörstadt). Other studies will focus on the population density and distribution of the crab in Norwegian waters (Institute of Marine Research, Bergen S. Ohlsen)

Studies on the introduced non-indigenous red algae *Polysiphonia harveyi* in southern Norway will be carried out by J. Rueness, Oslo University.

1.4.1.8 Spain

In spite of the fact that the number of marine non-indigenous species is increasing in Spain, only *Caulerpa taxifolia* is object of a research programme. The first programme on *C.*

taxifolia was carried out in 1993-94, supported by the European Union (LIFE, DG XI) entitled "Spreading of the tropical seaweed *Caulerpa taxifolia* in the Mediterranean". In 1994 the "Second International Workshop on *C. taxifolia*" was held in Barcelona involving more than 150 scientists (Ribera et al. (eds.) 1996). An additional research Programme (1996-98) was supported by the EU as well (LIFE, DG XII) entitled "Controle de l'expansion de *Caulerpa taxifolia* en Mediterranee". In September 1997 the Third International Workshop on *Caulerpa taxifolia* was celebrated. Both programmes were focused on monitoring and control of the spread of *Caulerpa taxifolia.* Studies about taxonomy, biology and ecology of *C. taxifolia*, the secondary metabolites of this species and its toxicity effects, impacts of *C. taxifolia* on the Mediterranean communities, eradication methods and a programme of arising public awareness are considered (Ribera pers. comm.)

1.4.1.9 Sweden

Sweden prepared a questionnaire to countries bordering the OSPAR Convention Area (i.e. the NE Atlantic including the North Sea) concerning non-indigenous species in the marine environment. The purpose was 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 (IMPACT95/14/1, §8.7). 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). For many species the introducing vector is unknown, but e.g. aquaria and pleasure fishing (bait and gear) are known to have provided additional routes for intentional and unintentional species introductions. 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)

An estimation of the amount of ballast water discharged in Swedish waters based on data from port authorities and shipping companies revealed 20 million tonnes (Jansson pers. comm.).

The geographical distribution, variation of population and biomass, preference in habitat and substrat as well as associated taxa of *Sargassum muticum* off and along the west coast of Sweden was investigated 1993-1995. In 1996 the sampling sites were investigated again in order to quantify changes in abundance and impacts (J. Karlsson, University of Göteborg).

Infestations of the European Eel *Anguilla anguilla* with the introduced Nematode *Anguillicola crassus* were studied in 1992-1994. The nematode was introduced by live eel imports (J. Thulin, Institute for Marine Research, J. Höglund, National Veterinary Institute).

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 ballast water of ships. The project also included a regional survey of dinoflagellates along the province of Bohuslan at the Swedish west coast.
The result of this pilot study is focused 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 taxonomically work of ballast water and sediment samples, experiments in culturing the found species will be carried out. Although few living cells were observed in the samples, results of the cultures show that there are large numbers of living organisms present in the ballast water and tank sediment. These species might hatch and grow after their discharge in Swedish waters (Persson, Godhe and Wallentinus pers. comm., Swedish Environmental Protection Agency 1997).

In 1997 a risk assessment desk study for the ports in the Stenungssund (Swedish west coast) was carried out by A. Godhe, University of Göteborg.

Associated to the Finish NorFA project Risk Assessment of Marine Alien Species in Nordic Waters (see above, Finish chapter) a desk study entitled as: “Ballast Water - Transportation

Patterns and Volumes" will be carried out under the co-ordination of Kristina Jansson. The Project objective are described as an inventory of volumes and patterns of ballast water is needed 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 will document main transport routes and volumes of ballast water imported to and from Swedish ports.

1.4.1.10 The Netherlands

In co-operation with the North-Eastern University, Maryland, USA, a shipping study based at the 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 phyto- and zooplankton content. The sampling design enabled an estimation of the number of species and specimens introduced in both ports. Beside other non-indigenous species toxic phytoplankton species stand into focus. 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 (van Gool pers. comm., Gotje pers. comm.).

1.4.1.11 United Kingdom

Port sampling revealed two newly introduced species in the area of Cardiff docks: the decapod *Rhitropanpeus harrisii*, native to The Netherlands, was first found in 1996, and a brackish water zebra mussel *Mytilopsis leucophaeta* (Family Dreissenoidea) was found in 1996 at the Cardiff docks. The species had been described in Belgium (under a different name). It also is present in other European countries, but it is not clear if this species has arrived in Britain from the European continent or its native range in America (ICES 1997)

An inventory of non-indigenous species in U.K. waters lists 16 marine algae, 5 diatoms, 1 angiosperm plant and 31 invertebrates. Red algae, polychaetes, crustaceans and molluscs represent the majority of species listed. More than half of the introduced species were believed to be introduced associated with shipping (Eno 1996).

Questionnaire

A questionnaire was sent to 127 ports in **England** and **Wales**, 111 (87.4%) of which responded. Ballast water is discharged into just under half (48.7%) of ports in England and Wales. Few accurate records are kept by these ports but it is possible to gain a general picture of the current situation from the information supplied. To get a more accurate assessment it would be necessary to extract the information from individual ships' log books. It is estimated from the information supplied that there are more than 36,000 ballast water exchange operations annually, so this would be a major and expensive undertaking.

Ports in England and Wales are net importers of bulk cargoes and so ships are more likely to load ballast water than to discharge. Nine ports reported that ballast water exchange involved only loading operations. About 1.6 times more ballast water is loaded compared with the amount of discharge.

An estimated 16.8 million tonnes of ballast water is discharged annually at ports in England and Wales. Oil and gas tankers contribute over 75% of this total. This compares with an estimated 25.7 million tonnes of ballast water discharged at Scottish ports, 90% of which is received by just three ports. In comparison, in England and Wales, ballast water discharge is more frequent and at a greater number of ports, but amounts discharged at individual ports are generally smaller, through the operation of more, smaller vessels.

Ports in Bristol, King's Lynn, Middlesborough, and Milford Haven were the only ones to report discharge of ballast water originating from outside continental Europe. By volume, ballast water from this origin accounted for about 11% of the total for all ports, compared with 47% at ports where discharge originated only from other United Kingdom and Northern European ports. These results must be treated with caution as accurate information on port of origin was not always available and ballast water may have been loaded at a site other than the previous port of call. Overall, the results indicate that the main risk is of further dispersal of unwanted marine organisms that may have been introduced at other UK or European ports.

Sampling of ballast water was carried out at only four ports and only three of the 111 respondents were aware of any problems associated with the discharge of ballast water.

This study was designed to assess the risk of introductions of non-indigenous marine organisms into coastal waters of **England** and **Wales** through discharge of ballast water from ships. Further assessment of the risk will be made by a sampling programme, in which the number and type of viable marine organisms transported in ballast water into the coastal waters of England and Wales will be determined. The strategy for this sampling programme is based on the results of the questionnaire survey.

This project was initiated on behalf of the Ministry of Agriculture, Fisheries and Food as a research project. It started on the 1st July, 1996 and will end on the 30th June, 1999. The research is being carried out at the School of Ocean Sciences, University of Wales, Bangor. The objectives are 1) to establish a sampling strategy for the collection of ballast water and sediment from ships docking at ports around England and Wales, 2) to investigate the range and numbers of organisms present in the ballast tanks of the selected ships, 3) to investigate the changes in the transported organisms with respect to the port of origin and the season in which the transportation occurs and 4) to assess the potential risk of introduced organisms and chemical agents in ballast water and sediment to the coastal waters of **England** and **Wales**.

From information collected in a survey carried out at CEFAS, Conwy, contacts have been established with harbour masters at many major ports in England and Wales where ballast water is discharged, and other contacts have been made with shipping agents and fleet operators. Various ports have been visited, including Liverpool, Immingham, Teeside, Fowey, Milford Haven, Cardiff, Swansea and Southampton. Other ports have been contacted and visits to Bristol, Kings Lynn, London, Ipswich and Felixstowe are planned. Analysis of samples is underway. Data will be provided for a database to be compiled by SOAEFD for the UK.

The SOAEFD Ballast Water sampling programme has recently started and revealed samples of vessels, ranging from small coasters to oil tankers. Ballast water and sediments were sampled during 128 sampling visits to ships docking in 10 **Scottish** ports. Ballast water originated from over 80 ports spanning 25 countries, mainly from the northern hemisphere. Samples of ballast water and ballast tank sediments were collected for biological and chemical analyses. Samples will be taken for zooplankton, phytoplankton and chemical analysis. Another sample is pumped up from as close to the bottom of the ballast tanks as possible in order to collect sediment which is examined for dinoflagellate cysts. Until today 29 phytoplankton species of 12 genera were determined. Experiments in germination of the sampled phytoplankton cysts resulted in 51 % successfully germinated tests. Studies on the effectiveness of a mid-ocean exchange of ballast water in order to minimize the amount of introduced specimens will be undertaken (Macdonald & Davidson 1997, McCollin et al. 1997, Laing pers. comm.).

The distribution and the abundance of the commercially interesting non-indigenous American tingle (*Urosalpinx cinerea*) is studied by the Fisheries Department.

Unsuccessful attempts have previously been made to eradicate the introduced seaweed *Sargassum muticum* and the Slipper limpet *Crepidula fornicata*.

1.4.2 Baltic Sea

A (proposed) Database on Alien Species of the Baltic is under construction. The aims of the database are as follows:

- development of an up-to-date and standardized inventory of non-indigenous species in the Baltic Sea area;
- documentation of effects and impacts (ecological, economic and social) posed by unwanted non-indigenous species and the
- elaboration of schemes for fast dissemination of information on new invasions and introductions within and outside the Baltic Sea region.

Specialists from all countries bordering the Baltic Sea will be involved. At present about 50 scientists dealing with the subject from various parts of the Baltic Sea are involved. The Environment Committee (EC) of the Helsinki Commission requested the HELCOM Contracting Parties to take action in reducing risks associated with intentional introductions and to consider possibilities of monitoring the distribution of already established species within the Baltic Monitoring Programme and Coastal Monitoring Programme.

In the Baltic Sea region Germany, Poland, Lithuania, Latvia, Estonia and Russia have established routine monitoring programmes on marine environmental quality since the end of the 1970s. Within these ongoing programmes, biological observations are performed on phytoplankton, zooplankton and macrozoobenthos. These sampling programmes are considered an instrument to reveal non-indigenous species. It was in this way possible to document newly introduced species, e.g. the dinoflagellate *Prorocentrum minimum*, the polychaete *Marenzelleria viridis* and the crustacean *Cercopages pengoi*. The monitoring programmes will be continued (Olenin pers. comm.).

1.4.3 Black Sea

Economic activities, accompanied by changes in the maritime environment, are the object of monitoring activities. Secondly the condition of the Black Sea environment and the preservation of its ecological equilibrium, preventing pollution, salinisation and introduced alien species are monitored.

Alien species of concern in the Black Sea are the "Dutch crab" *Rhithropanopeus harrisi*, the sand mussel Mya arenaria, the blue crab Callinectes sapidus and the ctenophore *Mnemiopsis leidi*. The predatory American ctenophore began to prey large quantities of zooplankton, especially fish larva. This has provoked a catastrophic reduction in recent Georgian harvests of anchovy and other fish in the Black Sea. In addition to the impact of the ctenophore, overfishing of anchovy and other species by Georgian, Russian, Ukrainian, Bulgarian and Turkish fleets enforces the decline of this fishing industry.

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. Uncontrolled discharge of ballast may have a fatal effect on the marine environment of the Black Sea (Shotadze pers. comm.).

1.4.4 Israelian activities

As mentioned above, scientists from Israel and the United States established a co-operation programme with the Smithsonian Environmental Research Centre (SERC), Edgewater, Maryland (USA) to sample vessels before their departure in the USA and after arrival in the port of Hadera (close to Haifa), and vice versa. This sampling design allows an estimation of the survival rate of species during inter-oceanic voyages. The results have clearly shown that either the number of species or the number of specimens in ballast water dramatically decreased with the time spent in ballast tank.

The transport of protists in ballast water was studied by a German expert in co-operation with the Israel Oceanographic and Limnological Research Ltd, Haifa (B. S. Galil). During the survey several ships calling for Israelian Mediterranean ports were sampled at the Mediterranean harbours Haifa and Ashdod. The protist community present in the 17 sampled ballast water tanks was documented. In total 362 records of living protozoan species (in total 198 species) were made. These belong to 82 heterotrophic genera. The maximum number of protists in one ballast water tank was 138 species (!). Most of the ballast tanks examined showed a comparable diversity and were therefore determined as uniformity of protist communities. These enable a classification of protist communities regarding food web interactions in ballast water in a) bacteria-grazing protozoans, predatory protists and more intricate associations including parasites and metazoans (Polychaeta, Cnidaria, Nematoda, Gastrotricha, harpacticoid Copepoda, Rotifera and Turbellaria) (Galil & Hülsmann 1997).

1.4.5 American activities

1.4.5.1 North America

Canada

Various ballast sampling studies have been undertaken by different agencies in different regions of Canada for several years. Testing of ballast water for the presence of zooplankton, bacteriae (Aeterotrophic Picoplankton and Autotrophic Picoplankton) was carried out.

In 1980, the Canadian Department of the Environment commissioned a study to assess the effect of ballast water discharges, specifically in regard to ballast water taken on board in foreign ports and discharged into the Great Lakes. Introductions of several new predators of fish into the Great Lakes caused concern in the commercial and pleasure fishing industry. Authorities are examining several prevention options; one likely option being the exchange of ballast water in mid-ocean as it is thought that mid-ocean organisms are less likely to survive in Great Lakes waters. Samples were taken via opened manholes of the ballast tanks and from discharge points at ballast pumps. Sediment was not sampled. In total ballast water from 55 ships, representing 10 different geographic origins were sampled as the vessels entered the St. Lawrence-Great Lake system. One ballast tank contained raw sewage indicating that potential hazards exist if this ballast was discharged. The study concentrated on aquatic flora and fauna (> 80 µm) and the assessment of the potential impact of these species if released into the Great Lakes. Over 150 genera and species of phytoplankton and 56 aquatic invertebrates were determined, many of them found to be non-indigenous to the Great Lakes. In the light of these

results it was recommended that an additional study should include sediment samples, focus on ballast origins (shipping routes) that had not been covered in the present study, and take into account ballast water mixing of more than one origin, such referring to the need of a detailed log book documenting the ballast operations.
The study indicated that several marine organisms may provide potential risk in becoming established in the St. Lawrence estuary (Howarth 1981).

Transport Canada has conducted a ballast water sampling study in the Welland Canal and the Science Department of the Department of Fisheries and Oceans has initiated a study to examine the possibility of using organic acids to treat residual ballast water.

In the beginning of the 1990s the effectiveness of mid-ocean exchange of ballast water was analyzed. Both, freshwater and coastal zooplankton was tested. Calculations revealed that a total of several 10.000s or even millions of organisms were transported in the ballast water of a single ship (Locke et al. 1991, 1993).

An on-going research project, initiated in 1993 by the Department of Fisheries and Oceans aims to assess the risks for the introduction of non-indigenous species through ballast water discharges in the St. Lawrence estuary and Gulf of St. Lawrence. The evaluation of these risks is important in the light of current Canadian regulations and guidelines which allow ballast water exchanges by foreign ships in the Gulf of St. Lawrence in situations where it has not been feasible to exchange ballast water in the Atlantic Ocean (Gauthier & Steel 1995, SGBWS Report 1997).

In 1994 a risk assessment based on foreign maritime traffic and on surveys of ballast water discharge practices and species diversity in ballast tanks of foreign ships bound for ports of the area was carried out. It is estimated, that 12 million tonnes of ballast water are discharged annually in the estuary and Gulf of St. Lawrence. About 1.6 million tonnes originate from the last port of call of regions as Northeast Atlantic, Mediterranean Sea and Black Seas. The results of the study (see below) could be used as a scientific rationale to extend the application of the existing voluntary IMO guidelines to all foreign ships entering the Gulf of St. Lawrence. In addition the results showed that the guidelines (when complied) were effective in reducing the potential risk for ballast water mediated introductions in the marine ecosystem of the St. Lawrence area (Gilbert & Harvey 1997, SGBWS 1997).

During a ballast water study in 1992, 62 % of all 60 ballast water samples taken from ships in the dockyards of Iles-de-la-Madeleine contained four potentially toxic dinoflagellates of the genus *Alexandrium* and three *Dinophysis* spp. (Gosselin et al. 1995) and eight of nine sediment samples of three ships contained resting stages of *Alexandrium* spp. (Roy 1994).

In 1994 Subba Rao et al. published a study of exotic phytoplankton species from ballast water and their potential spread and effects on mariculture localities. Ballast water was analysed from 86 foreign vessels that visited the Great Lakes area during 1990 and 1991. Due to the enormous number of parameters that regulate the successful transport and establishment in non-indigenous areas it is quite uncertain to predict which species may be introduced. The existing potential risk of negative impact of these species on Canada's east coast aquaculture sites was noted. Therefore practices to deal with ballast water are necessary (Subba Rao et al. 1994).

An ongoing research study conducted by the Canadian Coast Guard aims to identify safety aspects related to the mid-ocean exchange of ballast water. Both of the investigated two bulk carriers had not been to follow the advice set out in the voluntary ballast water guidelines to enter the Great Lakes because of bending moment limitations and of shear forces limitations during bad weather situations (Prior 1995).

In-between the timeframe of 1999-2002 different research projects are planned e.g. on the survival of species in ballast water during voyages,an inventory of introduced species in the Estuary and Gulf of St. Lawrence, ballast water treatment approaches including filtration methods, design criteria for new ship constructions and a ballast water exchange location assessment.

USA

The new National Invasive Species Act of 1996 (see below) authorises and directs the U.S. Coast Guard to sample vessels regularly and to require ballast management if voluntary compliance is insufficient. No routine monitoring programme in the USA focuses on the arrival of specific marine organisms in ballast water or sediments. Instead the law requires regular vessel sampling in order to determine if and to what extent ballast exchange occurs. This requirement reflects the U.S. decision to seek protection from all types of foreign organisms (Carlton & Cangelosi 1997).

The investigations in 1982 and 1985 (Carlton et al. 1982, Carlton 1985) focused on bulk carriers entering North American ports without any cargo but with high loads of ballast water. Most of the sampled vessels filled in addition to ballast tanks cargo holds with ballast water (Carlton & Geller 1993). Shipping studies revealed that in total 367 different species were sampled on 159 vessels calling for the port of Coos Bay, Oregon, USA. The study concentrated on one specific shipping route (Japan to the North American west coast) (Carlton & Geller 1993). It is estimated that every hour an average of almost two and 1,900 tonnes of foreign ballast water will be released in U.S. waters (Carlton et al. 1995).

CHESAPEAKE BAY AREA

Smithsonian Environmental Research Center (SERC), Edgewater, Maryland USA Co-operating Institutions Williams College-Mystic Seaport Maritime Studies Programme, Mystic, Connecticut USA and Marine Sciences Center, Northeastern University, Nahant, Massachusetts

Projects:

NATIONAL BIOLOGICAL INVASIONS SHIPPING STUDY (NABISS). Biological Invasions by Non-Indigenous Species in United States Waters: Quantifying the Role of Ballast Water and Sediments [in Chesapeake Bay]. The project was funded by the National Sea Grant / U.S. Coast Guard 1993-1995. This work has been completed and the final report submitted in 1996 to the United States Coast Guard. Year 2 / Part II involved sampling 70 vessels in Chesapeake Bay. A manuscript is now in preparation (L.D. Smith, senior author) for publication. The final report to the USCG is as follows: L. David Smith, Marjorie J. Wonham, Linda D. McCann, Donald M. Reid, Gregory M. Ruiz, and James T. Carlton. 1996. Shipping Study II. Biological Invasions by Non-Indigenous Species in United States Waters: Quantifying the Role of Ballast Water and Sediments, Parts I and II. The National Sea Grant College Programme / Connecticut Sea Grant Project R/ES-6. Prepared for U.S. Coast Guard Research and Development Center, Groton CT and United States Coast Guard Marine Safety and Environmental Protection, Washington, D.C. Report No. CG-D-02-97, Government Accession No. AD-A321543, xxv + 97 pp. + Appendices A-M. (Final Report July 1996).

BIOLOGICAL INVASIONS OF THE CHESAPEAKE BAY BY NON-INDIGENOUS SPECIES: THE RELATIVE CONTRIBUTION OF BALLAST AND FOULING ASSEMBLAGES TRANSPORTED BY U. S. NAVY VESSELS. Funded by: Department of Defence, Legacy Programme, 1994-1997. This work is in progress. It involves both directly sampling of U.S. navy vessels and experimental studies, the latter both in U.S. naval bases in Spain and in the United States. No published results are available as yet (Carlton pers. comm.).

THE RELATIVE IMPORTANCE OF BALLAST WATER FROM DOMESTIC SHIP TRAFFIC IN TRANSLOCATION OF NONINDIGENOUS SPECIES AMONG U.S. PORTS. Funded by the National Sea Grant Programme this project (commenced in 1997-1998), will sample ballast water being moved along the Atlantic coast of the United States.

Smithsonian Environmental Research Centre (SERC)

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

Over the past 7 years a collaborative research programme at the Smithsonian Environmental Research Center (SERC) was developed to address a broad range of issues in marine and estuarine invasion biology. The overall goal of the programme was to:

(1) measure patterns of non-indigenous species transfer, invasion, and impact;
(2) test specific and general mechanisms that underlie these patterns;
(3) assess the efficacy of management strategies to limit the spread and impact of non-indigenous species.

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

The programme in addition included research at an increasing number of sites outside of the Chesapeake Bay region to measure variation among sites and test for generalities in invasion processes. Within the U.S., research projects in Alaska, California, Florida, and Massachusetts primarily, and this work often involves collaboration with scientists based outside of the Chesapeake region. Furthermore contacts to collaborative overseas research institutions in Australia, Germany, Israel, Italy, Netherlands, and New Zealand were established.

The current research at the SERC is focused on a variety of implemented research projects that examine patterns of NIS transfer, invasion, and impact, and that begin to assess the effect of some control measures. A large component of our research on transfer examines the volume, content, dynamics, and management of ballast water.

Ballast Water Management and Delivery Patterns

SERC invasion / ballast water biologists continue to sample ballast water and sediments in ships coming into Chesapeake Bay on an "as needed" basis to obtain organisms for experimental studies and to continue selected monitoring programs. The most extensive surveys related to the transport of marine and estuarine organisms via shipping are being conducted during the ongoing ballast water research programme of the SERC. International vessels are being sampled at the ports of Norfolk (lower bay, marine waters) and Baltimore (upper bay, oligohaline to freshwater). Sampling programmes revealed the presence of living species in ballast water of 25 of 27 ships entering the Chesapeake Bay.

Additional experimental studies are being carried out on vessels including one experimental voyage conducted in 1996 between Israel and the Chesapeake Bay.

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

Ballast Water Content

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

Survival Patterns of Organisms in Ballast Tanks (Transit Success)

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

Condition of Organisms arriving in Ballast Water

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

Efficacy of Ballast Water Exchange

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

Patterns of NIS Invasion

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

Effects of NIS Invasions

- Quantifying ecological effects of selected NIS invasions on resident populations and communities in the U.S. (Chesapeake Bay, California, Massachusetts) and Australia; selected NIS to date include species of crabs, bivalves, hydroids, barnacles, and bacteria (1994-1997)
- Testing predictability and variability of invasion effects among multiple communities; current focus has been measuring impact(s) and population characteristics of a single invader in California, Massachusetts, and Australia (1995-1998).
- Testing the effects of *Vibrio* bacteria on the survival and demography of planktonic organisms

Future Directions

Although a large component of the research will continue to examine the invasion processes discussed above, this research is increasingly done in a comparative and collaborative context to measure (in parallel) patterns of NIS transfer, invasion, and impact among sites. A limited scale including both national and international sites to measure variation in invasion processes on various spatial scales was established. Only this broad and co-ordinated approach will sufficiently describe key patterns, effects, and mechanisms of invasion that extend beyond single estuaries or regions.

To achieve this comparative perspective on invasion processes, two elements will play an especially critical role, and were describe below:

National Ballast Information Clearinghouse

One key element in this programmatic approach is the development of the National Ballast Information Clearinghouse at SERC as part of the National Invasive Species Act of 1996 (NISA). NISA requests that all ships arriving to U.S. ports from overseas follow voluntary guidelines for ballast water exchange to minimize the transfer of non-indigenous species (see below). The Clearinghouse was established to track the effectiveness of these NISA guidelines in (a) increasing the rate of ballast water exchange, (b) changing overall the rate and patterns of ballast water delivery, and (c) reducing the rate of ballast-mediated invasions. At present, the Clearinghouse is implementing a nation-wide programme with U.S. Coast Guard to measure ballast management practices and delivery patterns of all vessels that arrive to the U.S. from foreign ports. The Clearinghouse is responsible for the management and timely statistical analysis of the extensive data collected under this programme, and is assisting in the development and implementation of appropriate data collection techniques and selective "ground-truthing". This programme will result in a comprehensive biennial report to the U.S. Congress on ballast water management and delivery patterns.

Additional goals of the Clearinghouse include a similar synthesis and analysis of national data on invasion patterns. These data will be used to (a) assess the effectiveness of NISA in reducing invasion rates and (b) create a national resource centre (i.e., *Information Clearinghouse*) and database for current, comprehensive information on both ballast water and marine invasions.

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

Marine and Estuarine Non-Indigenous Species Database (see below)

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

The development and maintenance of a relational database for each non-indigenous species of Chesapeake Bay at the SERC includes extensive details of taxonomy, distribution, life history, reproductive and population biology, environmental tolerances, habitat distribution and ecology by life-stage, and documented economic and ecological impacts. Recently the SERC begun to expand the database to include similar records for all non-indigenous marine and estuarine species in the Indian River (Florida) and Prince William Sound (Alaska). The long-term goal is to expand this database to include non-indigenous marine species from many additional sites in the U.S. and overseas through collaboration with other research groups. We have already begun this process for a number of national and international sites, using our format as a standard approach. Through this work, we are establishing a formal network of sites to document both the patterns of invasion and the attributes and impacts on non-indigenous species among regions (Ruiz & Hines 1997).

ALASKA

PRELIMINARY STUDIES ON BALLAST WATER BIOLOGY IN TANKER VESSEL TRAFFIC [not the formal title]. The study was funded by Prince William Sound Regional Citizens' Advisory Council, Valdez, Alaska and began in 1997. No results are yet available.

Involved institutions are the Smithsonian Environmental Research Center (SERC), Edgewater, Maryland USA, Marine Sciences Center, Oregon State University, Newport, Oregon USA, Williams College-Mystic Seaport Maritime Studies Programme, Mystic, Connecticut USA (Carlton pers. comm.).

NORTH CAROLINA

A study at the University of North Carolina at Wilmington entitled MOLECULAR STRATEGIES TO CHARACTERIZE MICROBIAL DIVERSITY AND PATHOGENS IN MARINE BALLAST WATER was funded by the National Sea Grant. This work will commence in 1997-1998 (Carlton pers. comm.).

Ballast water Management practices are in place for Cholera detection.

SYNTHESIZING SCIENCE AND POLICY TO REDUCE THE PROBABILITY OF MARINE BIOLOGICAL INVASIONS DUE TO BALLAST WATER DISCHARGE IN THE PORT OF MOREHEAD CITY, NORTH CAROLINA

This study provides a preliminary biological profile and potential policy alternatives for the management of ballast water discharged from ships in the Port of Morehead City, North Carolina, USA. The Port of Morehead City is particularly vulnerable to a successful invasion of an exotic organism for several reasons. First, the port is one of the deepest on the eastern seaboard (45 foot maximum draft), providing ships with no reason to release ballast water until they are safely berthed in the estuarine port environment, increasing the survival rate of organisms. Secondly, the top two exports by volume out of Morehead City (woodships and phosphate) are shipped in bulk carriers that typically arrive without import cargo, thereby discharging more ballast water and accompanying biota than most ships. Since 1985, Morehead City has been the number one exporter of woodships on the US east coast and projects to double exports to a million metric tons by the year 1999. Thirdly, the waters associated with the Port of Morehead City are fed by interconnected bodies of water cited for excess pollution and deteriorating water quality. Fourthly, these waters are contained within the unique North Carolina cusp of barrier islands, reducing the potential "flushing out" of exotics during daily tidal cycles. These factors culminate in a dynamic environment that is unstable and vulnerable. At any particular point in time, changing water conditions may become singularly hospitable to the invasion of a non-indigenous species introduced via ballast water.

In effort to ascertain the taxonomic status of ballast water released into the Port of Morehead City, 21 ships were boarded during the period from May to July 1997. Samples of ballast water were collected from nine ships that were releasing water from Japan, Spain, Dominican Republic/ Florida, Belgium/ Mid-Atlantic, and New Orleans, Louisiana. Two of the ships sampled had just taken on ballast water, providing an opportunity to access the types of organisms successfully taken in through ballast pumps and exported from Morehead City waters to other discharge locations.

Recognizing the species richness of live biota observed in the ballast water of ships in Morehead City, proactive public policy in the form of ballast water management is warranted. Due to economic pressures and lack of effective regulatory power, it does not seem feasible for the Port of Morehead City to implement a mandatory ballast water control strategy until the world does via an international mandate. Yet, three actions towards ballast water management can be realistically recommended for implementation on the local level at this time in the Port of Morehead City: 1) submit comments and suggestions to the federal level, 2) accurately implement and report ballast water surveys, and 3) encourage and educate visiting captains to practice ebb tide discharge of ballast water while in port and follow the International Maritime Organization's guidelines for mid-ocean ballast exchange prior to entrance into the Port of Morehead City, North Carolina (Walton & Crowder pers. comm.).

GREAT LAKES

The ALGONORTH Experiment

This is the major filtration experiment now in progress using the M/V ALGONORTH, funded by the Great Lakes Protection Fund. Involved institutions are Northeast Midwest Institute, Lake Carriers Association. The first season of sampling was completed in November 1997. Initial results are scheduled for publication in spring 1998. The purpose of the experiment is to determine the biological and mechanical efficiency of various levels of filtration, testing of mechanical devices and the biological efficiency of filter systems. For the biological experiment, two matched upper wing tanks have been isolated for use as test and control tanks. Water from the sea is drawn from a ballast tank, sent through the filter and discharged into the test tank. Water discharged into the control tank bypasses the filter system. The experimental design involves sampling both tanks for phytoplankton and zooplankton and comparing size, abundance and condition of organisms from major taxa. Since this is not a taxonomic survey, but a filter effectiveness test, the major salt and fresh water taxa were determined representing size and morphological categories of organisms. Taxa include diatoms, dinoflagellates, eggs, rotifers by genus, cladocerans, copepods (harpactacoids separately), bivalve veligers, copepodites, and nauplii).

In addition microbial taxa are investigated. The ballast residuals in fully-loaded incoming vessels into the Great Lakes system were studied with molecular detection analysis for viruses and bacteria with pathogenic potential. The filtration system will be tested for its effectiveness at screening non-pathogenic surrogates / or indicator microbial taxa (Cangelosi pers. comm.).

HAWAII

Williams College-Mystic Seaport Maritime Studies Programme, Mystic, Connecticut USA and Hawaiian institutions commenced a study in 1997 - 1998, entitled MARINE NONINDINGEOUS SPECIES IN HAWAIIAN HARBORS AND BALLAST WATER STUDIES [not the formal title]. The funding source is: Packard Foundation and Dingell-Johnson funds. No preliminary data available (Carlton pers. comm.).

1.4.5.2 South America

It was noticed during several personal communications that in some regions of Brazil and Chile local regulations dealing with ballast water of non-indigenous origin have been discussed (see 5.2.5).

A new method to treat ballast water, the dilution method, was developed by Petroleo Brasiliero S.A. (PETROBRAS) and presented at the IMO MEPC meeting 40 and 41 (C. Goncalves Land, pers. comm.).

1.4.6 Australian activities

Australia recognized the potential of ballast water to create problems since the late1970s but it was only in recent times that the matter has become a significant issue. Early studies in New South Wales in 1973 gave warning that non-indigenous fish species were introduced.

In 1986 two cases of paralytic shellfish poisoning occurred in Tasmania. In 1989 the Australian Quarantine and Inspection Service (AQIS) became involved in the ballast water issue. Introduced marine pests posed a greater threat to the Australian environment than oil spills, land degradation, and rabbits warned the AQIS. Australian scientists were among the first to realise the risk of unintentionally species introductions with ballast water. Early studies in New South Wales reported and warned that exotic fishes had been introduced (Jones 1991). In addition several studies dealing with non-indigenous species and their introductions with ships were carried out in the past, are ongoing or are planned for the future. Research is being carried out and organized by the Australian Quarantine Inspection Service (AQIS) and the Australian Centre for Research on Introduced Marine Pests (CRIMP). The objectives of CRIMP are to develop and promote the application of tools for an earlier warning, more precisely prediction and more effective assessment of risks and costs of marine pest species introduced to Australia, as well as the development of new methods or improvement of existing measures to control the spread and to minimize the impacts of introduced marine species. In the three years since its inception, CRIMP has expanded from two part-time positions to twelve permanent staff members and international researchers and students. CRIMP is organized in three groups: Invasion Process, Impacts and Demographics as well as Pest Management and in addition a small administrative group managing the centre (Thresher 1997 a, b).

The estimated cost of US$ 5 billion will be spent over this decade to control species introduced in Australian waters (Jones 1991).

Australian studies of ballast water were focused on phytoplankton species and their resting stages (Williams 1982,Williams et al. 1988, Pollard & Hutchings 1990 a, b, Hallegraeff & Bolch 1991, Rigby et al. 1993, Kerr 1994). A phytoplankton shipping study carried out between 1987 and 1989 revealed several species sampled from the ballast water of 200 ballast tanks (Hallegraeff & Bolch 1991). Until 1990in total 343 ships were sampled in 18 different Australian ports. In addition to ballast tanks, cargo holds filled with ballast water were sampled as well by several hauls with the plankton net (Hallegraeff & Bolch 1992).

A zoological study involving in total 23 samples of ballast water and 9 sediment samples resulted in the determination of 67 taxa. Crustacea (mainly Copepoda) and Mollusca were the most abundant taxa found (Williams et al. 1988).

Several of the key projects (MSC/Circ.625/Add.3) are summarized as follows:

A study reviewing the current scientific results on introduced and established harmful species threatening the marine environment, commercial fisheries and human health was completed in 1991 (Manning et al. 1996).

A study on ballast water treatment for the removal of marine organisms considered three ballast water treatment options: ship board treatment, port treatment and land based treatment. Shore based treatment of ballast water was the preferred method (completed in 1992) (AQIS 1993, Manning et al. 1996).

A study completed in 1992 investigated the possibility of exchanging ballast water in open seas / mid ocean (re-ballasting studies). Trials on large bulk carriers showed some of the practical aspects and assessed the effectiveness of the method of exchanging ballast water, sediments and associated organisms (Manning et al. 1996).

Ballast water management options were reviewed according to type of vessel. Recommended appropriate practical management procedures and practices to minimize or eliminate the uptake of exotic organisms with ballast water were listed (completed in 1993) (Thomson Clarke Shipping Pty Ltd et al. 1993, Manning et al. 1996).

A port and shipping study (completed in 1993) reported the amount and origin of ballast water entering Australian waters. The receiving tonnage of ballast water from each particular Australian port and country of origin as well as the number of ship visits by port and country of origin was listed (Kerr 1994, Manning et al. 1996).

An epidemiological review of possible fin fish and shell fish diseases which may result from ballast water and sediment discharges in Australian waters lists the pathogens of concern by region of origin and seriousness of threat. The report was completed in 1993; it lists pathogens of concern by area of origin and hazards involved if the species will establish (MEPC35/INF.19, Munday et al. 1994, Manning et al. 1996).

A ports and disease study, completed in 1993, identifies and ranks Australian ports according their risks of receiving infected ballast water as well as the countries or regions of threat as donor of contaminated ballast water and exotic diseases. There were ranked according to the threat that they pose to Australian aquaculture and wild fisheries (Herfort & Kerr 1995, MEPC35/INF.19).

A pilot study on the potential application methods of heat treatment in order to inactivate potentially harmful organisms present in ballast water was carried out. The heat treatment trials showed that treatment with 40 to 45 °C on the IRON WHYALLA effectively killed both phytoplankton and zooplankton (MEPC35/INF.19, Rigby & Hallegraeff 1993, Manning et al. 1996).

A dye-staining diagnostic test for the detection of the presence of dinoflagellates, their cysts and other harmful organisms in ballast water was cancelled (Manning et al. 1996).

The port water sampling programmes determined the presence or absence of potentially harmful organisms that could be transmitted to other Australian ports via ships` ballast water in order to minimize the risk of the transport of harmful species. The study covers selected Australian ports (Manning et al. 1996).

The development of standards for re-ballasting guidelines using the results of the IRON WHYALLA trials and the ballast water management report (in progress).

To enforce public awareness brochures and videos will be produced to educate governments, industry and the public about the ballast water problem, current research activities and possible solutions (temporarily suspended) (Manning et al. 1996).

It has been planned to determine the capacities and limitations of the port of Newcastle in supporting a ballast water treatment plant and evaluate the gross dimensions as well as the capacities of such a plant, but the project was cancelled (Manning et al. 1996).

Reviews of the introduced Pacific Starfish *Asterias amurensis* and the seaweed *Undaria pinnatifida* summarised information on their introduction, growth and effects on native environments (Munday et al. 1994). A preliminary trial with 9 herbicides showed limited success against the sporophytes. Another trial has commissioned in order to treat the gametophytes with other herbicides (ICES 1997).

A technical overview report listed conclusions and recommendations of the completed ballast water reports (Manning et al. 1996).

A bio-economic risk assessment compiled information on risks and costs, both biological and economic, concerning the treatment of ballast water. Thus was published as Report No. 6 of the AQIS Ballast water research series (ACIL Economics 1994, Manning et al. 1996).

A project regarding the development of standardized re-ballasting guidelines (based on e.g. the results from the IRON WHYALLA trials) were presented by Rigby and Taylor (Manning et al. 1996). The study concluded that the decision whether to exchange ballast water and by which method must rest by the ship´s Master. It was noted that for some ships a complete exchange of ballast water was unsafe and that in the cases the flow through method (or continuos flushing method) should be used (Manning et al. 1996, Sipes et al. (eds.) 1996).

Future action will cover the monitoring of non-indigenous species and in particular toxic dinoflagellates and continue with port testing studies. The development of a national strategy for ballast water management will be enforced.

A hull fouling study shall compile information via literature search on the organisms likely to be introduced into Australian waters by hull fouling (Manning et al. 1996).

A strategy dealing with vessels that have been confirmed carrying Cholera bacteria is being developed.

The infected case study will examine the ship management on ballasting practices of a vessel that has been re-infected after cleaning of ballast water and sediment from its ballast tanks. The study is still in progress (Manning et al. 1996).

Australia further identified a short list of target species that could be of major threat to Australian waters. In addition Cholera testing of ballast water has been commenced.

In summary, Australia sees the implementation of the IMO Guidelines as just the first step in overcoming this major problem (MEPC35/INF.19)

Community based coastal monitoring as a joint effort between CRIMP, the Australian Department of the Environment, Australian Ballast Water Management Advisory Council (ABWMAC) and fisheries including the development of a national network of regional co-ordinators will link scientific and management agencies to local community groups for rapid detection of new introductions. A national „incursion response„ plan was established to deal quickly and effectively with new invasions or range extensions.

A general risk assessment framework for ballast water introductions is being developed as a joint CRIMP and ABWMAC initiative. It is using port survey information, data on ballast water tank configurations and management as well as biological data on pest species to calculate for each vessel and voyage the risk of introducing a new pest species. The risk assessment will be used in order to determine the level of management action required for each vessel (Thresher 1997 a, b).

Ballast water management practices are in place for Cholera detection and the indication of toxic dinoflagellates. A feasibility study of a rapid diagnostic test to prove the presence of toxic dinoflagellates in ballast water was approved as high priority (Scholin et al. 1995, Manning et al. 1996).

A desk study on the Mediterranean polychaete *Sabella spallanzani* introduced and spreading in Australia was carried out to reveal natural enemies for use as biocontrol agents. Further investigations are needed in order to evaluate the specificity of these agents and to prevent damages to native polychaete populations or other species. Die-backs in different places in Australia were noted in 1996 without knowing the causative agent (ICES 1997).

Another non-indigenous invader that has been requested to treat with biocontrol is the European Shore Crab (*Carcinus maenas*). A desk study indicated that natural enemies such as *Sacculina carcini* (Cirripedia), ciliates, parasitic dinoflagellates (*Hematodinum* spp.) and viruses may be worthwhile to investigate (ICES 1997).

Within a joint CRIMP and ABWMAC project the distribution of planktonic organisms in ballast water tanks is being examined. Sampling methods obtaining representative samples will be tested in order to demonstrate their effectiveness in detecting target organisms of known densities in the ballast uptake. On board trials are ongoing and should be completed in 1997.

Another group of experts is involved in a study to test the effectiveness of ballast water heat treatment, hull fouling as a transport vector across the Tasman Sea and the ability of organisms to survive in ballast tanks. Major studies on the effects of port management techniques on the progress of colonization, and the role of hull fouling as a transport vector are scheduled to start in 1997 / 1998 (Thresher 1997 a, b).

At the CSIRO/CRIMP an international ballast water survey, focused on sampling methodology of world-wide relevant projects was initiated. Results of this study will be published in 1998 (Sutton, Martin pers. comm.).

1.4.7 New Zealand's activities

In late 1988 a group concerned about the growing evidence linking ballast water discharge with the arrival of exotic organisms met to discuss the issue, called the Ballast Water Working Group (BWWG). The BWWG was particularly concerned about toxic dinoflagellates which cause Paralytic Shellfish Poisoning. This had so far not been recorded to occur in New Zealandian waters (MEPC34/INF.3).

In addition, a research programme entitled “Foreign Organisms entering NZ Coastal Waters via Discharge of Ballast Water” was carried out by the Cawthron Institute in 1996 / 1997. The goal of this research project concerns the international problem of translocating non-indigenous marine life in ships ballast tanks. In this context it quantifies the diversity and the abundance of foreign marine species entering NZ waters. By sampling the ballast tanks of a representative range of ships, the study aims to identify potentially invasive species, with the view to assessing the risk of their introduction. In addition the study considers methodologies for sampling ballast tanks, relates the analyses of ballast water samples to such variables as water origin, containment time, ship and tank types and effectiveness of mid-ocean exchange, considers the design of a computerised data base to store and export ship and sample related data for statistical analysis and provides suggestions for assessing the risk of introducing foreign marine life to NZ via ballast water discharge.

A practical, reliable and consistent method of obtaining quantitative water and sediment samples from all types of ballast tanks via sounding pipes, manholes, and from ballast holds was developed. This procedure is independent of ships personnel and causes no inconvenience to cargo handling. Measurements of water quality (e.g. salinity) and of phytoplankton and zooplankton diversity and abundance were made both at dock-side and in the laboratory. Together with the history (e.g. origin and containment time) of the water in the ballast tanks, tank capacities, ship statistics (e.g. registration, DWT) and details about mid-ocean exchange, all data were entered into a customized computer data base. Until now 161 ballast tanks from 75 vessels were sampled from a wide range of ship types but mainly container ships, using a sounding pipe sampling method.

The sampling method via sounding pipes has shown to be of significant advance, and is consistent with requests to develop a practical, representative sampling procedure. The method permits sampling of all vessels with sounding pipes; i.e. at least 90% of ships plying NZ trade-routes. Recently this method has been adopted by two other research agencies (Ministry of Fisheries Policy 1997, Taylor pers. comm.).

1.4.8 Southafrican activities

Information of ballast water discharges have been collected from several ports. The available information was limited to a short period of time and a selection of port authorities. The amount of ballast water discharged was estimated as 20 million tonnes annually (Jackson in prep.).

Currently a sampling study of ships ballast water is carried out. The pilot study at the Sea Fisheries Research Institute investigates the possibility of introduction of non-indigenous phytoplankton species (especially toxic forms) into South African waters at Saldanha Bay on the Cape West Coast. Saldanha Bay is South Africas second busiest port and is destined to become the busiest port when the facilities for additional export of iron ore are completed. The project was commenced as a pilot study in 1996. One of the major problems was the access to sample ballast water preferably via opened manholes. In addition to the ship sampling 4 monitoring stations in Saldanha Bay are sampled so as to be able to get base line data on what phytoplankton occurs in Saldanha Bay, both in the water and in the sediments. Preliminary results are not available (Jackson, Pienaar pers. comm.)

1.4.9 China

In China, the Dalian Maritime University has started a project on ballast water. The initial phase of this pilot study will summarize relevant information (activities of other countries, summary of shipping studies etc.) and will list objectives for the sampling phase. The sampling will be concentrated on target vessels (Pughiuc & Dianrong 1998).

1.4.10 Japanese activities

The Japanese Ship-owners Association completed in 1995 on board experiments using the ore carrier Ondo Maru (56.062 Gross Tonnage, LOA 245m, B 41.8m, D 21m) to develop effective methodologies on how treat marine organisms in ballast water. The study was concentrated on the treatment of phytoplankton in the ballast water, but zooplankton was investigated as well. The heat exchanging unit from the cooling circuit of the main engine of this vessel was modified in order to lead the heated water into the studied ballast tank. Before the experiments were carried out a feasibility study had been conducted to investigate as to whether a heating unit as planned will be able to solve the problem. It was believed that the ballast water temperature has to be heated up to 45 °C. Using the planned heat treatment would heat up the ballast water up to 46 °C with a flow rate of 100 tonnes / h. One single ballast tank was used in this investigation. The studied ballast tank (sidetank No.4) is characterised by a surface area in contact with the atmosphere of 456 m², seawater covered surface of 642 m² and area touching holds 693 m². The results showed that the quantity of species in the ballast water was effectively reduced by the heat treatment.

For future investigations it was noted that firstly, the temperature of the ballast water was not uniform in the whole tank, secondly that during the mid-ocean exchange of ballast water additional species of plankton were taken on board and thirdly that all living phytoplankton species were not able to survive the 24 day voyage due to the lack of light. In this connection it was documented, that 7 different phytoplankton species were found in total. After the mid-ocean exchange of the ballast water the *Thalassiosira* sp. was not found anymore, but all other species that had been determined prior to the ballast water exchange and in addition *Thalassiothrix* sp.

Summarising these facts, Fukuyo et al. (1995) recommend to develop new methods of ballast water treatment suggesting the application of new electrolysis technologies (MEPC36/18/2, Fukuyo et al. 1995).

Voluntary ballast water management practices are in place to prevent the introduction of human disease agents as Cholera but no binding regulations dealing with ballast water are in place (Muramatsu pers. comm.).

1.5 Results of ship sampling studies

In this chapter the results of a selected number of shipping studies are presented. The incomplete list shall give an overview on the variety of species which can be found in the ballast water, ballast tank sediments and as fouling on the ships hull.

1.5.1 Ballast water

1.5.1.1 Germany

A shipping study supported by the German Government revealed that in none of the ballast water samples abiotic parameters were estimated to be of lethal nature. However, not all samples contained organisms. Organisms were found in 73.5% of all ballast water samples. Among the factors determining survival in ballast water tanks, tolerance towards changing environmental conditions seems to be the most important factor as evidenced during a voyage on board a container vessel from Singapore to Bremerhaven (Germany). Daily sampling of different ballast tanks revealed dramatically varying temperature and oxygen contents. These are important factors influencing the survival of organisms inside the ballast tanks.

The main phytoplankton groups recorded in ballast water were diatoms, dinoflagellates and Chlorophyceae. All phytoplankton species that were recorded are occurring in a wide range of geographical areas and had probably been spread by earlier transport of ships. Of the total 147 species, 11 non-indigenous phytoplankton species were recorded, 8 diatom species in ballast water, and 3 dinoflagellates in sediment samples. Among the 11 non-indigenous species were 2 dinoflagellate genera (Alexandrium and Gonyaulax) which are known for toxin production.

The zoological results of the ballast water investigation were dominated by Copepoda and Rotatoria, and up to 20 cm long fishes found in ballast water samples. The maximum number of different species in one sample was 12. With increasing age of ballast water (time period spent in the tank), the number of species and specimens decreased. Of the 257 species identified, 150 were classified as non-indigenous species to German waters. 37 of these were found in ballast water, 60 in sediment, and 83 in hull samples.

In general, about 1 animal per 1 l ballast water was recorded. This means an introduction of 69 organisms per second or 6 million per day with ballast water from outside Europe. A maximum of 110,000 unicellular algae were recorded from 1 l of ballast water and 300 empty cysts per 1 ml sediment

The potential for the establishment of non-indigenous species was classified into three categories according to how the climatic conditions in the area of origin compared to those in German waters (low, medium, and high risk of introduction). Ballast water was estimated as an important vector for future introduction of non-indigenous species in our waters, since most of the species with the highest potential for survival and establishment have been recorded here, and not in sediment and hull samples (Gollasch 1996, Lenz et al. in prep.).

The survival of plankton organisms in ballast water tanks was studied during a voyage of 23 days with a container vessel from Singapore to Bremerhaven (Germany). Previous ballast water investigations during ship voyages showed the decrease of specimens and the reduction of diversity according to the time the ballast water stayed in the ballast tanks. As expected, the number of specimens decreased dramatically in one of the two investigated tanks. In the second tank the number of individuals of one harpacticoid copepod, *Tisbe graciloides*, increased from 11 specimens per 100 litre at the beginning of the investigation to more than 1,000 specimens at the end. An increase of specimens during ship voyages has never been documented before. This new dimension of species transportation in ships ballast tanks shows that ballast tanks may be incubators under special conditions and emphasises the risk of species transport with ships (Lenz et al in prep).

1.5.1.2 United Kingdom

Biological analyses focused on planktonic organisms, including motile phytoplankton and zooplankton in ballast water, and resting cysts of dinoflagellates in ballast tank sediments. Full resting cysts of dinoflagellates were found in 62% of sediment samples, including cysts belonging to potentially toxic species associated with Paralytic Shellfish Poisoning (PSP). These were partly cysts representing the resting stages of the dinoflagellates Alexandrium minutum and Gymnodinium catenatum, species not currently described from UK waters. 51%of cysts incubated in culture media during preliminary investigations into the viability of cysts hatched into motile dinoflagellate cells, and many phytoplankton species also flourished in sediment slurries incubation experiments. Motile phytoplankton was found in 133 of the 134 ballast water samples. These samples contained a wide range of organisms, reflecting the diversity of their geographic origins and characteristics. Potentially toxic species of diatoms (Pseudonitzschia spp.) and dinoflagellates (Dinophysis spp. and Alexandrium spp.) were observed. The problems of identifying toxic flagellates were outlined. Phytoplankton assemblages taken from ballast tanks prior to and following mid-water exchange in the North and Irish Seas were compared. This practise appeared to be less effective at reducing the diversity and abundance of phytoplankton cells than mid-water exchange in oceanic waters, and these are important implications for future ballast water management guidelines.

Analyses of zooplankton in ballast tanks showed the great diversity in taxa transported in ballast water, and demonstrated that many organisms appeared to survive the ballasting operations and voyages. Two non-indigenous species of calanoid copepod were observed, and five species (four copepods and one polychaete) only rarely seen in Scottish waters were found. The results showed further that resting cysts of toxic dinoflagellates are a major problem which should be addressed in future ballast water treatment options (Macdonald & Davidson 1997).

1.5.1.3 Norwegian "Sture" study

Preliminary results of the ballast water samples partly investigated so far showed that live phytoplankton were found in 96 % of the vessels, live copepods were found in 90 % of the vessels, live Cirripedia were found in 80 % of the vessels, live Polychaeta were found in 50 %, and fish eggs in 20 % of vessels. In addition many more taxonomic groups are present in the samples, and live fish and crabs have been observed (Botnen pers. comm.).

1.5.1.4 USA

Several North American studies were undertaken to sample the ballast water of ocean-going vessels. Main focus of the North American studies was the zooplankton introduced with ballast water (the Australian working groups were concentrated on phytoplankton (see below).

A shipping study revealed that in total 367 different species sampled on 159 vessels calling for the port of Coos Bay, Oregon, USA. The study concentrated on one specific shipping route (Japan to the North American west coast) (Carlton & Geller 1993). An earlier investigation of Carlton et al. (1982) and Carlton (1985) focused on bulk carrier entering North American ports without any cargo but with high loads of ballast water. The predominantly found taxa of all studies belonged to Crustacea, Mollusca and Polychaeta.

An additional sampling programme at the Smithsonian Environmental Research Centre (SERC) revealed the presence of living species in ballast water in 25 of 27 ships entering the Chesapeake Bay (Ruiz pers. comm.). The minimum number of species found in ballast water arriving to the Chesapeake is reported as 221 in (Smith et al. 1996).

1.5.1.5 Canada

The Canadian study revealed that existing data on pH, temperature, oxygen and salinity of the ballast water does not inhibit a broad range of organisms from surviving.

In four ballast samples streptococci were found. The concentration in two samples exceeded the criteria level for public surface water supplies. The maximum number of coliform bacteria (4,600 per 100 ml) were slightly less than the maximum permissible level (5,000 per 100 ml).

In total more than 150 species of phytoplankton were identified. All ballast water samples contained aquatic flora. The macrophyt component consisted of fragments only. In 76 % of the ships in minimum one viable algae had survived the transport in ballast water. Of the

eleven major phytoplankton divisions only Chloromonadophyta were absent. 9 species were estimated to have the potential of becoming introduced into the St. Lawrence estuary.
The aquatic fauna (over 56 species) consisted entirely of invertebrate species. Zooplankton represented the majority of animal organisms found in the ballast water samples. 89% of all ships contained at least one viable invertebrate form. The assembly of found species consisted of Protozoans, Rotifera, Nematoda, Mollusca, Annelida, Tardigrada, Acarina, Cladocera, Ostracoda, Copepoda, Cirripedia, Mysidacea, Isopoda, Amphipoda, Diptera, Decapoda, Chaetognatha. Occasionally terrestrial insects were found. Their occurrence in the ballast water was quoted as probably accidental. 9 species of flora and fauna were estimated to have the potential to become introduced into the St. Lawrence estuary (Howarth 1981).

The results of the ballast water sampling of 455 ocean-going vessels entering the St.-Lawrence Seaway carried out by Locke et al. (1991, 1993) revealed 107 taxa. All sampled ballast tanks contained living zooplankton. Predominately found organisms were copepods, water fleas and rotifers. The maximum number of specimens was comparably high with more than 50,000 species per m³ of ballast water. A sample with the minimum number of specimens contained 21 specimens per m³ (Locke et al. 1991, 1993).

Subba Rao et al. (1994) published a study of exotic phytoplankton species from ballast water and their potential spread and effects on mariculture localities. Ballast water was analysed from 86 foreign vessels that visited the Great Lakes area during 1990 and 1991. In total 102 taxa of 7 taxonomical groups were determined, 69 diatoms and 30 dinoflagellates were collected. Most of the phytoplankton were found in a good condition. Culture experiments were carried out. In total 21 potentially bloom-forming (red tide) and / or toxin producing phytoplankton species were found in the ballast water samples. Several of the species were found for the first time is this geographical region (Subba Rao et al. 1994).

Additional sampling on 94 ships revealed at least 106 different zooplankton species in the ballast water. 25 species had never been reported from the St. Lawrence region. The number of species ranged from 5,000 to 8,000 per m³ depending on the season. The number of species ranged from 11 to 24 on average per sample. The results of the study could be used as a scientific rationale to extend the application of the existing guidelines to all foreign ships entering the Gulf of St. Lawrence. In addition the results showed that the guidelines (when complied with) are effective in reducing the potential for ballast water mediated introduction in the marine ecosystem of the St. Lawrence area (Gilbert & Harvey 1997, SGBWS 1997).

1.5.1.6 Australia

A zoological study revealed that in 23 samples of ballast water 67 taxa were determined. Crustacea (mainly Copepoda) and Mollusca were the most abundant taxa found (Williams et al. 1988).

Additional sampling carried out before 1990 showed that in 35 % of 343 samples of ships entering 18 different Australian ports dinoflagellates were found. In total 53 species of planktonic and benthic species of dinoflagellate and diatom were collected. Due to the frequent findings of phytoplankton in ballast tanks it was assumed that the world-wide distribution of some species could be related to the transport in ballast water. The toxic dinoflagellates *Alexandrium catenella*, *A. tamarense* and *Gymnodinium catenatum* were found in samples from 16 vessels (Hallegraeff et al. 1986, Rigby et al. 1993, Hallegraeff & Bolch 1992). It is known that one vessel filled its ballast tank during a phytoplankton bloom of toxic species in the port of Muroran (Japan). After its voyage to Australia the ballast water of this vessel was sampled, revealing more than 300 million cysts of the species *Alexandrium*.

1.5.1.7 New Zealand

Results of the research programme entitled „Foreign organisms entering NZ coastal waters via discharge of ballast water„ showed that about 80% of tanks sampled contained live phyto- and zooplankton. About half of these tanks were reported to have been exchanged in mid-ocean suggesting that mid-ocean exchanges do not remove coastal marine life. Some zooplankton taxa (e.g. polychaete worms with their tubes still intact) appear to be persistent residents in the tank sediments. Many of the invertebrates found were larvae which hindered taxonomic resolution (Taylor pers. comm.).

1.5.2 Tank sediments

1.5.2.1 Germany

As early as 1933 Peters noted the presence of the Chinese Mitten Crab (*Eriocheir sinensis*) and of an amphipod after the investigation of the bottom of a vessels ballast tank. The investigation was carried out in 1932 and documented the possibility of successful species introductions into German waters (the Chinese Mitten Crab was first recorded in 1912).

Samples of the sediment inside ballast tanks were difficult to collect due to safety provisions. Rotting material could have produced bad air conditions with limited oxygen content. Therefore, during the German shipping study, sampling was only possible after intensive tank ventilation. Inspection of the ballast tanks could be carried out 71 times, nearly half as much as for ballast water and hull samples. 74.6% of the sampled sediments contained living organisms: diatoms, dinoflagellates and their cysts as well as Chlorophyceae. Bivalvia and Cirripedia were the most common animals found in sediment samples. The maximum number of species in one sample was 25, more than twice as much as in the ballast water (Gollasch 1996, Lenz et al. in prep.).

1.5.2.2 Australia

In 1975 a report documented the presence of live invertebrates in ballast water and sediment in a ship arriving at Twofold Bay Eden (New South Wales) from Japan (MEPC35/INF.19) and therefore proved the presence of living organisms in ballast water of ocean -going vessels after its intercontinental voyage (Medcof 1975).

A zoological study revealed in total 9 samples of ballast tank sediments. Crustacea (mainly Copepoda) and Mollusca were the most abundant taxa found (Williams et al. 1988).

Additional sampling until 1990 revealed 343 samples of ships entering 18 different Australian ports In about 35 % of all ballast tank samples cysts of dinoflagellates were found. In total 53 species were determined. Due to the frequent findings of phytoplankton in ballast tanks it was assumed that the world-wide distribution of some species could be related to the transport in ballast water. The toxic dinoflagellates *Alexandrium catenella, A. tamarense* and

Gymnodinium catenatum were found in samples from 16 vessels (Hallegraeff et al. 1986, Hallegraeff & Bolch 1992).

1.5.3 Hull fouling

Further development of the toxic components of anti-fouling paints improved the effectiveness of this hull paints tremendously (MEPC/38/INF.9).

During the German shipping investigations access to ship hulls was only permitted in dry docks, most of the vessels investigated entered the dock in order to renew their anti-fouling paints after several years. Therefore nearly all samples (98.5%) of the hull fouling contained organisms. Hull samples investigated for macroalgae revealed mainly widespread green algae of the genus *Enteromorpha* and brown algae of the genus *Ectocarpus* were found. Non-indigenous algae to German waters were not found. All species of macroalgae that were found are spread over a wide range of geographical areas.

Bivalvia and Cirripedia represent the dominant fauna in the hull samples as well as in the sediment samples. The highest species number per sample was 15, less than in sediment samples but 20 % higher than in samples of the ballast water. Hull fouling contained a higher number of non-indigenous species than ballast water and tank sediments. Most of the 83 non-indigenous species are distributed over a wide geographical range possibly spread by hull fouling during earlier shipping (Gollasch 1996, Lenz et al. in prep.). Even a species unknown to science was found in one sample. This turbellarian species was named after the site of its first finding *Cryptostylochus hullensis* (Faubel & Gollasch 1996).

1.5.4 The need for standardisation of sampling methods

For all of the above mentioned sampling programmes specific sampling methodologies were used. The development of globally applicable standard sampling methodologies for collecting and analysing ballast water from ships is needed. Sampling methods may vary according to the behaviour and the taxa of species considered to be harmful. It may be necessary to consider different techniques according to the local conditions of each port, country or region. Protocols need to be developed to address these issues.

1.5.4.1 IMO / MEPC sampling plan

The IMO / MEPC Ballast Water Working Group considers the development of ballast water management plans identifying the location and suitable points for sampling ballast water or sediment. This would enable the ship´s crew to provide maximum assistance when port authority inspections require samples of ballast water or sediments.

1.5.4.2 EU Concerted Action

In co-operation with 5 European countries: Finland, Ireland, Sweden and the United Kingdom (England and Scotland) and Lithuania, Germany is co-ordinating the Concerted Action programme entitled: "Testing Monitoring Systems for Risk Assessment of Harmful Introductions by Ships to European Waters". Several experts from all over the world (e.g. North America, Mediterranean Countries, Australia and Asia) will be participating. This two year Concerted Action (starting early 1998) was recently funded by the EU. Various methods of monitoring ballast water species will be studied evaluating qualitatively and quantitatively the fate of exotic species in ballast water. Sediments accumulating in ballast tanks and fouling biota on ship hulls will also be examined. Treatment measures for the control of exotics will be discussed. Assessment of potential risks from hazardous introductions and their control is an increasing problem of importance.

The main objectives of the Concerted Action include state of the art of ballast water studies (case histories), evaluation of the various sampling methods presently used for ballast water studies in selected EU member countries, validation of the reliability of sampling methodologies (through intercalibration workshops, also on board of ocean-going ships) to assess in-transit survival capabilities, standardisation of sampling methods and development of intercalibrated monitoring systems for use by EU countries and by inter-governmental bodies such as ICES, BMB (Baltic Marine Biologists), IOC and IMO. In addition interested institutions (National Governmental Organizations) from other countries will be invited as guests for specific tasks.

1.6 International Network for Marine Invasion Research (INFORMIR)

International co-operation is necessary in order to co-ordinate scientific studies avoiding double work to standardize sampling methods for international comparison of results and to develop measures to deal with ballast water.

Over the past decade research on aquatic non-indigenous species has increased all over the world, resulting in several studies carried out in many different countries (see above). The development of management strategies on non-indigenous species and ballast water depends on the understanding of both generalities and sources of variation. The development of a co-ordinated effort is underway for ballast water management including treatment options implemented by the IMO. As a result of meetings of several expert groups dealing with the ballast water issues first steps are being developed to co-ordinate activities around the world and to increase the effectiveness of e.g. research, to develop standards and to promote comparisons. An International Network for Marine Invasion Research (INFORMIR) is under construction to derive comparative approaches due to summarising the individual studies carried out. Beside IMO, the IOC of the UNESCO and the ICES are working in the field covering aspects that fall within their mandates, i.e. IOC in relation to research on harmful algal blooms (see section 2.1), and ICES concerning the introduction of species and their effects on aquaculture.

In contrast, co-ordinated research on patterns and impacts of non-indigenous marine and estuarine species marine lags far behind. Missing data include the abundance, distribution and impacts within regions (national and international). It is suggested that a strong benefit would result from establishing an International Network for Marine Invasion Research what may be used to comparative and collaborative research in this field.

2 Case histories of introduced species and their effects to environment and ecology

The Australian Bio-Economic Risk Assessment report from 1994 estimated that with an application of effective treatment options costs of US $ 292.5 million of damages in regard to domestic and international tourism, public health and aquaculture could be avoided (ACIL Economics 1994). Until today this has been the only report listing costs what may be saved by the implementation of effective ballast water treatment options and the associated minimization of potentially harmful species introductions.

Selected examples of unwanted introduced species and their ecological and economical impacts are listed in the following section:

2.1 Flora

Toxic algal blooms (harmful algal blooms (HAB))

The potential of ballast water as a vector to introduce phytoplankton species outside their native range was firstly suggested by Ostenfeld (1908) after a phytoplankton bloom of *Odontella sinensis* in the North Sea in 1903. More recent concerns arose after increasing phytoplankton blooms around the world in the 1980s (Smayda 1990, Hallegraeff & Bolch 1992, Rigby et al. 1993). Increasing toxic algal blooms of non-indigenous species in Australian and New Zealandian waters have been associated with ballast water releases. Australian scientists have since intensified their ballast water studies (Hallegraeff & Bolch 1991, 1992, Baldwin 1992).

In 1992 an IOC-FAO Intergovernmental Panel on Harmful Algal Blooms (IPHAB) had its first session focusing meeting on the negative impacts of these blooms on public health and economy. The expansion of these blooms are related (at least at part) to the increasing exploitation of coastal waters (waste disposal, aquaculture, maritime commerce and other anthropogenic influences) as well as to the dispersal and proliferation of such species. It was noted that in order to foster the effective management of, and scientific research on harmful algal blooms to understand their causes, predict their occurrences and mitigate their effects a lack of information exists.

Several international institutions were interested in harmful algal blooms as e.g. UNEP, EEC, ICES and SCOR and formed the IOC-FAO Intergovernmental Panel on Harmful Algal Blooms. The IPHAB organized discussion / expert groups, training programmes on the taxonomy of harmful phytoplankton, design and implementation of monitoring programmes, funding research and forming an information network starting with the first issue of a newsletter Harmful Algal News published in 1992. The panel recognized in its1993 report that the problem of the transport of harmful algal blooms via ballast water was of major concern (IOC-FAO IPHAB 1992, 1993).

Particularly in regard to toxic marine phytoplankton species such as *Alexandrium minutum*, *Gymnodinium tamarense*, *G. catenatum* and *Gyrodinium aureolum* which are known to have occurred in blooms all over the worlds oceans.

Alexandrium species have caused outbreakes of Paralytic Shellfish Poisoning (PSP) in Norwegian waters and coastal areas of the United Kingdom. *A. minutum* was observed for the first time at the Swedish west coast (Skagerrak) being abundant during end of June (Lindahl & Edler 1997) it was also present in samples of the North Sea and the Atlantic, the Mediterranean Sea, east coast of the USA, Japan, Australia and New Zealand (ICES 1997).

Gyrodinium aureolum has caused fish kills in the British Channel, western areas of United Kingdom, Danish, Norwegian and Swedish waters (Swedish Environmental Protection Agency 1997).

In January 1993 the whole New Zealand shellfish industry (export and domestic use) was closed as a result of toxic algal blooms. Knowing that the transport the exotic phytoplankton species in ballast water may result in new phytoplankton blooms after discharge of the ballast water, vessels were requested not to discharge ballast water in any Australian or New Zealandian port or to exchange their ballast water before releasing it in an Australian or New Zealandian port.

Caulerpa taxifolia

The accidental introduction of the alga *Caulerpa taxifolia* into the Mediterranean Sea and its spread through regional shipping and boating had been subject of research by the European Union. The seaweed *Caulerpa taxifolia* was probably introduced into the Mediterranean Sea in the mid 1980s: First records were made in the Monaco area (Meinesz & Hesse 1991). *Caulerpa* covered in 1984 a surface of 1m². In 1990 it covered 3 ha, in 1991 30 ha, in 1992

427 ha, in 1993 1,300 ha, in 1994 1,500 ha and in 1996 more than 3,000 ha. Today it covers the surface of thousands of hectares along the coasts of France, additional records were documented from Spain (the Balearean islands (21 ha covered)), Italy and Croatia (Adriatic Sea).

Caulerpa replaces the native seagrasses (e.g. *Posidonia oceanica)* limiting the habitat for larval fish and invertebrates. It therefore endangers the continuity of their populations (Meinesz et al. 1997, Ribera pers. comm.).

In 1992 an international programme was launched to combat the further spread of the algae (Nolan 1994, UNEP(OCA)/MED WG.89/Inf.9 1995, Ribera et al. (eds.) 1996).

Undaria pinnatifida

The Japanese Brown Kelp *Undaria pinnatifida* is believed to have been introduced in Australia in a similar way as the North Pacific Seastar *Asterias amurensis* (see below) and has negatively effected fishing stocks in Tasmania. In 1988 it was first recorded, but it is known to have become established at sites of France as well as in New Zealand before 1988 (Byrne et al. 1997). By 1991 the temperate algae had spread over an area of 16 kilometres. It is likely to continue its spread as its spores are easily dispersed by currents and at this stage an eradication seems impossible. Based on temperature tolerances it may potentially survive from Cape Leeuwin (Western Australia) to Wollongong (New South Wales). The kelp has had already a detrimental impact on the abalone industry, as it attaches to rocks that are abalone feeding sites. It also makes the abalone extremely difficult to harvest. The kelp will have an even greater impact when it reaches oyster and other mussel farms and settles on racks, lines and other culturing material (MEPC33/INF.26). Physical removal of *U. pinnatifida* from a marine reserve area was undertaken. The success of this action is not yet known (ICES 1997).

In 1991 a proposal reached the European Commission requesting financial support for the introduction of the kelp (*Undaria* spp.) to the French coast of the Channel area for commercial exploitation. The proposal has been supported and "justified" by the planned provision of employment and the use of this additional food sources (Nolan 1994).

Sargassum muticum

Unintentionally introduced in France as packaging materials or as fouling species on imported oysters from Japan in the 1970s. This large brown algae is now being found along the coasts of Portugal, Spain (Atlantic coast), France (Atlantic coast), United Kingdom, The

Netherlands, Germany (North Sea) Denmark (North Sea), Norway and Sweden (west coast). Negative effects to native species are the competition with native species and a negative impact concerning light-penetration and water exchange, as well as the hindering of local fisheries (Swedish Environmental Protection Agency 1997).

2.2 Fauna

Dreissena polymorpha

The Zebramussel *Dreissena polymorpha*, a pontocaspian element was unintentionally introduced into the Great Lakes (USA). Nowadays it occurs in very high densities. Besides an ecological harm, this species causes economical problems. Water supplies of power plants are densely clogged by this species and have to be cleaned by man (Roberts 1990, Lodge 1993).

The pontocaspian Zebra Mussel has and will in future cause billions of dollars of damage by fouling underwater pipes in the Great Lakes area. The control, repair and actions to remove the introduced Zebra mussel in the Great Lakes costs US$ 4 - 8 billion in the next 10 years. The mussels are displacing native bivalves, clogging water intakes and fouling vessel hulls, fishing nets and other submerged hard material as port installations, piers and buoys.

Long before this mussel invaded many areas of Europe via shipping or by natural distribution via freshwater waterways and canals as well as by birds. Mass occurrences appeared in 1850s and 1970s in some German rivers and lakes.

In recent times un-confirmed records of the mussel were mentioned for the Shannon Estuary (Ireland) and the River Plate (Argentina). In Argentina the new species creates habitats on drain outlets, industrial and drinking water intake pipe systems clogging the flow rate and threatening the water quality.

Eriocheir sinensis

The first introduction into European waters occurred probably early this century. First European findings were recorded from the German river Aller in 1912 (Schnakenbeck 1924, Peters 1933, Panning 1938, a, Anger 1990, Reise 1991, Zibrowius 1991, Michaelis & Reise 1994). Marquard (1926) found some specimens in empty "shells" of cirripeds on a ships hull. Another vector for the introduction is probably the ballast water of ships (Peters 1933, Jazdzewski 1980, Howarth 1981, Carlton 1985). After multiple introductions *E. sinensis* was able to establish with a self-reproducing population (Panning 1938, b) and spreading throughout Europe (Pax 1929, Boettger 1933, Panning 1938 a, b, 1950). This happened probably by the active migration of the species via rivers and canals (Arndt 1931, Boettger 1933, Luther 1934, Rosenthal 1980, Nyman 1993). Specimens were found 700 km upstream the river Elbe (Kaestner 1970) in many estuaries at the German North Sea coast and in 1924 in the Tegeler Lake (Berlin, Germany) (Sukopp & Brande 1984).

After its introduction a further spread to many different areas was documented in rivers up to Prague (Czechoslovakia) (Marquard 1926, Gruner et al. 1993), spread into the Baltic Sea probably via the Kiel Canal. First finding in the Baltic Sea (German coast) 1926. Occurrence in Lakes of the former Eastern-Germany (state Mecklenburg-Vorpommern) in 1931 / 32 (Boettger 1933). Findings outside Germany were noted in The Netherlands, Denmark, western Baltic Sea up to the Finnish coasts in the 1920s and 1930s (Rosenthal 1980, Jansson 1985), United Kingdom in 1935 (Ingle 1986), Hawaii in the 1950s (Edmondson 1959), Mediterranean Sea (Zibrowius 1991), North-America, Detroit River 1965 (Gruner et al. 1993) and Great Lakes 1973 (Nepszy & Leach 1973) without establishing (Hebert et al. 1989). It is not clear if the introduced specimens came from Europe or China (Carlton 1985).

The area of origin are waters in temperate and tropical regions between Wladiwostock and South-China (Peters 1933, Panning 1938, a), including Japan and Taiwan. The main area of distribution is the Yellow Sea (temperate regions of North-China) (Panning 1952, Kaestner 1970, Anger 1990).

During mass occurrence damages on dikes, other coast protection and harbour installations were observed because of *E. sinensis´* burrowing activities. In addition feeding on fishes in nets reduced the harvest of the river fishing industry. Therefore some controlling mechanisms (e.g. selective fishing, traps) had been introduced however, with little success (Panning & Peters 1932, Peters et al. 1936, Leppäkoski 1991, Gruner et al. 1993).

Increasing water pollution in German rivers resulted in a decrease of the number of specimens due to the decrease of the population density of its food-organisms. Now, where the condition of the rivers become better and better (Reincke 1993), the population density of *E. sinensis* is increasing again (Pfeiffer pers. comm.)

Crepidula fornicata

This unintentionally introduced species is native to the north American east coast; it presumably arrived as adult species with imported live mussels or as larvae in the ballast water of ships. First records in European waters were made in the 1880s in England (Robson

1915, Nordsieck 1969, Utting & Spencer 1992). In 1934 records were made in Denmark and Germany. Additional findings were noted in France and Ireland (Minchin et al 1993), Sweden (Farnham 1980), Japan (Walford & Wicklund 1973), North American west coast (Carl & Guiget 1957, Hanna 1966) and the Mediterranean Sea (Zibrowius 1991).
The slipper limpet has a negative impact as food competitor on scallop and other shellfish culture in France and Ireland (Campbell 1987, Eno et al. 1997).

Bythotrephes cederstroemi

Introduced to the Great Lakes from Europe the Cladocera *Bythotrephes cederstroemi* threatens native fish stocks as a food competitor (Sprules et al. 1990, Berg 1991; Mills et al. 1993).

Mnemiopsis leidyi

The ctenophore *Mnemiopsis leidyi,* endemic to the North American Atlantic coats is spreading in the Black Sea area. After its first record in the Black Sea in 1982 additional findings were reported in 1986. Nowadays the comb jelly is well established and occurs in masses. It has played a major role in the profound decline of the local anchovy industry. The population of native ctenophores has almost been completely removed by the American Comb Jelly *Mnemiopsis leidyi*. The fishing harvest of the Anchovies fishery in the Black Sea decreased to 10 % compared with fisheries of the times before the comb jelly invaded the Black Sea (Vinogradov et al.1989, Shushkina & Musayeva 1990, Reeve 1993). Proposed predators as carnivorous fish (e.g. cod from the Baltic, butterfly fish or chum salmon from North America) or ctenophore predating other ctenophore; e.g. *Beroe* sp. from Atlantic North America waters could be intentionally introduced into the Black. A GESAMP report issued in 1997 reviews control strategies and possible predators for biocontrol, as well as the viability of other, non-biocontrol options (Leppäkoski 1994, Harbison 1994 a, b, Harbison & Volovik 1994, GESAMP report 1997). By 1992, the species had spread into the Mediterranean Sea (Harbison 1994).

Sabella spallanzani

The giant Mediterranean Fan Worm *Sabella spallanzani* and the Northern Pacific Sea Star (see below) are threatening aquaculture and fishing industry in Australian waters. This species is characterised by its rapid growth of up to 10 cm annually. The first Australian record was made in early 1980s. Die-backs of the polychaete were reported from different areas without knowing the causative agent (Furlani 1996).

Asterias amurensis

Established populations of the North Pacific Seastar *Asterias amurensis* have been discovered in the cool temperate waters of Southern Tasmania. The seastar is native to Japanese and Alaskan Waters and has been known from Tasmanian waters since the late 1980s (first records in 1986). The introduction is believed to have occurred with the discharge of ballast water containing the larvae of the species in Australian waters. The impacts of this starfish on e.g. shellfish industries and the marine environment causes concern. The Pacific Starfish threatens the shellfish industry causing damages of US $ 367.5 million by eating mussels. The prognosis for its future potential is not good. It may settle as far as Sydney (New South Wales) since it has an appropriate water temperature tolerance. A status report on *A. amurensis* by the Commonwealth Scientific Industrial Research Organization (CSIRO) in June 1993 concluded that only physical removal seemed to be a viable in reducing starfish numbers. The application of biocontrol methods is expected, but a success is not guaranteed. It is believed that a disease agent could be used to control the population of the starfish. There are several problems in biocontrol, especially the need to test the control measures treatment in regard to a selective effect on the target organisms and no native species. A possible species for biocontrol could be the Japanese ciliate *Orchitophyra* sp.. After infection, this species disables the host's reproduction. Tests, if this species is able to cause problems by infesting native Echinodermata are being carried out (Furlani 1996, Thresher and Goggin pers. com., Report of ICES SGMBIS 1997)

Carcinus maenas

The European shore crab was introduced at several places around the world presumably with the discharge of ballast water or sediments from ballast tanks. *Carcinus maenas* was probably introduced to Hawaii (Alcock 1899) [uncertain], the North-Americas west coast (Alcock 1899, McDermott 1991, Hedgpeth 1993), Bay of Panama (Alcock 1899) North-Americas east coast (Vermeij 1981), Brazil (Alcock 1899) [uncertain], South.-Africa (Joska & Branch 1986, Jackson 1993), Madagascar (Christiansen 1969), Red Sea, India (Alcock 1899) Burma (Boschma 1972) as well as to the coast of Australia and Tasmania (Bourne 1990, Pollard & Hutchings 1990 a). The crab was first found in Australia in the late 19th century. At this time the ballast of ships were predominantly sand and rocks. It is believed that this species is robust enough to survive a several week long voyage from Europe to Australia with this solid ballast. It has been discovered only within the last decade in Tasmania. C. maenas is a omnivorous species what may have negative predatory impacts on the shellfish industry. A possible biocontrol of this species is considered using parasites selectively hosting in *C. maenas*. Such parasite is the rhizocephalan cirripede *Sacullina carcini*. Australian studies are ongoing to determine the specification of the parasite. Trials with native decapods will show if the parasite is able to host and threat native species.

Anguillicola crassa

Anguillicola crassa (Nematoda), first recorded in German waters in the 1970s (Koops & Hartmann 1989) was introduced with imported eels for aquaculture (Williams & Sindermann 1991). It now occurs in all waters of Germany and is increasingly affecting eel populations. In the river Elbe an infestation rate of nearly 100% is reported and similarly high infestation rates are occurring in other river systems.

In many lakes of the German state Schleswig-Holstein, the ruffe seems to be an important carrier of the swimbladder nematode. A study on its prevalence in other fish species has recently started. Scientific discussions on management options regarding the control of the parasite include suggestions to increase fishing of ruffe and to ongrow juvenile eels to larger sizes before stocking them into natural waters (Rosenthal pers. comm.).

Marenzelleria viridis

The Polychaeta *Marenzelleria viridis* after its introduction probably with ballast water in 1982 is spreading rapidly along the German coast. It was first observed in the Ems estuary (Essink & Kleef 1988, 1993). First records in the Baltic were made in 1985 (Laine 1995) often close to ports, indicating a possible introduction via ballast water (Olenin pers. comm.) Now it is occurring in the various brackish waters of the southern shore of the Baltic Sea (e.g. the Boddens) in great numbers. Its extension to the eastern parts of the Baltic seems to continue and specimens have been found in Finnish waters up to Tvärminne (H. Rumohr, Kiel, pers. comm.).

The occurrence of the American polychaete has initiated a number of studies on ecology, distribution and reproduction of the species in German coastal areas and in coastal waters of neighbouring countries.

Ensis americanus (=E. directus)

This bivalve species is suspected to compete with native molluscs for food and space resulting in suppressing native species. Potential positive effects of this unintentionally introduced species are reported, such as additional food source for native species or even human consumption (Cosel et al. 1982, Essink 1984, 1986, Carlton & Geller 1993).

2.3 Human disease agents

Pfiesteria piscicida

The Phantom algae *Pfiesteria piscicida* has not yet been found in European waters, but was recently introduced into the Chesapeake Bay. It is believed that this species may be transported and subsequently introduced via ballast water or tank sediment (Macdonald per. comm.).

P. piscicida and are dinoflagellates that have been made responsible for recent estuarine fish kills on the U.S. eastern seaboard (see below) and have also been reported to be associated with human illness. These dinoflagellates appear similar under light microscopy and require scanning electron microscopy for definitive identification. *Pfiesteria piscicida* is known in 24 different forms and is able to produce dormant cysts that may remain for years. The dinoflagellate feeds on fish body fluid. The waste from fish swimming above resting stages of the dinoflagellate in the sediments makes the cysts change to a toxic life form. These migrate towards the water surface and anaesthetise the fish with their poison and start to feed on the fish fluids from the body tissue after the have bored in. After the fish died, *Pfisteria piscicida* starts to reproduce and the next generation of cysts return to the bottom waiting for their prey.

Human Health Impacts

Thirteen people who worked with dilute toxic cultures of *Pfiesteria* sustained mild to serious adverse health impacts through water contact or by inhaling toxic aerosols from the cultures. These people generally worked with the toxic cultures for 1-2 hours per day over a 5-6 week period. The effects include a suite of symptoms such as narcosis (a "drugged" effect), confusion, development of acute skin burning (in areas that directly contact water containing toxic cultures of *P. piscicida*, and also on the chest and face), uniform reddening of the eyes, severe headaches, blurred vision, nausea / vomiting, sustained difficulty breathing (asthma-like effects), kidney and liver dysfunction, acute short-term memory loss, and severe cognitive impairment (= serious difficulty in being able to read, remember one's name, dial a telephone number, headaches, skin rash, eye irritation, upper respiratory irritation, muscle cramps, and gastrointestinal complaints (i.e., nausea, vomiting, diarrhoea, and / or abdominal cramps).

Most of the acute symptoms proved reversible over time, provided that the affected people were not allowed near the toxic cultures again. Some of these effects have recurred (relapsed) in people following strenuous exercise, thus far up to six years after exposure to these toxic fish-killing cultures. The first known fish kills in adjacent waters to the Atlantic Ocean caused by *Pfisteria* were documented in 1988 in fish culture sites of North Carolina (USA). Fish kills and fish disease events linked to *Pfiesteria* can extend for 6-8 weeks in North Carolina's estuaries (Pamlico Sound region), thus potentially providing the circumstances for humans in field settings to be hurt due to this dinoflagellate toxins. Since 1991 a billion fish have been killed by Pfisteria in eastern U.S. waters. Most recently un-confirmed findings of Pfiesteria were noted from the Chesapeake Bay region (USA). However, it will not be possible to determine the extent to which people in European estuaries are being affected by *Pfiesteria* toxins, or whether it is safe to consume fish from toxic outbreak areas, until we have a way to diagnose the presence of these toxins. That will require identification of the chemical toxins produced by *Pfiesteria*, which is the subject of intensive research.

Lung disease

In Asia a fatal lung disease caused by the parasite *Paragonimus westermani* (Trematoda) results in cough, peritonitis and pneumothorax (Ichiki et al. 1989) such threatening mammals as rats, dogs, pigs and humans (Davis 1986). The life cycle of this parasite includes two intermediate hosts, the gastropod *Thiara granifera* and the crab Eriocheir spp. The gastropod was introduced to the USA (Florida and Texas)(Abbott 1950), and the crab as second intermediate host as well (occasional findings in the Great Lake area and established in San Francisco Bay) (Nepszy & Leach 1973, Cohenet al. 1995, Cohen & Carlton 1997). If both the introduced intermediate hosts will spread and become common in overlapping areas this would complete the life cycle of the parasite. Therefore, it could happen that the lung disease will introduce to the USA.

Cholera

A Cholera epidemic (disease agent: *Vibrio cholerae*) commenced in Easern Celebes (Indonesia) during 1961 and finally completed its encirclement of the globe in 1991. In South

America the epidemic wave started on the coasts of Peru and was documented later from several ports of Latin America. Therefore, it is believed that the Cholera had been introduced by maritime traffic (Epstein 1993). In November 1991 and June 1992 the USA documented the detection of active Cholera bacteria in ballast water of vessels coming from South America (McCarthy & Khambathy 1994). Therefore Australia introduced a testing programme for cholera in 1992 of all vessels from South America and other ports known for Cholera outbreaks. This programme is continuing. A number of presumptive positive test for cholera were documented. Six vessels that had been taken ballast on board in ports of the Persian Gulf, Singapore and Indochina provided presumptive readings, indicating possible Cholera. On serological testings all were subsequently proven to be negative. Since that time studies are being carried out in order to evaluate the risk of Cholera introductions to Australia via ballast water.

The introduction in coastal waters of Latin America caused a serious threat to thousands of peoples health after consumption of seafood as bivalves (oysters), crustacean and finfish caught in affected areas (Murphree & Tamplin 1992).

3 Treatment options

It has so far been concluded that no single or simple solution exists for shipboard treatment of ballast water. However, a combination of techniques might at least be partially effective and feasible in terms of economic and shipboard constraints. These would most likely comprise of some form of mechanical removal of organisms followed by a physical or chemical treatment method.

Ballast water management procedures have been investigated to a certain extent but insufficient research has been carried out to assess the effectiveness of applicable ballast water treatment techniques.

Shipboard treatment of ballast water is considered preferable to land based reception / treatment facilities. Particular emphasis has therefore been placed on potential options for shipboard treatment.

A quarantine system does not provide an absolute barrier to prevent the introduction of unwanted non-indigenous species (Carlton et al 1995). It is also assumed that no single treatment process was likely to achieve the required inactivation or removal of unwanted organisms. A two stage approach seems to be most likely. After an initial mechanical treatment process followed by disinfection, a physical treatment process or a technique involving manipulation of the environmental conditions within the ballast tank could provide a solution. Thus when considering the options reviewed, it should be assumed that the mechanical options are largely viewed as preliminary treatment method.

At this stage various methods of treatment that have been put forward and are described as a "tool box" from which the most practical (easy and safe to apply, not damaging existing ship installations as ballast tank coating, isolators and sealing rings), cost effective safe and environmentally sound combination should be selected. To date, international guidelines have been adopted as the IMO Assembly Resolution A.868(20).

Several of the listed options are straightforward statements of good practice but in many circumstances the choices available to an operator will be very restricted. There are indeed two different possibilities of using the ballast water treatment options listed below. First of all, the ballast water is treated en-route. Secondly, a treatment of ballast water may take place at the port of destination. In this way only the countries concerned need to invest, ports can maintain the treatment equipment and the operation would meet port quarantine and local environmental protection laws. But, the IMO does not promote regional (different) systems, emphasising that the ballast water problem is a global issue. Using different provisions and options could result in unwanted regional restrictive practices, restraints of trade and competitive advantages.

The following list gives an overview on the amount of ballast water introduced into the waters of several countries. Estimated by scientists and technicians the amount of annually transported ballast water has been summarises world-wide to 10 billion tonnes (Gerlach 1992, Bettelhäuser & Ullrich 1993, Rigby & Taylor 1995).

No country seems to keep records or statistical data on the release of ballast water in their waters. The volume of the water of overseas origin released in territorial waters of a country would be only an indicator of the potential for further species introductions. The degree of risk depends also on the characteristics of the port of origin and port of arrival. In addition, several shipping studies showed, that one single vessel is able to introduce an unwanted species by discharging its ballast water.

The quantitative data on ballast water discharges have to be gathered from individual ports respectively through port authorities or the shipping industry. Therefore the mentioned data are estimated amounts of ballast water discharged. The reason for mentioning these data here is to demonstrate which amounts of ballast water could have to be treated in order to minimize the risk of introduced species.

Europe

Ballast water discharges per year in English and Welsh ports amount to 16.8 million tonnes (Laing 1995) and in Scottish ports to 25.7 million tonnes (Macdonald 1994). About 10 - 15 % of the discharged ballast water originated from outside Europe. In Ireland less than 2 million were discharged, most of it from Europe (Minchin & Sheehan 1996). The estimations of the amount of ballast water in German ports and waterways varied from 8 to 38 million tonnes. The non-European origin was estimated to range from 1.4 to 7 million tonnes (Golchert, pers. comm., Gollasch 1996). Data from Norway are available from one port only: 8 - 10 million tonnes, 15 % of non-European origin (Swedish Environmental Protection Agency 1997)

North America

In all 226 US ports (including Great Lakes) in total 79 million tonnes of ballast water were dumped from vessels from abroad. (Carlton 1995, Carlton et al. 1995).

Gauthier and Steel (1995) estimated that 62 million tonnes of ballast water were discharged.

South Africa

Information on ballast water discharges were collected from several ports around the South African coastline. The estimation summarised relevant data to more than 12 million tonnes (based on data from 1991 / 1992). Data from some ports are missing until today. It is likely that one of these, e.g. Port Elisabeth, does receive about 20 million tonnes of ballast water each year. Roughly a third of these ballast waters are from Far East. Remarkable is that a relatively high percentage of the water was exchanged en route. It is assumed that this is the result of controls introduced in many ports of the world (Jackson in prep.).

Australia

Vessels calling for Australian ports are discharging approx. 121 million tonnes of ballast water each year (Jones 1991, Mills 1992, O´Reilly 1992, Paterson 1992, Kerr 1994, MEPC35/INF.19). In addition over 4,000 vessels per year move more than 34 million tonnes of ballast water between Australian ports.

New Zealand

The total amount of discharged ballast water, mostly of Asian origin, was estimated as 4.5 to 4.7 million tonnes each year (Hayden 1995).

IMO Recommendations

A set of recommended actions have been adopted by IMO in relation to the uptake of ballast water. The taking in of ballast water in shallow habitats, during prevailing turbidity of water, nearby sewage outfalls, when a tidal stream is known to be more turbid, in areas where tidal flushing is known to be poor, during phytoplankton blooms or relevant disease outbreaks and near dredging sites have to be avoided to minimize the risk of up taking species. In addition ballast water should be wherever possible not be taken in darkness (when bottom dwelling organisms may rise up in the water column) and in very shallow waters or when propellers may stir up sediments.

Ballast water uptakes in port areas characterised by slow tidal currents could result in the uptake of ballast water formerly used by another vessel and just released. This scenario could enable some organisms discharged in the ballast water from one vessel to become transported again pumped in with the ballast water of another vessel.

It has been proposed that ballast water may be analysed in a laboratory on board and that the investigation may provide a certificate of cleanness of the ballast water documenting the absence of harmful aquatic organisms. However, this may not be an effective method of risk minimization due to e.g. taxonomically problems regarding the identification of the organism and pathogens.

Another option deals with the fact that populations of species decrease with their increasing stay in the ballast tanks. The absence of light provides an uncomfortable environment for some species. Water that has been located in a ballast tank longer than 100 days provides a small risk discharging unwanted species. Research showed that even after 116 days living macrobenthos organisms were found (Gollasch 1996). In addition, some species, as phytoplankton organisms may form cysts during unfavourable conditions surviving in the sediment of ballast tanks for a long period. Some zooplankton species may form resting stages as well. These cysts may remain active over longer periods of up to several years. In this way e.g. cysts of dinoflagellates may be transported over long distances. After sediment discharges the cysts may hatch in foreign waters. If these dinoflagellates are toxic they may cause harm to local aquaculture. It is assumed that many phytoplankton blooms may be initiated by these discharges (Hallegraeff et al. 1986, Bolch & Hallegraeff 1993, 1994).

3.1 Mechanical removal of species in ballast water

3.1.1 Filtration

Filtration of ballast water seems to be the most environmentally sound method, but the amounts of ballast water that has to be treated are immense. Ultra-filtration methods have not yet been tested or proven with large volumes of ballast water and high loads of sediments, which can occur in ballast water even if ballast water uptake in water with high sediment loads should be avoided (Sipes et al. (eds.) 1996, IMO Assembly Resolution A.868 (20)).

The efficacy of removing particles larger than the meshsize of these filter units is with 95 - 98 % very effective. In addition some percentage of the smaller particles may be removed. Another advantage of this method is the use during ballast water intake. Therefore the backwashing (filter cleaning) water may be returned immediately to the port water from which the ballast water was taken without any treatment. The use of vacuum filtration to treat ballast water was listed by AQIS (1993).

3.1.1.1 Self cleaning filter system ("The ALGONORTH experiment")

Located in the Great Lakes a joint U.S. / Canada project will test one potential technique to control the spread of unwanted organisms. An US$ 1.3 million filtering unit, testing laboratory and peripheral equipment were installed on the Canadian Algoma Central Marine`s bulk carrier ALGONORTH in 1996. The filter unit is containersized and located on deck. This first-of-its-kind-experiment will get underway to measure the effectiveness of filtration as a means to control the spread of unwanted organisms with ballast water. Filtration was identified by the U.S. National Research Council’s Marine Board as one of the most promising technologies for ballast water treatment, offering several advantages:

- enhancement of the number of secondary treatment options such as ultraviolet light, chemicals and heat;
- it represents a preventive measure and as such is carried out when at the port ballast is taken on board. The waste of the self cleaning filter unit can be backwashed to the port before the vessel departs; and
- it addresses safety concerns associated with the ballast water exchange at open seas since the system would be operated at a port and not in high seas.

In the beginning of the project the filtration unit will treat the ballast water of one wing tank with a capacity of 225 tonnes may be accessed through manholes on the deck. The multi-level filter technique designed by Ontario Hydro is operated by a diesel-powered pump with a 6 tonnes per minute capacity.

The project involves both, biological and mechanical testing protocols. Biological tests will be carried out with samples for the identification of zooplankton, phytoplankton, bacteria and for water chemistry. The mechanical protocols will take into account the filters efficiency over time and frequency of backwash required. Both kinds of test will be carried out in fresh water an the marine environment in each of the seasons of the year during which the vessel operates using up to 5 different filtration levels (Changeless 1997).

3.1.1.2 "Microfiltration"

Ballast water systems generally incorporate coarse and fine screens with openings in the region of 80 µm and 10 µm, respectively. Particles down to the size of seaweeds and large zooplankton species could be removed by reducing the opening size further or incorporating additional smaller mesh sizes. However, removal of smaller organisms would be poor. Fine mesh screens are used extensively in the offshore oil industry and are capable of handling 5,000 m³ per hour. With mesh sizes of 500 µm and 50 µm filter surfaces require spaces of approximately 3 and 4 m². An automatic back-washing facility, utilising a sensor for monitoring pressure differential, may be incorporated (AQIS 1993).

A related system of 'microfiltration' installed downline of the ballast pumps has also been proposed as an option for reducing marine organisms (Carlton et al. 1995). This would consist of two or more 'coarse' filters (300 mm mesh) followed by two or more 'fine' filters (25 mm mesh). Woven mesh filters, made from synthetic fibres, are available as automatically self-cleaning units. They could potentially be retro-fitted to existing ships or incorporated into the design of new vessels. Automatic cleaning of the filters could be programmed either for specific time intervals or at specific pressure differences across the filters. This would involve stainless steel brush and suction scanner filter mechanisms for 'coarse' and 'fine' filters, respectively. Disposal of the collected residues would occur at the location of ballasting rather than at the destination port, thereby avoiding the transfer of non-native species. It is claimed that the 'coarse' filters would remove most of the larger zooplankton whilst the second in-line 'fine' filters would remove most of the smaller zooplankton and much of the large and medium sized phytoplankton. Filter capacities of 1,000 m³ per hour are possible at both the 300 mm and 25 mm filter mesh size. As most pump capacities are below this figure filtration would not slow the ballasting or de-ballasting operations. However, resizing of the pumps may be required to cope with the increased filter resistance. Alternatively, with no modification, a reduction in pump capacity and concomitant increase in ballasting time would result.

3.1.1.3 Granular filtration

The ballast water could pass a granular filtration unit before the microfiltration. Granular filtration will remove larger particles. It is supposed that a land-based unit equipped with sand

and anthracite media could be effective. In cases of clogging a backwashing procedure can be applied to remove the clogging material (AQIS 1993).

3.1.2 Separation unit ("The Norway-Model")

Cyclonic separation has been proposed as a relatively simple and inexpensive way of removing larger particles and organisms from ballast water.

Liquids / particulates enter a separation unit tangentially, thus setting up a circular flow. The liquids / particulates are then drawn through tangential slots and accelerated into the separation chamber. Centrifugal action tosses particles heavier than the liquid to the perimeter of the separation chamber. The solids gently drop along the perimeter and end up in the calm collection chamber of the separator. The liquid freed from or reduced in particulates is drawn to the vortex and up through the outlet of the separator. Solids may be periodically purged or continuously bled from the separator. A flow rate of up to about 2,900 m³ per hour may be achieved by a unit weighing 3,000 kg. The resistance of this separator is not thought to be significant, so that the pumps already present on the ships should be sufficient.

It seems feasible that this system could be used on board ship by incorporating the separator in a ballast tank recirculation system. The separated particulates would have to be collected or drained overboard in open ocean waters. Since the flow rate achievable by the larger separator is comparable to that of ballasting pumps on ships, it may also be possible to use cyclonic separation during ballasting / deballasting.

Cyclonic separation of organisms with a specific gravity similar to that of sea water as sea water (as jellyfish, chaetognaths) is limited (Armstrong 1997).

Norway has put forward a solution model based on the technique previously used in offshore oil production. Over a period of 20 years of time it was found that injections of large volumes of water into offshore wells to enhance the production increased the growth of bacteria.

The method consist of a low-pressure / high capacity centrifugal device to remove suspended solids, followed by a UV (ultra violet) -light unit. Although the UV dose delivered is sufficient to produce sterile water but should not be considered as providing a complete sterilisation. Firstly neither the tanks nor tubes would be sterile in a new-built ship, and secondly it practically would be impossible to ensure that no contaminated water enters the tubes and tanks after treatment.

Using this method a high proportion of the multicelled animals and plants, as well as eggs, larvae and seeds (possibly including the resting spores of harmful algae, which tends to follow the sediment) were destroyed, harmful e.g. pathogenic bacteria in the bulk of the water would be killed. In addition, a large fraction of the sediment usually deposited in the ballast water tanks could be removed.

There are several options for the application of this method, each with their own advantages and disadvantages.

Treatment at ballasting port. This means that one can potentially reduce the problem of sediment deposition in the ballast tanks substantially. By removing the sediment and removing a large fraction on the carbon („bacterial food„), from the tanks, the anoxic corrosion in ballast tanks may be reduced or even eliminated. A small risk for regrowth of harmful bacteria exists. Studies should be carried out to quantify this risk.

Treatment on board. Essentially the same effects could be accomplished as above. The installation and operational costs and eventual space problems would determine as to whether this could be an attractive solution.

Treatment at deballasting port. The positive effect with respect to sediment removal would be lost. However, as the effluent water would be effectively sterilized, this option would probably be the safest from a biological point of view.

The optimal solution would be to treat ballast water at BOTH ballasting and deballasting ports (Jelmert pers. comm.).

3.1.3 Flow-through system

A continuous flow through system that is a continuous sea-to-sea circulation of ballast water while the ballast tanks remain filled, would enable a permanent ballast water exchange at sea via continuos pumping. This flushing method would turn over the complete ballast water, but requires a especially designed piping system. The water flow could be realised by using the present ballast water pumps or using the vessels`s momentum to create a flow through system from the bow to the stern.

In contrast to ballast water exchange at high seas at bad weather the continuous flow through system does not impose excessive bending moments or shearing forces and minimizes stability problems.

Rigby & Hallegraeff (1993, 1994) demonstrated that by emptying certain ballast tanks on the bulk carrier IRON WHYALLA the still water bending moment may be much higher than the maximum allowable value. This fact, in combination with the high number of specimens in the remaining water bodies in the ballast tank after emptying (see below) made the flow through option favourable.

Methylene blue dye dispersed in the ballast water was used in order to examine the necessary time for a complete exchange of the ballast water by an ongoing sea water flow through the ballast tanks. After an exchange of 3 times the volume of the ballast water tank only 5 % of the previously containing ballast water was present. After exchange of 4 times the volume of the ballast tank 98.2 % of the previously taken ballast water was exchanged. Accordingly IMO in 1993 when adopting ballast water guidelines recommended an exchange of ballast water in open seas of at least three times of the volume of the ballast tanks wherever possible.
Armstrong (1997) calculated for the 190,000 DWT bulk carrier ORMOND that the complete ballast water exchange (ballast water capacity max. 81.379 m³ including a cargo hold) with the ballast pump on board (pump capacity of 2.500 m³ per hour) of all ballast tanks and possibly filled cargo holds would take 4.07 days. A container vessel as the JERVIS BAY with a capacity of 4,000 TEU and a length of 292.2 m with a maximum ballast water capacity of 16.613 m³ it will take 4.15 days for a complete exchange (pump capacity 500m³ per hour). Cruise ships usually carry comparably little amounts of ballast water. The GRAND PRINCESS (242m LBP) has a ballast water capacity of 4.345 m³. A complete exchange would take 2.17 days using the pump with a capacity of 250 m³ per hour (Rigby et al. 1993, Paterson 1996, Armstrong 1997).

This method may have limited application possibilities for existing vessels. The current design of pipes and tanks in some cases are limiting such operations.

3.1.4 Brazilian Dilution Method

Developed by Petroleo Brasiliero (PETROBRAS) the dilution method is a further development of the continuous flow through system. As decribed in 3.1.3 (see above) the continuous flow through method can only be applied for completely filled ballast tanks. The dilution method enables a continuous flow through even in incompletely filled ballast tanks.

After the installation of an additional pipework on board of the vessel a continous ballasting via one pipe system and at the same time a continuous deballasting by the second pipe system may be carried out. In this way the method solves the problem of the continuous flow through method but teh installation of additional pipework is needed.

Mathematical modelling of the effectiveness of this method was carried out resulting in a comparable effectiveness as the ballast tank flushing for three times the ballast tank volume. Trials on board of a vessel will be carried out in Summer 1998. The results of these trials will be presented at the IMO MEPC 42nd session late 1998.

The method was presented during the IMO MEPC 40th and 41st session submitted by Brazil (C. Goncalves Land pers. comm.).

3.1.5 Sedimentation and flotation

Other mechanical treatment processes such as sedimentation and flotation have also been discussed in terms of their application to ballast water treatment. The former essentially entails the settling of material from the water column under gravitational forces, with or without the use of coagulant chemicals to assist sedimentation. The latter also entails the use of coagulants and the injection of fine air bubbles into a ‘flotation tank’. The bubbles attach themselves to coagulated organisms or particulates and float them to the surface.

Although some consideration has been given to a design of ship that would allow ballast tanks to be used as sedimentation tanks, it is unlikely that either of these techniques would be suitable for shipboard application. They could, however, form a useful component in a land based treatment system (Müller 1995, Müller & Reynolds 1995, AQIS 1993).

3.1.6 Pump velocity

The increase of the water flow rate has been proposed to mechanically destroy organisms (Carlton et al. 1995). The use of a high velocity ballast water pump during ballast water intake and discharge could minimize the survival rate of macro-organisms due to their mechanical damage (Woodward 1990).

The installation of additional units in order to create high velocity jets of water in ballast tanks or pipework would involve high costs. Data on the efficacy of this method are not available (Carlton et al. 1995).

3.1.7 Ballast water exchange in open ocean IMO Assembly Resolution Guidelines

3.1.7.1 IMO Assembly Resolution Guidelines

The International Maritime Organization's (IMO) Marine Environment Protection Committee (MEPC) had a specific interest in the field of unwanted introduced species by ballast water as demonstrated in 1973 when the International Conference on Marine Pollution adopted resolution 18, drawing attention to the transport of aquatic organisms and pathogens around the world in ships ballast tanks.

Australia was the first country to bring the ballast water problem into focus and has played a key part in proposing the development the control mechanisms for the introduction of the ballast water in the early 1990s.In 1990 (MEPC29/WP.8) Australia, Canada, Denmark, Federal Republic of Germany, Japan, Norway, USA and ICS submitted a paper based on their discussion to consider in greater depth the problems raised by Australia in its paper from on the need for controls to be introduced on the discharge of ballast water from overseas vessels entering Australian ports. It was mentioned that via the potential threat to human health and the aquaculture business through the introduction on non-indigenous species enormous costs could be involved. The Australian shellfish industry is a US $ 264.6 to 376.5 million business per year (MEPC29/21/2, MEPC29/WP.8, MEPC35/INF.19). In late 1990, the Marine Environment Protection Committee (MEPC) of IMO formed a working group to consider research information and solutions proposed by Member States of the IMO and by non-governmental organizations. The working group concluded that voluntary guidelines were the appropriate first step in addressing this problem. The 27 November 1990 working group reviewed and modified the Canadian delegation's draft resolution and guidelines. MEPC adopted guidelines by resolution in 1991 and in 1993 these were adopted by the IMO Assembly under resolution A.774 (18) entitled "International Guidelines for Preventing the Introduction of Unwanted Aquatic Organisms and Pathogens from Ships Ballast Water and Sediment Discharges". In 1997 the IMO Assembly adopted Resolution A.868 (20) "Guidelines for the Control and Management of Ship's Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens". This IMO Assembly Resolution is extremely important towards the development of provisions in addressing this international, world-wide problem. IMO has put forward these guidelines to limit the movement of organisms by ballast water world-wide which include the informing of ships on areas where ballast water uptake should be avoided due to the presence of harmful algal blooms and known unwanted contaminants, precautionary procedures when taken on ballast water in shallow areas, ballasting with freshwater, discharging ballast water and sediments to on-shore facilities (if available) and the exchanging ballast water at sea.

The IMO Assembly Resolution A.868 (20) recommends an exchange of ballast water in open oceans as far as possible from the shore. The mid-ocean exchange of ballast water is believed to be currently the most reliable method in order to minimize the risk of transfer of unwanted organisms. Compared with coastal waters, deep ocean waters contain less organisms and species occurring in open ocean waters very often are not able to survive in coastal zones and vice versa. Where open - ocean - exchange is not possible, requirements developed within regional agreements may be applicable, particularly in areas within 200 nautical miles from shore. If safety permits all of the ballast water should be released until suction is lost. Stripping pumps or eductors should be used if possible. Where the flow- through method is employed (see below) in open ocean by pumping ballast water into the tank or hold and allowing the water to overflow, at least three times the tank volume should be pumped through the tank. This method is non-polluting the environment at discharging and comparable in-expensive.

In 1995 the MEPC Ballast Water Working Group produced a first draft of a set of legally binding regulations which could form a new Annex to MARPOL 73/78 together with implementation guidelines and a ship ballast water management plan to be incorporated into each ship´s safety manual. The working group scheduled to present the final draft of the guidelines to the committee in 1997. The final draft is scheduled for 1998.

3.1.7.2 Effectiveness of the ballast water exchange

A Canadian survey carried out 1990 by Locke et al. (1991) studied the ballast water transported by foreign vessels into the Laurentian Great Lakes and upper St.-Lawrence River in order to monitor the compliance with the Great Lakes Ballast Water Control Guidelines and their effectiveness. The effectiveness of mid-ocean ballast water exchange eliminating living freshwater zooplankton specimens from ships originating in freshwater ports was 67 %. It was noted that live freshwater organisms may still survive a mid-ocean exchange of the ballast water in their dormant stages. Therefore, each vessel which has ever taken on ballast in a freshwater port may pose a risk to the North American Great Lakes, even after a ballast water exchange in marine waters. In addition it was estimated that nearly half of the vessels entering the Great Lakes carried ballast water in previously emptied ballast tanks (remaining water bodies below the level of the ballast pump intakes in the ballast tanks). This "unpumpable" ballast water represents a reservoir of specimens at the tank bottom. These specimens could be discharged after re-filling of the ballast tank followed by ballast water discharges (Locke et al. 1991).

In an Australian study on board of the bulk carrier IRON WHYALLA 95 % of ballast water was discharged at open ocean. In the remaining 5 % of the original ballast water approx. 25 % of the specimens of the previously filled ballast water were found (Rigby & Hallegraeff 1993). The proportion of original plankton and detritus remaining after exchange of ballast water flushing the ballast tanks of two tank volumes while underway was lower. The proportion of living organisms surviving ocean exchange would be significantly less than 10 to 20 %, depending of the species composition (especially the possibility to generate resting stages as cysts) and the change of temperature as well as salinity (MEPC35/INF.19).
A problem in using open – ocean - exchange is the sediment in the ballast tank. Exchanging ballast water at sea does not affect the sediments at the bottom of the ballast tanks. Hallegraeff & Bolch (1992) investigated 32 vessels which had carried out an ballast water exchange. 15 vessels still contained significant amounts of sediment. A method needs to be developed to re-suspend the sediments into the ballast water above. They concluded that the mid-ocean exchange was not always an effective method of control for ballast water and sediment on its own. In addition a complete ballast water exchange at sea is unsafe in case of bad weather. A sequential operation of continuous flushing of tanks with ocean water would be a workable option (Rigby & Hallegraeff 1993). The guidelines of the IMO recognized in addition that many aquatic organisms are present in sediments and that all sources of sediment (as e.g. ballast tanks, anchor chains, chain lockers) should be cleaned routinely.

As long as safety permits, open – ocean – exchange should be used as a first step in order to minimize the number of species and specimens unintentionally introduced with ballast water. Every eventuality must be taken into account when deciding as to whether it would be safe to exchange ballast at sea. It is agreed that flushing the ballast tanks three times during voyages

in open oceans could extend the efficiency of this method (Rigby & Hallegraeff 1993, 1994, MEPC31/14/1).
The advantage of this method is that it involves no major investment and is thus comparably in-expensive. In addition this method may be carried out in transit without disrupting the vessels schedule.

The IMO guideline in addition lists that a responsible officer should be appointed to maintain appropriate records and to ensure that ballast water management and / or treatment procedures are followed and recorded. It also advises to document during taking on or discharging ballast water dates, geographical locations, ship's tank(s) and cargo holds, ballast water temperature and salinity as well as the amount of ballast water loaded or discharged should be recorded. A suitable form is shown in the annex 1 of the guidelines.

3.1.7.3 Safety aspects

A study of the "Ship Operational and Safety Aspects of the Ballast Water Exchange at Sea" was carried out by Woodward et al (1992) who concluded that ballast / deballast operations may be carried out safely if wave heights were below a maximum value. Using hydrostatic data furnished by the ship owners hull bending moments and stabilities are investigated to find the tank-emptying operations representing the maximum safety. At-sea analysis for hull bending moment, shear and rate of slamming was carried out using both linear and non-linear analysis. From the used small sample of three ships (a dry bulk carrier, a tanker and a container ship) it appears that the critical wave height lies between 10 and 20 feet. The sample is to small to support a more definite conclusion on the maximum safe height.

In addition the IMO sub-committee on Ship Design and Equipment prepared a guidance on safety aspects of ballast water exchange considering structural integrity, stability of ships and crew safety and in particular stated (e.g.) to avoid over and under pressurisation of ballast tanks, free surface effects on stability and sloshing loads in tanks that may be slack, admissible weather conditions, maintenance of adequate intact stability in accordance with an approved trim and stability booklet, permissible sea-going strength limits of shear forces and bending moments in accordance with an approved loading manual, torsional forces, minimum / maximum forward and aft draughts, wave induced hull vibration. It was mentioned that the ballast water management plan should include designated control personnel responsible of the ballast water exchange and crew training to familiarisation. Furthermore it was noted that a need exists to evaluate the safety of long term aspects taking into account relevant safety matters, including safety of crews and ships, ship´s position, weather condition, ballast system inspection and maintenance, machinery performance and availability (MEPC39/WP.8, MEPC39/7, MEPC39/7/1, MEPC39/7/4).

3.2 Physical removal of species in ballast water

3.2.1 Heat treatment

Temperatures below 60°C will inactivate organisms often present in ballast water. It has been proposed as an appropriate target temperature to kill most toxic marine organisms (AQIS 1993). For example, exposure to temperatures of 36 to 38°C over a period of 2 to 6 hours were sufficient to kill zebra mussels in pipes.

Heat treatment using excess engine heat or the exhaust from the engine cooling unit is supposed to be the most promising treatment option but would be unfeasible for ships with several 10,000 tonnes of ballast water. The minimum temperature needed is over 40 °C to kill the target species. The temperatures and dwell times sufficient for eradicating the marine lifeforms in the ballast water have been obtained from scientific studies. In a laboratory study Bolch and Hallegraeff (1993) demonstrated that short-term (30 to 90 seconds) exposure to temperatures above 40°C were effective in killing dinoflagellate cysts of Gymnodinium catenatum and Alexandrium tamarense. They subsequently confirmed their findings in an experiment on board ship, which was retro-fitted to enable heat exchange between the ballast water and the main engine cooling circuit. At a flow rate of 500 m^3 per hour the ballast water was heated to above 40°C for about 8 minutes within the heat exchange unit. Subsequent sampling revealed that this exposure had been lethal to all organisms.

Initial suggested temperatures of 40 - 45 °C for 30 seconds would be sufficient. Recent data show that 35 - 38 °C exposed for a period of 4 - 5 hours effectively kills cysts and vegetative cells of toxic and non-toxic dinoflagellates (Bolch 1997).

Ballast water containing very resistant algal cysts can only be treated effectively with higher temperature as 50 °C and more. These temperatures have to last over a period of several hours up to days (Bolch & Hallegraeff 1993). An 8 minute exposure of water heated to 40 °C was lethal to many organisms.

Effective temperature to kill organisms in ballast water are listed as 50 °C ("instant" death), 45 °C for 30 sec, 43 °C for 60 sec or 40 °C for 90 sec (Bolch & Hallegraeff 1994).

The temperature of ballast water may be raised by:

(1) connecting the ballast water with the engine cooling circuit

(2) heating by a repeated passage of the ballast water through the cooling system; and

(3) generating additional heat

All of these possibilities would generally require the retro-fitting of pipework. The first option would require pipework to re-route the ballast water to the engine room, so that the ballast water becomes part of the main engine cooling water system. This concept may not be viable due to the size and hence heat producing capacity of particular main engines. A 'once-through' passage of ballast water through the cooling system may not sufficiently elevate the temperature of the water, or maintain it. Utilisation of other sources of heat to be installed on board ships would also require installation of heated pipelines on most ships.

There are numerous difficulties that are likely to be encountered with the thermal treatment of ballast water. In particular, thermal stresses to the vessel would have to be considered. Little information exists with regard to the thermodynamic heat transfer of large volumes of water on board of vessels not primarily designed for the carriage of hot liquids. Conversely, heat loss may be rapid as ballast tank walls are of situated near the hull of the vessel. Many ballast tanks are, by virtue of design, irregularly shaped, and this would create problems when trying to establish an homogenous temperature throughout the body of water to be treated. Furthermore, such treatment would unlikely be suitable in those situations where cargo tanks are used for ballasting a vessel. Dependent on the temperature involved thermal treatment may have adverse effects on pipework, pumps or coatings.

Generally, it has to be ensured that the heating up process does not take longer than the actual voyage. For existing vessels economic considerations are likely to be the overriding factor against thermal treatment because of the high costs of retro-fitting pipes. Energy requirements of 45 MW on top of the 20 MW of waste heat from the ship's main engines have been quoted for a ship carrying 45,000 tonnes of ballast water (Bolch & Hallegraeff 1993). It has also been pointed out that more power would be required to reach the desired temperatures in the ballast water in colder waters such as the North Sea. Rather than heating all the ballast water

simultaneously, it has been suggested to apply the heat sequentially to individual ballast tanks, or to pump the ballast water during ballasting or deballasting through an on-deck heat exchanger and a smaller well-insulated tank. It has been estimated that this system could reduce the consumption of heat energy for this purpose by 5 - 10 %. Research into the feasibility of thermal treatment is being continued in Australia.
On health and safety grounds thermal treatment is likely to be acceptable, although the subsequent discharge of heated water to some open waters may be undesirable on environmental grounds.

Two different systems, a shore based portable and one on board system, could be used. A seagoing trial of ballast water treatment with heated clean water had been conducted successfully on a small bulk carrier in Australia. The temperature of the untreated ballast water was 15 °C. After pre-heating the temperature reached 32 °C leaving the heating unit. Afterwards the incoming water passes the main engine heat exchanger. The water temperature leaving this unit is heated to 50 °C and is collected in an hold tank on board where it is held at that temperature for treatment. The water retains its heat until returning to the pre-heater, where it loses approx. 50 % of its temperature by pre-heating the ballast water pumped aside for treatment.

The shore-based system is designed of several heat exchangers, a holding tank and a heat source. It could have a treatment capacity of 1,000 tonnes per hour of ballast water, raising the temperature to 50 °C and cooling it down to within 2 °C of the starting temperature. Additional heat exchangers could attain up to 80 °C (Bolch & Hallegraeff 1993).

It has since been suggested that it may even be sufficient to kill organisms simply by raising the temperature of the ballast water by between 2° and 5°C above its original temperature (Matsuoka et al. 1989, Anderson 1993) at least with dinoflagellate cysts.

The following disadvantages of the heat treatment have to be considered:
1) Increasing temperatures of ballast water in single ballast tanks could bring up structural stresses to ships due to expanding metal. In addition damages to the tank coating could occur (Yount 1990, Armstrong 1997).

2) It is likely, that higher temperatures would be required to deal with thermophilic (heat loving) organisms or more resistant forms such as bacterial spores. It has to be taken into account that temperature between 30 and 40 °C would support the growth of bacteria as e.g. *Vibrio cholerae* (!).

3.2.2 Cooling treatment

In order to retard (bacterial) biofouling of reverse osmosis membranes of industrial water systems beside biocides (see below) the possible use of freezing was mentioned in order to remove the bacterial biofilm (Mittelman 1991). The application of ethylene glycol at - 12 °C destabilises the biofilm matrix and detaches it. Practical experiments were not reported (Costerton 1983, Flemming 1991). A reduction of the temperature of the ballast water to the freezing point requires e.g. a cooling unit, additional pipework, and power. Further studies to evaluate the feasibility should take into account the temperature related impact on the pipework and ballast tank as well as trials on the treatment effectiveness on ballast water organisms.

3.2.3 Ultraviolet radiation

Ultraviolet (UV) radiation is commonly used for sterilising potable or waste water and for the purification in aquaculture and fisheries. UV radiation operates by causing photochemical reactions of biological components such as nucleic acid (DNA and RNA) and proteins. The lower UV wavelengths are generally more effective. However, radiation at these wavelengths shows a lower transmission in water. Due to a higher concentration of inorganic solutes, the transmission in seawater is slightly less than in freshwater. It may further be affected by organic solutes, particulates or bubbles. For practical reasons, UV radiation is commonly divided into three wavelength ranges: UV-A (400-320 nm), UV-B (320-280 nm) and UV-C (280-200 nm).

The effectiveness of UV treatment depends largely upon the size and morphology of organisms. Those with a smaller surface / volume ratio tend to be less susceptible to the radiation. In relation to the shape of the bacteria capsules, bacteria with more resistant capsules that can be stained (Gram positive strains as e.g. streptococci) are more resistant to UV than Gram negative strains (e.g. coliform bacteriae, salmonellae). Viruses require similar dosages to bacteria. Algae require larger dosages than bacteria due to their size and their pigmentation. Blue green algae have shown to be particularly resistant to UV radiation and radiation values of 2 to 3 orders of magnitude greater than that used to kill bacteria have been quoted (Meulemans 1987). It has been postulated that this was due to the fact that they evolved during a geological time when the Earth had only little protection against UV radiation. Preliminary data with different stages of the zebra mussel *Dreissena polymorpha* suggest that a low pressure lamp is only partially effective in inducing mortality. In contrast, a medium pressure lamp caused 100 % kill of all stages except the adults where mortality was reduced, presumably due to their opaque shells.

A bactericidal curve shows that the mortality is most effective in the UV-B and UV-C range with a peak at a wavelength of around 265 nm. Until recently, low pressure mercury lamps have predominantly been used, which emit radiation at 253.7 nm, i.e. close to that peak. However, they are now increasingly replaced by broad spectrum medium pressure mercury lamps, which cover a wavelength range of about 200 to 400 nm, claiming to combine high biological effectiveness with good water transmittance.

The biological effectiveness of UV treatment is not necessarily a simple function of irradiance and exposure time. Experiments with a phytoplankton species showed that a short exposure at high irradiance was found to be more effective than long exposure at low irradiance (Cullen & Lesser 1991). Montani et al. (1995) have shown that the germination of cysts of *Alexandrium*, *Gymnodinium*, *Protoperidinium*, *Scrippsiella* and *Gyrodinium* occurred after exposure to UV radiation. It has been suggested that some organisms have a repair mechanisms which may enable them to recover from the UV treatment provided their exposure does not exceed a certain time. Similar observations were made with bacteria and other phytoplankton species, demonstrating the importance of specifying exposure time as well as irradiance level.

Volumetric flows greater than those necessary for most ballast water systems are treated with UV radiation in municipal treatment plants as a postchlorination treatment (Carlton et al. 1995). It has been reported that a UV plant to treat 4,000 m^3 per hour would require an area of 10 x 5 meters and consequently space may be a limiting factor on existing ships (AQIS 1993). In-line flow treatment would appear feasible and the most practical option for retro-fitting a UV treatment system on ships. Treatment could take place at the time of ballasting or de-ballasting. However, greater effectiveness is likely to be achieved if the water was treated on de-ballasting to avoid any recontamination of the water after it entered the ballast tanks.

This method is likely to be practicable and environmentally sound (no toxic side effects) and no adverse effects in pipework pumps, sealing rings or coating are known (Müller 1995, Müller & Reynolds 1995).

No specific health, safety or environmental concerns appeared to be associated with the use of UV systems on board ship, however, the possibility exists that UV radiation might cause mutation of genetic material in the organisms treated. Capital and running costs for suitable systems were likely to be significant, suggesting that regulatory pressure or financial incentive would be required before UV treatment of ballast water on board ship would be considered seriously (Müller 1995, Müller & Reynolds 1995).

Disadvantaging is the effect that some smaller organisms could pass the UV unit in the shadow of larger organisms without any treatment (Armstrong 1997) and the reduced penetration of UV-radiation in turbid waters (Rigby et al. 1993).

As part of its contribution to the discussion at IMO on the transfer of unwanted organisms in ballast water, the UK Marine Safety Agency initiated a study to undertake a programme of research aimed at evaluating disinfection options for ballast water. This provided information whether the Cu / Ag electrode system (see below) and UV method were, in principle, effective for ballast water disinfection. Dosing requirements were also evaluated under relatively defined and reproducible conditions. Laboratory based experiments aimed to simulate shipboard applications as far as was possible.

UV radiation appeared to significantly reduce the viability of the bacterial, phytoplankton and zooplankton species tested. However, there was some evidence for recovery of the phytoplankton following exposure to UV radiation. Effects on dinoflagellate cysts and diatom resting stages were unclear on account of the experimental design and the analytical process for determining the viability of test organisms which did not allow the unambiguous interpretation of results.

Analysis of the feasibility of employing UV treatment on board ship suggests that few problems would be encountered in installing suitable systems on board new ships. However, retrofitting systems on existing ships would be problematic and the feasibility would need to be examined on a case by case basis. On the basis of the experimental results, UV appeared promising for the treatment of ballast water.

3.2.4 Gamma radiation

Beside the UV-radiation the use of the highly penetrating gamma rays (wave length < 0.1 nm) was listed as possible ballast water treatment techniques. The application of gamma rays is relatively new and was developed for waste water pasteurisation (AQIS 1993).

3.2.5 Ultrasonics

The use of ultrasonics for controlling hull fouling dates back to the 1950's, however, its potential application for ballast water treatment purposes remains largely uninvestigated (Subklew 1963, Müller 1995, Müller & Reynolds 1995). The action or ultrasound is thought to be mediated through various responses that may be fatal to marine organisms. These are heat generation, pressure wave deflections, cavitation and possibly the degassing effect of ultrasound causing removal of much of the oxygen. Cavitation, the formation of gas cavities within liquids, is affected by the frequency of the ultrasonics, power level, volume of water, temperature of the water and the concentration of dissolved matter and gases. Higher frequencies, warmer temperatures and lower concentrations of dissolved matter have been found to increase the effect of ultrasound pulses. Plankton mortality has also been observed in the presence of ultrasound and is considered in part to be attributable to the cavitation process. The application of sonic disruption as treatment to the ballast water was so far not been tested (Armstrong 1997).

Effects range from simple 'shock' to extensive physical tissue disruption. In at least one case it has been reported to kill bacteria. Varying degrees of mortality have been achieved for zebra mussel larvae with exposure times of under 10 seconds (Carlton et al. 1995). In the ballast water context the effectiveness of this method can also be related to the exposure time, the pipe diameter and the effective pipe length.

The implementation of ultrasonics would require the installation of in-line transducers because ultrasound is unlikely to penetrate sediments. The relatively high exposure time for significant mortality may require the installation of parallel piping systems to avoid a decrease in pumping rate. In addition, colder water requires greater power levels for the cavitation process to be effective. Reliable cost estimates for the installation of ultrasonic treatment systems do not appear to be available.

With respect to health and safety aspects, problems may arise with noise from some transducer types. There may also be some as yet unknown implications for the ship's structural integrity and health of personnel following repeated exposure to ultrasound. Additionally, reducing concentrations of dissolved oxygen would enhance metal corrosion. It has also been suggested that the cavitation process could cause physical damage to tank coatings or structures. Such reservations would suggest that ultrasound was an unlikely proposition for ballast water treatment purposes (Müller 1995, Müller & Reynolds 1995).

3.2.6 Microwave

Beside the use of ultrasonics the application of microwaves (wave length 0.1 - 1 nm) for ballast water treatment has been listed. The application of microwaves is relatively new but has been developed to treat waste waters (AQIS 1993).
The size and costs of a microwave unit would prohibitively high as a 50 kW microwave generator costs about US$ 2 million and a unit like this would even be too small to microwave one large ballast tank (Carlton et al. 1993).

3.2.7 Rapid pressure changes

A comparable effect to ultrasonics might be reached through rapid pressure changes produced by e.g. an airgun, as used for seismic investigations. Both methods would probably damage many species but involved disadvantages such as noise from the transducers could affect the health of shipping crews and cause physical damage to tank coatings or structures (Müller 1995, Müller & Reynolds 1995) .

3.2.8 Electrical removal of species in ballast water

Ballast water treatment with electrical currents may cause serious damage to macro-organisms (Woodward 1990). The inactivation of dinoflagellate cysts had been readily achieved by the use of an electric chock during the exposure to 100V for 5 sec (Montani et al. 1995).

Experiments on electrical treatment of ballast water using porous graphite elecrtodes are planned in Japan (Japan Association of marine Safety pers. comm.).

The installation of an electronic unit in the sea chest of the vessel near the ballast water intake could during the intake of the ballast water in addition chase away macro-organisms. Comparable units were used in intake areas of power plants to prevent the unwanted impact of macro-organisms.

3.2.9 Magnetic fields

Water what has to be treated could pass a strong magnetic field generated by ferromagnetic or electromagnetic devices. The biological and chemical impact of magnetic systems are not well understood. It is supposed that the organic and inorganic components of living specimens in the water could be modified by strong magnetic fields. magnetic water treatment under laboratory conditions has been effectively used in the treatment of e.g. fresh water bivalves. The method was not applied for salt water treatment (Sipes et al. (eds.) 1996).

3.3 Chemical removal of species in ballast water

A large number of chemical disinfectants are commercially available. These have been used successfully for many years in land-based potable and wastewater treatment applications. Target organisms include protozoa, vegetative and resting cells of bacteria and algae, and viruses. Bolch & Hallegraeff (1994) noted that copper sulphate and high or low pH values are completely ineffective to treat phytoplankton cysts.

A number of other inorganic biocides are used for water treatment purposes. These include bromine, potassium permanganate and hydrogen peroxide. However, their use is generally restricted to small scale and / or specific applications. Moreover, high costs suggest that their use for the treatment of ballast water was unlikely on economic grounds (Müller 1995, Müller & Reynolds 1995).

It has to be considered that despite the costs, the storage of the chemicals on board could be impracticable. Several tonnes were needed to treat the large amounts of ballast water on a bulk carrier calling for a port area without any cargo.

In addition, both inorganic and organic biocides would present a range of health and safety problems related to the storage and handling of chemicals, their compatibility with cargoes carried on board ships, as well as those related to the direct and indirect handling of chemicals by crew members.

As regards the chemical disinfection options, most of the traditional biocides produce by-products which are likely to be environmentally unacceptable and / or might require specialist operator skills. Suitable dispersal mechanisms in the ballast tanks would also need to be addressed, in particular mechanisms for penetrating the sediment layer. In addition in cases where ballast water in cargo holds would be treated with chemicals, these tanks would have to be cleaned intensively before cargo could be loaded in the same tanks (Carlton et al. 1995).

3.3.1 Chlorination

Study of Lloyds Register Engineering Services

Chlorine is a strong oxidising agent. The precise mechanism by which chlorine kills aquatic organisms is not known (Twort et al. 1985, Sterritt & Lester 1988), however, it is assumed that this occurs due to the destruction of the cell wall or channels in the cell membrane.

The effectiveness of chlorine as a disinfectant is dependent on temperature and contact time. Organism mortality rate varies with changes in temperature between 2°C and 20°C. Kills have been substantially reduced with lowering of temperatures (Tebbutt 1983). Chlorine effectiveness is further reduced with increasing pH. At pH values up to 6.7, more than 90 % of "free chlorine" comes from HOCl, when ammonia is not present. With increasing pH dissociation favours production of OCL^- ions so that only 4.5 % of the "free chlorine" is present as HOCl at pH 9.

Chlorine could easily been added to ballast water via a chlorinator installed in-line. However, the significant amounts of organic material and sediment in ballast water will exert a high chlorine demand. This material may also act as a shield to some organisms and compromize the effectiveness of the chlorine.

Dosage rates between 100 and 500 mg per litre have been quoted for ballast water disinfection (AQIS 1993). Such high dosage rates may create a storage problem. For dosing with chlorine following a filtration step, low concentrations of around 5 mg per litre may be possible.

Improved filtration however, is likely to entail additional modification, significant costs and increased space requirements.

The use of chlorine as a disinfectant and the use of electrochlorination as a means of preventing marine growth are well known. In principle these could be applied to ballast water treatment, however, the effectiveness of chlorine treatment in the marine environment is difficult to predict in all circumstances (Armstrong 1997). Reactions with ammonia, organic material, iron and magnesium may minimize the wanted effect as well as the influence of temperature, pH level and time of exposure. The application of chlorine must be carried out during ballast water uptake with an injection because the effective addition of chlorine to filled ballast tanks is almost impossible. Sounding pipes may be used to add chlorine but one cannot actively homogenise the chlorine content thorough the ballast water. In order to guarantee a disinfection the chlorine application has to be calculated in an overdose resulting in negative effects for the receiving environment in relation to the discharge of the chlorinated ballast water.

Therefore, prior to discharge of the ballast water it would be necessary to remove the free excess chlorine through dechlorination achieved by injection of sulphur dioxide which reacts with residual chlorine to form chloride. Dechlorination involves the use of a similar apparatus to the chlorinator. At the concentrations proposed, chlorine is unlikely to have any adverse effects on pipework or pumps. However, effects on tank coatings may require consultation with producers or possibly further investigation by experimentation.

It is unlikely that the use of chlorine as a biocide would be widely adopted due to health and safety concerns with respect to the use of chlorine in a gaseous form causing problems associated with storage as the liquefied gas under pressure. Additional problems may arise from the venting of ballast tanks. There may also be environmental risks associated with the discharge of ballast that has not been dechlorinated. In addition, research has demonstrated that the reaction of chlorine with organic compounds can produce a number of chlorinated organic compounds, some of which are known or suspected carcinogens. This has led to the re-evaluation of chlorine in existing treatment processes (Smethurst 1988).

Chlorine dioxide (ClO_2)

Chlorine dioxide has a bactericidal efficiency that is comparable with, and possibly greater than, that of free chlorine, although its viricidal efficiency has not been extensively investigated (Twort et al. 1985). Ridgway & Safarik (1991) are listing typical concentrations of 0.5 - 2 mg / l. It is suggested that ClO_2 has a number of advantages over chlorine (Sterritt & Lester 1988, Smethurst 1988). Most importantly ClO_2 does not react with ammonia and thus application of large doses to produce sufficient ‘free chlorine’ is avoided. In addition, disinfection is more effective than for chlorination at high pH values, significant chlorinated by-products, such as trihalomethanes, are not produces and a relatively stable disinfectant residual is produced.

ClO_2 is usually produced by adding chlorinated water to sodium chlorite solution and is generally applied at concentrations between 0.1 and 0.5 mg per litre. Costs of sodium chlorite are very high and on a per unit weight basis ClO_2 is more expensive than chlorine.

Chlorinated water is produced from chlorine which is then added to the sodium chlorite solution via a chlorinator. Health and safety problems associated with chlorine would therefore still apply. As ballast water is likely to have a high chlorine demand because of the presence of ammonia, organics and manganese and iron in solution, ClO_2 is likely to perform superior disinfection at less cost. If excessive doses of ClO_2 are applied sulphur dioxide may be used for dechlorination as for chlorine. Effects on coatings, pumps and pipework are likely to be similar to chlorine (Müller 1995, Müller & Reynolds 1995). Disadvantaging are safety problems due to the explosive character of the gas and toxic by-products (Flemming 1991).

Chloramines (NH_2Cl)

Chloramination, also known as the ammonia-chlorine process, is a form of chlorination. Involving the deliberate formation of monochloramine by the addition of ammonia to water followed by chlorination. The ratio of ammonia to chlorine is usually in the range of 1:3 to 1:4 (Twort et al. 1985) and has to be controlled to prevent the formation of di- and tri-chloramine. As an alternative to controlling the ammonia / chorine ratio, performed monochloramine has at times been used. Inorganic chloramines have found to be less effective disinfectants than free chlorine in laboratory studies (Smethurst 1988).

At higher pH values (8.5-9.0) chloramines have been found to be a better disinfectant than free available chorine. Chloramine treatment is said to have a low overall cost of application and systems maintenance and it is less expensive than other alternative disinfection methods including ozone and chlorine dioxide. The chloramine residual is longer lasting than free chlorine. For shipboard use the biggest problem is likely to arise from maintaining the correct ammonia-chlorine ratio.

As chloramination is a form of chlorination, chlorine would have to be carried onboard ship. Consequently associated health, safety and environmental considerations would need to be taken into account (Müller 1995, Müller & Reynolds 1995). Disadvantaging is the resistance of micro-organisms (bacteria) against chloramine treatment (Flemming 1991).-

Sodium / calcium hypochlorite (Na ClO / Ca(ClO))²

Sodium hypochlorite solution is freely available as an ordinary household disinfectant, containing 1 to 15 % of available chlorine. The solution rapidly loses strength upon exposure to atmosphere or sunlight and consequently is typically supplied in small containers so that the contents may be used quickly. Larger quantities may be available in carboys which require return to the manufacturer for filling. Dosage would need to be carried out by a simple chemical feeder based on hydraulic control of a solution to provide a constant rate of discharge regardless of the level in the storage container.

A less expensive alternative might be the electrolytic generation of hypochlorite onboard ship using seawater as the source of chloride. This could possibly be a cost-effective way of pursuing this option. A brine solution is often used in preference to seawater because the latter would require filtering before use. The presence of manganese in solution in seawater will impair electrode efficiency. However, hydrogen gas also produced by this process would have serious implications for health and safety, particularly for tankers and this does need careful consideration. Solutions with 8g or more of chlorine per litre may be produced with electrical power consumption of 5-6 kWh/kg of chlorine (Twort et al. 1985).

In order to kill *Gymnodinium catenatum* cysts amounts of free chlorine levels as high as 500 ppm have been quoted. This would require approximately 400 tonnes of an industrial solution of 12.5 % NaClO to treat 50,000 tonnes of ballast water. Consequently, economic as well as health and safety considerations are likely to prohibit the use of NaClO for ballast water disinfection.

A study of the Japanese Association for the Prevention of Marine Accidents documented that even a solution of 1 ppm of hypochlorous acid (CLO^-) only was sufficient to kill unwanted aquatic organisms (Fukuyo et al. 1995).

As an alternative, hypochlorite is available in a granular form as calcium hypochlorite (Ca(ClO)2) which contains between 65 and 68 % by weight of chlorine. The product is generally supplied in 45-50 kg plastic lined drums. Granules are readily soluble and may be dosed directly to the water or made up as standard strength solutions. Dosing would be by a simple hydraulic feeder as for sodium hypochlorite. Although Ca(ClO)2 granules are substantially cheaper than the equivalent NaClO solution economic reasons are again likely to prohibit the use of Ca(ClO)2 for ballast water disinfection (Müller 1995, Müller & Reynolds 1995).

Flemming (1991) underlined the low costs and effectiveness of this chemical, but noted disadvantaging toxic by-products and corrosive effects.

Additional studies revealed that free chlorine peroxide killed cysts e.g. *G. catenatum* , but high dose rates make use of the chemicals expensive and high organic sediment loads of ballast water limit the effectiveness of chlorine and hydrogen peroxide (Bolch & Hallegraeff 1993).

3.3.2 Metal ions

Electrolytically generated copper (Cu) and silver (Ag) ions are being successfully used in the treatment of freshwater, particularly potable water and swimming pools. Although the efficiency of the various systems that are commercially available does vary, the effectiveness of electrolytically generated copper and silver ions has to be found superior to chlorination for the inactivation of various bacterial strains (Landeen et al. 1989).

Although most organisms have requirements for small concentrations of Cu and Ag and both metals have important biochemical functions, excessive concentrations are toxic to most organisms. This is largely mediated through the inactivation of enzymes and other biological components by substitution of the metals in reactive sites (Tebbutt 1983).

The disinfecting capacities of Cu and Ag are dependent upon the type of organisms treated. Simple, single-celled organisms are usually more susceptible than larger higher organisms. Different stages in the life-cycles of organisms will vary in their susceptibility, with resting stages generally being more resistant. Environmental conditions might also play a part, particularly in the case of pH and viral susceptibility to metal ions (Thurman & Gerba 1989).

Although high concentrations of Cu and Ag ions may not have a lethal effect on exposed organisms, they may prevent successful reproduction and would thus serve the purpose of preventing the establishment of non-native organisms in new areas.

Unlike many other disinfectants, however, chemical and behavioural mechanisms exist which provide tolerance for some organisms to elevated copper and silver concentrations. For example, in situations of high environmental copper concentrations some barnacles are able to bind copper within an organic complex resulting in ‘copper granules’ (Walker 1977). Similar phenomena have been observed in crayfish, isopods and scallops. In addition a direct behavioural response is exhibited by bivalves which rapidly close their shell when exposed to unacceptable high copper concentrations (Powell & White 1989).

There is less data at hand on the effect of silver, but its toxicity is considered to be superseded only by mercury. Bioaccumulation of silver, mostly in form of the very stable silver sulphide, has been recorded for young oysters in response to experimentally induced elevated silver concentrations (Martoja et al. 1988). There appears to be little or no data on the complementary or synergistic effect of copper and silver on the mortality of organisms.

Despite the various metal ion tolerance mechanisms apparent in marine organisms, the use of copper and silver ions for disinfection of ballast water may still be worthy of consideration, since many of the tolerance mechanisms are associated with larger organisms: there could however, be removed by preliminary mechanical treatment processes (section 4.1).

At the present time, there is a lack of data regarding application of copper / silver ion disinfection systems to seawater, although such systems have been used in aquaria and dolphinaria. Trials are also underway for aquacultural and fisheries purposes (Rosenthal pers. comm.).

Concerns over the precipitation of Cu or Ag salts in seawater appear unfounded. Calculations suggest that even the low solubility of the silver chloride salt would not result in precipitation at the silver ion concentrations likely to be required for ballast water disinfection purposes. Moreover the suitability of eletrolytically generated Cu and Ag ions in seawater is understood to be superior as compared with ions deriving from the metal salts.

Application of this technique to ballast water has so far not been tried in practice. It is proposed that the treatment of ballast water could take place during the ship’s passage by continuously recirculating water from a ballast tank through an electrolytic cell. Copper / silver alloy electrodes with a copper:silver ratio of around 10 : 1 should be used. The overall size of the system would relate to the required release rate for the metal ions. This, in turn would be dependent upon the volume and characteristics of the water to be treated. The level of organic material present would be of particular importance since complexing of metal ions by organic ligands will reduce the proportion of free metal ions available for disinfection purposes (Müller 1995, Müller & Reynolds 1995).

In contrast to traditional chemical disinfection agents, the use of electrolytically generated copper (Cu) and silver (Ag) ions would be unlikely to pose comparable levels of health and safety concerns since the carriage and handling of chemicals on board would be avoided. Environmental concerns over the discharge of Cu and Ag enriched waters and dispersion of Cu and Ag ions in the ballast tanks would, however, still need to be addressed. The environmental impact is less certain and would largely be dependent upon the copper and silver ion concentrations required for effective kills and metal ion dispersion characteristics at the point of ballast water discharge (Müller 1995, Müller & Reynolds 1995).

There was some evidence that the copper / silver electrode system might have affected the viability of both the zooplankton and the dinoflagellate cysts, although not the diatom resting stages. This was somewhat surprising considering that zooplankton and dinoflagellate cysts would anticipated to be more resistant than either bacteria or phytoplankton to adverse conditions. Whilst it could not entirely be ruled out that the copper / silver electrode system would have an impact on these organisms under normal operating conditions, it is more likely that the effects observed were due to the inordinately high concentrations of copper to which these organisms were exposed, either during the treatment process itself or during the viability analyses. In contrast, silver concentrations were always below the detection limit of the analytical method (10 to 100 $\mu g.litre^{-1}$) and Cu : Ag ratios were in excess of 96 : 4.

The copper / silver electrode system as tested within this project appeared far less promising than the additional tested UV-treatment (see above) of ballast water. Neither bacterial nor phytoplankton viability appeared to be significantly affected by the copper / silver treatment process. The results of the bacterial trials may, however, have been influenced by the high DOC content of the test media which may in turn have reduced the effective toxicity of the metal ions in the test system. However, the DOC concentrations recorded were consistent with those encountered in natural environments (Müller 1995, Müller & Reynolds 1995).

3.3.3 Ozone

Ozone is a fairly powerful but unstable, oxidising agent which rapidly destroys viruses and bacteria, including spores, when used as a disinfectant in conventional water treatment (Reynolds et al. 1989). O_3 quickly decomposes to oxygen, with a half life in water at 20°C of less than 30 minutes. The process is dependent on the production of O_3 on-site, by passing high tension, high frequency electrical discharges through dry air.

Effects of O_3 are rapid, with contact times of 5 to 10 minutes at a dosage of 1-2 mg per litre. Where water was of poor quality much larger concentrations have to be applied. Over a range of pH between 6.5-8.0 the reactivity of O_3 is constant unless colour present in the water was due to reactions with fulvic and humic acids. High pH will lead to slowing down of the kill rate.

Ozone gas is highly toxic and has an odour detection threshold of about 0.01 ppm. A high level of safety measures, including monitoring of carbon scrubbed vented gas, therefore has to be adopted with its use. Although O_3 leaves no residual in the water, it may cause precipitation of manganese and iron and is not suitable for water with high turbidity. In addition to the associated high costs of this treatment it is possible that O_3 may be a potentially corrosive agent in ballast systems (Flemming 1991, Carlton et al. 1993).

3.3.4 Hydrogen peroxide

The use of hydrogen peroxide (H_2O_2) is common for control of fouling in water cooling systems. Cysts of phytoplankton as e.g. *Gymnodinium catenatum* can be destroyed at minimum concentrations of 1 % (Rigby et al. 1993). Typical concentrations are listed with 0.1 - 2 g/l (Ridgway & Safarik 1991).

The major advantage over other chemicals is the effect that residual amounts decompose readily to water and oxygen and are therefore environmentally sound. One potential disadvantage is that applied to ballast water with high loads of organic material the effectiveness decreased due to oxidation of this material. From a practical point of view, a bulk carrier with 50,000 tonnes of ballast water would require 1,000 tonnes of hydrogen peroxide. Lower concentrations would require longer exposure periods of time (Rigby et al. 1993).

Hydrogen peroxide killed cysts e.g. *G. catenatum* , but the dose rates make its use expensive. In addition, the high organic sediment load of ballast water limits the effectiveness of hydrogen peroxide (Bolch & Hallegraeff 1993).
It has been assumed that in combination with other options (as UV-treatment) low concentrations of hydrogen peroxide could be effective (Müller 1995, Müller & Reynolds 1995).

The German chemical company DEGUSSA AG, Frankfurt is testing several mixtures of the peroxigene based fluid „Degaclean“ for ballast water treatment. Until today, it was mentioned that the advantage of this new treatment chemical (based on several components) is the comparably low costs involved and that remaining decomposits of the chemical have non polluting impacts to the environment. First preliminary results of trials on the effectiveness are scheduled for 1998 (Huss pers. comm.).

3.3.5 Oxygen deprivation (de-oxygenation)

Reducing agents, such as sulphur dioxide or sodium sulphite may be used to de-oxygenate water creating anaerobic conditions which may effect the viability of marine organisms. However, de-oxygenation is thought to have little effect on algae, anaerobic bacteria, possibly viruses, and resting stages of algae and bacteria (AQIS 1993). Full de-oxygenation would be difficult to achieve in unsealed tanks. Treatment would therefore be only partial and a number of problems would be associated with this approach. In particular, hydrogen sulphide and other sulphur compounds would accumulate leading to potential corrosion problems. The discharge of anoxic, sulphur rich water would also likely to be environmentally unacceptable (Müller 1995, Müller & Reynolds 1995, Sipes et al. (eds.) 1996).

3.3.6 Coagulants

Coagulants were discussed to increase the effectiveness of filtration and gravity (sedimentation / flotation) process. Coagulants are charged ions which destabilise the counter charges on suspended colloidal material and allow the formation of larger particles in the water due to agglomeration. These larger particles could be removed by filters or extracted by floatation methods. In drinking water treatments coagulants were used (aluminium and ferric sulphate, ferric and poly aluminium chloride as well as cationic polymers). Useful application doses and chemicals need to be studied under sea water conditions (AQIS 1993).

3.3.7 pH adjustment

The likely sensitivity of some organisms to pH change, especially large short term variations in pH, has led to investigations of the suitability of this option for ballast water treatment (Müller 1995, Müller & Reynolds 1995). The pH value could be adjusted by the addition of lime (AQIS 1993).

Bolch & Hallegraeff (1994) believe that treatment with pH adjustment was not effective in the wide range of 2 to 10.2. In contrast, Ridgway & Safarik (1991) are listing useful pH values with 2 - 12. Impacts of ballast water discharged with even higher or lower pH values would be absolutely not acceptable for the environment.

Lowering of pH is generally undesirable because of corrosion problems. Temporarily raising the pH to around 12 by the addition of an alkali has been suggested as an alternative; however, such high pH conditions may well result in alkaline attack of pipework, coatings, ballast tanks and so on.

Little real data currently exist with respect to the efficiency and effectiveness of pH adjustment. Inactivation of viruses by pH elevation has been demonstrated (Sproul 1980). However, exposure of dinoflagellate Gymnodinium catenatum cysts to a pH range of 2 to 10 was unsuccessful in preventing germination. On account of the foregoing, adjustment of pH is unlikely to be a suitable option for ship-board treatment of ballast water. Moreover, health and safety concerns would accompany the storage and handling of large quantities of the alkali required for raising pH and acid needed for pH restoration prior to discharge of the water (Müller 1995, Müller & Reynolds 1995).

3.3.8 Salinity adjustment

In the simplest cases this would entail the addition of fresh water to salt water or salt water to fresh water in order to disturb the osmoregulatory processes of the salt or fresh water organisms which were present in the raw ballast water. This method is known not to effect all types of organisms.

The high saline exhaust of an on board desalination unit mixed with the ballast water could have an sterilising effect. This method would probably harm organisms in the area of discharge, if large volumes of high saline water are released. It is believed that this method could be useful for ships carrying very small amounts of ballast water, as e.g. cruise liners. This method has to be tested.

3.3.9 Antifouling paints as ballast tank coatings

The use of anti-fouling pollutants in the inside ballast tank coating could help to minimize fouling (Woodward 1990, Carlton et al. 1995). However, inside tank fouling is not occurring frequently as shown during shipping studies (Gollasch 1996, Lenz et al. in prep.).

Optimal treatment by anti-fouling paints is only given during water movements. High wind forces during the voyage of a vessel can result in water movements in ballast tanks, especially if the tanks are not filled completely. Calm seas and completely filled ballast tanks prevent water motion inside the tanks and therefore would reduce the effectiveness of the anti-fouling paint.

However, the use of poisonous wall coatings could not be applied for cargo holds (Carlton et al. 1995). In addition, the discharge of ballast water contaminated by these toxins would affect the receiving ecosystems.

3.3.10 Organic biocides

There are a number of commercially available organic biocides, however, their overall effectiveness on marine organism mortality is virtually unknown and costs are likely to be prohibitive. Moreover, a dose at 30 times the recommended rate of one particular biocide was found to be completely ineffective against dinoflagellate cysts (Bolch & Hallegraeff 1993). To ensure that active biocide or decay products did not enter the receiving waters the application of a detoxification agent would almost certainly be required (Bolch & Hallegraeff 1994, Müller 1995, Müller & Reynolds 1995). For some of the listed chemicals no detoxification products are known and therefore the use is environmentally unsafe and not recommended.

3-trifluoromethyl-4-nitophenol

The sea lamprey, introduced to the North American Great Lakes caused serious losses in the harvest of local fisheries. The lamprey was treated effectively with biocides. After a trial testing of more than 6,000 chemicals, a chemical (3-trifluoromethyl-4-nitophenol) was found causing damages to the larvae of the lamprey with minimum effects to most of the other species present. Since the first application in 1960 the population of the sea lamprey decreased to 5 % of the population in 1960 (Morse 1990). Each year chemicals are being applied in order to prevent an increase of this unwanted species (Cangelosi pers. comm.).

The following list of chemicals was mentioned by Flemming (1991), Mittelman (1991), Ridgway & Safarik (1991) and references, as well as by AQIS (1993), as possible treatment biocides in order to retard (bacterial) biofouling of reverse osmosis membranes of industrial water systems:

Bromine

The application of this chemical seems to be very effective against a broad microbial spectrum. Unwanted effects are toxic by-products and the development of resistance.

Formaldehyde

The mentioned typical concentrations were 1 % (treatment duration 2-3 h). The low costs involved, the broad treatable antimicrobial spectrum, stability and the easy handling during application was listed as advantage. Disadvantaging and restrictions in use are the resistance of some organisms, toxicity, suspect to promote human cancer disease.

Glutaraldehyde

Glutaraldehyde is an effective toxin even at low concentrations (5 - 25 g/l). The chemical is in-expensive, non-oxidising and non-corrosive.

Isothiazolone,

Recommended typical concentrations of this toxin are 0.1 - 5 g/l. It is therefore effective in low concentrations and a wide spectrum of micro-organisms may be treated. Disadvantaging is the effect of inactivation by primary amines.

Quaternary ammonia compounds

Typical concentrations are between 0.1 - 5 g/l. Disadvantaging is the inactivation by low pH, Ca^{2+}, Mg^{2+} and the development of resistance.

Sodium amines and **EDTA**

Sodium amines and EDTA were typically concentrated in low doses (0.1 - 5 g/l).

Peracetic acid

Peracetic acid is very effective, even in small concentrations (0.1 - 2 g/l). The treatment of a broad spectrum of bacteria, including spores. No toxic by-products known. Disadvantaging are instability and corrosive impacts.

Bisulfite

Typical concentrations for effective applications with bisulfite are between 10 - 100 mg/l.

Iodine (periodate)

The lowest concentrations of all listed chemical with 0.1 - 2 mg/l were effective.

In addition the use of bacterial **pyrogens** (**endotoxins**) has been discussed. Other mentioned biocide treatments in the aquatic habitats is the use of the organic algaecide Kathon WT (a chemical containing Isothiazolone) (Ridgway & Safarik 1991, Bolch & Hallegraeff 1994).

3.4 Constant volume of ballast water

Another option is the carriage of a constant volume of ballast water on board without any discharges or uptakes of additional water. This option seems to be applicable on a very little number of vessels. Ships which usually carry very little amounts of ballast water as e.g. cruise liners, could minimize their ballast water discharge to a minimum or even could prevent any discharge by pumping the ballast on board from one tank into another (Gollasch 1995).

Due to the constant volume of ballast water the time the ballast water remains on board would considerably increase as compared with current practices. Scientific ballast water studies showed that with increasing duration the number of species and specimens in the ballast water is decreasing for many organisms (Williams et al. 1988, Gollasch 1995). Therefore Carlton et al. (1995) pointed out that the increased length of voyages (increased time of ballast water on board) would reduce the number of introduced species by ballast water discharge. However, resting stages, especially from phytoplankton species, can remain viable for several years in the tank sediments (Carlton et al. 1995).

3.5 Alternating salinities in ballast water and area of discharge

Wherever possible alternating salinities of ballast water and area of discharge of this ballast water could be used. Firstly, to discharge marine ballast water in freshwater areas (e.g. The North American Great Lakes, freshwater ports) and secondly, to discharge freshwater ballast in marine ports could help to minimize the survival of organisms after discharge into a new aquatic habitat. It is believed that most of the freshwater organisms cannot survive marine water conditions and vice versa. Knowing that there are exceptions of this rule, this option could be used to minimize the risk but cannot exclude further species introductions.

The North American approach of vessels entering the Great lakes took into account that the survival of most marine organisms in the freshwater of the Great Lakes is limited (see below).

In addition there are many trading routes in the world where ships do not have the opportunity to take freshwater ballast on board. The use of an on board desalination unit for this purpose is probably extremely time consuming and associated with enormous need of energy. The additional air pollution caused by running the desalination unit has to be taken into account.

(see also Treatment option "Salinity adjustment")

3.6 Fresh Water Ballasting

Providing ships with city treated fresh water appears to be a useful option in unique circumstances, as e.g. regional shipping routes serving determined cities. Specific arrangements need to be made with port authorities involved (Carlton et al. 1995).

An International Seminar on Fresh Water Ballasting in 1983 discussed the use of fresh water ballast for oil carriers. One issue listed was that the oil carrier could load fresh water instead of cruising back to the oil exporting country without any cargo. Many of the oil exporting countries are located in arid or semi-arid climates where rainfall is scarce. The agriculture of some countries could benefit from this fresh water for irrigation supplied by incoming vessels. The use of the fresh water ballast for agricultural use could help to protect natural fresh water resources.

A number of investigations have been undertaken dealing with the economic feasibility and the tolerance of agriculture to oil contaminated water (Meyer 1983).

Fresh water transported in cargo holds of oil carriers can contain on discharge 1 to 5 ppm of oil. These amounts may be removed at land-based facilities (Leitner 1983).

Short term (3 years) plant tests showed that the content of naphtalenes and phenantrenes varied (7 - 140 µm) according to different agricultural techniques. These contents may not represent health hazardous levels (Persson 1983). Other experiments showed that the effects of oil contaminated water on seed germination and seedling growth was in maximum 25 % of the tested seeds if the contamination was little. Inhibiting of seed germination increases with the cruide oil concentration (Elmehrik & Ben Hamieda 1983).

But using untreated lightly contaminated fresh water from these tanks one will probably enrich the oil content on the agricultural site and pollute the ground water. Using the brackish water from the donating country without desalination an increasing salinity of the agricultural site cannot be avoided.

The benefits of this method could be the minimization of discharging oil polluted ballast water in the marine environment (in countries where land based reception facilities are not available) and cost savings in areas where desalinated water have to be used for agricultural purposes (Meyer 1983). In addition the contaminants (chemicals and biological e.g. pathogens and disease agents) of the water (Maramorosch 1983), as well as costs for water at source and delays during loading and unloading, have to be taken into account (Sadler 1983).

It is supposed that the costs for cleaning and installations are to high for economic feasibility of this method. Today, in addition to the economical point of view, water is a limited source in some countries. Therefore, the applicability of this option is limited to very special circumstances on certain trading routes.

3.7 Biological removal of species in ballast water

Biocontrol methods to remove organisms has been practiced at several occasions in regard to terrestrial habitats after an unwanted species introduction for hundreds of years. The use of imported predators, parasites and diseases is very risky due to the impact of the intentionally introduced species on native species (Center et al. 1997).

Until today no species was intentionally released into the wild in the marine environment following this purpose. A new Study Group on Marine Biocontrol of Invasive Species (SGMBIS) was established in 1997 under the chairmanship of Prof. Dr. J. T. Carlton. The working group will focus their activities on the risk assessment of potential biocontrol species in order to control unwanted non-indigenous species as e.g. *Caulerpa taxifolia* in the Mediterranean Sea, *Mnemiopsis leidyi* in the Black Sea and *Carcinus maenas* in Australian waters (SGMBIS 1997). A parasite, native to Europe (*Sacculina carcini*, Cirripedia) is affecting *Carcinus maenas* in its native European range. If currently undertaken intensive studies showed that *Sacculina carcini* will only affect the introduced European Shore Crab in Australian waters this species may be introduced to control the population of the European

Shore Crab. The second example in this field is the planned introduction of the exotic herbivorous sea slug feeding on the introduced *Caulerpa taxifolia* in the Mediterranean Sea. The sea slug will not feed exclusively on the introduced Caulerpa but as well on the native *Caulerpa* species, but it may be assumed that the introduced *Caulerpa* could remove the native species of *Caulerpa* taking into account its tremendous growth rate.

No current activities or studies exist in order to remove species in ballast water by biocontrol.

3.8 Dewatering

The objective of dewatering is to produce an analogous substance to water that may be easily handled, transported, stored and disposed. Typical dewatering is carried out by the addition of solid material (up to 40 %). The added material may be extracted by using vacuum filtration or centrifugal separation (AQIS 1993).

3.9 Land-based facilities

The possibility of land-based facilities has not been ruled out for the treatment of smaller volumes of ballast water. The reception facility has to be placed in certain areas of ports taken into account quarantine regulations. Land-based reception facilities for ballast water discharge could provide an acceptable means of control, but seemed to be unfavourable due to the costs involved e.g. for pipework of enormous dimensions.

3.10 Shipboard treatment of ballast water

3.10.1 Commercial vessels

If the treatment units may be installed as small scale facilities as e.g. container size, a shipboard use is possible (AQIS 1993). Safety on board as well as additional manpower for the ship crew for the ballast water treatment have to be taken into account.

3.10.2 Treatment vessels

In order to reduce costs for the pipework an especially designed tanker could act as reception facility for ballast water. The ballast water to be discharged could be pumped to this vessel located along side the discharging vessel (AQIS 1993).

It has further been estimated that several land-based treatment plants (connected to the vessels by pipework or serviced by barges which collect the ballast water from the vessels discharging it later to the treatment plant on land) and treatment vessels were needed (AQIS 1993).

3.11 Summary of treatment options

From the foregoing it is apparent that no single or simple solution presently exists for shipboard treatment to prevent the transfer of viable non-native organisms in ballast water. None of the listed treatment options seem to be 100 % effective, environmentally sound, cost effective and safe during application. A combination of technologies may however, be at least partially effective and feasible in terms of economic and shipboard constraints. The most promising method seems to be a combination of heat treatment and filtration of ballast water or heat treatment and changing salinities of the ballast water.

Some form of mechanical removal of debris and the larger organisms would appear a prerequisite to any other treatment. This would most likely take the form of straining, microfiltration or even cyclonic separation.

As a second step, physical treatment techniques, in particular application of UV radiation or heat treatment, would appear to be more acceptable than chemical options on both environmental and safety grounds. An exception is the ozonization of ballast water. Although ozone leaves no residual environmental polluting components, as it quickly decomposes to oxygen, in the water and it is a considerably more effective biocide as other chemicals than e.g. chlorine.

However, environmental concerns will still exist with respect to genetic mutation and discharge of warm water respectively.

As regards the chemical disinfection options, most of the traditional biocides produce by-products which may be environmentally unacceptable and may require specialist operator skills on account of the complexity of ballast systems and problems associated with the application of chemicals. Suitable dispersal mechanisms in the ballast tanks would also need to be addressed, in particular mechanisms for penetrating the sediment layer. In addition, both inorganic and organic biocides would present a range of health and safety problems related to storage of chemicals, compatibility with cargo carried on board as well as direct and indirect handling of chemicals by crew members. Nevertheless the use, for example, of hypochlorite may be useful as an emergency treatment measure.

In contrast to the traditional chemical disinfection agents, the electrolytic generation of copper and silver ions would be unlikely to pose the same level of health and safety concerns since the carriage and handling of chemical on board would be avoided. Environmental concerns may however, be expressed over the discharge of copper and silver enriched waters and dispersion mechanisms would still need to be addressed. Nevertheless, this technique is considered worth of further investigation.

Of the remaining options reviewed, adjustment of ballast water salinity is clearly a useful technique where supplies of fresh or seawater, as appropriate, are freely available. Indeed this technique is already being used for the treatment of ballast water for ships entering the Great Lakes.

On the basis of the available data, none of the other techniques reviewed appear particularly suitable for shipboard application to ballast water on account of effectiveness, practicality, cost, environmental health and / or safety considerations. As regards those that have been identified as potentially feasible and effective, further research will be needed before firm recommendations for shipboard installation can be made (AQIS 1993, Müller 1995, Müller & Reynolds 1995, Sipes et al. (eds.) 1996).

4 Costs of treatment

The costs involved in the application of the various treatment options were only calculated for very few methods:

4.1 Filtration

Data on the costs of running a self cleaning filtration treatment on board the ALGONORTH in the Great Lakes will not be available at this time.

(AQIS 1993) estimated the costs and applicability for filtration with higher meshsize compared to the ALGONORTH experiment. Filter units are simple to operate and do not require a large amount of additional space. If the treatment units may be installed in small scale facilities as e.g. container size, a shipboard use is possible. Safety on board as well as additional manpower for the ship crew for the ballast water treatment have to be taken into account. The estimated capital costs to install e.g. a filtration unit for ballast water treatment are US $ 2.9 million, running the unit was estimated as US $ 117.6 per 1,000 m³. Total costs summarise to US $ 1000 per 1,000 m³. The estimated costs for 50 µm and 500 µm strainers appear to be prohibitively high at US $ 2.4 million and US $ 1.6 million. Filtration unit with a larger meshsize of 2,000 µm is estimated to cost US $ 0.9 million for units capable to handle 4,000 m³ per hour and of 0,5 million m³ of ballast water what has to be treated per annum (AQIS 1993).

Woven mesh filters with smaller meshsize (300 and 25 µm) have a larger filter surface area than screening systems. Space requirements for each filter having a capacity of 1,000 m³ per hour would be in the region of 2.8 m high by 1.7 m wide. Capital costs were quoted as US $ 16,000 per ‘coarse’ filter and US $ 20,400 for the ‘fine’ filter (Carlton et al. 1989). However, when compared to the high capital cost of the fine screening devices, it must be assumed that these costs either do not relate to provision of the entire system or the estimated costs for the fine screening system are inordinately high. Maintenance costs for the microfiltration system are reportedly low, with screen replacement required every few years. However, this system would not be suitable where gravitation is used for ballasting (Müller 1995, Müller & Reynolds 1995).

4.2 Ballast water exchange in open ocean

Costs for an mid-ocean exchange of ballast water determined in 1990 by Canadian officials (including the costs of diesel, power generating costs to operate pumps) are approx. US$ 900 per vessel with 7,000 to 10,000 tonnes of ballast on board, as usual for a vessel calling for Great Lakes ports. In this year 455 ocean going vessels entered the St. Lawrence River. Of these 198 or 44 % carried ballast water. Reporting and record keeping costs will probably add US$ 35 per vessel. Calculating the costs until the year 2000 (including inflation rate compensation of 4%) will summarise in US$ 2,112,744 (if number of vessels would not change per year. The Coast Guard experts emphasise that the cost for consumers would be minimal. Assuming that all costs will be passed on to the customer the costs per ton of cargo on vessels subject to the regulations has increased to US$ 0.099 calculated for 1993. The exchange of ballast water in open ocean areas prior to entering the great Lakes and discharging ballast water in the Great Lakes would help to prevent additional introductions of unwanted non-indigenous species (MEPC34/INF.22).

The costs for the installation of additional pipeworks and valves to allow a flow through exchange of ballast water, including remote operation, on a bulk carrier as the investigated ORMOND (190,000 DWT) or a suezmax tanker raises up to US $ 860,000; for a container vessel (e.g. the P & O Jervis Bay with a capacity of 4,000 TEU and length of 292.2 m) with a maximum ballast water capacity of 16,613 m^3: US $ 532,200. The cruise liner P & O GRAND PRINCESS (242m LBP) has a ballast water capacity of 4,345 m^3. A complete exchange will take 2.17 days using the pump with a capacity of 250 m^3/h. Costs in total would be US $ 277,700 (Armstrong 1997).

The Australian Bureau of Transport and Communication Economics estimated that the costs for reballasting at sea (during transit) was between 17 and 30 A cents (and 0.6 to 3.0 cents in a safe haven) per tonne of cargo, depending on the type and size of vessel (MEPC31/14, 1991). The total dry bulk export cargo in Australia in 1989 was 244 million tonnes. The total cost for this treatment would have been between US $ 60.3 million and US $ 107.3 million For the vessel IRON WHYALLA complete ballast water exchange using the flushing method replacing 3 ballast water volumes would require approximately 3 days. The fuel costs were estimated as US $ 3,380 (Rigby et al. 1993).

The IMO Assembly Resolution A.868 (20) advises that a responsible officer should be appointed to maintain appropriate records and to ensure that ballast water management and / or treatment procedures are followed and recorded. It also advises to document as minimum during taking on or discharging ballast water the dates, geographical locations, ship's tank(s) and cargo holds, ballast water temperature and salinity as well as the amount of ballast water loaded or discharged. These costs for documentation seemed to be very little.

4.3 Heat treatment

To improve the heat exchanger utilising heat from engine cooling water costs about US $ 94,000 per vessel. The costs for additional pipework were estimated for a 147,000 metric ton bulk carrier at US$ 50,000. A re-design of the vessel is needed (Bolch & Hallegraeff 1994). Running the unit would be comparable in-expensive and depend on several parameters (as e.g. required temperature, amount of ballast water what has to be treated, location of ballast tank, route of the vessel etc.).

The engine room equipment would have to consisting of an additional heat exchange, hold tank, instruments controlling the water temperature and piping.
A comparable heat system was successfully used on a trial basis on board the 4,226 gt bulk carrier SANDRA MARIE during a voyage from Sidney to Hobart in May 1997. The modification of the vessel was approved by Lloyd’s Register and the Australian Maritime Safety Authority. The system was based around the existing jacket cooling water heat exchanger with a minimum of additional pipe work. The usual seawater cooling circuit was by-passed and replaced by water drawn from the ballast tank and returned to the ballast tank after heating. As every ship is different the on board heating system has to be designed individually. The constructing company Hi-Tech Marine, who designed the unit and installation used during this trial, estimates the costs for a system designed to treat 500t/h at around US$ 350,000 (Müller 1995, Müller & Reynolds 1995).

4.4 Ultraviolet radiation (UV)

For the treatment of most bacteria the capital costs for three to four units capable of treating 1,000 m³ per hour are currently in the range of US $ 98,000 to US $ 130,400. In order to treat the more UV-resistant blue-green algae the cost could be tenfold. Power requirements are typically between 10 and 20 Wh m³, with a large plant in the former USSR reporting the treatment of 3,000 m³ per day of surface water at an average electrical consumption of 10-16 Wh m³ (Twort et al. 1985). Other than the input of electricity the ongoing costs would also include replacement of UV lamps every 4,000 hours and quartz sleeves at intervals of approximately two years. Costs for each of these items are approximately US $ 500. The application of UV radiation for the treatment of seawater has so far not been widespread. However, it could be an effective and environmentally acceptable ballast water treatment option once the larger organisms have been removed by mechanical processes (e. g. filtration). The technique is likely to be acceptable on health and safety grounds and is unlikely to have any adverse effects on pipework, pumps or coatings. There are no known toxic by-products, although it is has not been ruled out that the alteration of genetic material and the generation of new characteristics in lower organisms may occur as a result of non-lethal doses of UV (AQIS 1993). Since UV radiation catalyses the oxidation reactions with ozone or hydrogen peroxide, a combination of UV treatment with low concentrations of these biocides may also be worth exploring (Müller 1995, Müller & Reynolds 1995).

4.5 Chlorination

Costs for dosing with low concentrations of chlorine at 5 mg/1 have been quoted as approximately US $ 4:9 per 1,000 tonnes of water. Larger amounts of chlorine would be required for ballast water disinfection at the higher dosage rates and consequently costs will be in the order of 20 to 100 times higher for the same volume of water. Between 4 and 20 tonnes of chlorine would be required for the treatment of 40,000 tonnes of ballast water. In co-operation with a filtration method the chlorine requirement would be reduced to 200 kilograms for the same volume of water. At these lower application rates chlorine would be a relatively inexpensive option (Müller 1995, Müller & Reynolds 1995, Rabe & Katzenbach pers. comm.).

AQIS (1993) estimated the costs of a system that may be used to treat 4,000 m³/h with 2 mg/l chlorine on less than US $ 376;500.

The needed concentration of free chlorine was estimated as 500 ppm for 24 hours. Approximately 30 % of the initial free chlorine remains after 24 hours application. It was calculated that 2.4 t of 12.5 % NaHOCl per 50,000 t vessel would be needed per voyage. The costs involved were estimated as US $ 294,000 per treatment. It has to be taken into account that the effectiveness of chlorination is decreased in cases of high organic loads of the ballast water (Bolch & Hallegraeff 1994). Lower dosages (e.g. 50 ppm) could be acceptable if one is willing to tolerate a small fraction of residual cysts. In order to prevent environmentally unsound ballast water discharges after chlorination treatment a neutralisation with an additional chemical (e.g. sodium metabisulphite) is necessary and brings additional costs (Rigby et al. 1993).

4.6 Metal ions

For the use of electrolytically generated copper and silver ions estimated space requirements for a system suitable for treating 20,000 tonnes of ballast water has been given as 3 x 2 x 2 m. An equally tentative capital cost estimate of $100,000 has also been provided. Running costs largely relate to electrical power consumption and periodic electrode replacement (Müller 1995, Müller & Reynolds 1995).

4.7 Ozonation

Ozone gas is highly toxic and has an odour detection threshold of about 0.01 ppm. A high level of safety measures and related costs, including monitoring of carbon scrubbed vented gas, therefore have to be adopted with its use. Capital costs of O_3 generation units are high when compared to chlorine systems. Equipment for the generation of O_3 to treat 4,000 m³ per hour is likely to cost in excess of US $ 2;9 million, whilst a chlorine dosing plant for the same treatment volume is less than US $ 376,500 (AQIS 1993). Operation and maintenance costs are very much higher than for chlorine (Reynolds et al. 1989). In addition to the associated high costs of this treatment it has been assumed that O_3 may be a potentially corrosive agent in ballast systems (Flemming 1991, Carlton et al. 1993).

4.8 Hydrogen peroxide

A concentration of 5,000 ppm for 24 hours application is needed. It is estimated that 150 tonnes of 35 % hydrogen peroxide are needed to treat the ballast water of a 50,000 t vessel. The costs involved were summarised as $A 2 million per treatment. Not only the high costs involved make this option un-acceptable, but it was documented that during high organic load of the ballast water the effectiveness is decreasing (Bolch & Hallegraeff 1994).

In another example costs are calculated for a bulk carrier containing 50,000 tonnes of ballast water requiring 1,000 tonnes of hydrogen peroxide (as an industrial 50 % aqueous solution costing approx. US $ 2,940 per tonne) resulting in US $ 2;9 million per voyage. Lower concentrations may be acceptable for some cysts or for extended periods of time. But even concentrations of 50 ppm seem to be very expensive (US $ 14,700 for 50,000 tonnes of ballast water) (Rigby et al. 1993).

4.9 Salinity adjustment

To treat the ballast water with an adjustment of salinity enormous volumes of NaCL are needed. For a small vessel 210 tonnes. The treatment material is high corrosive (Bolch & Hallegraeff 1994) and may damage ballast tanks, holds or pipework. Additional costs result in delays during loading 210 tonnes bulk material and storage on board

4.10 Organic biocides

The costs involved concerning biocide treatment are known in two cases: the bacterial treatment on Norwegian oil drilling platforms and the treatment of the introduced Sea Lamprey in the Great Lakes.

4.10.1 Bacterial treatment

Treatment of the injection water of Norwegian drilling platforms in the North Sea started two decades ago. The price per treated tonne injection water was in the 1970s approximately US$ 0.12. The price was reduced to US$ 0.0184 per ton today. The sixfold price reduction was possible by the use of alternative chemicals. Monitoring in addition had made a more optimal dosage possible (Jelmert pers. comm.).

4.10.2 Sea Lamprey

Introduced into the Great Lake system the sea lamprey has to be controlled each year by the application of chemicals to treat their larvae (Morse 1990). Costs involved in the chemical control and habitat modification summarised to more than US$ 100 million in 1993 (Leach 1995, Cangelosi pers. comm.).

4.11 Land-based facilities

The calculation of the costs was based on the need of 11,5 million m³ of ballast water that has to be treated per year. The equipment costs (including tanks, filtration units, UV-system, chemical application system, residual treatment and control) were estimated for a 52,000 m³ treatment plant to US $ 13;2 million up to US $ 27;9 million The operational costs per 1,000 m³ of ballast water were estimated as US $ 132 (including chemicals, electric power, maintenance, manpower, testing and residual disposal). Total costs were estimated as US $ 500 - 900 per 1,000 m³ of ballast water (AQIS 1993).

4.12 Shipboard treatment

The calculation of costs was based on the need of 0,5 million tonnes of ballast water that has to be treated per annum (in average one vessel per month).

4.12.1 Commercial vessels

The estimated capital costs to install e.g. a filtration unit (see below) for ballast water treatment are extremely high and therefore this method will probably not be established (AQIS 1993).

4.12.2 Treatment vessels

The costs involved for the floating treatment facilities were estimated as US $ 30;9 million based on a treatment capacity of 4,000 m³/h. This estimation includes purchase of the vessel (second hand), ship modifications and installation of (several) treatment units as well as additional pipework and power supply. Costs to operate the ship-based treatment were estimated as US $ 400 per 1,000 m³ and total costs summarise to US $ 790 per 1,000 m³ (AQIS 1993).

It has further been estimated that several land-based treatment plants (connected to the vessels by pipework or serviced by barges which collect the ballast water from the vessels discharging it later to the treatment plant on land) and treatment vessels were needed. The total costs to install treatment facilities (land-based and ship-based) in major Australian ports was estimated as US $ 470.4 million (AQIS 1993).

5 Ballast water regulations and associated guidelines in place and planned

Ballast water management and control regulations and associated implementation guidelines are being developed by IMO. IMO is concerned in regard to uni-lateral actions that have been developed or are considered by port states regarding the control of ballast water discharge in their ports or in areas under their jurisdiction. Currently there is no cost effective, technically sound, safe and environmentally safe treatment method for ballast water available. It should also be noted that the IMO voluntary international ballast water guidelines (resolution A.774 (18), since November 1997 replaced by resolution A.868 (20) have so far been applied in a relatively small number of countries only.

5.1 Intergovernmental requirements to deal with ballast water and / or non-indigenous species

In fact there are a number of recommendations and guidelines in place or under consideration in various regions dealing with non-indigenous species:

To regulate the working with non-indigenous species internationally several international working groups were formed. The first initiative which was supported 1969 of the American Fisheries Society and the Society Of Ichthyologists And Herpetologists was the Invitational Conference On Exotic Fishes And Related problem (Lachner et al. 1970, Kohler & Courtenay 1986). Several quarantine methods for the import of exotic species were developed.

An increasing number of countries have become aware of non-indigenous species and their potential threats posed to the environment, human health and economy as shown. The need to take common action has been recognized with several taxa, e.g. at the expert workshop on introduced species organized by DG XII and CIESM in Monaco 1993 (European Commission 1994). At the International Council for the Exploration of the Sea (ICES) Annual Science Conference at Aalborg, Denmark in 1995 the ballast water issue was the opening theme session and documenting the international interest and importance of this issue. ICES´ Advisory Committee on the Marine Environment (ACME) identifies introductions and transfers of non-indigenous organisms as one of the six major environmental issues within the ICES area over the next decade (ICES 1995 a, b).

Risks in relation to transfers of harmful species by aquaculture in ICES member countries are now considerably reduced because deliberate introductions of species should follow the 1994 ICES Code of Practice. As to minimize the risk of negative effects of introductions through aquaculture, six countries (Ireland, Island, Norway, Spain, The Netherlands and the United Kingdom) reported that the ICES Code of Practice is applied. Germany and Sweden are well aware of the Code of Practice, but the extent of this application is uncertain.

Among most of the following regulations marine introductions are largely ignored. This points out the need for an international and effective regulation to deal with non-indigenous species introduced by shipping as one of the most important factors for unintentional introduction into aquatic environments.

HELCOM

The Helsinki Commission which administrates the Convention on the Protection of the Marine Environment of the Baltic Sea Area, at its 16th meeting in 1995 considered the issue of unwanted organisms in ballast water as a matter of highest priority of Helcom Activities (item 15).

EC, Environment Committee, Marine Committee (MC) (MC 21/15)

Paragraph 5.1 The Committee noted document MC 21/5/1, submitted by Russia, concerning the proposal for a Baltic Strategy related to harmful marine organisms in Ballast waters.

Paragraph 5.3 Furthermore, the Committee encouraged the Contracting Parties to apply the IMO Assembly Resolution A.774 (18) for preventing the introduction of unwanted aquatic organisms and pathogens from ship´s ballast water and sediment discharges (Assembly Resolution A.774(18)) and to submit information on experiences in their application to the next meeting of the Committee.

OSPAR

The OSPAR commissions responsible for the administration of the Oslo and Paris Conventions for the Prevention of Marine Pollution concerned the hazards caused by non-indigenous species on the agenda of the Working Group on Impacts on the Marine Environment (IMPACT). At IMPACT 1996, Sweden presented an overview on national activities concerning non-indigenous species in the Convention Area. IMPACT 1996 made a number of proposals concerning non-indigenous species to its parent committee ASMO (Assessment and Monitoring Committee) e.g.: a report on non-indigenous species should be updated and included into the Quality Status Report of the Convention Area prepared for the year 2000. The monitoring of non-indigenous species will also be included in the Commissions Joint Assessment and Monitoring Programme (JAMP) and ICES has been requested to consider a reporting format for non-indigenous species.

EIFAC

The EIFAC (European Inland Fisheries Advisory Commission of the Food and Agricultural Organization of the United Nations) Code of Practice was adopted in 1987 dealing with quarantine measures of intentionally introduced species.

ICES

In 1991 the ICES (International Council for the Exploration of the Sea) Code of Practice to reduce the risks of adverse effects arising from introductions and transfers of marine organisms was prepared by the Working Group on Introductions and Transfers of Marine Organisms (WGITMO) (see above).

IMO

A first guideline for Preventing the Introduction of unwanted Aquatic Organisms and Pathogens from Ship´s Ballast Water was adopted in 1991 by the Marine Environment Protection Committee (MEPC) of IMO. The Ballast Water Working Group prepared new guidelines which were adopted by the IMO Assembly in 1997 (see below).

Bern Convention - Convention on the Conservation of European Wildlife and Natural Habitats, 1979, requires that parties shall undertake to strictly control the introduction of non-native species, Article 11.2.

Council Directive 79/43/EEC of 2nd April 1979 on the Conservation of Wild Birds

Member States shall observe that any introduction of bird which does not occur naturally in the wild state in the European territory of the Member States does not prejudice the local flora and fauna.

United Nations Convention on the Law of the Sea, 1982

Article 196 provides that States shall take all measures necessary to prevent, reduce and control the intentional or accidental introduction of non-indigenous species, or new, to a particular part of the marine environment, which may cause significant and harmful changed thereto.

Bonn Convention - Convention on Nature Conservation and Landscape Protection, 1982

States have to prevent, control or eliminate non-indigenous species that are detrimental to the migratory species of wild animals (Article III.4 and Annex I, Article V.4)

Benelux Convention on Nature Conservation and Landscape Protection, 1982

The Benelux Convention provides that Benelux governments prohibit introduction of non-native species into the wild without authorisation (Article 11)

Barcelona Convention 1982

The Convention addresses the subject non-indigenous species and associated impacts in respect of protected areas. The protocol concerning the Mediterranean Sea as a specially protected area obliges Parties to take measures in order to protect these areas. The measures may include the prohibition of the introduction of exotic species and the regulation of the introduction of zoological and botanical species in protected areas.

The Recommendation No. R(84) of the Council of Europe. Ministers of the Member States Concerning the Introduction of Non-Indigenous Species did not focused especially on the aquatic environment.

EC Council Directive 1866/86

The directive lists measures to protect the fishery resources of the Baltic, Belt Sea and Öresund. The release of non-indigenous species in these areas is prohibited. The intentional or un-intentional release of non-indigenous species in the mentioned areas of the Baltic represents and infringement.

EC Council Directive 91/67/EEC

All EU member countries have to comply with the EC Council Directive concerning health requirements for the translocation of aquaculture concerning the animal health conditions governing the placing on the market of aquaculture animals and products). The directive allows the free movement of live fish and shellfish across national borders between cultivation units and zones of similar health status.

Rio Convention on Biological Diversity, 1992

In the Convention on Biological Diversity (Article 8.h.) 155 member states undertake actions to „prevent the introduction of, control or eradicate those non-indigenous species which threaten ecosystems, habitats or species„ as far as possible and appropriate. This convention has been ratified by 148 States and the European Community (1996) and offers therefore an opportunity to approach globally the issue of intentional and unintentional introductions of non-indigenous species and their eradication and control (Glowka & de Klemm 1996).

Council Directive 92/43/EEC of 21st May 1992 on the Conservation of Natural Habitats and of Wild Fauna and Flora

Member States shall ensure that deliberate introduction of any non-indigenous species into the wild is regulated so as not to prejudice natural habitats within their natural range or the wild native fauna and flora and, if they consider it necessary, prohibit such introduction (Article 22.b).

Agenda 21

In 1992 the United Nations Conference on Environment and Development (UNCED) provided in Agenda 21, Chapter 17 on the Protection of the Oceans and All Kinds of Seas that IMO consider „the adoption of appropriate rules on ballast water discharge to prevent the spread of non-indigenous organisms“.

The Recommendation No. 45 of the Council of Europe on controlling proliferation of *Caulerpa taxifolia* in the Mediterranean Sea. The recommendation was adopted in 1995. It was recommended e.g. to control *C. taxifolias* spread by routine exploration, eradication of colonies and spread the information in countries not Party of the Bern Convention.

EC Regulation No. 338/97 (CITES)

The new EC regulation on the protection of species and wild fauna and flora by regulating trade therein - CITES (The Convention on Trade in Endangered Species) - 338/97, contains specific reference to the control of non-indigenous species. Article 3(2)(d) States that Annex B shall contain „species in relation to which it has been established that the introduction of live specimens into the natural habitat of the Community would constitute an ecological threat to wild species of fauna and flora indigenous to the Community„. Such species will therefore require import and export permits (Article 4(2)(a)) and impose restrictions on countries of origin (Article 4(6)(d)). To date the only species added to Annex B specifically for this purpose are the American Bullfrog and the red-eared terrapin, both traded by the pet shop trade with invasive capacities (seen in the UK).

IUCN

In 1987 a Position Statement on Translocation of Living Organisms was compiled for the International Union for Conservation of Natural Resources (IUCN) this organization prepared a updated position statement on trade in non-indigenous species for the CITES Conference of the parties in June 1997, supporting a proposal by the USA and New Zealand encouraging CITES to: „recognize that non-indigenous species can pose significant threats to biodiversity...; recognize that CITES may play a significant role in this issue; and other recommendations... including implementation of IUCN´s Invasive Species Specialist Group guidelines for the prevention of biodiversity loss due to biological invasions (Report of the ICES WGITMO, La Tremblade, France 1997).

5.2 National regulations in place

In addition to the listed guidelines, regulations and requirements for the control and management of ships` ballast water some countries have established ballast water regulations:

5.2.1 Europe

The IMO Assembly Resolution A.868 (20) is to be applied in Sweden in national law as voluntary guidelines. Spain, Ireland and the Netherlands consider the implementation of the IMO Assembly Resolution A.868 (20) or any national regulations. Ireland is planning to regulate the ballast water discharge at the oil terminal of Bantry Bay. Authorities in the Netherlands are awaiting results from a research project currently carried out as an initial desk study (see above) and probably extended for ship sampling as well as results from a co-operative ship sampling of ships calling for Rotterdam and ports in the Chesapeake Bay region.

United Kingdom

The United Kingdom has some kind of practice in place to minimize the risk of unintentionally introduced species via ship´s ballast water. Compliance with IMO Assembly Resolution A.774 (18) was requested by 10 of 66 ports. A national quarantine procedure in regard to ballast water management is used in 4 of 66 ports (Macdonald 1994).

At the time of these surveys the ports applying procedures in compliance with IMO Assembly Resolution A.774 (18) were Flotta, Glensanda, Hound Point, Nigg, Sullom Voe, Barry, Berwick, Cardiff, Fowey and Milford Haven, i.e. 10 ports of the 66 (UK total) where ballast water is discharged.

The United Kingdom has developed management policies on ballast water to protect the marine environment. In Scotland, planning applications associated with he development of coastal activities have brought this issue in the public spotlight. In addition to the introduction of organisms from abroad the marine environment managers are aware of the possibility of secondary transport within the United Kingdom. Various agencies require advice on ballast water management strategies for example in relation to coastal planning applications or in the case of port authorities reviewing or designing ballast water management and treatment options (Macdonald & Davidson 1997).

A questionnaire was sent to 127 ports in England and Wales, 111 (87.4%) of which responded. Ballast water is discharged into just under half (48.7%) of ports in England and Wales. Most ports (79%) have no policy or regulations on management of ballast water discharge. Of the 13 ports which do have regulations, these are mainly related to operational safety. Only five ports request ships to apply IMO Assembly Resolution A.774 (18) on ballast water management now replaced by the IMO Assembly Resolution A.868 (20) (Laing pers. comm.).

5.2.2 Black Sea

Most introductions of non-indigenous species result from ballast discharge and sediment from vessels after ocean crossings. Georgia is an exporting country. Most vessels arriving in Georgian ports discharge ballast and then load oil. According to the Convention on the Protection of the Black Sea emptying segregated, un-contaminated ballast water is allowed. But different countries of the region enforce the Convention differently. For example, vessels calling for the port of Odessa have to change their ballast water immediately upon entry into the Black Sea area. This has to be recorded in the ship logbook. This policy is not a viable solution, since ballast waters are emptied upon arrival in the Black Sea.

5.2.3 Israel

Israel requires, since 1996, that a ship must exchange any ballast water on board which was not pumped on board in open ocean. Ships visiting the port of Eilat must exchange their ballast water outside the Red Sea and those visiting Mediterranean ports of Israel must exchange ballast water in the Atlantic ocean. It was noted that the best way to exchange the ballast water is in the open ocean, beyond any continental shelf or freshwater impact. Vessels failing to comply will not be permitted to exchange ballast water in Israelian waters. It is expected that a record of location, date and time of the ballast water exchange in open ocean waters should be documented in the ship´s log book or other suitable documentation as e.g. an official record book on ballast water operations. Ship masters are requested to complete a ballast water exchange report (State of Israel, Ministry of Transport, Administration of Shipping and Ports, Notice to Mariners No. 4/96, Galil & Hülsmann 1997).

5.2.4 North America

Canada and the USA applied the IMO Assembly Resolution A.774(18).

5.2.4.1 Canada

The Canada Shipping Act (CSA) places numerous requirements on the shipping industry in Canada, including registration of ships, certification of officers, working conditions for seamen, safety, pollution prevention and liability. In addition, the Act gives the Minister of

Transport the authority to pass regulations in many areas. There are over 100 regulations which have been promulgated under the Act. The CSA and its associated regulations may be found on the internet (see below).

The Canada Shipping Act (CSA) does currently not include federal regulations concerning the prevention of harmful introductions of non-indigenous species through ballast water or sediment discharges. However, the following guidelines and area specific requirements are currently applied:

- Notices to Mariners #995 has imposed ballast water discharge restrictions for the Grande Entrée Lagoon of the Iles-de-la-Madeleine to reduce the threat of introduction of toxic phytoplankton to local mussel farming industries since 1982. Under this notice discharging of ballast water within 10 nautical miles of the Islands is prohibited unless the ballast water were pumped on board in a designated area off Canada's east coast at minimum distance of 5 miles from the shore;
- The governments of Canada and the USA signed the Great Lakes Water Quality Agreement in 1987. This agreement was established to co-operate in development and implementation of Remedial Action Plans, Fishery management Plans and lakewide Management plans. The pollution from ships (including ballast water) was addressed in this agreement as well. The goal of the plans is the identification of necessary remedial actions to reduce pollution to the Great lakes; and
- Canadian guidelines for controlling ballast water discharge into the Great Lakes were introduced in 1989 by the Canadian Coast Guard. The Canadian Coast Guard developed these guidelines in full consultation with the U.S. Coast Guard, the Department of Fisheries and Oceans, the Great Lakes Fishery Commission and representatives from commercial fishing. These guidelines apply for all vessels carrying ballast water with an origin from outside the Exclusive Economic Zone (EEZ, beyond 200 nautical miles from the shoreline). The guidelines encourage all vessels transiting the Eastern Canadian Region Vessel Traffic Service Zone inbound for the St. Lawrence River and the Great Lakes to exchange freshwater ballast collected in foreign harbours or near coastal waters for saltwater ballast collected from open ocean. The exchange was to occur far enough from any coastline such that the new ballast water contained few organisms, if any, that could survive in the freshwater of the Great Lakes (MEPC34/INF.22). The exchange of the ballast water has to be carried out if the required port of call lies west of 63° W longitude (SGBWS 1997). The ballast water exchange has to be carried out at depths greater than 2,000 m. If this is not feasible ships are permitted to

exchange their ballast water in a "backup exchange zone" within the Laurentian Trough of the Gulf of St. Lawrence east of 63° W longitude in water depths greater than 300 m. A ballast water exchange form has to be completed listing information on ballast water on board and compliance of the guidelines. A fine of max. CAN$ 50,000 may be imposed for providing false information (Gauthier & Steel 1996,. Hartwig et al. 1996).

In addition, very recently the Vancouver Port Corporation (VPC), B.C. introduced a ballast water exchange programme. Vancouver has become the first Canadian port to make a complete midocean exchange of ballast water of all incoming ships from abroad on a voluntary basis if the vessels carry ballast water in excess of 1,000 tonnes. Vessels carrying ballast water from the Cape Mendocino, California north, including Alaska are exempted. On arrival at the port documentary evidence of the exchange is required via a log entry or any other administrative format. Any vessel unable to provide the information is not permitted to discharge ballast water in the harbour area. These vessels will have to depart and exchange the ballast water in the outgoing current of the Strait of Juan de Fuca. Acceptable reasons for the avoidance of an midocean exchange of the ballast water are stress from weather conditions, stability or hull stresses. Vessels which used bad weather conditions as excuse for no ballast water exchange for numerous visits will be randomly sampled after reporting the midocean exchange was carried out to confirm their announcements. Following the official launch of the programme in March 1997 a nine month reprieve period will be established before the regulation becomes mandatory in January 1998. The VPC announces that the regulation have been well received by the industry as well as the community.

Recently, as a result of the preliminary draft being prepared by the Vancouver Port Co-operation a working group of the Puget Sound - Georgia Basin International Task Force, recommends that other ports in British Columbia follow the regulations of the Vancouver Port Corporation (Kieser pers comm.).

5.2.4.2 USA

In 1990, the U.S. Congress approved the Non-Indigenous Aquatic Nuisance Prevention and Control Act. The Act established ballast water management guidelines for vessels entering the Great Lakes. These regulations became mandatory in 1992 and have been incorporated in the Title 33 of Code of Federal Regulations (33CFR). The Act also established a Aquatic Nuisance Species Task Force responsible for co-ordinating efforts related to non-indigenous aquatic nuisance species in US waters and is composed of representatives from the National Oceanic and Atmospheric Administration (NOAA), U.S. Fish and Wildlife Service (FWS), Army Corps of Engineers, Department of Agriculture, Department of State, Environmental Protection Agency and the U.S. Coast Guard. The Coastal Waters Project, located at Rockland, Maine is attempting to further the efforts of the Aquatic Nuisance Species Task Force, particularly in the Gulf of Maine region States and North Carolina (Huber pers. comm.). The task force is responsible for developing and implementing an Aquatic Nuisance Species (ANS) Programme to prevent the introduction and dispersal of ANS, monitor, control and study ANS and disseminate related information. The ANS programme has undergone public review and was submitted to the U.S. Congress in 1993. In early 1994 the U.S. Congress has taken into account the growing problem of introduced species via ballast water discharge of vessels (Crosby 1994, Edwards 1994).

In 1996 the U.S. Congress re-authorized the Act to providea programm for ballast water management to prevent the introduction and spread on non-indigenous species into the waters of the United States and for other purposes (preferred cited as: National Invasive Species Act of 1996) was established on October 26th 1996 (Public Law 104-332-Oct.26.,1996).

In addition to previously mentioned aspects, the legislation also mandates a national ballast water management demonstration programme to test and evaluate technologies and practices. Currently ballast water exchange is voluntary but under the amended act it must become mandatory if the voluntary compliance is not adequate. Currently the salinity of ballast water is tested to verify the compliance with the required exchange of ballast water at sea. Vessels would be expected to exchange any ballast water at sea before entering US waters and ports**.** An increase of funding of over US$ 2 Million had been made available to cover costs in relation to compliance procedures, in total US$ 33.17 Million This is an indication of the tremendous costs involved controlling the establishment of non-indigenous species in your waters.

In 1992, The Coast Guard published a notice of proposed rulemaking entitled "Ballast Water Management for Vessels Entering the Great Lakes" in the Federal Register (57 FR 45591). The final regulation implements the regulatory requirements of the Non-Indigenous Aquatic Nuisance Prevention and Control Act 1990, Public Law 101-646. The Act required the U.S. Coast Guard, in consultation with the Government of Canada, to issue voluntary guidelines to help prevent the additional introduction and spreading of aquatic nuisance species into the

Great Lakes through ballast water of vessels, by 1991. The U.S. Guidelines are comparable to those of the Canadian Coast Guard (see above). Including those vessels that only partial exchange, the participation by the commercial shipping industry has been estimated to be 90% of voluntary compliance as monitored through salinity measures of the ballast on board indicating the amount of ballast water exchanged in cases where the last port of call was in brackish or freshwater areas. Currently the U.S. Coast Guard carries out research in regard to a method to assess whether sufficient exchange has occurred in vessels arriving to and from saltwater ports (Carlton & Cangelosi 1997).

The regulations will replace the voluntary guidelines. The act requires that the regulation apply to vessels that enter a U.S. port of the Great Lakes after operating in waters beyond the Exclusive Economic Zone (EEZ) (in a depth of not less than 2,000 meters). The Act further requires that the regulations shall prohibit the operation of a vessel in the Great Lakes if the master of the vessel has not certified to the Secretary or Secretary's designee, by not later than the vessel's departure from the first lock in the St. Lawrence Seaway, that the vessel has complied with the requirements of the regulations. The Act provides civil and criminal penalties. Any person who violates the regulations shall be liable for a civil penalty not to exceed US$ 25,000**.** The Act provides a three year window-of-opportunity for vessels arriving in U.S. ports to exchange their water on the high seas. After this period of time the U.S. Coast Guard will assess the level of compliance with this regulation. If levels are found to be insufficient, ballast exchange will become mandatory.

The currently most practical method to protect the Great Lakes from the introduction of unwanted non-indigenous species may exist in the exchange of ballast water of incoming vessels in the open ocean beyond the continental shelf (depth exceeding 2,000m). If this option is impossible to carry out one of the following actions have to be taken:

- return to sea and undergo ballast water operations
- retain the vessels ballast on board
- use alternative environmentally sound method of ballast water management or under extraordinary conditions (safety, weather conditions or equipment failure) discharge ballast water in designated areas. Requests of this methods have to be given to the commandant of the U.S. Coast Guard.
- discharge ballast water to land based facilities or to reception vessel

In addition:

- no sediment should be discharged from tanks or holds containing ballast water unless it is disposed of ashore
- ballast water carried in any tank containing oil or any other contaminants must be discharged in accordance with the applicable regulations.

Nothing in this regulation relieves the master of the responsibility for reinsuring the safety and stability of the vessel or the safety of the crew and passengers or any other responsibility (MEPC34/INF.22, Carlton & Cangelosi 1997).

In 1993 the U.S. Coast Guard rule requiring Ballast water management practices for vessels entering the Great Lakes after operating on waters beyond the U.S. exclusive economic zone became effective (MEPC34/INF.31).

In November 1996, the United State passed the National Invasive Species Act (NISA), which requires that vessels entering US waters from the outside the 200 mile Exclusive Economic Zone (EEZ) must exchange their ballast water before entering the EEZ. The guideline is initially voluntary, but would become mandatory after two years if compliance was recognized as insufficient.

In 1996, reauthorizing legislation expanded that programme to include all US waters and coastlines. The Coast Guard is currently developing its specific regulations pursuant to the latter statute. If they resemble the Great Lakes programme (and this is likely) they will request that vessels entering US waters after operating outside the EEZ undertake high-seas ballast exchange or an alternative ballast management measure approved by the Coast Guard which is equally effective or more effective than ballast exchange prior to entering US waters. This leaves the door open to alternate technologies as they are developed. This national protocol will be "voluntary" for at least three years, depending upon compliance under a voluntary regime. If after three years, the Coast Guard determines that compliance is not adequate then the Coast Guard must add an enforcement component to the programme. Thus, industry has the opportunity to police itself. However, if that system fails to achieve adequate participation, then the Coast Guard must undertake the policing role (which it already does for the Great Lakes) (Cangelosi pers. comm.).

5.2.5 Latin America

Panama

Discharges of any kind of ballast water is prohibited in the Panama Canal.

5.2.6 South America

Argentina

Since the beginning of the 1990s, the port authorities of Buenos Aires require a chlorination of ballast water of ships calling for their port. This binding instruction is still in practice. Chlorine is added to the ballast water via ventilation tubes of the tanks. In Argentina, inspection crews are randomly visiting the vessels in order to control the compliance with this instruction (Capt. Rabe, Capt. Katzenbach pers. comm.).

Chile

Unilateral mandatory requirements for preventing introductions of harmful organisms from ballast water are in place, adopted in 1995. The "order for preventive measures to avoid transmission of harmful organisms and epidemics by ballast water" states that any ship coming from zones affected by cholera or a similar contagious epidemic is requested to renew the ballast water at a minimum distance from the coast of 12 nautical miles. The ballast water operation has to be documented in the bridge or engine room logs. In cases where no proof of the ballast water exchange is available chemicals must be added to the ballast water prior deballasting in a port. Per tonne of ballast water 100 grams of powdered sodium hypochloride or 14 grams of powdered calcium hypochloride has to be added allowing in minimum 24 hours to elapse before beginning the emptying process (MEPC/Circ.308, Gauthier & Steel 1996, Sipes et al. (eds.) 1996).

5.2.7 South Africa

A number of exotic marine species have already become established in South African waters resulting in potential negative impacts as shown by the occurrence of the toxic dinoflagellate *Gymnodinium* sp. Because of the rapid growth of the South African mariculture business serious consideration should be given to instituting a control over ballast water discharge.

The need to protect the South African mariculture industry, South Africa is a signatory to the International Convention for the Prevention of Pollution from Ships 1973/78 (MARPOL). The provisions are enacted into domestic legislation in the forms of the International Convention for the Prevention of Pollution from ships.

The South African Transport Service Act 65 of 1987 (now applicable by virtue of the Legal Succession to the South African Transport Services Act 9 of 1989) provides the control of waste discharges in port areas. In the act waste is described as "stones, gravel, ballast, cargo dirt, ashes, bottles, rubbish ...".

Since it is likely that international legislation to control ballast water discharges will take the form of an Annex to MARPOL, it is important that South Africa recognized the need to give attention to this issue. An additional consideration is that there have been suggestions that ports „exporting" ballast water contaminated with potentially harmful organisms could be held liable for any subsequent damage. While the question regarding liability might be uncertain, South Africa emphasises that there would be no harm in guarding against it (Pughiuc & Dianrong 1998, Jackson in prep.).

5.2.8 China

China is concerned about the introduction of non-indigenous species since the prawn industry suffered from introduced bacteria or pathogens in 1993 and 1994. The total loss was estimated to be higher than 363 million US$. In addition in 1993 a total of 19 red tides were observed along the Chinese coastline. In China a total loss of about 60 million US$ is caused by red tides each year.

Three government authorities are involved in ballast water management: Maritime Safety administration (or Harbour Superintendency Administration), the Frontier Health and Quarantine Authority and the Frontier Plant and Animal Quarantine Authority. Ballast water discharges are mentioned in two national instruments: the Regulations Governing the Prevention of Pollution from Ships and the Frontier Health and Quarantine Law of the People's Republic of China.

Ballast water regulations include requirements to report to the Harbour Superintendency Administration prior the discharge of the ballast water a) the quantity of ballast water to be discharged, b) the origin of the ballast water, c) whether the ballast water is oil contaminated or free of oil and d) whether the vessel is equipped with a separate pipe system for ballast water operations.

If the area of origin of the ballast water is listed as infected point by the World Health Organization, the Chinese Health Authority requires a ballast water treatment gefore discharging the ballast water in Chinese ports or waterways. In case, a quarantine officer will enter the vessel and a chemical ballast water treatment on board will be carried out with biocides. The most frequently used biocides contain chlorine compounds (Pughiuc & Dianrong 1998).

5.2.9 Australia

In 1990, the Australian Quarantine and Inspection Service (AQIS) introduced voluntary ballast water management guidelines for ships entering Australian waters. These guidelines were formed to minimize the amount of ballast water and sediments discharged in Australian water loaded abroad. The guidelines are based on the IMO international ballast water guidelines of Assembly Resolution A.774 (18).

In addition ships need to report to the port authorities where the ballast water comes frm, if they are going to discharge ballast water in Australian ports.

The Australian Ballast Water Management Advisory Council's (ABWMAC) membership consists of parties of the shipping industry, Australian Maritime Safety Authority, State and Territory Governments, seafood production industries, ports and harbour administration, Australia Quarantine and Inspection Service, research agencies and the Governments environmental management. The Council is responsible in the first instance for the provision of advice to the Minister and all relevant agencies to oversee the administration of its Ballast Water Strategy defined as: "to seek to avoid adverse economic and environmental impact of unwanted aquatic marine organism by minimizing their risk of entry, establishment and spread in Australian marine environment from ballast water and other shipping activities involving international and domestic shipping, whilst not unduly impeding trade" (Hutchings 1992, MEPC37/INF.24)

P&O bulk carrier serving regularly between Australia and Japan exchange their ballast water in open ocean, during calm weather conditions where ballast water exchange places no stress on the ship and poses no threat to safety on the crew. Compliance with the guidelines is

monitored by AQIS staff members. About 80 % of the ships entering Australian ports in the beginning of the 1990s reported compliance with the guidelines (Jones 1991) and 90 % of all Australian shipping industries has either entered into compliance with the arrangements of the AQIS or were in the progress of doing so in the near future. Overall 65 % of vessels claimed to re-ballast at sea and 13 % undertook not to release ballast water in Australian waters. The major non-compliers are the general cargoes and tankers with 76 % of these vessels not complying the guidelines (MEPC33/INF.26). Possibly this could reflect the fear of the Masters concern of structural stresses to the hull during mid-ocean exchange of ballast water.
Bulk carriers have a high level of compliance with the guidelines as shown by 83 %. Container vessels also have a high level of compliance with 89 %.
In 1991/1992 a random sampling programme on ships arriving Australian ports from overseas destinations was carried out. Of about 200 samples only 11 contained toxic dinoflagellates of the Alexandrium spp. Most of these samples were taken out of ballast water of Asian origin, mainly from ports in Japan, China and Korea (MEPC33/INF.26).

5.2.9.1 Australia's International Guidelines for Shipping

Strategies for Minimizing the Introduction of Unwanted Aquatic Organisms and Pathogens from Ship's Ballast water and Sediment Discharges
These guidelines include e.g. ship operational procedures as ensure to load clean ballast, avoid taking on ballast water in shallow areas, areas of dredging, areas with known outbreaks of diseases or phytoplankton blooms. When taking on ballast water records should be made upon date, geographical location, salinity and amount of ballast water taken on board. All sources of sediment on board (e.g. anchors, cables, chain lockers) should be cleaned. In addition, options for ballast water management are listed:
- non-release of ballast water wherever possible
- ballast water exchange and sediment removal in deep ocean areas
- produce evidence of the re-ballasting at sea en-route
- if at sea exchange of ballast water is not possible, carry out flow through exchange
- designate a responsible officer on board familiar with the procedures which should be included into the ship's operational manual.
- document actions that have been taken

In cases appropriate control actions have not been taken, the vessel is allowed to discharge its ballast water normally based on risk assessment results taken into account the type of vessel, its origin, risk factors at the port of entry including tidal flow and distance to aquaculture facilities or withholding discharge until samples of water / sediments are taken, analysed and fount free of harmful organisms or giving the vessel the option of departing Australian territorial waters to carry our appropriate re-ballasting. In exceptional circumstances operations may be carried out in Australian territorial waters after agreement with AQIS and after consultation with State and local authorities (MEPC37/INF.24)

5.2.9.2 Australian Coastal Ballast Water Guidelines

The Australian Agricultural Council agreed in 1991 upon a need for coastal and interstate shipping. The Australian Coastal Ballast Water Guidelines were formed.

As international guidelines do not provide a satisfactory solution for the majority of domestic coastal vessels, additional guidelines were developed to minimize the spread of harmful exotic marine organisms between ports. A system should be introduced for the management of ballast water that is taken in Tasmanian waters by vessels that afterwards call for other Australian ports. This practice could minimize the translocation of the Northern Pacific starfish and Undaria seaweed to other Australian ports. The system should also apply immediately to any other port where a toxic algal bloom exists or becomes present.

The guidelines consist of the following options:

- port authorities will inform other ports the presence of toxic algal blooms
- port authorities are being made responsible for issuing permission to ship's masters for the discharge of any ballast into their ports
- use of certification of port contamination / health / clearance from the ballasting port
- effective management for the uptake of ballast water in contaminated ports minimize the risk of uptake of this species on board the ballasting vessel
- re-ballast at sea or in defined areas or taking on ballast from "clean areas"
- on board in-tank treatment systems (not currently available)
- commitment not to discharge ballast water
- discharge ballast in defined areas

Other optional practices include avoiding taking on ballast during toxic algal blooms or in shallow areas, ensurance that ballast water is free from sediment wherever possible, ensurance that ballast tanks are being kept clean, ballasting of freshwater during toxic algal bloom if available (MEPC37/INF.24)

5.2.10 New Zealand

After initial research in 1989 the Cabinet Environment Committee directed officials from the government departments to develop a policy that will minimize the risk of the introduction or establishment of exotic marine organisms through the discharge of overseas ballast water. The New Zealandian Ballast Water Working Group (BWWG) decided in 1991 that in the interim the most practical and effective way to restrict ballast water discharge would be to institute a set of voluntary controls on the discharge of overseas ballast water within New Zealand. Modified guidelines from Australia were used in order to rapidly implement this policy. The guidelines are in place since March 1992. The purpose of the guidelines was to:

- reduce of the amount of overseas ballast water discharged in New Zealand;
- collect information from vessels that would outline the scope of the problem; and
- inform the international shipping community on New Zealand views on the issue of ballast water discharge.

It was recognized that an immediate ban on the discharge of ballast water with overseas origin was not suitable because of safety aspects. As New Zealand is dependent on international shipping and an immediate ban could preclude some vessels visiting the country.

The voluntary guidelines contain the following aspects:

Ballast water which had been loaded in the territorial waters of other countries should not be discharged in New Zealand waters without reporting to an inspector (border protection officer, of the Ministry of Agriculture and Fisheries) prior to discharge.

Evidence of the origin of the ballast water to be discharged should be given to the inspector and certification from a government or other approved agency that the water and seabed of the port at which the ballast was loaded has been tested within the previous 6 months and found to be free of toxic dinoflagellates, or documented evidence existed that the ballast water has been exchanged at sea on route to New Zealand, or documented evidence was given that the ballast has been disinfected.

If the vessel cannot provide documented evidence of the origin of ballast water and requires to discharge ballast water in New Zealand waters the ballast water should be discharged into an onshore facility or should be treated prior to discharge, or should allow a representative sample of the water to be taken for testing for the presence of toxic dinoflagellates. A nil result would allow ballast discharge in situ. In addition no sediment or mud from the cleaning of holds, ballast tanks or anchor lockers may be discharged in the sea in New Zealand without the permission of an inspector.

Since March 1992 officers of the Ministry of Agriculture and Fisheries have been monitoring compliance with the voluntary controls and collected data on the ballast discharged. In total 35 % of the vessels comply with the voluntary controls by exchanging their ballast water at sea; 57 % claim to comply by not having to discharge overseas ballast water while in New Zealand waters and 7 % cannot or will not comply. In-between the 7 % which did not comply the following reasons for doing so were noted: vessel to old to consider juggling the ballast, controls are voluntary (one master only), not aware of controls, sea conditions to rough for safe ballast exchange at open seas, master believes that ballast water from the Pacific Islands is safe and ship incapable of complying this voyage.

In addition to the Ministry of Agriculture and Fisheries the Department of Conservation has interests in ballast control stemming from two pieces of legislation:

- the Conservation Act which is an Act to promote the conservation of New Zealand’s natural and historic recourses; and
- the Resource Management Act the purpose of which is to promote the sustainable management of natural and physical recourses.

The Ministry for the Environment administers two statutes relevant to the control of ballast water discharge: the Environmental Act of 1986 and the Resource Management Act of 1991 (MEPC34/INF.3)

Controls are voluntary, i.e. there is no regulatory obligation to comply. However, where a specific biosecurity risk is identified, controls may be enforced. For example, following the discovery of the Pacific Seastar in Tasmania, the New Zealand imposed mandatory controls on discharge of ballast water from Tasmania. Controls on the discharge of sediment from overseas vessels are also mandatory. Sediment from the cleaning of holds, ballast tanks, or anchor chains can only be disposed of in a landfill approved by a New Zealand border official.

In 1998, New Zealand plans to formalise its controls through the introduction of an Import Health Standard (IHS) under the Biosecurity Act 1993. An IHS describes the conditions which must be met, in respect of biosecurity risk, before any "risk goods" may be brought into

New Zealand. The IHS will be developed in consultation with the shipping industry and other stakeholders. It will outline New Zealand's requirements for ballast water discharge and options to satisfy an Inspector. The desired outcome is that water that does not comply with this standard will not be discharged within New Zealand territorial waters.

An IHS provides the regulatory approach called for by most of the submissions on the 1996 Public Discussion Paper. However, it is not intended to impose sanctions (e.g. fines etc.) immediately, unless a specific organism present in a specified overseas port is considered a risk to New Zealand as is currently the case for northern pacific seastars from Tasmania. These instances will be made known to mariners (Ministry of Fisheries, New Zealand 1997)

6 Further approaches in development

6.1 Risk assessment

A structured approach to decision making concerning the risk posed by individual vessels is highly desirable for the effective administration of any country's ballast water management regime. Critical factors can be taken into account concerning the potential risk posed by any vessel voyage and as a consequence the action required of an individual vessel (MEPC40/INF.7).

6.1.1 Decision Support System

As a possible way of minimizing the risk of introducing non-indigenous species with ballast water, Australia has proposed a Decision Support System. This system is designed to evaluate the risk posed by each incoming vessel due to arrive in a given port. The Decision Support System is composed of a risk assessment system and a decision support framework. The risk assessment component takes into account such criteria as the port of uptake of the ballast water (climate and species composition), the treatment of the ballast water en-route, the tolerance of the species which could have been taken onboard with ballast water and transported to the area of planned discharge and the estimated survival rates of the species in the ballast water during its voyage. The estimation of the survival rate is based on results achieved through sampling a ballast tank before departure as well as immediately after the ballast water uptake and further respectively during the voyage. Other factors in this estimation are the length of the journey and the daytime of the ballast water uptake. Several studies sowed that with increasing time in the ballast tank the number of species and specimens decreased dramatically. The importance of the daytime of the ballast water uptake is due to the daily migration of species in the water column.

Vessels calling for Australian ports may come from more than 300 ports of 53 counties around the world introducing approx. 121 million tons of ballast water each year (Jones 1991, MEPC35/INF.19). In addition over 4,000 vessels per year move more than 34 Million tonnes of ballast water between Australian ports. The volume of water from overseas origin released in Australian waters is an indicator of the potential for further species introductions. The degree of risks depends also on the characteristics of the port of origin and port of arrival. Two very serious introductions to Australia (i.e. the toxic dinoflagellate *Gymnodinium* *catenatum* and the Japanese kelp *Undaria pinnatifida*) have occurred near the port of Triabunna (Tasmania) despite the fact it receives relatively little ballast water.

Any vessel that is considered to be of high risk might be required to follow a port authority contingency plan. A generic plan has been developed under Australia's strategic ballast water research programme (see above) which gives details for the procedure of safe de-ballasting in designated areas close to the port of call. The Decision Support Framework is a computerised programme summarising data input from the vessels as ballast water uptake and ship design. The programme is available on an internet server allowing agencies to add and extract data to enable decisions to be made on the potential risk involved. One key advantage is that a decision of the risk involved may be made prior the arrival of the vessel in Australian waters which enables the ships` crew to take action in advance (MEPC40/INF.7).

6.1.2 Port sampling, define hot spot areas

Monitoring species present in port waters could help to assess the risk involved with the uptake of ballast water. Monitoring carried out at least weekly, the ballast water uptake during the presence of phytoplankton bloom or mass occurrences of other (target) species could be avoided especially for ships departing port areas located in the same climate zone as the originating port of the ballast water.

6.1.3 Sampling an board

Ships could carry out sampling and analysis on board and send the results ahead to the port authorities of the next port of call. Each sample would have to represent the abundance of species of the entire ballast tank. In the case of container vessels, even if the crew knows which tank they were going to discharge in the next port of call, 10 different ballast water tanks might necessarily to be sampled.

A good sample would require on board manual to ensure the sample quality. The standardisation of sampling methods and especially marked sampling points for each type of ship **or preferred each single vessel** will be needed in order to standardize sampling procedures. A concerning manual will be prepared by the ICS and INTERTANKO listing (e.g.) sampling points on board and procedures for managing ballast on board (MEPC39/7/3).

In addition to the location of the sampling points a standardisation of sampling methods, including size and meshsize of the plankton net, number of hauls, depth of the sample, number of samples etc. is needed.
A larger problem will probably shows up after sampling. Each sample should be examined by an trained expert at least in determining its content as compared with a list of chosen target species. Because the time schedule on board is pressing additional manpower of trained experts as part of the crew in determining species is probably needed.

6.1.4 Target species

6.1.4.1 Australia

A list of target species representing high risk species, compiled by Australian scientists and authorities is in preparation. At present Australia's target species, recognized as harmful and unwanted, are:
- toxic dinoflagellates (e.g. *Gymnodinium catenatum, Alexandrium* spp.)
- North Pacific Seastar (*Asterias amurensis*)
- Cholera (*Vibrio cholerae*)
- Japanese Kelp (*Undaria pinnatifida*)
- Giant Fan Worm (*Sabella spallanzani*)
- European Shore Crab (*Carcinus maenas*)
- fish pathogens

The list will be modified from time to time as additional information is available (Paterson 1996. Lockwood pers. comm.).

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 problems of scheduling 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. Scholin *et al.* (1995) reviewed the feasibility of developing a rapid diagnostic test for cyst-forming dinoflagellates in ballast water. They concluded that while tests that met the criteria could be developed within 1–3 years, the costs involved could range as high as US$ 500,000. To date no similar review has been undertaken for other target species. In most cases identification of phyto- and zooplankton species require microscopic identification by specialists in the laboratory and positive identification of pathogens generally requires histological examination and / or laboratory culturing. Such procedures usually have turn-round times of a minimum of several days.

The occurrence of the introduced **North Pacific Seastar** (*Asterias amurensis*) in the Port of Hobart provides an opportunity to assess the effectiveness methods for sampling target species in ballast water and to test the application of rapid genetic screening techniques for the identification of larvae. CRIMP has an ongoing sampling programme for larvae of *Asterias* in the Port of Hobart which provides information on the seasonal abundance of larvae in port waters and earlier this year initiated a project to develop methods to genetically "finger print" *Asterias* larvae using PCR amplification techniques. It is anticipated that this technique will be ready for testing on larvae in ballast water samples soon.

Larvae in the Derwent Estuary reach peak concentrations in excess of 300 / cu. m and ballast loaded in the port during this period is almost certain to contain seastar larvae. Selected vessels will be sampled following ballasting in the port to establish concentrations of seastar larvae in ballast loaded at different times throughout the breeding season. If possible larvae will be resampled in deballasting ports to provide some initial data on the survival of *Asterias* larvae in ballast tanks. As this component will commence before sampling protocols have been fully assessed, standard water column sampling methods (nets or pumps) will be used for initial sampling. Material for genetic screening will be fixed in alcohol for PCR amplification and mDNA analysis. The possibility that this sampling programme will form part of a collaborative project with New Zealand agencies (Sutton, Martin pers. comm.).

6.1.4.2 USA

Information on North American target species are 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).
Biological pollution, in the form of exotic species, is now one of the leading threats to the ecological integrity of our forests, grasslands, and waterways. Surprisingly, these exotic species often strike at the heart of those natural lands and waters that we most cherish-our national parks and nature preserves. They also are pushing many of our rarest plants and animals even further toward the brink of extinction.

These non-indigenous species arrive here in many ways. Some are the product of misguided efforts to correct other environmental problems. Many non-native fish species were introduced for sport or recreation. Many more, however, end up here 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 our economy or ecology. This report entitled "America's Least Wanted", focuses on those intruders that threaten our nation's rich natural heritage.

The economic and ecological consequences of surrendering our shores to these foreign invaders make controlling them a national imperative. Safeguarding the United States' natural heritage from harmful non-indigenous species requires work on four fronts:

1. Prevention of Additional Introductions. The best and most cost-effective solution is to prevent the arrival of new non-indigenous pests in the first place. Once exotic species gain a foothold in a new area, they often are capable of spreading with breathtaking speed, making eradication and control efforts difficult or impossible-and almost always costly. One way to prevent the spread and introduction of fouling species (as e.g. Zebra Mussels or Hydrilla) is to clean boats and boating equipment before transporting them from one water body to another. Leave behind unused bait and bucket water. Clean your boots and camping gear before setting out for other regions or countries, and again before returning home. On horse-packing voyages, make sure that feed is certified weed-free.

2. Early Detection and Eradication of New Pests. Finding new outbreaks early, together with aggressive eradication campaigns, is the next best solution. Attacking the problem while it is still small and limited in range offers the prospect of total elimination, saving both money and natural resources.
3. Control and Management of Established Problem Species. If the invaders cannot be eradicated, or already are established, containing their spread and controlling their numbers can help minimize their effects on natural systems and biological diversity. Control efforts can vary enormously, relying on mechanical, chemical, or biological means, or employing environmental management strategies. Fighting exotic species within natural areas or around endangered species, however, presents special challenges to ensure that the control measures do not inadvertently cause further harm to these sensitive species or systems.
4. Protection and Recovery of Native Species and Ecosystems. Controlling problem species is not enough; the affected native species and ecosystems also must be restored and protected. Simply removing non-indigenous species without working to repair or restore the ecosystem conditions often leaves natural areas susceptible to re-invasion by the same or other pests.

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 our native species and ecosystems. The "Dirty Dozen" were chosen 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 (Nature Conservancy 1998).

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. Species in this list of low risk introductions should be removed after the first indication of an unexpected impact of the species and further importation should be forbidden (Ruesink et al. 1995, Wade 1995, Simberloff et al. 1997).

6.1.4.3 Nordic Countries

The finish study on Risk Assessment of Marine Alien Species in Nordic Waters will study beside other items (see above) the application of risk assessment models to one or more key / target species. A semi-quantitative model (low - medium - high risk) will be identified and applied to a vector of introduction and a target organism. Relevant parameters should be described, and data needs and availability identified. A tentative list of parameters for ballast water introductions could include, but not be limited to; vessel ballasting characteristics, ballast water treatment applied (if any), characteristics of donor and receiving ports or geographical areas, voyage route and duration, relevant biological information for the key / target species. Information on the key / target species could include, but not be limited to; environmental requirements such as temperature, salinity, and light / energy requirements during different stages of the life cycle (including resting stages), habitat requirements, known biotic interactions

6.1.4.4 Germany

During the German shipping study carried out from 1992 to 1996 all non-indigeneous species sampled from the ballast water, tank sediments and ship hulls were characterized by an estimated probability of establishment in German waters. All species were sorted into three categories. Category 1: establishment in German waters im-probable, category 2: establishment in German waters medium probale and category 3: establishment in German waters highly probable. The potential for an establishemnt was estimated in accordance to the scheme developed by Carlton (1985) taken into acount the climate in area of origin (donor area) and recipient area where the species could be introduced to.

Probability of colonization of non-indigenous species, according to matching salinity in donor and recipient region, after Carlton (1985)

	DONOR region		
RECIPIENT region	Fresh water	Brackish water	Salt water
Freshwater	high	medium	low
Brackish water	medium	high	high
Salt water	low	high	high

In addition a comparable scheme structure was employed to compare the salinity tolerance of the species and the salinity conditions of the receiving waters.

Probability of colonization of non-indigenous species, according to matching climate in donor and recipient region, after Gollasch (1996)

	DONOR region			
RECIPIENT region	Arctic & antarctic	Cold-temperate	Warm-temperate	Tropics
Arctic & antarctic	high	medium	low	low
Cold-temperate	medium	high	medium	low
Warm-temperate	low	medium	high	medium
Tropics	low	low	medium	high

It was concluded that along the German coasts freshwater, estuarine and marine areas are located and that the salinity might not be the limiting factor for successful species introductions. Therefore, all species native to cold-temperate climate areas were quoted in category 3: establishment highly probable. It was noted during the shipping study that the number of species and specimens decreased with an increasing duration in the ballast tank. Following this observation, species native to cold-temperate regions of the northern hemisphere of the Atlantic Ocean (North American east coast and the upwelling area off western Africa) were quoted as high risk species for an introduction due to the comparable short duration of the ships voyage and matching climates.

About 12 % (32 species) of the determined non-indigenous species were quoted in this category. Beside others the decapod Hemigrapsus penicillatus, native to the cold-temperate areas of Japan, was listed in this category. H. penicillatus is believed to be the most recent macrozoen invader to European waters (first record from French Atlantic coast). The introduction of H. penicillatus indicates that the applied model gives an useful estimation on the probability of establishment and therefore indicates the importance of matching climates in donor and recipient regions for the colonization of new habitats as well as short durations in a ballast tank for the survival during voyages.

7 Implementation problems / Removal of Barriers

The need to develop ballast water regulations of any kind is being demonstrated by the great number of non-indigenous species that have been intentionally and accidentionally introduced all over the world.

The IMO considered this matter as a global issue, emphasizing further the necessity to find a globally applicable effective, inexpensive and environmentally sound treatment option for ballast water.

7.1 Public awareness

In some countries awareness concerning the unintentional introduction of species and their potential harmful and sometimes disastrous impacts are unknown and need to be developed. One step forward would be the distribution of case histories on introduced species. In this way the potential negative impacts of such species introductions can be shown. Beside negative ecological impacts and commercial interests, the human health may be threatened as listed in chapter 2.

After creating awareness relevant to the issue, the next important and possibly most problematic fact would be to solve financial problems in regard to this matter.

Financial problems in relation to the establishment and implementation of ballast water treatment facilities or control measures do occur. The development of an inspection authority for the control of activities to minimize the risk of unwanted species introductions by ballast water is needed. In North America the Canadian and United States Coast Guards, in Australia the AQIS supervises the application of appropriate treatment or management options concerning ballast water on incoming vessels.

It seems to be complicated to develop such institutions, especially in countries which are not financially or politically stabilised. The identification and removal of barriers that permit the implementation of effective guidelines in developing countries is needed.

7.2 Financial aspects

The control of un-intentional ballast water imports will probably pay off in the longer run due to the minimization of negative ecological and ecological impacts. Costs for the implementation and control of ballast water treatment options or management strategies will result in benefits in regard to species which have not been able to establish. Especially the mariculture industry, as well as the touristic and other users of the sea will be effected by unintentionally introduced species introduced via shipping. The volume of trade of such businesses can be important to the economy of the entire country itself. In 1988 the world total aquaculture production was estimated to provide 14 million tonnes of food (FAO 1990).

If one of these industries is affected, impacts could results in nation-wide problems as shown in the Black Sea by the decrease in the anchovy fishery after the unintentional introduction of the ctenophore *Mnemiopsis leidyi* (see above). On the other hand, an introduction of a disease agent affecting target aquaculture species would result in a loss of mariculture harvest.

7.3 Political aspects

Other reasons to establish ballast water guidelines are the need to reach agreement on options in a region. To solve the problem in a comparable way in order to prevent international trade competition due to different costs involved in carrying out the required regulations. This approach would assist to prevent a decrease of ships calling for ports where the guidelines are implemented on a mandatory basis when at the same time neighbouring countries would not require any ballast water treatment or management control measures.

8 Recommendations

All non-native species are potentially harmful unless it is shown that the involved risks are low or the introduction of the species is even beneficial. Therefore it is most wanted to minimize the number of intentionally or unintentionally introduced species and specimens. Knowing that the eradication of introduced species requires great technical and financial efforts and that these activities are believed to be in-effective or impossible in some cases, preventing measures are needed.

As several shipping studies showed, each single vessel has the potential to carry or introduce non-indigenous species. The IMO guidelines represent a method to reduce this potential in removing most of the un-intentionally transported organisms in the ballast water. Mandatory regulations or guidelines minimizing the introduction of non-indigenous species would be of immense help to prevent unwanted introductions of harmful species. Therefore, it is concluded to enforce the application of this guidelines in a global scale.

The IMO guidelines have apparently so far been implemented in some countries and there is need to apply the guidelines in a broader scale due to the lack of other effective, technically and environmentally sound and safe treatment options. Therefore every IMO Member State is requested to implement the Guidelines.

It is concluded that many countries do not consider the ballast water issue as a major problem / danger. Therefore further activities should include the field of raising public awareness.
The importance of ballast water management and control as a means of human intervention to ensure the stability of aquatic ecosystem and biodiversity is not generally appreciated. Press releases could create a more realistic focus on the essential environmental concerns related to ships' ballast water and sediment and hull fouling while highlighting some potential preventive measures in order to minimize risks to changes or loss of biodiversity from transmitted species. In addition the early involvement of all involved authorities, institutions (of the scientific and non-scientific community) and parties is needed to develop and implement guidelines and regulations successfully. The development of ballast water management or control will be most effective at the international level. National approaches of this world-wide problem could end up in intricate regulations resulting in difficulties in

compliance. Verification methods for the compliance with the developed guidelines and / or regulations are needed in order to ensure the application of the se methods.

The concern of other working groups and experts, especially in the biodiversity and aquaculture section as well as ship constructors should be raised. Many reports on wastes or discharges from ships list pollutants as exhaust emissions, oil spills, halon, $CO_{2,}$, but do not include ballast water and tank sediments. being aware that ballast water and associated sediment discharges are not considered as pollutants as it has to be emphasized that they could cause severe damages to the environment.

Further research is needed in order to evaluate and judge so far empirical developed treatment options. The prediction of future introductions is impossible, until today. The development of new and improved practices dealing with ballast water and the training of ship crews in this field would provide a significant contribution towards the reduction of further species introductions. Studies should include the:

- effectiveness of ballast water treatment options;
- survival rate of organisms during ships voyages;
- effectiveness of risk assessment models;
- prevention of the spread of human diseases (as e.g. Cholera) by ballast water treatment; and
- consideration of financial aspects related to aquaculture.

The unwanted impact of ballast water may be managed through the development of international ballast water guidelines and treatment options as a step towards the adoption of legally binding provisions, taking into account the conditions of donor and recipient region and the survival rates of species in ballast tanks during voyages.

International co-operation is needed, because the problem of introduced species will not stop at borders. Co-ordinating research in the field of species introductions would help to prevent duplication of work. This should challenge interested working groups to provide information on ongoing and planned research or legislative issues.

There are only a few countries carrying out monitoring programmes in regard to specific non-indigenous species or their presence in special areas. Sampling of ballast water is only undertaken for research purposes and not as standard procedure. Therefore the records listing non-indigenous species occur mostly in the frame of marginal observations during other studies. Regular surveys could document the introduction of non-indigenous species at an early time and therefore help to minimize the further spread of new populations. In order to solve this problem regular coast sampling programmes could be extended in list the present distribution of non-indigenous species.

Warning systems for newly introduced species should be encouraged in order to document their way of spread and possibly to co-ordinate control measures.
Preparation and implementation of monitoring and risk assessment studies for selected case histories of unintentionally introduced species should be carried out to provide additional information for future considerations of control and prevention methods.

Provide the databases as e.g. INFORMIR (USA) and the Concerted Action Partners with information about newest aquatic invaders, regulations etc.

Ship designers and constructors should be made aware of the problem of ballast water in order to take into consideration possibilities of ballast water treatment and their installation on board or differing design of ballast tanks compared to „old fashioned“ ships.

In addition existing treatment methods in regard to ballast tanks including sediments and ship´s hull fouling has to be developed in the near future in order to minimize the risks of unwanted species imports by ships. The ballast water control and treatment is a helpful step towards risk minimization regarding the un-intentional introduction of aquatic species. Several shipping studies have shown that in addition to ballast water, species were also transported in sediments of ballast tanks as well as in the fouling of the ships´ hulls.

It is recommended that hindering governmental structures and problems of in-adequate funding could be solved through relevant information, supported by educational programmes and creating public awareness. Therefore, the spread of information relevant to the subject is an essential topic.

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10 Definitions

The following list of definitions follows is based on definitions of the
(1) IMO Assembly Resolution A.774 (18) for the Control and Management of Ships` Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens;
(2) Code of Practice of the International Council for the Exploration of the Sea (ICES), Working Group on Introductions and Transfers of Marine Organisms WGITMO;
(3) draft IUCN Guidelines for the Prevention of Biodiversity Loss due to Biological Invasions
(4) Carlton (1996);
(5) draft Risk Assessment Protocol for the Introduction on Non-Native Species of Fish. Regional Non-Native Species Introduction Committee, Winnipeg, Manitoba. October 1996;
(6) AQIS report No. 9. Ballast water - Technical overview report (1996); and
(7) Committee on Ships´ Ballast Operations. Marine Board;, Commission on Engeneering & Technical Systems, National Research Council (1996): Stemming the tide: controlling introductions of nonindigenous species by ships´ ballast water.

"**Alien species**" see "Introduced species"
"**Brackish**" water is saline water with salinities lower than ocean water (6)
"**Clean ballast**" is ballast carried in cargo tanks after an intensive cleaning of the cargo department (in contrast to ballast carried in dedicated ballast tanks) (7)
"**Competition**" is a situation in which organisms need the same resources and compete for these (6)
"**Country of origin**" is the country where the species is native (2)
"**Cryptogenic species**" is a species that is not demonstrably native or introduced. (from crypt-, Greek, kryptos, secret; -genic, New Latin, genic, origin (3)
"**Disease agent**" is understood to mean all organisms, including parasites, that cause disease (2)
"**DWT**" (Dead Weight Tonnage) is the weight in metric tonnes (1,000 kg) of cargo, stores, fuel, crew and passengers carried by a ship when loaded to the maximum level.
"**Established species**". Species occurring as a reproducing, self-sustaining population in an open ecosystem, i.e. in waters where the organisms are able to migrate to other waters (5)
"**Exotic species**" see "Introduced species"

"**GRT**" (Gross Registered Tonnage) is the estimated maximum ship´s carrying capacity, as it is derived from the total volume of enclosed spaces which are available for cargo, stores, crew, passengers etc. within the hull and superstructure.

"**Intentional introduction**" is a deliberately made introduction by humans, involving the purposeful transport of a species or subspecies (or propagules thereof) outside its natural range. Such introductions may be either authorised or unauthorised (3)

"**Introduction**" An introduction of an organism is the dispersal, by human agency, of a living organism outside its historically known range (3)

"**Introduced species**" (= alien species, = exotic species, non-indigenous species) Any species intentionally or accidentally transported and released by humans into an environment outside its present range (2).

"**Member States**" means States that are members of the International Maritime Organization (1).

"**Native species**" is a species, subspecies or lower taxon, occurring within its natural range and dispersal potential (i.e. within the range it occupies naturally or could occupy without direct or indirect introduction by humans) (3)

"**Non-indigenous**" see "Introduced species"

"**Organism**" is an individuum of any plant or animal species

"**Pathogens**" are disease causing organisms (6)

"**Plankton**" aquatic, free-drifting organisms suspended in water (plant = phytoplankton, animal = zooplankton)

"**Port State Authority**" means any official or organization by the government of a port state to administer guidelines or enforces standards and regulations relevant to the implementation of national and international shipping control measures (1)

"**Secondary introduction**" is one that takes place as the result of an intentional or unintentional introduction into a new area and the species disperses from that point of entry to other areas that it could not have reached without the initial (primary) human mediated introduction (3)

"**Transferred species**" (= transplanted species) Any species intentionally or accidentally transported and released within its present range (2)

"**Translocation**" Movement of native or introduced species to habitats outside its historically known range (6)

"**Treatment**" means a process or mechanism, physical, chemical or biological method to kill, remove or render imterfile, harmful or potential harmful organisms within ballast water (1)

"**Un-Intentional introduction**" is one made as a result of organisms utilising humans or human transport systems as vector for dispersal into new areas. The introduction is incidental to the main transaction taking place (often trade and in the marine environment aquaculture) (3)

"**unwanted**" (used in the sense of unwanted species or unwanted introductions)

Any species which causes relevant changes to native species composition, including economical and ecological harm

11 Relevant internet locations (last update November 1998)

In response to the recent call for information from subscribers to the BIODIV-CONV listserver (see below), we received a number of references to homepages on the world-wide web. Given the present and future value of the web as a medium of information, we will begin to post regular updates of web sites relating to biodiversity policy and law, along with our other information postings (calendar of events and recent publications).

Most of the listed information below were selected from a report prepared for ICES/IOC/IMO Study Group on Ballast Water and Sediments ICES Working Group on Introductions and Transfers of Marine Organisms, La Tremblade, France, 21-25 April, 1997 by Kristina Jansson, SWEDEN and the IMO Library Information Services, IMO Library Directory of sites of interest on internet.

It has to be considered that the internet is an continuously changing instrument. Therefore, all listed addresses could have been changed after printing of this report in 1998.
Please not that if an error as e.g. "URL (location of web site) wrong" or "unable to locate server, server has no DNS" the page or server you are looking for could have been removed from the web (temporarily). Sometimes it helps to type in the Server name in capital letters. If even this is hopeless, type in the first part of the address (as: http://www.aquasense.com) and try to locate the relevant page on your own.

11.1 Home pages, information on the INTERNET (World Wide Web)

Listed in alphabetical order:

Abbreviations
http://www.icc.ie/info/net/acronyms/index.htm

Alien species of crayfish in Europe (University of Firence, Italy):
http://www.unifi.it/ (select „EVENTI„)

Aquasense
http://www.aquasense.com/species/newspec.htm
http://www.aquasense.com/about/welcome.htm

Australia
- CBD Clearinghouse Mechanism Homepage
http://www.erin.gov.au/life/chm/chm2.html
- Environmental Resources Information Network
http://kaos.erin.gov.au/general/erin_info/intro.html
- Development of a nation-wide system of marine protected areas
http://kaos.erin.gov.au/general_info/bodiv_debate/Marine2.html
- Australian Nature Conservation Agency
http://www.anca.gov.au
- *Australia - AQIS Ballast Water Programme*
"The Australian Quarantine and Inspection Service (AQIS) is the lead Commonwealth Agency for the management of ballast water issues, including policy development, implementation of a strategic research plan and quarantine operations. The Ballast Water Programme which includes and Australian Ballast Water Management Advisory Council (ABWMAC) and its Research Advisory Group (RAG) is administered by AQIS in Canberra."
Available topics include: - Australian Ballast Water Bulletins, - Australian Ballast Water Management Strategy, - Australian Ballast Water R&D Programme and - Australian Ballast Water Guidelines
http://www.dpie.gov.au/aqis/homepage/imadvice/ballast.html
CRIMP - Centre for Research on Introduced Marine Pests (Australia)
Many links to related sites! (type in CRIMP in capital letters)
http://www.marine.csiro.au/CRIMP/
Portfolio Marine and Coastal Environment Strategies - An Overview
http://www.erin.gov.au/portfolio/dest/env_strat/marine.html#HDR1

BALLERINA - Baltic Sea Region On-Line Environmental Information Resources for Internet Access
"BALLERINA is the place to go when you seek information on the Baltic Sea Region, have information to provide, or wish to communicate with others in the region. BALLERINA is a virtual meeting place, providing an opportunity for persons and institutions to find like-minded in the Baltic Sea Region. BALLERINA is the result of a co-operative effort to provide comprehensive information about issues on environment, natural resources and sustainable development relating to the transboundary Baltic Sea Region."
The information gateway to the Baltic is available at (type in BALTIC in capital letters):
http://www.BALTIC-region.net/
New Species in the Gulf of Finland and the Gulf of Bothnia
http://www2.fimr.fi/algaline/arc95/newspec.htm
Baltic Marine Environment Bibliography
http://www.otatrip.hut.fi/vtt/baltic/intro.html
BMB WORKING GROUP 30
Home page of the BMB Working Group 30 on NEMOs. The webside includes information and first entries of the Klaipeda database on non-indigenous species of the Baltic.
http://www.ku.lt/nemo/mainemo.htm
http://www.ku.lt/ (select: projects --> NEMO in the Baltic)

Bern Convention (Council of Europe)
http://www.coe.fr/eng/legaltxt/104e.htm
http://www.coe.fr/eng/legaltxt/treaties.htm

Biodiversity Action Network (BIONET)
http://www.igc.org/bionet

Biodiversity Data Management Homepage, Costa Rica
http://www.inbio.ac.cr/~bdm/home.html

BIOPOLICY: ONLINE JOURNAL (began 1996)
http://www.bdt.org.br/bioline/py

BIOSIS; Taxonomy & Nomenclature
http://www.york.biosis.org/zrdocs/tax_nom.htm

Canada
Canadian Biodiversity Information Network (CBIN)
http://www.doe.ca/ecs/biodiv/biodiv.html
Canadian website on ballast water. Includes information on Commercial Ships & Shipping, Aquatic Nuisance Species, Guidelines & Legislation and other References & Resources
http://www.renc.igs.net/~jdesigns/ccg/
THE STATE OF CANADA'S ENVIRONMENT: 1996 Edition. Government of Canada. Includes information from the past five years on every aspect of Canadian environment complied by a contributing staff of over 200 leading Canadian scientists.
http://www.doe.ca
Exotic Phytoplankton from Ships´ Ballast Water. Risk of Potential Spread to Mariculture Sites on Canada's East Coast. A summary of Canadian activities, some case histories of introduced species and shipping studies is included at:
http://www.maritimes.dfo.ca/science/mesd/he/ballast.html
Canadian CD on Ballast Water - A Vector for Introduction of Aquatic Nuisance Species which was distributed at the ballast water working group at MEPC 40
http://www.renc.igs.net/~jdesigns/ccg/bw_index.html)
The Canada Shipping Act (CSA)
There are over 100 regulations which have been promulgated under the Act. The CSA and its associated regulations may be found on the internet at:
http://www.tc.gc.ca/actsregs/CSA/TOCcsa.htm
Canadian Coast Guard
http://www.ccg.org

Caulerpa taxifolia at Laboratoire Evironnement Marin Littoral (LEML), Université de Nice-Sophia Antipolis. Photographs, maps, references etc.
http://www.unice.fr/LEML
http://com.univ-mrs.fr/gisposi/gisposi.htm
The GIS Posidonie bibliographic database on the spread of the tropical algae Caulerpa taxifolia in the Mediterranean Sea is now available at the following web address:
http://www.com.univ-mrs.fr/basecaul [in French]

For the latest news on the distribution of *Caulerpa taxifolia* in the Mediterranean Sea choose "Pour avoir les dernieres nouvelles sur la Caulerpa" on the home page.

CBD - Convention on Biological Diversity (UNEP)
http://www.unep.ch/biodiv.html

CBD Clearinghouse Mechanism Site
Official CBD Clearinghouse Mechanism (CHM) Pilot Phase
http://www.biodiv.org/chm

CBD Clearinghouse Mechanism Homepage, Belgium
http://www.kbinirsnb.be/bch-cbd/homepage.htm

CBD Clearinghouse Mechanism Homepage, Mexico
http://www.conabio.gob.mx/

CIEL - Centre for International Environmental Law
http://www.econet.apc.org/ciel/

CITES/Washington Convention
http://www.unep.ch/cites.html

Commission on Sustainable Development
CSD-5/UNGASS
- CSD Country Profiles
http://www.un.org/DPCSD/dsd
- Earth Summit +5
http://www.un.org/dpcsd/earthsummit
- Linkages & ENB
http://www.iisd.ca/linkages/csd/

Environmental and Natural Resources Law Center, Costa Rica
http://www.inbio.ac.cr/~bdm/info_inst/cedarena.html

ETI - Expert Center for Taxonomic Identification (UNESCO)
http://145.18.162.199/default.shtml

European Environment Agency Homepage
http://www.eea.dk/

FAO - Food and Agriculture Organization; International Agreements etc.
http://www.fao.org/waicent/faoinfo/fishery/agreem/agreem.htm
http://www.fao.org/waicent/faoinfo/fishery/statist/fisoft/dias/index.htm
FAO's Domestic Animal Diversity Information System (DAD-IS)
http://www.fao.org/waicent/faoInfo/agricult/AGA/AGAP/Default.htm

Fifth North Sea Conference; Intermediate Ministerial Meeting 1997, Assessment Report
http://odin.dep.no/md/publ/conf/report.html

FishBase (ICLARM, Philippines)
http://161.76.121.2:80/fish-bin/fishfam.p

Fourth World Documentation Project
http://www.halcyon.com/FWDP/fwdp.html

Germany
- German CBD Clearinghouse Mechanism Homepage
http://www.dainet.de/bmu-cbd/homepage.htm
- German shipping study on non-indigenous species transported via international shipping
Abstract of German shipping study, Institut für Meereskunde, Kiel
http://www.ifm.uni-kiel.de/pl/transpor/default.htm

Global Biodiversity
http://www.ecomall.com/class/bio.htm

Global Environment Facility (GEF)
http://www.worldbank.org/html/gef/gateway/gefrelat.htm

GLODIR - Global Directory of Marine Scientists (!), a database "containing information on scientists and their scientific interests" at
http://www.unesco.org/ioc/isisdb/html/habd.htm

Greenpeace international Environmental Conventions
http://www.greenpeace.org:80/~intlaw/

HELSINKI COMISSION - Baltic Marine Environment Protection Commission
http://www.helcom.fi/

ICES - International Council for the Exploration of the Sea
http://www.ices.dk/
Information on the ICES Working Group on Introductions and Transfers of Marine Organisms (WGITMO)

ICLARM - International Center for Living Aquatic Resources Management
http://www.cgiar.org/iclarm/

IFREMER - Institut Français de Recherche pour l'Exploitation de la Mer
http://www.ifremer.fr

IMO - International Maritime Organization
IMO homepage (http://www.imo.org)
http://www.imo.org/imo/welcome.htm

Indigenous Peoples Biodiversity Information Network (IBIN)
http://www.ibin.org

Inter-Links
http://www.nova.edu/Inter-Links/

Introductions of non-native genotypes of plants
http://www.naturebureau.co.uk/pages/floraloc/floraloc.htm#index

IOC - Intergovernmental Oceanographic Commission

http://www.unesco.org/ioc/iochome.htm
IOC - Intergovernmental Oceanographic Commission; Harmful Algal Blooms
Via IOC's Home Page you can find information on IOC's Harmful Algal Blooms Programme (HAB) and the IOC Science and Communication Centre on Harmful Algae (http://www.unesco.org/ioc/oslr/oslr.htm, http://www.unesco.org/ioc/oslr/hab.htm). Electronically available documents include reports from meetings and workshops, the newsletter Harmful Algae News, and access to IOC's databases, e.g.
HABDIR - IOC Harmful Algae Bloom Expert Directory at
http://www.unesco.org/ioc/infserv/director/habdir.htm
http://www.unesco.org/ioc/iochome.htm

IUCN - World Conservation Union
http://www.iucn.org/index.html

Linguistic & biological diversity--Terralingua Conference
http://cougar.ucdavis.edu/nas/terralin/english.html
http://ucjeps.berkeley.edu/Endangered_Lang_Conf/Endangered_L
ang.html

Lloyd's Register
http://www.lr.org/news

MEPC, a list of 50 ecological journals
http://www.ng.hik.se/~nmato

Natural Resources Research Information Pages
http://sfbox.vt.edu:10021/Y/yfleung/nrrips.html

Netcoast, guide to integrated coastal zone management
http://www.minvenw.nl/projects/netcoast/index.htm

North East Atlantic Taxa (Tjarno MBL, Sweden)
http://130.241.163.21/TMBL/taxon/taxa

OECD publications, coastal zone management
http://www.oecd.org/publications/catalog/97/97_93_03_1.html

OSPAR - The Oslo and Paris Commissions and the OSPAR Convention for the Protection of the Marine Environment of the North-east Atlantic
http://ourworld.compuserve.com/homepages/ospar/homepage.htm

Ozone Secretariat, contact address (UNEP)
http://www.unep.ch/ozone/contact.htm

Pfiesteria piscicida
General information (including pictures) of the Phantom Algae were given on:
http://www2.ncsu.edu/unity/lockers/project/aquatic_botany/pfiest.html
http://www.cdc.gov/nceh/press/1997/970929pf.htm
http://www.epa.gov/OWOW/estuaries/pfiesteria/hilite.html

RAFI Communique
http://www.rafi.ca/communique/

Seaweed (University College, Galway, Ireland)
http://www.seaweed.ucg.ie/seaweed.html

Third World Network
http://www.twnside.org.sg/souths/twn/twn.htm

Treaty Summaries from 1933 (!) to 1993(do NOT type in "www.")
http://sedac.ciesin.org/pibd/summaries-menu.html
very useful (!); access failed sometimes, therefore try alternatively:
http://sedac.ciesin.org/ (select "ENTRI" -->"summaries of some of the treaties in the ENTRI collection " (right column, close to the bottom) --> "chronological list" gets you to the list of treaties as: international conventions for prevention of pollution from ships, nature protection and wildlife preservation...)

Tropical Coasts - newsletter for policy makers, environmental managers, scientists and resource users. "Marine updates" sponsored by GEF/UNDP/IMO
http://www.skynet.net/users/imo

UN
http://www.unsystem.org/

UNEP; Trade and Environment
http://www.unep.ch/trade.html

UNESCO
http://www.unesco.org/mab/collab/diver1.htm

UNESCO-IOC Register of Marine Organisms (UNESCO)
http://145.18.162.199/database/urmo/default.shtml

United Kingdom
Aquaculture, fisheries and natural resources, *Fishing for Information Home Page: Guide to online resources in aquaculture, fisheries and aquatic science*
http://www.stir.ac.uk/aqua/fishing/
HM Coastguard
http://www.netlink.co.uk/users/coasties/hmcg.html

USA
Alien species invasions of U.S. Ecosystems (with links to other organizations involved)
http://www.consci.tnc.org/library/pubs/dd/toc.html
American Association of Port Authorities
http://www.coe.fr/eng/legaltxt/104e.htm
aapa-ports.org
Coastal Resource Centre, University of Rhode Island
http://www.brooktrout.gso.uri.edu/index.html

http://www.bdt.org.br/bioline/py
Great Lakes, Exotic species in the Great lakes
http://www.great-lakes.net/
NOAA; Environmental Research Laboratories
http://www.erl.noaa.gov/
Non-indigenous aquatic species:
http://www.nas.nfrcg.gov/nas.htm
Live Marine Specimens (Woods Hole MBL, U.S.)
http://www.mbl.edu/html/MRC/specimens.html
Multilaterals (Tufts University, Mass., U.S.)
"The Multilaterals Project, begun in 1992, it is an ongoing project at the Fletcher School of Law & Diplomacy, Tufts University, Medford, Massachusetts to make available the texts of international multilateral conventions and other instruments. Although the project was initiated to improve public access to environmental agreements, the collection today also includes treaties in the fields of human rights, commerce and trade, laws of war and arms control, and other areas. Although the vast majority of texts date from the second half of this century, the collection also includes historical texts, from the 1648 Treaty of Westphalia to the Covenant of the League of Nations." (and also including full text versions of e.g. UNCLOS - United Nations Convention on Law of the Sea)
http://www.tufts.edu/fletcher/multilaterals.html
NAS – Non-indigenous Aquatic Species (U.S.)
http://www.nfrcg.gov/nas/nas.htm
National Sea Grant; Non-indigenous Species Research and Outreach (U.S.)
http://mdsg.umd.edu/NSGO/research/nonindigenous/
Ocean planet - Smithsonian Institution
http://www.seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTM/peril_alien_species.htm
Office of Technology Assessment (U.S. Congress). Carries the OTA 1993 report "Harmful Non-Indigenous Species in the United States" in pdf.-format)
http://www.ota.nap.edu/pdf/1993idx.html
Ohio Sea Grant: Aquatic Nuisances (U.S.)
http://www.osc.edu/OhioSeagrant/osgrant/com/nuisances/nuisances.html
SanFrancisco Case Study
http://nas.nfrcg.gov/sfinvade.htm
The complete study of approx. 225 pp. can be downloaded from the website.
U.S.C.G. - Marine Safety Newsletter
http://www.dot.gov/dotinfo/uscg/hq/g-m/gmhome.htm
U.S. EPA
http://www.epa.gov/
Western Zebra Mussel Task Force Home Page (U.S.)
http://www.usbr.gov/zebra/wzmtf.html
Woodshole Oceanographic Institution
http://www.whoi.edu/
Woodshole Oceanographic Institution lists a page on harmful algae:
http://habserv1.whoi.edu/hab/
Zebra Mussel links
http://www.science.wayne.edu/~jram/zmlinks.htm
Zebra Mussel resources
http://www.nfrcg.gov/zebra.mussel/

WCMC - World Conservation Monitoring Centre
http://www.wcmc.org.uk/index.html
WCMC - Protected Areas Virtual Library
http://www.wcmc.org.uk/protected_areas/data/pavl.html

11.2 Mailing lists

11.2.1 Marine-Pests (CSIRO/CRIMP)

CSIRO Centre for Research on Introduced Marine Pests (CRIMP), Hobart, Tasmania, Australia
"This is a public mailing list co-ordinated and owned by the CSIRO Centre for Research on Introduced Marine Pests (CRIMP). Despite the list name, we are more generally interested in introduced species, not just those introductions that attain pest status. It is intended that this list will serve to increase communication in the growing international community of researchers concerned with various aspects of biological invasions in the marine environment. We hope that we will attract and encompass people generally interested in biological invasions in all environments, not just marine. The sort of postings we anticipate include:
- upcoming events related to species introductions such as meetings and symposia related to biological invasions, biological control or eradication techniques
- new websites, newsgroups or mailing lists which might be of interest to the general discussion group
- general information concerning new invasion research groups or projects information (or alternatively questions) about suspected introduced species."
In order to get more information use *majordomo@ml.csiro.au*
Do not type in any text in the subject field and type in as message: „help„ - and nothing else. The return mail will provide information on the system, how to subscribe, how it is organized etc.
In order to subscribe send a mail and type in as message:
subscribe marine-pests
On the next line type in „end„ or ensure that there is no text which will follow the above command by switching off your signature.
The mailing list will provide you with information about new human mediated intentionally and accidentally introduced non-indigenous species, upcoming events on species introductions as meetings and symposia related to biological invasions, their control and a general discussion group, information on new web sides.

11.2.2 Invasive Species Listserver ALIENS-L (ISSG/IUCN)

Department of Conservation, Auckland, New Zealand
"ALIENS-L - listserver of the Invasive Species Specialist Group (ISSG) of the IUCN Species Survival Commission - has been established. ISSG aims to "reduce the threats posed by invasive species to natural ecosystems and their native species, through increasing awareness of invasive species and means of controlling or eradicating them". This listserver is a contribution to that mission. It allows users to freely seek and share information on invasive species and the threats which they pose to the biodiversity of our planet. This listserver is not limited to members of ISSG but is available to all who might be interested in the invasive species subject."

The listserver of the Invasive Species Specialist Group (ISSG) of the IUCN Species Survival Commission may be subscribed at *majordomo@ns.planet.gen.nz*
In order to subscribe do not type in any text in the subject field and type in as message: „subscribe ALIEN-L„ - and nothing else.
On the next line type in „end„ or ensure that there is no text which will follow the above command by switching off your signature.
The ISSG aims to reduce the threads by invasive species by increasing the awareness in this field and the spread of information on methods for control and eradication.

11.2.3 WEEDS

WEEDS to encourage idea sharing on noxious weeds that impact on U.S. agriculture. They hope to hear from weed specialists, the nursery industry, environmental and natural resources organizations, agronomists, farmers, scientists in academia and the government sector, and regulatory officials in the plant health arena. Sponsored by and housed at the headquarters offices of the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS) in Riverdale, Maryland, U.S.A. Address a message to *majordomo@info.aphis.usda.gov*. In the body of the message type *subscribe WEEDS*. Type nothing else in the message. Switch off your automatic signature.

11.2.4 WWD-L

WWD-L is a discussion group on a database of weeds of the world (agricultural and environmental) Address a message to MAISER@PLANTS.OX.AC.UK In the body of the message type SUBSCRIBE WWD-L Type nothing else in the message. Switch off your automatic signature.

11.2.5 INFOTERRA

INFOTERRA is intended for exchanging information on environmental topics; posing queries to the Infoterra network; requesting information from the United Nations Environment Programme and raising environmental awareness in general. Address a message to MAJORDOMO@ CEDAR.UNIVIE.AC.AT. In the body of the message type SUBSCRIBE INFOTERRA YOUR@EMAIL ADDRESS. Type nothing else in the message. Switch off your automatic signature.

11.2.6 BIODIV-CONV

BIODIV-CONV is devoted specifically to the Convention on Biological Diversity and its effective implementation. Address a message to MAJORDOMO@IGC.APC.ORG In the body of the message type SUBSCRIBE BIODIV-CONV YOUREMAILADDRESS Type nothing else in the message. Switch off your automatic signature.
BENE is designed to foster enhanced communications and collaborations among those interested in biodiversity conservation and ecosystem protection, restoration and management. Address a message to LISTPROC@STRAYLIGHT.TAMU.EDU In the body of the message type SUBSCRIBE BENE YOURNAME Type nothing else in the message. Switch off your automatic signature.
Introduction to the BIODIV-CONV Listserver (BIODIVERSITY - BIODIV-CONV)

TO: All parties interested in effective implementation of the Convention on Biological Diversity (CBD)
FROM: Sheldon Cohen & Stas Burgiel, Biodiversity Action Network (BIONET)
SUBJECT: ANNOUNCING A NEW INTERNET "LIST-SERVER" FOR DISTRIBUTING INFORMATION RELATED TO THE CONVENTION ON BIOLOGICAL DIVERSITY (CBD) (DATE: 7 May 1996)

INTRODUCTION

We are pleased to announce the establishment of a special "list-server" (or electronic mailing list) on the Internet devoted specifically to the Convention on Biological Diversity (CBD) and its effective implementation. It is entitled BIODIV-CONV. A list-server is simply an automated mechanism that uses e-mail addresses to disseminate information over the Internet to large numbers of people throughout the world.

First off, for your information, BIONET is an NGO (National Governmental Organization) network working to strengthen biodiversity policy and law, with a sharp focus on promoting effective implementation of the CBD. Over the past few months, we have consulted with BIONET member organizations and other partners concerning the establishment of such a list-server. Based on these consultations, and related research, we have identified a clear need for this type of Internet information tool.

The CBD implementation phase is moving forward rapidly:

- Over 170 governments have now signed the CBD, and over 140 have ratified (and are referred to as Parties).
- The CBD Secretariat has been permanently established in Montreal, headed by Dr. Calestous Juma.
- Two meetings of the CBD's governing body, or Conference of the Parties (COP), have already been held, and have resulted in a number of substantive decisions.
- The "Jakarta Mandate on Marine and Coastal Biodiversity" was adopted by the COP last November.
- The COP-3 meeting is scheduled for 4 - 15 November 1996 (Buenos Aires), and will address several important substantive issues.
- The first meeting to negotiate a CBD protocol on biosafety is scheduled for 22-26 July in Denmark.
- The Global Environment Facility (operating the CBD's financial mechanism on an interim basis) has begun to disburse grants to support CBD implementation in developing countries.
- A growing number of CBD Parties have already developed, or are in the process of developing, their national biodiversity strategies and action plans.

Successful implementation of the CBD will require broad and active participation of a wide range of stakeholders committed to translating the legally-binding obligations under the CBD into action that produces meaningful, on-the-ground results. These stakeholders will require a growing amount of solid and timely information. This list-server is intended to help provide such information and to help mobilise world-wide support for effective CBD implementation.

We are establishing this list-server with an initial e-mail distribution list of about 1,000 individuals representing: non-governmental organizations (NGOs), intergovernmental organizations (IGOs) such as U.N. agencies and international treaty secretariats, governments, private foundations, the private sector and others who have been participating actively in the CBD process or have shown a strong interest in this general area. For example, our distribution list includes most of the NGO and IGO participants in the most recent CBD intergovernmental meeting (COP-2), held in November 1995 in Jakarta. The list also includes many of the individuals designated as the CBD "focal points" within governments. And in the coming months, we will include additional e-mail addresses of these and other key CBD stakeholder groups.

This is an "open access" list and any individuals or organizations are welcome to join. (As such, particularly sensitive and confidential information will not be posted.) We expect the distribution list to grow rapidly in the months ahead. In this regard, we need your help to identify others who would be interested in being on the list. strongly encourage you to alert your colleagues to its existence.

To help save you time and on-line charges, we will include in the subject line for each posted document a KEYWORD (to describe the topic of the document) and the page length. By doing this, you will be able to delete any messages that are not of interest. We are aware that some of you on select APC "nodes" will be incurring extra gateway charges. If this is the case and it becomes cost-prohibitive, please contact us and we can discuss alternative transmission options.

TYPES OF INFORMATION THAT WILL BE POSTED

The list-server will provide diverse information to help promote effective implementation of the CBD, including action at the international, national and sub-national levels. The list-server, which will be moderated by the BIONET Secretariat office, will include:

- information about CBD intergovernmental meetings and other activities related to these meetings;
- information on CBD Secretariat activities;
- information produced by the CBD Secretariat appropriate for general circulation;
- reports and analyses of CBD meetings;
- timely alerts about other particularly relevant upcoming meetings (e.g., Global Biodiversity Forum, UN Commission on Sustainable Development, Global Environment Facility);
- reports on recent events/processes (e.g., conferences, workshops, Global Environment Facility, CSD Intergovernmental Panel on Forests, etc.);
- issue-specific reports, position papers and other materials by NGOs, IGOs, governments, industry, etc.;
- pre-print versions of the BIODIVERSITY BULLETIN newsletter;
- periodic calendars of biodiversity events;
- lists of key contacts;
- lists of recent publications; and
- information on biodiversity-related internet sites.

IF YOU WOULD LIKE INFORMATION POSTED TO THE LIST-SERVER

To make this list-server useful, we are counting on you and others to provide us with relevant announcements and information that you would like posted. Posted documents will automatically be circulated to the entire distribution list of over 1,000 persons. While we expect that nearly all requests falling within the scope of this list-server will be posted, some may be rejected for pertinent reasons. We are in the process of developing criteria in this regard, and will circulate them for comment.

The list-server could function not only as a general information clearinghouse on the CBD implementation process and related issues, but also could become a forum for publicising new initiatives and successful programs, and for presenting proposals for needed action. In addition, it could serve as a vehicle for facilitating contacts, partnerships and collaboration.

ACCOMPANYING ELECTRONIC CONFERENCE

Accompanying the list-server is an electronic conference (biodiv.conv) containing a comprehensive, virtual archive of all the documents ever posted to the list-server. As people subscribe to the list-server, this will become a useful, maintenance-free, vehicle to quickly review past issues and information, and to download those documents of interest. It should be noted, however, that the conference can only be accessed if you subscribe to a computer network that is a member of the Association of Progressive Communications (APC), such as: Econet (US), Greennet (UK), Pegasus (Australia), Glasnet (CIS), Alternex (Brazil), and Nicarao (Nicaragua). The conference should be accessible under the conferences section of your APC node, under the title <biodiv.conv>.

HOW TO CONTACT

We welcome any suggestions you might have concerning the above information and ways that this list server may be most useful. To communicate with us in this regard, or for further information, please contact:

Sheldon Cohen or Stas Burgiel
Biodiversity Action Network (BIONET)
1400 16th Street NW, Suite 502, Washington, DC 20036, USA
Telephone: ++1.202.547.8902, Fax: ++1.202.265.0222
E-mail: bionet@igc.apc.org
http://www.igc.agc.org/bionet
http://www.access.digex.net/~bionet

11.2.7 Biological Control Discussion List (biocontrol-L)

"This discussion list is directed to scientists, educators, students, legislators, extension specialists and practitioners of biocontrol of pests around the world. Technical discussions, queries and news on this area of interest are welcome. The list should not be used for commercial purposes.

To subscribe to the list, please send the following message to listserv@bdt.org.br:
SUBSCRIBE BIOCONTROL-L your name
To send messages to the list, just address them to BIOCONTROL-L@bdt.org.br

11.2.8 IRRO Discussion List (IRRO-L)

"IRRO is an information network, run on a non-profit basis, which aims to provide access to all types of information relevant to the release of animals, plants and micro-organisms into the environment. IRRO is an acronym for the Information Resource for the Release of Organisms to the Environment. The decision to establish the IRRO was taken in 1991, under initial impetus from the United Nations Environment Programme (UNEP), and the intervening period has been used to establish priorities and to search for funds.

Information of interest for IRRO might include details of, for example, releases of non-indigenous, novel or genetically modified organisms. It might cover ecological data relevant to receiving environments. It could include information on the regulatory oversight of releases of non-indigenous organisms or genetically modified organisms. It could include information on the impacts of biodiversity. There are many other possibilities.

IRRO is intended to be a network which will facilitate access to existing relevant databases and other information sources located throughout the world. It is envisaged that there will be many types of users of the IRRO with many different interests. They could include NGOs (non-governmental organizations), policy makers, scientists interested in academic issues or those interested in accessing information relevant to regulatory/oversight purposes.

The aim of this list is to discuss any topic of interest to the development of the IRRO.

In order to subscribe to this list, send a message to listserv@bdt.org.br with a single text line in the body of your message that says: SUBSCRIBE IRRO-L your-full-name"

11.2.9 Sites with additional information on electronic mailing lists

Information on listservs on all topics
http://www.tile.net/tile/listserv/index.html

Aquatic Animals Mailing Lists
http://www.actwin.com/fish/lists.html

BIOSCI mailing lists and newsgroup archives
http://www.w3.org/hypertext/DataSources/bySubject/Bio/Overview.html
BIOSCI/bionet Electronic Newsgroup Network for Biology
http://www.bio.net/

Guides to Listserv and bitnet mailing lists
http://galaxy.einet.net/GJ/lists.html

Listserv Lists
http://www.clark.net/pub/listserv/listserv.html
LISTSERV Home Page
http://www.tile.net/tile/listserv/viewlist.html
Liszt: Searchable Directory of e-Mail Discussion Groups
http://www.liszt.com/

12 Databases on non-indigenous species

As far as known, six major relevant databases are available or in preparation listing the aquatic non-indigenous species of their region. The Australian database is not available on the Internet but one can order a file containing the relevant information.

12.1 FAO - Food and Agriculture Organization, the FAO Database on Introductions of Aquatic Species (DIAS)

http://www.fao.org/waicent/faoinfo/fishery/agreem/agreem.htm

http://www.fao.org/waicent/faoinfo/fishery/statist/fisoft/dias/index.htm

The FAO Database on Introductions of Aquatic Species (DIAS) can be searched through search forms. Users can provide new data to the database by filling in an input form. Web pages on "Highlights on Introductions", statistics on the database and a glossary are linked. The home page is located at the FAO Fisheries Home page by selecting "Databases and Statistics". The webside is expected to grow as users provide new records of introductions and as new information and relevant publications become available. This site represents an important source of information on both the benefits and risks of species introductions. The FAO database on introductions of aquatic species was initiated by R. Welcomme in the early 1980's. It considered primarily only freshwater species of fish and formed the basis for the 1988 FAO Fisheries Technical Paper no. 294. The database has been expanded to include additional taxa, such as molluscs and crustaceans, and marine species. In the mid 1990's a questionnaire was sent to national experts to gather additional information on introductions and transfers of aquatic species in their countries. The database, which contains now almost 2900 records, can be queried through the Search Form. Users aware of other introductions of aquatic species not already included in the database or that have additional information on the records in the database are requested to fill in the Input Form. Periodically this information will be validated and added to the database.

12.2 Baltic

A database on non-indigenous species of the Baltic ins under development. At two meetings of the working group on Non-Indigenous Estuarine and Marine Organisms of the Baltic Marine Biologists (held in Klaipeda 1995 and in Gdynia 1996) a standardized entry format for a joint database on the Baltic non-indigenous species was elaborated (see the relevant Internet homepage http://www.ku.lt/nemo/mainnemo.htm and http://www.grida.no/prog/norbal/ballerin/environ/wg_alien.htm). The database should lead to the development of a complete (as far as possible) accounts of aquatic species to become established in the Baltic Sea region, including the Baltic Sea itself, its gulfs and coastal lagoons as well as adjacent water bodies which potentially can serve a recipient of new introductions (like, for example, Lake Ladoga). Special attention will be paid to numerous published and unpublished data written in different languages of the Baltic Sea countries in order to make it available for international readers. An entry to the database will contain following main topics: TAXONOMY (incl. local common names, if available), IDENTIFICATION, VECTORS OF INTRODUCTION (if known), DISTRIBUTION (incl. first record, present distribution, area of origin, etc.); ABIOTIC PREFERENCES & BIOLOGY; EFFECTS (incl. possible social and economical impacts); REFERENCES; SOURCE.

The Baltic Alien Species database will be used as a basis for environmental decision making (including issues related to ballast water treatment, etc.), it will also serve a factual source for university study courses on marine biology and ecology as well as for popular posters and information sheets for school classes, public aquariums and museums of natural history. Also it is believed that the research network on the Baltic non-indigenous species linking academic scientists and environmental monitoring specialists will continue its work also in the future after the present project is formally over. Presently the database on the Baltic NEMOs is under preparation.

For more information contact: Dr. Sergej Olenin, Klaipeda University, Lithuania (S.Olenin@samc.ku.lt) and see home page listed above.

12.3 North Sea

All data of the SOAEFD Ballast Water Project were archived in a dedicated relational database, resulting in a valuable resource on the biological and chemical composition of ships' ballast water (Macdonald & Davidson 1997).

12.4 Mediterranean Sea

http://com.univ-mrs.fr/gisposi/gisposi.htm

The GIS Posidonie bibliographic database on the spread of the tropical algae Caulerpa taxifolia in the Mediterranean Sea is now available at the following web address:

http://www.com.univ-mrs.fr/basecaul [in French]

For the latest news on the distribution of *Caulerpa taxifolia* in the Mediterranean Sea choose "Pour avoir les dernieres nouvelles sur la Caulerpa" on the home page.

A searchable literature database on *Caulerpa taxifolia* is available at "Si vous etes visiteur, vous pouvez consulter la base" on the homepage. A variety of search terms can be combined. The result of a research is a list of relevant references (without abstracts).

12.5 USA

12.5.1 SERC

The Smithsonian Environmental Research Centre hopes to develop a database on non-indigenous species in coastal environments of the USA. This database could be used to look for trends in invasion ecology. There is also a data base being developed by the US Geological Survey in Gainesville Florida, focusing primarily on terrestrial invading species (Ruiz pers. comm., Cangelosi pers. comm.).

12.5.2 NAS Non-Indigenous Aquatic Species (U.S. Geological Survey)

The National Non-Indigenous Aquatic Species Geographic Information System was established in 1993 at the U.S. Geological Survey, Biological Resources Division, Gainsville, Florida. Assessable to the public are information about introduced aquatic species since 1850 by general and scientific reports. The on-line database contains more than 36,000 geographically references of aquatic flora and fauna. The service is used to monitor the distribution of introduced species and to provide information of control and management.

http://www.nfrcg.gov/nas/nas.htm

12.5.3 Non-native Invasive Species Strategy (US)

http://jaguar.arw.r9.fws.gov/

"Various U.S. government Departments and Agencies are currently drafting a document regarding the subject topic. A draft is posted on the WWW at the listed address.

12.5.4. Hawaii

http://www.hear.org/

"The goal of the Hawaiian Ecosystems at Risk (HEAR) project is to provide resources (technique, methods, and information) to resource managers state-wide to aid in the fight against invasive non-indigenous species state-wide. The HEAR project is based at the CPSU office in the Botany Department of the University of Hawaii and funded by the U.S. Geological Survey's Biological Resources Division (formerly the National Biological Service)."

HEAR Websites include;

"The Harmful Non-Indigenous Species (HNIS) database is an in-progress product of the Hawaiian Ecosystems at Risk project. It will eventually comprise an online source of up-to-date information (names, locations, pictures, control methods) about harmful non-indigenous species in Hawaii. Additionally, it will provide a medium to allow feedback from scientists, professional resource managers, and the general public. As new information is received, it will be added to the database to ensure that the most current information is available.

Also available is the HNIS questionnaire. This questionnaire is used to collect detailed information about each species in the HNIS database. If you have information to report, or would like to assist in the progress of this project, you are encouraged to complete and submit one of these forms for a species which is on our "hit list" or for another species about which you are concerned."

12.6 Australia

A database of non-indigenous species established in Australian waters was compiled by CRIMP. The folder contains more than 75 records including taxonomical remarks of the species (picture), area of origin, the current distribution, associated effects / impacts to the environment and economy. The database was developed as a guide to Australia’s introduced marine species and some potential invaders. It is intended as a descriptive and informative work for researchers and others interested in. The handbook has been designed to be supplemented with updates on the occurring non-native species and further species introductions. The unbound file shape allows an open ending handling (Furlani 1996).

Distribution information available at:

http://www.ml.CSIRO.au/~spinks/CRIMP/index.html

Editorial board (looking forward to e.g. corrections additional findings):

crimp@ml.CSIRO.au

12.7 New Zealand

The Invasive Species Specialist Group (ISSG) of IUCN´s Species Survival Commission is planning to organize links between already established databases on non-indigenous species. Further development uncertain. The ISSG also publishes the newsletter *Aliens*, and the *aliens-L listserver* (see below for information on how to subscribe).

The ISSG has also developed draft "Guidelines for the Prevention of Biodiversity Loss due to Biological Invasion". The draft guidelines can be accessed at the IUCN website at: http://www.iucn.org/themes/ssc/memonly/invguid.htm

12.8 Database of Integrated Coastal Zone Management Efforts

This world-wide database was created and supported by the U.S. Agency for International Development. The database includes national specific notes on contact persons, habitat, water quality management and protection activities.

http://brooktrout.gso.uri.edu/First_Page.html or:

http://brooktrout.gso.uri.edu/world.html

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