

# Ballast Water Treatment R&D Directory

Ballast Water Treatment  
*R&D Directory*

AUGUST 2002







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August 2002



## **Acknowledgements**

This Ballast Water Treatment R&D Directory has been compiled by Leonard Webster and Steve Raaymakers of the GloBallast Programme Coordination Unit, International Maritime Organization, London.

Information contained in the Directory has been provided by the various research groups listed in the Directory or obtained from published reports.

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The Global Ballast Water Management Programme (GloBallast) is a cooperative initiative of the Global Environment Facility (GEF), United Nations Development Programme (UNDP) and International Maritime Organization (IMO) to assist developing countries to reduce the transfer of harmful organisms in ships' ballast water.

The opinions expressed in this document are not necessarily those of GEF, UNDP or IMO

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**Appendix One: Template for Submissions to be Included in the Directory.**

## Background

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The International Maritime Organization (IMO), with funding provided by the Global Environment Facility (GEF) through the United Nations Development Programme (UNDP), has initiated the Global Ballast Water Management Programme (GloBallast).

This programme is aimed at reducing the transfer of harmful marine species in ships' ballast water, by assisting developing countries to implement existing IMO voluntary guidelines on ballast water management (IMO Assembly Resolution A.868(20)), and to prepare for the anticipated introduction of an international legal instrument regulating ballast water management, currently being developed by IMO member countries.

To implement the programme, a Programme Coordination Unit (PCU) has been established at IMO in London. One of the many functions of the PCU is to establish and maintain an information resource centre and clearing house, in order to improve the global communication and dissemination of information relating to this issue, and thus facilitate increased coordination and cooperation between the many parties involved. This Ballast Water Treatment R&D Directory has been developed as part of this effort.

## Structure of the Directory

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This directory lists research and development projects that are focussed specifically on the physical, mechanical or chemical treatment of ballast water to prevent/reduce the transfer of aquatic organisms. It does not list broader research projects relating to ballast water or marine bio-invasion issues in general (see Aquatic Invasions Research Directory (AIRD) below).

The directory is organised into two primary divisions:

- Projects Completed
- Projects Under Way

Within each primary division research projects are listed by country.

Within each country they are listed in alphabetical order by name of the principal researcher.

Finally, information categories for each research project are:

- Name of project
- Treatment options researched
- Principal researcher
- Contact details
- Host institution
- Location of research
- Funding level
- Funding source(s)
- Timeframe
- Aims and objectives

- Research methods
- Results.

Where information categories are left blank for certain projects this indicates that the information was not provided/is not available.

## **Future of the Directory**

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This hard copy directory has been developed into a searchable database accessible on the GloBallast web site, <http://globallast.imo.org/research/>. It has also been provided to the Smithsonian Environmental Research Centre (SERC) for use in the Aquatic Invasions Research Directory (AIRD) (see below). The GloBallast PCU will periodically update the directory and disseminate updates in hardcopy and via the web site.

## **Request for Submissions**

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It should be noted that this directory is by no means exhaustive. There may be many ballast water treatment research and development activities underway around the world that have not yet been identified and/or entered into the directory. R&D groups conducting projects not currently listed are invited to complete the standard data form in Appendix One and submit it to the contacts listed below, preferably electronically. This form is available at <http://globallast.imo.org/research>.

## **The Aquatic Invasions Research Directory (AIRD)**

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It should be noted that a broader database of scientific research covering all disciplines relating to the issue of marine bio-invasions in general has been developed by SERC in Maryland, USA. This is called the Aquatic Invasions Research Directory (AIRD). AIRD can be accessed on <http://invasions.si.edu/aird.htm>.

This Ballast Water Treatment R&D Directory is far more focussed than AIRD. It is intended to supplement AIRD by providing more detailed entries on ballast water treatment R&D specifically. These are of greater immediate interest, relevance and utility to IMO's shipping and ballast water focussed constituencies than the general science of marine bio-invasions.





# 1. Projects Completed



## Australia

<b>Name of Project</b>	<b>Ports Corporation of Queensland Ballast Water Initiative No. 2: R&amp;D of Ballast Water Treatment Technology</b>
<b>Treatment options researched</b>	<i>pH adjustment, coagulation/flocculation, filtration, UV &amp; ozone.</i>
<b>Principal Researcher(s)</b>	Darren Oemcke.
<b>Contact Details</b>	United Water International Pty Ltd GPO Box 1875 Adelaide SA 5001, Australia Tel: +61 8 8301 2709 Fax: +61 8 8357 9728 Email: darren.oemcke@uwi.com.au.
<b>Host Institution(s)</b>	CRC Reef Research Centre.
<b>Location of Research</b>	Townsville, Australia.
<b>Funding Level</b>	Ports Corporation of Queensland (PCQ) (AUD\$92,000), CRC (AUD\$90,000).
<b>Funding Source(s)</b>	PCQ, CRC.
<b>Timeframe of the Project</b>	July 1995 to June 1998.
<b>Aims and objectives of the project</b>	<ul style="list-style-type: none"> <li>• Evaluate the effectiveness of treatment options tested and estimate cost for ballast water treatment.</li> <li>• Determine sizes of treatment plant, design a full-scale pilot treatment plant.</li> <li>• Evaluate environmental impacts of treatment options, assess expected risk reduction vs. cost.</li> </ul>
<b>Research Methods</b>	<ul style="list-style-type: none"> <li>• Literature review.</li> <li>• Ballast water sampling: <ul style="list-style-type: none"> <li>- Identification of potential problem species and characteristics of ballast water which affect the disinfection technologies.</li> </ul> </li> <li>• Disinfection testing: <ul style="list-style-type: none"> <li>- Ozone, ultraviolet light and membrane filtration.</li> <li>- Pre-treatments examined included: pH adjustment, coagulation/flocculation, filtration.</li> </ul> </li> <li>• Pilot Plant Design.</li> </ul>
<b>Results</b>	<p>The initial literature review suggested that ozone, UV irradiation and filtration were strong candidates for ballast water treatment.</p> <p>Experiments showed UV preceded by filtration to remove sediments and larger organisms as having the most potential as an effective ballast water treatment at doses which could be cost effective.</p> <p>A pilot plant design for follow-up research was proposed.</p>

<b>Name of Project</b>	<b>Ballast Water Exchange and Marine Plankton Distribution Trials on the M.V. <i>Iron Whyalla</i></b>
<b>Treatment options researched</b>	<i>Ballast Water Exchange</i>
<b>Principal Researcher(s)</b>	Geoff Rigby and Gustaff Hallegraeff
<b>Contact Details</b>	Geoff Rigby Reninna Consulting 36 Creswell Avenue Charlestown NSW 2290 Australia Tel: +61 2 49 430 450, Fax: +61 2 49 478 938, Email: rigby@mail.com.
<b>Host Institution(s)</b>	Australian Quarantine and Inspection Service (AQIS) and the Broken Hill Propriety Limited (BHP).
<b>Location of Research</b>	Onboard the Bulk Carrier M.V. <i>Iron Whyalla</i> .
<b>Funding Level</b>	
<b>Funding Source(s)</b>	AQIS and BHP.
<b>Timeframe of the Project</b>	Trials carried out in 1990 and 1992.
<b>Aims and objectives of the project</b>	Understand the behaviour of ballast tank sediments and identify procedures to minimise the transfer of marine organisms.  Identify practical aspects of ballast exchange in terms of efficiency and study the effect of enclosing a natural community of microscopic marine plankton, including algae and animals, in a closed tank during the ship's voyage.
<b>Research Methods</b>	Onboard full scale trials on a 150,000 DWT bulk carrier.
<b>Results</b>	Inspection of ballast tanks showed only minor amounts of sediment. Approximately 100kg of sediment was estimated in the 55,000 tonnes of water discharged, and 50% was present as inorganic sediment. 80% of this sediment was smaller than 10 µm. Containment of plankton resulted in differential survival of various organisms present. Computer based simulation of still-water shear forces and bending moments indicated that emptying and refilling ballast tanks is unsafe as a general practice for a ship of this size and design. Continuous flushing does not significantly affect stresses and bending moments. Exchange trials showed that approximately 4% of the original water remained after exchanging three tank volumes and about 5% of the dead plankton of Japanese origin was retained. The efficiency of exchange under stagnant conditions was less effective. For the <i>Iron Whyalla</i> , the cost of replacing three tank volumes was estimated at approximately AUD\$2,300.  References:  Rigby, G.R. and Hallegraeff, G.M. (1993). Shipping ballast water trials on the bulk carrier M.V. <i>Iron Whyalla</i> . <i>AQIS Ballast Water Series Report No.2, Sept.</i> 123 pages.  Rigby, G.R. and Hallegraeff, G.M.(1994). The transfer and control of marine organisms in shipping ballast water: behaviour of marine plankton and ballast water exchange trials on the M.V. <i>Iron Whyalla</i> . <i>J. Marine Env. Engg., Vol. 1</i> , pp 91-110.  Rigby, G.R. (2001). Ocean exchange as a means of mitigating the risks of translocating ballast water organisms - a review of progress 10 years down the line. <i>J. Marine Env. Engg., Vol 6</i> , pp. 153-173.

<b>Name of Project</b>	<b>Ballast Water Heating and Sampling Trials on the BHP Ship MV <i>Iron Whyalla</i></b>
<b>Treatment options researched</b>	<i>Heat Treatment.</i>
<b>Principal Researcher(s)</b>	Geoff Rigby, Gustaff Hallegraeff, Caroline Sutton.
<b>Contact Details</b>	Geoff Rigby Reninna Consulting 36 Creswell Avenue Charlestown NSW 2290 Australia Tel: +61 2 49 430 450 Fax: +61 2 49 478 938 Email: rigby@mail.com.
<b>Host Institution(s)</b>	Australian Quarantine and Inspection Service (AQIS) and the Broken Hill Propriety Limited (BHP).
<b>Location of Research</b>	Onboard the MV <i>Iron Whyalla</i> .
<b>Funding Level</b>	
<b>Funding Source(s)</b>	AQIS and BHP.
<b>Timeframe of the Project</b>	The project consisted of two shipboard tests – the first in April 1997 on a coastal voyage between Port Kembla in New South Wales to Port Hedland in Western Australia. The second in June 1997 between Mizushima, Japan and Port Hedland. The report was printed in October 1997.
<b>Aims and objectives of the project</b>	To test the viability of heat treatment as a means of minimising the risk of introducing new organisms into the ports where ballast is discharged.
<b>Research Methods</b>	Involved onboard trials using ship's engine heat to heat ballast water and sampling of ballast tanks for temperatures achieved and organism survival.
<b>Results</b>	<p>Earlier laboratory experiments indicated that toxic dinoflagellate cysts are killed after 4.5 hours at 38°C.</p> <p>The full-scale shipboard trial showed that all ballast water in the ballast tank exceeded 38°C after 30 hours of heating.</p> <p>They showed that none of the zooplankton and only limited phytoplankton survived the heat treatment.</p> <p>The report concluded that heat treatment holds considerable potential and deserves further R&amp;D effort. It is attractive since it does not necessitate the use of biocides that could be harmful to the environment. It is safe since the tanks are always full of water and cost effective since it makes use of waste heat normally discarded and is likely to be of practical use for a range of ships.</p> <p>Variables that affect the viability of this method include the length of the ship's voyage and the temperature of the surrounding seawater.</p> <p>References: Rigby, G.R., Hallegraeff, G.M. and Sutton, C. (1999). Novel ballast water heating technique offers cost-effective treatment to reduce the risk of global transport of harmful marine organisms. <i>Mar. Ecol. Prog. Ser.</i> 191: 289-293</p>

<b>Name of Project</b>	<b>Ballast Water Treatment to Minimise the Risks of Introducing Nonindigenous Marine Organisms into Australian Waters – A Review of Current Technologies and Comparative Costs of Practical Options</b>
<b>Treatment options researched</b>	<i>All treatment options of practical interest have been reviewed, especially those that have or are being demonstrated at practical scales.</i>
<b>Principal Researcher(s)</b>	Dr Geoff Rigby (Reninna Consulting) and Alan Taylor (Alan H Taylor and Associates).
<b>Contact Details</b>	Reninna Consulting 36 Creswell Avenue Charlestown NSW 2290 Australia Tel: +61 2 49 430 450 Fax: +61 2 49 478 938 Email: rigby@mail.com.
<b>Host Institution(s)</b>	Reninna Consulting and Alan H Taylor and Associates.
<b>Location of Research</b>	Australia.
<b>Funding Level</b>	Approximately AUD\$30,000.
<b>Funding Source(s)</b>	Funded from the Australian Quarantine and Inspection Service Ballast Water Research Programme budget, which has come from a levy on ships calling on Australian ports.
<b>Timeframe of the Project</b>	Project completed January 2001.
<b>Aims and objectives of the project</b>	The main objective was to review the current status and technical effectiveness of appropriate treatment technologies and to develop indicative cost data for use of these options as a basis for selection of the most appropriate technologies.
<b>Research Methods</b>	Desktop review through local and international networks of researchers together with links and contacts with the shipping industry, regulators, equipment vendors, classification societies and ship builders.
<b>Results</b>	Detailed results and summary available in <i>AFFA Ballast Water Research Series Report No. 13</i> , January 2001 ( <a href="http://www.affa.gov.au">http://www.affa.gov.au</a> ).  References: Rigby, G. and Taylor, A. (2001). Ballast water management and treatment. <i>Trans ImarE, Vol 113, Part 3</i> , pp 79-99;  Rigby, G.R. (2001). Ocean exchange as a means of mitigating the risks of translocating ballast water organisms - a review of progress 10 years down the line. <i>J. Marine Env. Engg., Vol 6</i> , pp. 153-173;  Rigby, G.R. and Hallegraeff, G.M. (2002). On the nature of ballast tank sediments and their role in ship's transport of harmful marine microorganisms. <i>J. Marine Environ. Engg.</i> In press.

<b>Name of Project</b>	<b>Ballast Water Exchange and Marine plankton Distribution Trials on the M.V. <i>Iron Whyalla</i></b>
<b>Treatment options researched</b>	<i>Ballast Water Exchange</i>
<b>Principal Researcher(s)</b>	Geoff Rigby and Gustaff Hallegraeff
<b>Contact Details</b>	Geoff Rigby Reninna Consulting 36 Creswell Avenue Charlestown NSW 2290 Australia Tel: +61 2 49 430 450 Fax: +61 2 49 478 938 Email: rigby@mail.com.
<b>Host Institution(s)</b>	Australian Quarantine and Inspection Service (AQIS) and the Broken Hill Propriety Limited (BHP).
<b>Location of Research</b>	Onboard the Bulk Carrier M.V. <i>Iron Whyalla</i> .
<b>Funding Level</b>	
<b>Funding Source(s)</b>	AQIS and BHP.
<b>Timeframe of the Project</b>	Trials carried out in 1990 and 1992.
<b>Aims and objectives of the project</b>	Understand the behaviour of ballast tank sediments and identify procedures to minimise the transfer of marine organisms.  Identify practical aspects of ballast exchange in terms of efficiency and study the effect of enclosing a natural community of microscopic marine plankton, including algae and animals, in a closed tank during the ship's voyage.
<b>Research Methods</b>	Onboard full-scale trials on a 150,000 DWT bulk carrier.
<b>Results</b>	Inspection of ballast tanks showed only minor amounts of sediment. Approximately 100kg of sediment was estimated in the 55,000 tonnes of water discharged, and 50% was present as inorganic sediment. 80% of this sediment was smaller than 10 µm. Containment of plankton resulted in differential survival of various organisms present. Computer based simulation of still-water shear forces and bending moments indicated that emptying and refilling ballast tanks is unsafe as a general practice for a ship of this size and design. Continuous flushing does not significantly affect stresses and bending moments. Exchange trials showed that approximately 4% of the original water remained after exchanging three tank volumes and about 5% of the dead plankton of Japanese origin was retained. The efficiency of exchange under stagnant conditions was less effective. For the <i>Iron Whyalla</i> , the cost of replacing three tank volumes was estimated at approximately A\$2,300.  References: Rigby, G.R. and Hallegraeff, G.M. (1993). Shipping ballast water trials on the bulk carrier M.V. <i>Iron Whyalla</i> . <i>AQIS Ballast Water Series Report No.2, Sept.</i> 123 pp.  Rigby, G.R. and Hallegraeff, G.M. (1994). The transfer and control of marine organisms in shipping ballast water: behaviour of marine plankton and ballast water exchange trials on the M.V. <i>Iron Whyalla</i> . <i>J. Marine Env. Engg., Vol. 1</i> , pp 91-110.  Rigby, G.R. (2001). Ocean exchange as a means of mitigating the risks of translocating ballast water organisms - a review of progress 10 years down the line, <i>J. Marine Env. Engg., Vol 6</i> , pp. 153-173.

Name of Project	<b>Suggested Designs to Facilitate Improved Management and Treatment of Ballast Water on New and Existing Ships</b>
<b>Treatment options researched</b>	<i>Design options for ballast water exchange (sequential and flow-through), heating via main engine cooling water, chemical, filtration, hydrocyclones, ultraviolet irradiation, fresh or recirculated water, discharge to shore based or dedicated treatment ships and best practice design aspects related to sea chests, ballast tanks (especially strength, water flow and minimisation of sediment accumulation), ballast pumps and pipework and chain lockers in relation to sediments.</i>
<b>Principal Researcher(s)</b>	Alan H Taylor (Alan H Taylor and Associates) and Dr Geoff Rigby (Reninna consulting).
<b>Contact Details</b>	Alan H Taylor and Associates Pty Limited 59 Hillcroft Drive Templestowe Vic 3106 Australia Tel: +61 (0)3 9846 2650 Fax: +61 (0)3 9846 2650 Email: aht@ahtaylor.com Web: www.ahtaylor.com
<b>Host Institution(s)</b>	Alan H Taylor & Associates and Reninna Consulting.
<b>Location of Research</b>	Australia.
<b>Funding Level</b>	Approximately AUD\$15,000.
<b>Funding Source(s)</b>	Funded from the Australian Quarantine and Inspection Service Ballast Water Research Programme budget which has come from a levy on ships calling at Australian ports.
<b>Timeframe of the Project</b>	Project completed January 2001.
<b>Aims and objectives of the project</b>	To suggest designs to enhance ballast water management on new and existing ships.
<b>Research Methods</b>	Review of designs of existing ships and new ships and develop further designs and enhancements to facilitated better ballast water management.
<b>Results</b>	Detailed results and summary available in the Department of Agriculture, Forestry and Fisheries Australia (AFFA) Ballast Water Research Series Report No.12, January 2001 ( <a href="http://www.affa.gov.au">http://www.affa.gov.au</a> ).



<b>Name of Project</b>	<b>Hi Tech Marine HT2001</b>
<b>Treatment options researched</b>	<i>Proprietary Biocide</i>
<b>Principal Researcher(s)</b>	Glenn Thornton, Dr. Marcus Scammell, Rohm & Haas.
<b>Contact Details</b>	Hi Tech Marine Pty Ltd PO Box 524 Newport NSW 2106 Australia Tel: +61 2 9997 7494 Fax: +61 2 9997 8962 Email: gthornton@htmarine.com.au
<b>Host Institution(s)</b>	
<b>Location of Research</b>	Hawkesbury River & Sydney, Australia; Philadelphia, USA.
<b>Funding Level</b>	US\$ 750,000.
<b>Funding Source(s)</b>	Joint venture Hi Tech Marine, Rohm & Haas.
<b>Timeframe of the Project</b>	2.5 years – 1991-1993.
<b>Aims and objectives of the project</b>	To evaluate the effectiveness and bio-degradability of a chemical Biocide technology, environmental risk assessment and indicative cost data.
<b>Research Methods</b>	Plate leaching trials, biota mortality trials, and environmental degradation trials.
<b>Results</b>	Positive. However, prior to sea trials in 1993, advised by AQIS (Department of Agriculture) that chemical treatment of ballast water was not acceptable.

Name of Project	Hi Tech Marine SeaSafe (Onboard) & WaterSafe (Shore based) Systems
<b>Treatment options researched</b>	<i>Biocidal Heat Treatment.</i>
<b>Principal Researcher(s)</b>	Glenn Thornton & Bob Prentice
<b>Contact Details</b>	Hi Tech Marine Pty Ltd PO Box 524 Newport NSW 2106 Australia Tel: +61 2 9997 7494 Fax: +61 2 9997 8962 Email: gthornton@htmarine.com.au
<b>Host Institution(s)</b>	Independent.
<b>Location of Research</b>	Sydney, Australia; Hobart, Australia.
<b>Funding Level</b>	AUD\$2,500,000.
<b>Funding Source(s)</b>	Hi Tech Marine Pty Ltd (principal), BDT Senior Thermal Engineering Pty Ltd, Hisaka Works Ltd., Intercontinental Ship Management Pty Ltd, Lloyds Register.
<b>Timeframe of the Project</b>	1995 – 2001.
<b>Aims and objectives of the project</b>	To evaluate the effectiveness of our heat treatment technology and to develop indicative cost data.
<b>Research Methods</b>	<p>SeaSafe sea trials Adelaide – Hobart; Sydney – Hobart; Geelong – Hobart, M.V. ‘Sandra Marie’ 1997.</p> <p>WaterSafe system first demonstrated June 1997. For methodology of systems see <a href="http://www.htmarine.com.au">http://www.htmarine.com.au</a>.</p> <p>Treatment time/temperatures based on mortality figures of toxic Dinoflagellate cysts (<i>G. catenatum</i>), from Bolch &amp; Hallegraeff, Hallegraeff &amp; Rigby, and human pathogen mortality figures from Dr. B.J. Hudson, Chief Microbiologist, Royal North Shore Hospital, Sydney.</p> <p>WaterSafe system now elevated to 90°C for 60 seconds.</p>
<b>Results</b>	<p>On-board (SeaSafe system): Sea trial (Sydney – Hobart) was conducted in gale-force weather and achieved an 80-90% kill rate for <i>G. catenatum</i> cysts, at temperatures of 50°C for 45 seconds. Trial monitored by AQIS, test results obtained by Dr. G. Hallegraeff in Hobart.</p> <p>Shore-based (WaterSafe system): Shore based demonstration at Sydney, Australia, monitored by AQIS, NSW Government and various shipping industry representatives. Results obtained by Dr. R. Campbell 100% mortality of all marine organisms including <i>G. catenatum</i> cysts at temperature of 80°C for a period of 60 seconds.</p> <p>WaterSafe system now elevated to 90°C for 60 seconds, which has resulted in a mortality of 99.9% of human pathogens including <i>Hepatitis A virus</i> (per Qld Dept Public Health).</p> <p>Reviewed by: Rigby G.R. and A.H. Taylor ‘Ballast Water Treatment Report No. 13 – Ballast Water treatment to Minimise the Risks of Introducing Nonindigenous Marine Organisms into Australian Ports.’ January 2001. Agriculture, Fisheries and Forestry – Australia ISBN 0-642-47669-1.</p> <p>Report on results of testing available on request or visit: <a href="http://www.htmarine.com.au">http://www.htmarine.com.au</a></p>

## Germany

Name of Project	Process for the removal of organisms from different waters
<b>Treatment options researched</b>	<i>Chemical treatment: oxidising, environmentally friendly biocide formulation Peraclean<sup>®</sup> Ocean; with and without separation of solids</i>
<b>Principal Researcher(s)</b>	Degussa AG
<b>Contact Details</b>	Degussa AG, BW-FEA-A, Rodenbacher Chaussee 4, D-63457 Hanau-Wolfgang, Germany Tel: +49 6181-59-3892 Fax: +49 6181-59-3311 e-mail: rainer-g.fuchs@degussa.com Web: www.degussa.com
<b>Host Institution(s)</b>	Degussa.
<b>Location of Research</b>	Germany.
<b>Funding Level</b>	Ca. US\$200,000.
<b>Funding Source(s)</b>	Federal Ministry for Research and Technology of Germany.
<b>Timeframe of the Project</b>	1998-2002.
<b>Aims and objectives of the project</b>	<ul style="list-style-type: none"> <li>• Develop laboratory test methods to compare different chemical treatment options as a prescreening to full scale testing.</li> <li>• Compare different treatment options in full scale testing.</li> <li>• Develop dosage equipment for full scale testing.</li> </ul>
<b>Research Methods</b>	<ul style="list-style-type: none"> <li>• Chemical treatment options were tested in the lab with the testing standard ATS = Artemia Testing Standard by Dr. Voigt-Consulting, Germany.</li> <li>• Full scale testing was enabled by taking part in a shipboard testing program by Maritime Solutions Inc., USA in 2001; more testing planned in 2002.</li> <li>• Field trials were conducted together with Hamann Wassertechnik, Germany in 2001; more testing planned in 2002.</li> </ul>
<b>Results</b>	<ul style="list-style-type: none"> <li>• Laboratory tests showed complete mortality of different species with 400 ppm Peraclean<sup>®</sup> Ocean or less.</li> <li>• Field trial aboard a ship (together with Maritime Solutions Inc.) in USA, 2001, showed 99-100% mortality of all examined zooplankton, phytoplankton and a 3 log. removal of culturable bacteria with 200 ppm Peraclean<sup>®</sup> Ocean (stand alone treatment).</li> <li>• Field trial at Hamburg, Germany in 2001, together with Hamann Wassertechnik showed complete killing and/or separation of the observed* or added** species at a dosage rate of 100 ppm Peraclean<sup>®</sup> Ocean or more.</li> <li>• Treatment with Peraclean<sup>®</sup> Ocean after separation of solids: planned for 2002.</li> </ul> <p>* Cyclops (Copepode), Daphnia, Copepode nauplii, Rotifiers, Ciliates, Nematodes, undetermined eggs, larval Polychaetes, Cladocera, Foraminifera.</p> <p>** Artemia nauplii and Artemia eggs.</p>

## Japan

<b>Name of Project</b>	<b>Unwanted Aquatic Organisms in Ballast Tank – Report of the ballast water management by heat treatment using main engine water cooling circuit and findings of the on-board research</b>
<b>Treatment options researched</b>	<i>Heat treatment.</i>
<b>Principal Researcher(s)</b>	Japanese Shipowners' Association.
<b>Contact Details</b>	Kaiun Bldg No 6-4, 2-Chome Hirakawa-cho Chiyoda-ku Tokyo 102, Japan Tel: +81 3 3264 7171 Fax: +81 3 3262 4760 Web: www.jsanet.or.jp.
<b>Host Institution(s)</b>	Japanese Shipowners' Association.
<b>Location of Research</b>	On board the ore carrier MV Onde Maru in the Japanese port of Kure and en-route to Port Walcott in Australia.
<b>Funding Level</b>	
<b>Funding Source(s)</b>	
<b>Timeframe of the Project</b>	February 1995.
<b>Aims and objectives of the project</b>	To determine: <ul style="list-style-type: none"> <li>• The results of treating ballast water with heat obtained from the cooling circuit of the main engine.</li> <li>• The effect of re-ballasting at sea.</li> <li>• The viability of the phytoplankton in the ballast tank.</li> </ul>
<b>Research Methods</b>	Conducted an at-sea analysis of heat treatment, re-ballasting and the viability of phytoplankton between Japan and Australia.
<b>Results</b>	The experiment discovered that: <ul style="list-style-type: none"> <li>• The marine organisms in the ballast tank were minimised by the heat treatment, but the question of how to make the prescribed water temperature uniform in the ballast tank still remained.</li> <li>• None of the phytoplankton in the original ballast tank survived the journey to Port Walcott, but there was still the possibility of cysts surviving in bottom sediments.</li> <li>• Other harmful aquatic organisms were taken into the ballast tank when reballasting at sea.</li> <li>• The ballast water was heated to a high of 43°C at the inlet but only reached 35°C at the point of the ballast tank furthest from the inlet.</li> </ul>

## Netherlands

<b>Name of Project</b>	<b>Global Market Analysis of Ballast Water Treatment Technology</b>
<b>Treatment options researched</b>	<i>All treatment options of practical interest are reviewed.</i>
<b>Principal Researcher(s)</b>	H.A. Schilperoord and F.J. Tjallingii
<b>Contact Details</b>	Royal Haskoning PO Box 94241 1090 GE Amsterdam Tel. +31 (0)20 569 77 83 Fax +31 (0)20 569 77 66 Email: h.schilperoord@royalhaskoning.com Www.royalhaskoning.com
<b>Host Institution(s)</b>	Royal Haskoning.
<b>Location of Research</b>	Amsterdam, The Netherlands.
<b>Funding Level</b>	
<b>Funding Source(s)</b>	Northeast/Midwest Institute, USA.
<b>Timeframe of the Project</b>	June-November 2001.
<b>Aims and objectives of the project</b>	Provide a global analysis of the market for a ballast water treatment technology industry. An insight in the probable market for ballast water treatment systems in light of forthcoming national and international ballast water management requirements.
<b>Research Methods</b>	Based on an analysis of Lloyds Register of Ships and discussions by an expert group consisting of representatives of the shipping and port industry and shipping experts at Royal Haskoning a number of assumptions regarding the IMO's Convention on ballast water are drawn.
<b>Results</b>	The study resulted in an estimation of the potential market (in number of vessels) in three time periods (-2003, 2003-2008 and 2008-2013). The calculations on potential turnover were made by multiplying the numbers of vessels with the cost of fitting a modal (existing or new) vessel with a treatment system. From 2008 the potential market is estimated to be between USD700 million and USD1 billion per annum.  The report is shown on: <a href="http://www.nemw.org/Haskoningreport.pdf">www.nemw.org/Haskoningreport.pdf</a>

## New Zealand

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<b>Name of Project</b>	<b>Heat Treatment of Ships' Ballast Water: Development and Application of a Model Based on Laboratory Studies</b>
<b>Treatment options researched</b>	<i>Heat Treatment.</i>
<b>Principal Researcher(s)</b>	D Mountfort, C Hay, M Taylor, S Buchanan, W Gibbs
<b>Contact Details</b>	Cawthron Institute 98 Halifax Street East Private Bag 2 Nelson Nelson New Zealand Tel: +64 (0)3 548 2319 Fax: +64 (0)3 546 9464 Email : doug@cawthron.org.nz Web: www.cawthron.org.nz.
<b>Host Institution(s)</b>	Cawthron Institute.
<b>Location of Research</b>	Nelson, New Zealand.
<b>Funding Level</b>	
<b>Funding Source(s)</b>	
<b>Timeframe of the Project</b>	Report printed 1999.
<b>Aims and objectives of the project</b>	To determine, using laboratory methods, the optimum conditions required for the application of heating to kill invasive species in ballast water.
<b>Research Methods</b>	Adult samples of the starfish <i>Coscinasterias calamaria</i> , the zoospores of the seaweed <i>Undaria pinnatifida</i> , and the larvae of <i>Crassostrea gigas</i> were used for laboratory study of effects of heat treatment.
<b>Results</b>	The study assumed that the organisms could be transported in ballast water in a viable state for the duration of a sea journey and therefore pose a threat. The study developed a linear model intended for use in the prediction of kill times over a temperature range of between 35-48°C.

Name of Project	Shipboard Heat Treatment of Ballast Water
<b>Treatment options researched</b>	<i>Heat Treatment.</i>
<b>Principal Researcher(s)</b>	D Mountfort, C Hay, M Taylor, S Buchanan, W Gibbs
<b>Contact Details</b>	Cawthron Institute 98 Halifax Street East Private Bag 2 Nelson Nelson New Zealand Tel: +64 (0)3 548 2319 Fax: +64 (0)3 546 9464 Email : info@cawthron.org.nz Web: www.cawthron.org.nz.
<b>Host Institution(s)</b>	Cawthron Institute.
<b>Location of Research</b>	RoRo vessel <i>Rotoma</i> .
<b>Funding Level</b>	
<b>Funding Source(s)</b>	
<b>Timeframe of the Project</b>	
<b>Aims and objectives of the project</b>	To test the shipboard efficacy of heat treatment.
<b>Research Methods</b>	Cawthron developed a shipboard system on the RoRo vessel <i>Rotoma</i> for the heat treatment of ballast water. Water from ballast tanks is pumped through a heat exchanger, which is heated by the vessel's engine exhaust.
<b>Results</b>	Studies have shown that a complete kill of test organisms can be achieved in 6-10 hours by heating to 36-38°C. Further tests are planned for early 2001.

<b>Name of Project</b>	<b>Oxygen Deprivation as a Treatment for Ships' Ballast Water – Laboratory Studies and Evaluation</b>
<b>Treatment options researched</b>	<i>Oxygen deprivation.</i>
<b>Principal Researcher(s)</b>	D Mountfort, C Hay, M Taylor, S Buchanan, W Gibbs.
<b>Contact Details</b>	Cawthron Institute 98 Halifax Street East Private Bag 2 Nelson Nelson New Zealand Tel: +64 (0)3 548 2319 Fax: +64 (0)3 546 9464 Email: doug@cawthron.org.nz Web: www.cawthron.org.nz.
<b>Host Institution(s)</b>	Cawthron Institute.
<b>Location of Research</b>	Nelson, New Zealand.
<b>Funding Level</b>	
<b>Funding Source(s)</b>	
<b>Timeframe of the Project</b>	Report printed in 1999.
<b>Aims and objectives of the project</b>	To demonstrate the potential for the use of oxygen deprivation as a treatment option for infected ballast water.
<b>Research Methods</b>	Adult samples of the starfish <i>Coscinasterias calamaria</i> , the zoospores of the seaweed <i>Undaria pinnatifida</i> , and the larvae of <i>Crassostrea gigas</i> were used for laboratory study of effects of nitrogen, sulphide and glucose in killing the sample organisms through oxygen depletion.
<b>Results</b>	Study concluded that lowering the level of oxygen to less than 3 mg l(-1) leads to effective kills of <i>Undaria</i> zoospores and <i>Coscinasterias calamaria</i> larvae. However, more research is required both into the species range affected by deoxygenation and into the practicality of the various methods before shipboard investigations of this technology can be conducted.



<b>Name of Project</b>	<b>Mid Ocean Ballast Water Exchange: Shipboard Trials of Methods for Verifying Efficiency</b>
<b>Treatment options researched</b>	<i>Ballast Water Exchange.</i>
<b>Principal Researcher(s)</b>	Michael Taylor (Cawthron Institute) and Elizabeth Bruce (Battelle).
<b>Contact Details</b>	Cawthron Institute 98 Halifax Street East Private Bag 2 Nelson Nelson, New Zealand Tel: +64 (0)3 548 2319 Fax: +64 (0)3 546 9464 Email : info@cawthron.org.nz Web: www.cawthron.org.nz.
<b>Host Institution(s)</b>	Cawthron Institute (New Zealand) and Battelle (USA).
<b>Location of Research</b>	Onboard testing conducted on the coastal container vessel MV <i>Spirit of Vision</i> and the trans-Pacific chemical carrier MT <i>Iver Stream</i> .
<b>Funding Level</b>	
<b>Funding Source(s)</b>	
<b>Timeframe of the Project</b>	Report published in August 1999.
<b>Aims and objectives of the project</b>	<ul style="list-style-type: none"> <li>• To review the availability of existing methods to measure and record the volumes of water pumped through the ballast tanks and determine the efficiency of mid-ocean ballast water exchange practice.</li> <li>• To verify ship compliance with mid-ocean ballast water exchange controls and guidelines.</li> <li>• To develop and pilot test, including on at least two ships with different ballast tank configurations, ballast water exchange verification methodologies.</li> </ul>
<b>Research Methods</b>	<p>The study used:</p> <ul style="list-style-type: none"> <li>• A series of laboratory-based experiments which assessed the suitability of Rhodamine WT tracer dye for measuring the dilution efficiency of mid-ocean exchange;</li> <li>• Three voyages on the <i>Spirit of Vision</i> and one voyage aboard the <i>Iver Stream</i>.</li> </ul>
<b>Results</b>	The study found that the tracer dye Rhodamine WT is particularly useful for measuring the dilution efficiency of mid-ocean ballast water exchanges. In each of the mid-ocean ballast water exchange trials, all of which used the flow-through dilution method, the dilution efficiency of the completed exchange was in excess of 90% for the <i>Spirit of Vision</i> (capacity tank = 114 cubic metres) and 99% for the <i>Iver Stream</i> (capacity tank = 1435 cubic metres).

## Norway

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Name of Project	Use of Gas Supersaturation to Remove Organisms in Ballast Water
<b>Treatment options researched</b>	<i>Injections of gas (air and N<sub>2</sub>) to create gas supersaturation</i>
<b>Principal Researcher(s)</b>	Anders Jelmert
<b>Contact Details</b>	Dr. O. Enger Forinnova A/S Thormøhlensgate 55 N-5008 Bergen Norway www.forinnova.no
<b>Host Institution(s)</b>	Forinnova A/S
<b>Location of Research</b>	Institute of Marine Research Austevoll Aquaculture Research Station N5392 Storebø, Norway
<b>Funding Level</b>	US\$35,000
<b>Funding Source(s)</b>	Norwegian Research Board: 50% Industry: 50%
<b>Timeframe of the Project</b>	Autumn 2000 – Summer 2001
<b>Aims and objectives of the project</b>	Studies on the effects of gas supersaturation on several organisms in ballast water.
<b>Research Methods</b>	Survival and other chosen end-point measures of organisms as a function of gas mixture, pressure and exposure time.
<b>Results</b>	(Preliminary) Increased mortality in <i>Artemia sp. naupleii</i> exposed to air at 1 ato for 18 hours, yielding 119% nitrogen supersaturation.

Name of Project	OptiMar Ballast Systems' Research 1998
<b>Treatment options researched</b>	<i>Mechanical separation (Lakos separator), UV treatment (MicroKill UV).</i>
<b>Principal Researcher(s)</b>	Halvor Nilsen.
<b>Contact Details</b>	OptiMarin AS Randbergv. 101 N-4027 Stavanger Norway Tel: +47 51542269 Fax: +47 51542439 E-Mail: halvor.nilsen@stavanger.online.no Web: www.optimarin.com & www.microkill.com
<b>Host Institution(s)</b>	Institute of Marine Research, Bergen, Norway.
<b>Location of Research</b>	Austevoll Aquaculture Research Institute Station.
<b>Funding Level</b>	ECU 50,000.
<b>Funding Source(s)</b>	Norwegian Maritime Directorate & OptiMarin AS.
<b>Timeframe of the Project</b>	March/April 1998.
<b>Aims and objectives of the project</b>	To develop a system of remove as many suspended solids and uni- and multi-cellular organisms through primary mechanical and secondary UV treatment.
<b>Research Methods</b>	The results were obtained in a semi-scale laboratory test of an integrated hydrocyclone-UV unit, designed for removal of exotic species in ballast water.
<b>Results</b>	The removal of particles and mortality of the various biota at four consecutive stages through the treatment system was recorded. Cysts of the brine shrimp <i>Artemia sp.</i> were removed at an efficiency of 13.7% in the hydrocyclone, and the naupilus-larva of <i>Artemia</i> were removed at an efficiency of 8.3%. Through the UV-unit, the naupleii showed a mortality of 99.5% and the numbers of hatching cysts was 26 % lower than the numbers before the unit. The microalga were removed with an efficacy of 10 - 30 % range in the hydrocyclone, and showed a mortality in the UV-unit of 84.7% and 87.6 %, respectively for <i>P. minimum</i> and <i>Tetraselmis sp.</i> The removal of bacteria in the hydrocyclone was negligible, while the bacterial numbers were reduced corresponding to a -2.3 log and -1.9 log elimination respectively, by UV treatment in two separate trials.

Name of Project	<b>OptiMar Ballast Systems Research 1999</b>
<b>Treatment options researched</b>	<i>Mechanical separation (Lakos separator), UV treatment (MicroKill UV).</i>
<b>Principal Researcher(s)</b>	Halvor Nilsen.
<b>Contact Details</b>	OptiMarin AS Randabergv. 101 N-4027 Stavanger Norway Tel: +47 51542269 Fax: +47 51542439 E-Mail: halvor.nilsen@stavanger.online.no Web: www.optimarin.com & www.microkill.com
<b>Host Institution(s)</b>	Institute of Marine Research, Bergen, Norway.
<b>Location of Research</b>	Austevoll Aquaculture Research Institute Station.
<b>Funding Level</b>	ECU 60,000.
<b>Funding Source(s)</b>	OptiMarin AS.
<b>Timeframe of the Project</b>	March/April 1999.
<b>Aims and objectives of the project</b>	Repeat of the 1998 test but with another separator.
<b>Research Methods</b>	The results were obtained in a semi-scale laboratory test of an integrated hydrocyclone-UV unit, designed for removal of exotic species in ballast water.
<b>Results</b>	Same as 1998. Subsequent to these tests, the Optimar Ballast Water Treatment System has been installed aboard the cruise-liner <i>Regal Princess</i> and is the first fully functional ballast water treatment system aboard an operating vessel. Further tests are required, especially in relation to scaling-up to handle larger quantities of ballast water on tankers and bulk carriers.

## Poland

<b>Name of Project</b>	<b>System for Destruction of Microorganisms Occurring in Ballast Waters Technical Assumptions</b>
<b>Treatment options researched</b>	<i>Heat treatment.</i>
<b>Principal Researcher(s)</b>	Zdzisław Sobol, Władysław Korczak, Bohdan Wojaliewicz.
<b>Contact Details</b>	Institute of Maritime and Tropical Medicine in Gdynia Department of Protection of the Environment and Hygiene of Transport Ul. Powstania Styczniowego 9B 81-519 Gdynia Poland Tel: +48 58 622 30 11 Fax: +48 58 622 33 54 Web: www.immt.gdynia.pl.
<b>Host Institution(s)</b>	Institute of Maritime and Tropical Medicine in Gdynia.
<b>Location of Research</b>	Gdynia, Poland.
<b>Funding Level</b>	
<b>Funding Source(s)</b>	
<b>Timeframe of the Project</b>	Report Date – 1995.
<b>Aims and objectives of the project</b>	Selection of appliances for the treatment of micro- and macro-organisms occurring in ballast water.
<b>Research Methods</b>	
<b>Results</b>	Heat treatment is preferable to chemical treatment as it does not require carrying chemicals onboard, and heat is continuously available from boiler steam or main and auxiliary engine cooling system. The costs are also small when compared with other methods. The chemical method required final deactivation before it is discharged into the sea, making heat more competitive. Use of UV was not considered, as ballast water is extremely dirty and coloured. Disinfecting methods using radiation was not considered, as its use is not neutral to a natural sea environment.

## United Kingdom

Name of Project	Ballast Water Sampling Project
<b>Treatment options researched</b>	NA
<b>Principal Researcher(s)</b>	Elspeth Macdonald
<b>Contact Details</b>	C/o Tracy McCollin FRS Marine Laboratory PO Box 101 Victoria Road Aberdeen AB25 2RQ Tel ++ 1224 295573 Fax ++ 1224 295511 E-mail mcollint@marlab.ac.uk
<b>Host Institution(s)</b>	FRS Marine Laboratory, Aberdeen.
<b>Location of Research</b>	Scotland, United Kingdom.
<b>Funding Level</b>	
<b>Funding Source(s)</b>	Scottish Office of Agriculture, Environment and Fisheries Department; Department of Transport/ Marine Safety Agency; Scottish Natural Heritage.
<b>Timeframe of the Project</b>	Three years 1994-1997.
<b>Aims and objectives of the project</b>	<ul style="list-style-type: none"> <li>• To investigate the transport of planktonic organisms and resting dinoflagellate cysts in ships' ballast water and sediments.</li> <li>• To collate information on selected physical and chemical parameters of ballast water discharges.</li> <li>• To assess the risk of organisms becoming established in Scottish waters by literature study, and identify the ports and origins most likely to contain these organisms.</li> <li>• To carry out heavy metal analyses on sediments from ships' ballast tanks.</li> </ul>
<b>Research Methods</b>	Samples of ballast water collected from vessels arriving at ports around Scotland were analyzed for phytoplankton, zooplankton and heavy metals. Selected physical and chemical properties of the ballast water were also measured. An initial analysis of phytoplankton abundance and diversity in samples collected before and after an exchange process was also undertaken.
<b>Results</b>	<p>Macdonald, E.M. and Davidson, R. (1997). <i>Ballast Water Project. Final Report</i>. Fisheries Research Services Report Number 3/97. Fisheries Research Services; Aberdeen. 83 pages.</p> <p>Macdonald, E.M. and Davidson, R.D. (1998). The occurrence of harmful algae in ballast water discharges to Scottish ports and the effects of mid-water exchange in regional seas. In: Reguera, B., Blanco, J., Fernandez, M.L. and Wyatt, T. (Eds). <i>Harmful Algae</i>. Xunta de Galicia and Intergovernmental Oceanographic Commission of UNESCO 1998. Pages 220-223.</p>

Name of Project	Disinfection of Ballast Water – A review of potential options
<b>Treatment options researched</b>	<i>Mechanical (filtration), physical (UV and heat treatment), chemical.</i>
<b>Principal Researcher(s)</b>	K Müller, J S Carlton
<b>Contact Details</b>	Lloyds Register Engineering Services Lloyds Register House 29 Wellesley Road Croyden CR0 2AJ United Kingdom Tel: +44 (0)20 8681 4040 Fax: +44 (0)20 8681 6814.
<b>Host Institution(s)</b>	Lloyds Register, Engineering Services, Technical Investigation, Propulsion & Environmental Engineering Department.
<b>Location of Research</b>	
<b>Funding Level</b>	
<b>Funding Source(s)</b>	
<b>Timeframe of the Project</b>	Report date – July 1995.
<b>Aims and objectives of the project</b>	Evaluate disinfection options for ballast water.
<b>Research Methods</b>	Study comprised desk based review of various disinfection options and laboratory-based trials to examine likely effectiveness of selected disinfection methods for onboard use.
<b>Results</b>	Treatment options for the disinfection of ballast water at sea or at the port of origin (as an alternative to the exchange of ballast water at sea) are described in terms of efficiency, practicality, cost, environmental impact and safety considerations.

## United States of America

Name of Project	AquaHabiStat™, or AHS™
<b>Treatment options researched</b>	<i>Removal of dissolved oxygen as water enters ballast tank through use of a vacuum tank. Maintaining low DO for duration of voyage.</i>
<b>Principal Researcher(s)</b>	Browning Transport Management, Inc.
<b>Contact Details</b>	Wilson Browning Jr and Wilson Browning III Browning Transport Management, Inc. 127 Bank Street Norfolk, VA 23510 United States of America Tel: +1 757 622 3321 Fax: +1 757 625 7456 Email: will@wjbrowning.com & leslie@wjbrowning.com Web: www.wjbrowning.com
<b>Host Institution(s)</b>	The Commonwealth of Virginia; Old Dominion University; Hampton Roads Sanitation District; Virginia Institute of Maritime Science.
<b>Location of Research</b>	Hampton Roads, VA.
<b>Funding Level</b>	>US\$2.5 million.
<b>Funding Source(s)</b>	Browning Transport Management and the Commonwealth of Virginia.
<b>Timeframe of the Project</b>	The project consisted of three 10-day time series tests completed in summer 2000 and two 10-day series tests completed December 2000.
<b>Aims and objectives of the project</b>	To measure the decline, by microscopic counts, of “ambient zooplankton other than copepods” as a marker group for larval forms to compare the deoxygenated water with the normal simulated ballast water. Did not consider copepods’ activities to mimic larval forms as much as would other zooplankton.
<b>Research Methods</b>	<p>A pump located near the bulkhead moved ambient water from Elizabeth River (VA) into a 5,000 liter (18 foot diameter) plastic swimming pool. From there, a computer controlled system pumped the water out of the first pool and used a propriety spray system to inject the water into a vacuum tank that was kept near or below 1 psia by a vacuum pump under the direction of the computer control system.</p> <p>A second pump pulled the water out of the vacuum and placed it in a duplicate, treated pool. Both pools were covered to simulate a ballast tank. Daily samples were taken.</p> <p>Of the first three 10-day series tests, the first two were done microscopically from relatively warm water (20-26°C). The third 10-day test, also in 20-26°C water, was analysed microscopically and by ATP analysis. The water arrived in the treated tank with a DO of 1ppm or less and in general declined to 0.5ppm in five days and to zero in ten days.</p>
<b>Results</b>	After ten days, the treated tank had no organisms present, while the untreated tank did.



<b>Name of Project</b>	<b>The Great Lakes Ballast Water Technology Demonstration Project: Filtration Mechanical Test Program</b>
<b>Treatment options researched</b>	<i>Mechanical filtration.</i>
<b>Principal Researcher(s)</b>	Allegra Cangelosi, MS (Northeast/Midwest Institute) and Richard Harkins, PE, (Lake Carriers' Association);  with Ivor Knight, PhD, James Madison University, Mary Balcer, PhD, University of Wisconsin – Superior; Michael Parsons, PhD, University of Michigan; David Wright, PhD, and Rodger Dawson, PhD, University of Maryland; and Donald Ried, MS, Napean, Ontario.
<b>Contact Details</b>	Northeast/Midwest Institute 218 D Street, SE Washington, DC 20003 United States of America Tel: +1 202 544 5200 Fax: +1 202 544 0043 Email: acangelo@nemw.org Web: www.nemw.org.
<b>Host Institution(s)</b>	Northeast-Midwest Institute.
<b>Location of Research</b>	Gulf of St Lawrence, Great Lakes, Duluth Harbor.
<b>Funding Level</b>	Over \$1.5 million
<b>Funding Source(s)</b>	Great Lakes Protection Fund, Legislative Commission on Minnesota Resources, US Environmental Protection Agency Great Lakes National Program Office.
<b>Timeframe of the Project</b>	1996 – 1998.
<b>Aims and objectives of the project</b>	To establish the biological and operational effectiveness of ballast filtration.
<b>Research Methods</b>	Testing was conducted on the Canadian seaway sized (222.5m x 22.86m) bulk carrier MV <i>Algonorth</i> in 1997 and a barge in Lake Superior in 1998. The test programme involved extended testing with 25 and 50 micron filter screens at 1500 US gpm with and without a prefilter. Bioeffectiveness was measured in matched treatment and control tanks and evaluated for relative zooplankton, phytoplankton and microbial concentrations.
<b>Results</b>	Study concluded that filtration at 25 and 50 microns yielded similar biological results: macrozooplankton removed at a rate of 96 percent or higher, 2) microzooplankton (rotifers) and total phytoplankton removed at rate of 70-80 percent; and 3) no significant reduction in total bacteria, though attached bacteria significantly reduced. Zooplankton width, rather than length, was dimension most predictive of removal efficiency. Filtration is suitable for some shipboard applications and particle removal will reduce sedimentation in ballast tanks. Future designs must have improved features to facilitate handling of the heavy filter screen elements.

<b>Name of Project</b>	<b>Electro-Ionization Treatment for Ballast Water; Shipboard Installation on Carnival M/S <i>Elation</i></b>
<b>Treatment options researched</b>	<i>NI-OX gas system interfaced with seawater electrolysis</i>
<b>Principal Researcher(s)</b>	C. E. Bud Leffler , William Paul, Marine Environmental Partners Dr. Andrew Rogerson Ph.D. & Courtney Campbell Nova Southeastern University, Ft. Lauderdale, Fla.
<b>Contact Details</b>	Marine Environmental Partners, Inc. 255 E. Dania Beach Blvd. Suite 220, Dania Beach, Fla. U.S. 33004 Tel: 954-924-5500 Fax: 954-924-5508 Web: www.mepi.net Email: bud@mepi.net jon@mepi.net  C.E. Bud Leffler – President & CEO, Jon Stewart – V.P. Sales & Marketing Bill Paul – Manager Installation & Service Engineering
<b>Host Institution(s)</b>	NOVA Southeastern University Oceanographic Research Center, Ft. Lauderdale, Fla.
<b>Location of Research</b>	Fort Lauderdale Florida USA and Long Beach, California USA.
<b>Funding Level</b>	Private.
<b>Funding Source(s)</b>	Private.
<b>Timeframe of the Project</b>	Installation was completed Jan 2002. Testing will be completed 17 March 2002.
<b>Aims and objectives of the project</b>	Evaluate and demonstrate the viability of utilizing multiple processes of electro-disinfection to eliminate biota in ship's ballast water.
<b>Research Methods</b>	<p>Verification of killing effectiveness was determined by indirect counting methods. These are all enrichment cultivation methods that rely on scoring the growth of organisms after treatment. Growth is a strong index of survival because only healthy, undamaged cells will reproduce. Bacteria were enumerated by standard plate counting methods using Marine agar 2216 to nourish total heterotrophic bacteria. Protists (algae and protozoa) were counted by growing cells in tissue culture wells after inoculating with a small aliquot (around 20 microliter) of treated water.</p> <p>Growth of any protists was assumed to have originated from a single cell inoculated into the well. In this way, an approximate count of each population was attained (i.e. amoebae, heterotrophic flagellates, ciliates, diatoms, dinoflagellates and autotrophic flagellates).</p> <p>The number of macroinvertebrates was determined by direct observation after collecting organisms on an 80 micron mesh. Typically 10 litres or more was processed.</p>
<b>Results</b>	<p>The current prototype system has been tested with the pending Coast Guard Protocol to obtain samples, provide a growth medium and then count the living organisms that have survived. The preliminary testing was done independently by NOVA' S Dr. Rogerson, Courtney Campbell and other graduate students.</p> <p>The initial results were very promising as they had 99.9% elimination of biota. These first tests were done looking at bacteria and a current round is under way to look at all levels of growth including zooplankton. From the results of these tests a permanent shipboard system has been designed capable of treating all of the ballast on the ship and having the redundancy of a back up system.</p> <p>This unit will be PLC controlled and be able to provide signals to verify that the system has operated for the required time and the ballast is now safe to discharge. This signal could be sent to the internet and this would allow any port to access this information. The system would also log when ballast was taken on board and where if that is required. The redundancy of the system is such that a failure of any component causes a spare to be turned on and thus maintain the optimum performance.</p>

<b>Name of Project</b>	<b>An Evaluation of the Feasibility and Efficacy of Biocide Application in Controlling the Release of Nonindigenous Aquatic Species from Ballast Water</b>
<b>Treatment options researched</b>	<i>Chemical - Use of glutaraldehyde.</i>
<b>Principal Researcher(s)</b>	Russell A Moll, Michael G Parsons, Larissa M Lubomudrov.
<b>Contact Details</b>	Dr Michael Parsons Department of Naval Architecture and Marine Engineering University of Michigan 236A NA&ME Bldg., Room 2145 Ann Arbor, Michigan, 48104 United States of America Tel: +1 734 763 3081 Fax: +1 734 936 8820 Email: parsons@engin.umich.edu.
<b>Host Institution(s)</b>	University of Michigan.
<b>Location of Research</b>	Ann Arbor, Michigan, USA.
<b>Funding Level</b>	
<b>Funding Source(s)</b>	Office of the Great Lakes, Michigan Department of Environmental Quality, Coastal Zone Management Program, Great Lakes Fishery Commission.
<b>Timeframe of the Project</b>	Report Date – April 1997.
<b>Aims and objectives of the project</b>	As per project title.
<b>Research Methods</b>	The results were obtained mainly through laboratory experiments and theoretical studies.
<b>Results</b>	Preliminary results indicated that treating ballast water with glutaraldehyde may prove to be a viable option if the chemical costs can be substantially reduced, however there are still critical gaps. Study concluded that treating ballast water with the chemical glutaraldehyde could be readily implemented by installing pumps to gauge the chemical into ballast tanks as they are filled. Glutaraldehyde demonstrates broad biocidal activity and can be effective in eliminating various organisms in ballast water, however it is considered non-biocidal at low concentrations. It is currently classified as a non-carcinogen and non-mutagen, however some studies have reported positive results for these effects under certain laboratory conditions. Studies show that the greatest human risks associated with glutaraldehyde exposure are irritation to the skin and respiratory tract. The half-life of glutaraldehyde will probably be short (between 12 and 24 hours) and may vary with pH, temperature and the amount of chemical constituents in the water. The residence time of the chemical in water will be an important factor affecting the concentration released into the environment. It decomposes into carbon dioxide under aerobic conditions, which helps to limit the environmental risks.

Name of Project	<b>Shipboard Trial of Primary and Secondary Ballast Water Treatment Systems</b>
<b>Treatment options researched</b>	<i>Voraxial (cyclonic separator), UV, Biocide (SEAKLEEN registered trade name).</i>
<b>Principal Researcher(s)</b>	Dr David Wright and Rodger Dawson.
<b>Contact Details</b>	Dr David Wright University of Maryland Center for Environmental Science Chesapeake Biological Laboratory P O Box 38 Solomons, MD 20688 United States of America Tel: +1 410 326 7240 Fax: +1 410 326 7210 Email: wright@cbl.umces.edu.
<b>Host Institution(s)</b>	University of Maryland, Center for Environmental Science, Chesapeake Biological Laboratory.
<b>Location of Research</b>	Baltimore, Maryland, USA.
<b>Funding Level</b>	US\$700,000.
<b>Funding Source(s)</b>	National Oceanic & Atmospheric Administration. Maryland Port Administration.
<b>Timeframe of the Project</b>	September 2000 – March 2002.
<b>Aims and objectives of the project</b>	Demonstrate the effectiveness and cost effectiveness of the above methods.
<b>Research Methods</b>	Ballast water taken onto the <i>Cape May</i> (with 37,000 MT – 23 Ballast tanks) from Chesapeake Bay will be subjected to UV or biocide treatments and their effectiveness and efficiency in killing organisms in the ballast water will be tested using plankton counts, a variety of methods for live/dead assessment, fluorescence (phytoplankton), laser particle counting, bacterial plating.
<b>Results</b>	UV was 90-94% effective at killing zooplankton at a dose of ca. 200 mWsec cm <sup>2</sup> using a 32kW system at a flow rate of ca. 350 tons h <sup>-1</sup> . Two biocides were completely effective at killing zooplankton. Peraclean Ocean <sup>®</sup> was effective at 100mg l <sup>-1</sup> . Seakleen <sup>®</sup> was effective @ <2 mg l <sup>-1</sup> . All three treatment were effective in inhibiting phytoplankton growth at lower doses. No primary separation/filtration was required to achieve these performances.

<b>Name of Project</b>	<b>Chesapeake Bay Ballast Water: An investigative assessment of excimer UV as a method of shipboard and dockside treatment</b>
<b>Treatment options researched</b>	<i>Ultra Violet</i>
<b>Principal Researcher(s)</b>	Dr David Wright and Rodger Dawson
<b>Contact Details</b>	Dr David Wright University of Maryland Center for Environmental Science Chesapeake Biological Laboratory P O Box 38 Solomons, MD 20688 United States of America Tel: +1 410 326 7240 Fax: +1 410 326 7210 Email: wright@cbl.umces.edu.
<b>Host Institution(s)</b>	University of Maryland.
<b>Location of Research</b>	Solomons and Maryland.
<b>Funding Level</b>	US\$247,000.
<b>Funding Source(s)</b>	
<b>Timeframe of the Project</b>	Oct 1, 1998 - June 30, 2002.
<b>Aims and objectives of the project</b>	
<b>Research Methods</b>	
<b>Results</b>	Using benchtop and mesocosm-scale systems it was determined that an effective UV treatment for ballast water would require a dose in the region of 200 mW sec cm <sup>2</sup> at flow rates of above 1000 gallons per min. To effectively treat large vessels many systems would have to be mounted in parallel and the over power requirements would be in the megawatt range.



## **2. Projects Under Way**





## Australia

Name of Project	Australian Ballast Water Treatment Consortium
<b>Treatment options researched</b>	<i>Filtration, UV, Sonic, Micro-bubbles</i>
<b>Principal Researcher(s)</b>	Steve Hillman (Principal Project Officer).
<b>Contact Details</b>	School of Engineering James Cook University Townsville QLD Australia. E-mail <a href="mailto:steve.hillman@jcu.edu.au">steve.hillman@jcu.edu.au</a> Ph 61 7 4781 4997 Fax 61 7 4775 1184
<b>Host Institution(s)</b>	CRC: Reef Research Centre, James Cook University.
<b>Location of Research</b>	Townsville.
<b>Funding Level</b>	AUD\$675,000 (cash and in-kind).
<b>Funding Source(s)</b>	Environment Australia, Queensland Port Authorities, AMIAD, United Water International, CRC: Reef, James Cook University.
<b>Timeframe of the Project</b>	3 years.
<b>Aims and objectives of the project</b>	<p>Aim: To develop a portable Pilot Treatment Plant for Ballast Water using existing technologies.</p> <p>Objectives: To identify Best Available Technologies for ballast water treatment. To determine cost-effective and achievable standards of treatment for a range of potentially invasive organisms. To promote effective transfer of technologies to the shipping industry.</p>
<b>Research Methods</b>	Under development but largely empirical testing.
<b>Results</b>	To be determined.

## Canada

Name of Project	<b>Ballast Water Treatment Evaluation Using Copper and Sodium Hypochlorite as Ballast Water Biocides</b>
<b>Treatment options researched</b>	<i>Copper ion and Sodium Hypochlorite</i>
<b>Principal Researcher(s)</b>	Fleet Technology Ltd. 311 Legget Drive Kanata, Ontario, Canada K2K 1Z8  In partnership with ESG International Inc. Guelph, Ontario, Canada
<b>Contact Details</b>	David Stocks Fleet Technology Ltd. 311 Legget Drive Kanata, Ontario, Canada K2K 1Z8 Tel: 613-592-2830 Email: dstocks@fleetech.com  Barry Burns Michigan Department of Environmental Quality Constitution Hall 525 west Allegan Street Lansing, Michigan 48913 Tel: 517-335-3301 Email: burnsb@michigan.gov
<b>Host Institution(s)</b>	Michigan Department of Environmental Quality Constitution Hall 525 West Allegan Street Lansing, Michigan 48913
<b>Location of Research</b>	Field studies conducted in Europe and Great Lakes.  Laboratory studies conducted in Ontario, Canada.
<b>Funding Level</b>	US\$190,000.
<b>Funding Source(s)</b>	Michigan Great Lakes Protection Fund.  Office of the Great Lakes, Michigan Department of Environmental Quality.  U.S. Fish and Wildlife Service.
<b>Timeframe of the Project</b>	7/15/2001 – 6/1/2002.
<b>Aims and objectives of the project</b>	The project aims to help MDEQ to determine whether practical methods of treating ballast water are currently available. The determination is required by recent state legislation.
<b>Research Methods</b>	Laboratory and ship-board testing.
<b>Results</b>	To be determined.

<b>Name of Project</b>	<b>The effect of an integrated Cyclone/UV ballast water treatment system on the survivorship of marine phytoplankton and invertebrate larvae</b>
<b>Treatment options researched</b>	<i>Primary cyclonic separation and secondary UV irradiation.</i>
<b>Principal Researcher(s)</b>	Dr Terri Sutherland and Dr Colin Levings.
<b>Contact Details</b>	Fisheries and Oceans Canada DFO, West Vancouver Laboratory 4160 Marine Drive West Vancouver, BC V7V 1N6 Canada Tel: +1 604 666 8537 Fax: +1 604 666 3497 Email: sutherlandt@pac.dfo-mpo.gc.ca.
<b>Host Institution(s)</b>	Fisheries and Oceans Canada.
<b>Location of Research</b>	West Vancouver Laboratory.
<b>Funding Level</b>	Financial and in-kind support.
<b>Funding Source(s)</b>	Fisheries and Oceans Canada Industrial Research Assistance Program (IRAP) Velox Technology Inc.
<b>Timeframe of the Project</b>	Initiated in April 1999 – research ongoing.
<b>Aims and objectives of the project</b>	To determine the effect of the treatment system on the survivorship of marine invertebrate larvae and potentially harmful phytoplankton.
<b>Research Methods</b>	The research methods and results are currently under peer review and will be published in the Marine Ecology Progress Series.
<b>Results</b>	As above.

## Germany

<b>Name of Project</b>	<b>Bremer-Ballastwasser-Projekt: Development and Construction of an Efficient and Marketable Ballast Water Treatment Plant</b>
<b>Treatment options researched</b>	<i>To be decided in April 2002 (Presently different methods are investigated in order to evaluate possibilities to combine the most promising approaches).</i>
<b>Principal Researcher(s)</b>	Coordination and shipside technology: GAUSS (Chr. Bahlke / O. Kerschek) Biology, Methods, Standards: Dr. Stephan Gollasch Biological Analyses: Alfred Wegener Institute (Prof. Smetacek) Plant construction: Dr. St. Calenberg (Kraeft GmbH) A. Höppner (Motorenwerke Bremerhaven AG)
<b>Contact Details</b>	GAUSS mbH Werderstr. 73, 28199 Bremen, Germany Tel: +49 421 5905 4850 Fax: +49 421 5905 4851 Email: gauss@gauss.org
<b>Host Institution(s)</b>	Phase 1: GAUSS mbH. Email: gauss@gauss.org Phase 2: Motorenwerke Bremerhaven. AG. webmaster@mwb-bremerhaven.de Phase 3: shipboard test runs.
<b>Location of Research</b>	GAUSS mbH Werderstr. 73, 28199 Bremen, Germany Tel: 0049 421 5905 4850 Fax: 0049 421 5905 4851 Email: gauss@gauss.org
<b>Funding Level</b>	Financially supported by the Federal State of Bremen and Bremerhaven.
<b>Funding Source(s)</b>	Senator of Building & Environment, Bremen Ansgaritorstraße 2 28195 Bremen Tel.: 0421 / 361 2407 e-mail: ksagebiel@bau.bremen.de Ms Christine Wischer
<b>Timeframe of the Project</b>	Phase 1: 01.10.2001 – 30.07.2002. Phase 2: 01.07.2002 – 31.08.2003. Phase 3: 01.09.2003 – 31.08.2004. (Decision for successive phase is based on results of preceding phase).
<b>Aims and objectives of the project</b>	Creation of an efficient and cost effective shipboard system using the combination of different methods to treat ballast water. Persistent chemicals are to be avoided.
<b>Research Methods</b>	Phase 1: Theoretical investigation. Phase 2: Shore based practical method assessment. Phase 3: Test runs on board different ships.
<b>Results</b>	To be determined.

Name of Project	TREBAWA- Treatment of Ballast Water
<b>Treatment options researched</b>	<i>Primary hydrocyclonic separation followed by UV irradiation.</i>
<b>Principal Researcher(s)</b>	<p><i>European partnership of SMEs (Small and Medium-sized Enterprises)</i>  Prime proposer: Reederei Hesse (Germany); Other partners: Vinave (Portugal); Optimarin, Envirotech (Norway); Acomarin, FI; UV Systems (Germany); Sandvik (Norway); Fresti (Portugal)</p> <p><i>Research partners:</i>  TTZ Bremerhaven (René Surma, Dolores Fernández)  University of Strathclyde (Peilin Zhou)  Institute de Soldadura Qualidade (ISQ) (Nuno Cosme)</p>
<b>Contact Details</b>	Dolores Fernández An der Karlstadt 6 D-27568 Bremerhaven, Germany Tel: +49 471 9448-707 Fax: +49 471 9448 722 e-mail: dfernandez@ttz-bremerhaven.de
<b>Host Institution(s)</b>	TTZ Bremerhaven, Germany. University of Strathclyde, UK. Institute de Soldadura Qualidade (ISQ), Portugal.
<b>Location of Research</b>	Portugal, Germany, UK, Norway.
<b>Funding Level</b>	Total budget €856,000. European funding €425,000.
<b>Funding Source(s)</b>	European Commission, 5 <sup>o</sup> Framework, CRAFT program.
<b>Timeframe of the Project</b>	2 years. Estimated start date: October 2002.
<b>Aims and objectives of the project</b>	To develop a new technically and economically competitive ballast water treatment system based on a primary cyclonic separation and a UV treatment to achieve the critical points: <ol style="list-style-type: none"> <li>i. A high degree of separation of in seawater suspended particles;</li> <li>ii. A high performance for the UV system in inactivating and killing all the inwater remaining organisms; and</li> <li>iii. Integrated prototype compact in size, which fulfills the space requirements of a wide range of existing ships.</li> </ol>
<b>Research Methods</b>	1- Laboratory tests. 2- Prototype development and pilot tests. 3- Full-scale sea trials.
<b>Results</b>	To be determined.

Name of Project	Development of a ballast water treatment plant
<b>Treatment options researched</b>	<p><i>Physical separation:</i>  <i>gravity separation and filtration</i>  <i>Chemical disinfection:</i>  <i>non-toxic, chlorine-free, oxidising chemical</i>  <i>(Peraclean® Ocean)</i></p>
<b>Principal Researcher(s)</b>	Hauke Röpell, Dr. Matthias Voigt
<b>Contact Details</b>	<p>Hamann Wassertechnik GmbH            Brookdamm 6, D-21217 Seevetal, Germany            e-mail: Hauke.Roepell@HamannWassertechnik.de</p> <p>Dr. Voigt Consulting            Kampstraße7, D-24601 Stolpe, Germany            e-mail: m.voigt@drvoigt-consulting.de</p>
<b>Host Institution(s)</b>	Hamann Wassertechnik GmbH.
<b>Location of Research</b>	Lower Elbe River and Baltic Sea.
<b>Funding Level</b>	€ 260.000 .
<b>Funding Source(s)</b>	<p>AIF (Federal Ministry Of Research).            Hamann Wassertechnik GmbH.            Dr. Voigt Consulting.</p>
<b>Timeframe of the Project</b>	2000-2003.
<b>Aims and objectives of the project</b>	<p>Testing of various physical separation options in combination with chemical disinfection of ballast water.</p> <p>Design of a full scale treatment plant for land-based tests and evaluations.</p> <p>Identifying suitable combinations of above methods for various types of ships (e.g. ballast water management scenarios).</p> <p>Development of online monitoring systems for ballast water treatment.</p>
<b>Research Methods</b>	<p>Tests done with a flow rate of 135m<sup>3</sup>/h.</p> <p>Testing of different cyclones (gravity separation) and self-cleaning filters at 100 µm and 50 µm as well as dosing of 50 ppm to 200 ppm of Peraclean® Ocean.</p> <p>Tests carried out with in-situ plankton population as well as selected indicator organisms (different live stages of Artemia).</p>
<b>Results</b>	<p>Preliminary results indicate that:</p> <p>The combination of either gravity separation or filtration (50µm) with a dosage of 150 to 200ppm Peraclean® Ocean resulted in 100% removal / mortality of all test organisms.</p> <p>The application of all three methods (gravity separation + filtration + chemical disinfection) showed 100 % mortality of all tests organisms already at 100 ppm.</p> <p>Further full-scale tests will be carried out in 2002 and 2003 on land and onboard ship.</p>

Name of Project	Benchmark tests for ballast water treatment options
<b>Treatment options researched</b>	<i>Chemical treatments (oxidising chemicals and biocides).</i>
<b>Principal Researcher(s)</b>	Dr. Voigt Consulting.
<b>Contact Details</b>	Kampstr. 7 24601 Stolpe Germany Tel: +49 4326 987 37 Fax: +49 4326 987 38 Email: m.voigt@drvoigt-consulting.de Web: www.drvoigt-consulting.de
<b>Host Institution(s)</b>	Dr. Voigt Consulting.
<b>Location of Research</b>	Germany.
<b>Funding Level</b>	
<b>Funding Source(s)</b>	Contract research (consulting).
<b>Timeframe of the Project</b>	1998 – ongoing.
<b>Aims and objectives of the project</b>	To provide baseline data (benchmarks) for the efficiency of ballast water treatment options prior to costly full-scale testing. Compare different treatment options.
<b>Research Methods</b>	Chemical treatment options are tested in the lab with a specially developed testing standard (ATS = Artemia Testing Standard) for the efficiency of ballast water treatment options.
<b>Results</b>	To be determined.

## Japan

Name of Project	Study of Ballast Water Management
<b>Treatment options researched</b>	<i>Mechanical treatment system using a special pipe</i>
<b>Principal Researcher(s)</b>	Dr. Hiroshi Tokuda, Dr. Hiroharu Kato, Dr. Yasuwo Fukuyo, Takeaki Kikuchi, SEIJI KINO
<b>Contact Details</b>	Marine Pollution Prevention Research Department The Japan Association of Marine Safety Kaiyo-Senpaku BLDG., 15-16, Toranomom 1-Chome, Minato-ku, Tokyo 105-0001 JAPAN Tel:+81(3)3502-3543 Fax:+81(3)3581-6136
<b>Host Institution(s)</b>	Marine Pollution Prevention Research Department. The Japan Association of Marine Safety.
<b>Location of Research</b>	Laboratory of Marine Technology of Kushuu-Island.
<b>Funding Level</b>	US\$40,000 (1999), US\$55,000 (2001).
<b>Funding Source(s)</b>	The Nippon Foundation.
<b>Timeframe of the Project</b>	Phase 1: April, 1999-March, 2000. Phase 2: April, 2001-March, 2002. Phase 3: In 2002 continuation.
<b>Aims and objectives of the project</b>	Development of a ballast water treatment system to satisfy criteria related to ship's safety, operational complexity, capability to be installed on board ships, cost effectiveness and level of consequential environment impacts in addition to the effectiveness of treatment.
<b>Research Methods</b>	The experiments with the treatment system installed on land, using natural seawater collected in a harbour area.
<b>Results</b>	The special pipe system can terminate about 90% of total planktonic Crustacean (zooplankton) in natural seawater (in phase 2). The effectiveness of treatment to phyto/zoo planktons and the seawater flow rate will update in phase 3.



## New Zealand

<b>Name of Project</b>	<b>Shipboard trials on chemical carrier MT <i>Iver Stream</i> and use of models for designing heat treatment systems</b>
<b>Treatment options researched</b>	<i>Heat</i>
<b>Principal Researcher(s)</b>	Doug Mountfort, Tim Dodgshun and Michael Taylor (Cawthron).
<b>Contact Details</b>	Cawthron Institute 98 Halifax Street East Private Bag 2 Nelson Nelson, New Zealand Tel: +64 (0)3 548 2319 Fax: +64 (0)3 546 9464 Email : info@cawthron.org.nz Web: www.cawthron.org.nz.
<b>Host Institution(s)</b>	Cawthron Institute (New Zealand).
<b>Location of Research</b>	On-board heat treatment trials conducted on the trans-Pacific chemical carrier MT <i>Iver Stream</i> .
<b>Funding Level</b>	Confidential.
<b>Funding Source(s)</b>	New Zealand Foundation of Research Science and Technology.
<b>Timeframe of the Project</b>	2001-
<b>Aims and objectives of the project</b>	<ul style="list-style-type: none"> <li>• Using sea-going trials identify factors that must be considered for optimisation of heat treatment of ship's ballast water.</li> <li>• By developing models, achieve optimal design and performance standards for heat treatment systems.</li> </ul>
<b>Research Methods</b>	Trials on the chemical carrier <i>Iver Stream</i> (32,000 tons) were conducted during passage from Japan to New Zealand in February 2001 using tanks (1500 m <sup>3</sup> capacity) in the bottoms of which steam heated coils were fitted as standard equipment. Details on sampling and analysis can be found in Proc 1 <sup>st</sup> Int Ballast Water Treatment R&D Symposium, IMO. London, 2001.
<b>Results</b>	<p>The results of the first phase of this study showed that:</p> <ul style="list-style-type: none"> <li>• Temperature variability (thermocline) occurred in heated tanks in calm sea conditions. Uniform temperatures of tank contents could be achieved (raising the tank temperature to 35°C for &gt; 30 h) in moderate to rough sea conditions leading to effective kills of ballast organisms.</li> <li>• Heat loss from tanks was a key consideration in achieving the desired tank temperature.</li> </ul> <p>It was concluded that:</p> <ul style="list-style-type: none"> <li>• Some organisms might develop a tolerance to heating depending on whether the treatment is "fast" or "slow".</li> <li>• Priority should be given to optimising design of heat treatment systems so that heat losses are minimized and contents are adequately mixed during treatment.</li> <li>• Details on operating and installation costs of treatment systems need to accompany the design concept.</li> </ul>

## Norway

Name of Project	Ballast Water Treatment by Ozonation
<b>Treatment options researched</b>	<i>Ozone treatment.</i>
<b>Principal Researcher(s)</b>	Aage Bjørn Andersen, Egil Dragsund, Bjørn Olav Johannessen.
<b>Contact Details</b>	Det Norske Veritas Veritasveien 1 N-1322 Høvik Norway Tel: +47 67 57 85 86 Fax: +47 67 57 99 11 Email: aage.bjorn.andersen@dnv.com Web: www.dnv.com.
<b>Host Institution(s)</b>	DNV Høvik, Norway.
<b>Location of Research</b>	DNV Høvik and University of Oslo.
<b>Funding Level</b>	NOK 800,000 (NOK 500,000 for 1999-2000; NOK 300,000 for 2000-1).
<b>Funding Source(s)</b>	Barber Ship Management.
<b>Timeframe of the Project</b>	1999 – 2001.
<b>Aims and objectives of the project</b>	To evaluate and test whether ozone represents an appropriate risk reducing alternative for ballast water treatment.
<b>Research Methods</b>	<ul style="list-style-type: none"> <li>• Review of recent literature.</li> <li>• Laboratory testing of:               <ul style="list-style-type: none"> <li>- Efficiency of ozone disinfection.</li> <li>- Oxidant decay rates in seawater.</li> <li>- Corrosivity of ozone treated seawater.</li> </ul> </li> </ul>
<b>Results</b>	<p>Literature review has identified ozonation as a potentially efficient option representing a chemical method without environmental harmful side effects. Findings from the literature have been an input to the planning of the laboratory testing phase.</p> <p>The estimated increase in corrosivity of the ballast water is based on a limited short period experiment. Prior to a full-scale evaluation of ballast water ozonation, a more detailed long-term test on corrosion should be undertaken.</p> <p>Further work will encompass full-scale methodology verification aboard a vessel trading between the USA and Australia. This will be performed in co-operation with Australian Quarantine and Inspection Service (AQIS) and US Coast Guard (USCG). Final arrangements have not yet been formalised.</p>

# Singapore

Name of Project	Shipboard Ballast Water Treatment Technology Development
Treatment options researched	<i>Mechanical, physical, chemical and their hybrids.</i>
Principal Researcher(s)	Dr Jose Matheickal.
Contact Details	Environmental Technology Institute Innovation Centre, Nanyang Technology University Block 2, Unit 237 18 Nanyang Drive, Singapore 637723 Tel: +65 794 1556 Fax+65 792 1291 Email: jtmath@eti.org.sg Web: www.eti.org.sg.
Host Institution(s)	Environmental Technology Institute.
Location of Research	Singapore.
Funding Level	S\$2.5 million.
Funding Source(s)	Environmental Technology Institute, National Science and Technology Board, Maritime and Port Authority of Singapore, local ship building company.
Timeframe of the Project	2000-1.
Aims and objectives of the project	<ul style="list-style-type: none"> <li>• Evaluate various treatment alternatives at lab-scale, pilot scale and shipboard conditions;</li> <li>• Development of monitoring tools for evaluation of different technologies;</li> <li>• Development of shipboard treatment systems.</li> </ul>
Research Methods	<ul style="list-style-type: none"> <li>• Dockside pilot-scale evaluation and verification of technologies;</li> <li>• Research collaboration with Tropical Marine Science Institute for developing advanced bio-monitoring tools;</li> <li>• Hydraulic simulation studies;</li> <li>• Process optimisation/system modeling;</li> <li>• Flow cytometry analysis and DNA probes development.</li> </ul>
Results	Phase 1 was undertaken by ETI in Singapore in collaboration with Maritime and Port Authority (MPA) and the National University of Singapore (NUS) in 1999 and evaluated treatment technologies using a pilot scale facility of 1, 200 tonnes/ day. This flow rate was chosen, as it would allow a number of system modifications and optimisation experiments in a relatively short period of time, without having to face serious scalability issues. The study included hydraulic as well as biological performance evaluation of mechanical, physical and chemical treatment technologies. The study gave promising results for filtration systems, but "off-the-shelf" technologies may require significant modifications. Phase II efforts are underway to develop a hybrid ballast water treatment system, and to evaluate the system onboard ship.

<b>Name of Project</b>	<b>Dockside Studies on Integration of Filtration Technologies with Secondary Treatment Technologies</b>
<b>Treatment options researched</b>	<i>Filtration combined with UV, Ozone and Chemicals</i>
<b>Principal Researcher(s)</b>	Dr Jose Matheickal
<b>Contact Details</b>	Senior Research Scientist, Environmental Technology Institute, NTU, Innovation Centre, 18 Nanyang Drive, Singapore 637723 Email: jtmath@eti.org.sg
<b>Host Institution(s)</b>	Environmental Technology Institute.
<b>Location of Research</b>	Singapore.
<b>Funding Level</b>	
<b>Funding Source(s)</b>	ETI and Maritime and Port Authority of Singapore.
<b>Timeframe of the Project</b>	2002-2003.
<b>Aims and objectives of the project</b>	To develop a filtration system coupled with a secondary treatment system for ballast water treatment and to study the biological and hydraulic performance of the system.
<b>Research Methods</b>	Pilot-scale test runs using a dockside facility. Use flow cytometers, particle size distribution and specific DNA probes for system performance evaluation.
<b>Results</b>	Ongoing.

## United Kingdom

Name of Project	Efficiency of ballast water exchange in regional seas
<b>Treatment options researched</b>	<i>Ballast water exchange</i>
<b>Principal Researcher(s)</b>	Tracy McCollin
<b>Contact Details</b>	Tracy McCollin FRS Marine Laboratory PO Box 101 Victoria Road Aberdeen AB11 9DB Tel: +44 (0)1224 295 573 Fax: +44 (0)1224 295 511 E-mail: mccollint@marlab.ac.uk
<b>Host Institution(s)</b>	FRS Marine Laboratory.
<b>Location of Research</b>	Scotland, United Kingdom.
<b>Funding Level</b>	Approx £325 000.
<b>Funding Source(s)</b>	Scottish Executive Environmental and Rural Affairs Department and Scottish Natural Heritage.
<b>Timeframe of the Project</b>	July 1999-January 2003.
<b>Aims and objectives of the project</b>	<ul style="list-style-type: none"> <li>• Carry out a detailed assessment of the efficiency of in-transit exchange in the North Sea and Irish Sea on planktonic organisms in ship's ballast tanks.</li> <li>• Assess the survival of planktonic organisms whilst on passage in ballast tanks.</li> </ul>
<b>Research Methods</b>	Marine Laboratory staff travel with a vessel on the ballast leg of its journey back to the west coast of Scotland from ports within northern Europe. The vessel carries out a ballast exchange process and samples are taken from the ballast tanks before, during and after exchange.
<b>Results</b>	To be determined.

<b>Name of Project</b>	<b>MARTOB: On Board Treatment of Ballast Water (Technologies Development and Applications) and Application of Low-sulphur Marine Fuel</b>
<b>Treatment options researched</b>	<i>Most methods available for ballast water onboard treatment.</i>
<b>Principal Researcher(s)</b>	Prof. Atilla Incecik (Project Coordinator) Dr Ehsan Mesbahi (Project Manager) Miss Joanne Black (Project Administrator)
<b>Contact Details</b>	Department of Marine Technology, Armstrong Building University of Newcastle, Newcastle upon Tyne, NE1 7RU, United Kingdom Tel: +44 -191 222 6724 (Atilla.Incecik@ncl.ac.uk) : +44 -191 222 6723 (Ehsan.mesbahi@ncl.ac.uk) : +44 -191 222 5531 (Joanne.Black@ncl.ac.uk) Fax: +44-191 222 5491
<b>Host Institution(s)</b>	University of Newcastle, UK.
<b>Location of Research</b>	UK: UNEW, ABC, FRS, INTERTANKO, SOU, TQ, ICS Finland: AAU, VTT Netherlands: TNO, TME, BERSON, HW Norway: SINTEF, MARINTEK, Shell MP, WW, FUELTECH, NSA France: IFREMER, BV Sweden: ALFA LAVAL, SSPA Greece: EPE Denmark: MAN B&W.
<b>Funding Level</b>	Approximately €3.8 million.
<b>Funding Source(s)</b>	Partially funded by European Commission under the 5th Framework Programme for research, technological development and demonstration activities, GROWTH, (Directorate-General for Energy and Transport).
<b>Timeframe of the Project</b>	MARTOB started in April 2001 and will run for three years.
<b>Aims and objectives of the project</b>	The objectives of MARTOB are: <ul style="list-style-type: none"> <li>• To investigate methodologies for preventing the introduction of non indigenous species through ships' ballast water;</li> <li>• To develop design tools and treatment equipment to be used in the further development of ballast water treatment techniques;</li> <li>• To assess the direct and indirect environmental aspects of current and newly developed methods;</li> <li>• To develop cost-effective (capital and running), safe, environmentally friendly onboard treatment methods;</li> <li>• To produce guidelines for crew training and criteria for selecting appropriate ballast water management methods for different types of ship;</li> <li>• To assess the financial, technical and operational effects of a sulphur cap on marine bunker fuel in European waters, and propose a verification scheme ensuring compliance with a sulphur cap from all players in the market;</li> <li>• To help to facilitate the introduction of an important sulphur emission abatement measure without unintentional distortion of competition in the shipping market.</li> </ul>
<b>Research Methods</b>	Theoretical, laboratory tests and onboard sea trials.
<b>Results</b>	With the completion of MARTOB, it is envisaged that the results of this project would be able to provide an insight on global ballast water legislative measures and recommendations on probable future ballast water treatment solutions through research and shipboard trials. MARTOB will result in detailed recommendations for ballast water management solutions to IMO, ICES, IOC and other maritime organisations, marine environmental agencies and regulatory bodies.

## United States of America

<b>Name of Project</b>	<b>Electro-Ionization Treatment for Ballast Water; First Assessment of Effectiveness Against Marine Microbiota and Design of Shipboard, Shore Based, and Tender Ballast Treatment Systems</b>
<b>Treatment options researched</b>	<i>Electro Ionization(EIMS™)</i>
<b>Principal Researcher(s)</b>	Joe Aliotta, Ph.D – Marine Environmental Partners, Inc Dr. Andrew Rogerson, Ph.D – Nova Southeastern University, Ft. Lauderdale, FL
<b>Contact Details</b>	Marine Environmental Partners, Inc. 3001 W. State Road 84 Ft. Lauderdale, FL 33312 United States of America Tel: +1 954 791 3700 Fax: +1 954 791 2447 E-mail: mark@mepi.net Web: www.mepi.net  Capt. “Bud” C.E. Leffler, President Jon Stewart, Exe. VP Sales & Marketing Mark Yonge, Exe. VP – Maritime Affairs
<b>Host Institution(s)</b>	Nova Southeastern University, Ft. Lauderdale, FL.
<b>Location of Research</b>	Ft. Lauderdale, Florida USA.
<b>Funding Level</b>	Private.
<b>Funding Source(s)</b>	Marine Environmental Partners, Inc.
<b>Timeframe of the Project</b>	October, 2000 – January, 2001.
<b>Aims and objectives of the project</b>	To evaluate & demonstrate the effectiveness of electro-ionization technology in killing marine microbes similar to those found in ballast water and to design a best available technology treatment system process for ship, land based and tender installations.  To develop data from which to design an electro-ionization treatment system for the treatment of ballast water.
<b>Research Methods</b>	Marine Environmental Partners, Inc. supplied a pilot system to Nova Ocean Research Center. The system components are 150 gal. Tank containing seawater to mimic ballast tanks, a NI-OX/L™ gas generator and a Clorin™ gas generator. High-pressure pumps, & differential pressure injectors. Sea Water (salinity ca.32 g/l) from the port is used as well as seeding with ca.50liters of seawater enriched with a mixture of protists (algae and protozoa).  Bacteria were counted by standard plate counting methods. Plates incubated and number of colonies recorded. Protists are counted by enrichment cultivation using methods fully detailed in Rogerson and Gwaltney (2000).  All data converted to percentage survival levels to normalize for any differences in the numbers of starting organisms. Chlorine levels were kept below detection in the treated water.
<b>Results</b>	To be determined.

<b>Name of Project</b>	<b>Great Lakes Ballast Technology Demonstration Program Field Trials and Comparison of Commercially Available Primary and Secondary Ballast Treatment Alternatives</b>
<b>Treatment options researched</b>	<i>Filtration and UV; Cyclonic Separation and UV.</i>
<b>Principal Researcher(s)</b>	Allegra Cangelosi, MS (Northeast/Midwest Institute) and Richard Harkins, PE, (Lake Carriers' Association) with Ivor Knight, PhD, James Madison University, Mary Balcer, PhD, University of Wisconsin – Superior; Mike Parsons, PhD, University of Michigan; David Wright, PhD, and Rodger Dawson, PhD, University of Maryland; Donald Ried, MS, Napien, Ontario, and Nicole Mays, NEMWI.
<b>Contact Details</b>	Northeast/Midwest Institute 218 D Street, SE Washington, DC 20003 United States of America Tel : +1 202-544-5200 Fax : +1 202-544-0043 Email: <a href="mailto:acangelo@nemw.org">acangelo@nemw.org</a> Web: <a href="http://www.nemw.org">www.nemw.org</a>
<b>Host Institution(s)</b>	Northeast/Midwest Institute.
<b>Location of Research</b>	Barge-based tests: Duluth-Superior Harbor, MN and Two Harbors, MN; Ship-board tests: <i>M/S Regal Princess</i> Vancouver to Alaska voyages.
<b>Funding Level</b>	Approximately US\$600,000.
<b>Funding Source(s)</b>	US EPA Great Lakes National Program Office, National Sea Grant Association, US Coast Guard.
<b>Timeframe of the Project</b>	Fieldwork took place May-September 2000. Sample analysis is ongoing.
<b>Aims and objectives of the project</b>	To develop protocols for assessing biological and operational effectiveness of ballast treatments on a barge-based platform and ship installation; to assess and compare the relative effectiveness of filtration/UV and cyclonic separation/ UV under field conditions at a flow rate of 1500 gpm; to draw conclusions about the generalizability of barge-based information to ship context.
<b>Research Methods</b>	Barge-based biological tests involved sampling triplicate matched treatment and control collection tanks at two time intervals and turbidity levels. Samples were subjected to live/dead and density analysis of zooplankton; total chlorophyll a, growth rate, and density analysis of phytoplankton; inactivation rate of a spiked MS 2 bacteriophage; and total bacteria counts. Particle removal, flow rate, and power consumption were measured. <i>M/S Regal Princess</i> tests involved three before/after in-line tests; three ballast tank “time zero” tests (water was placed in matched treatment and control ballast tanks and then removed immediately); and three ballast tank “retention tests” (water was retained for 18-24 hours). Samples were analyzed for density/inactivation of zooplankton, phytoplankton and bacteria.
<b>Results</b>	To be determined.



<b>Name of Project</b>	<b>M/T Stolt Aspiration (Parcel Tanker)</b>
<b>Treatment options researched</b>	<i>OptiMar Ballast System (Separation and UV)</i>
<b>Principal Researcher(s)</b>	Allegra Cangelosi
<b>Contact Details</b>	Northeast/Midwest Institute 218 D Street, SE Washington, DC 20003 USA Tel : +1 202-544-5200 Fax : +1 202-544-0043 Email: <a href="mailto:acangelo@nemw.org">acangelo@nemw.org</a> Web: <a href="http://www.nemw.org">www.nemw.org</a>
<b>Host Institution(s)</b>	Great Lakes Ballast Technology Demonstration Project.
<b>Location of Research</b>	Great Lakes and Western Europe.
<b>Funding Level</b>	
<b>Funding Source(s)</b>	Great Lakes Protection Fund.
<b>Timeframe of the Project</b>	Summer/fall 2002.
<b>Aims and objectives of the project</b>	Verify effectiveness of the OptiMar System.
<b>Research Methods</b>	On board sampling.
<b>Results</b>	To be determined.

<b>Name of Project</b>	<b>Assessment of On-shore Treatment of Ballast Water Discharges (a programme of several ongoing, inter-related research projects, funded by various agencies)</b>
<b>Treatment options researched</b>	<i>Onshore treatment plants.</i>
<b>Principal Researcher(s)</b>	Dr Andrew Cohen (Senior Scientist, Biological Invasions Program, San Francisco Estuary Institute), Dr David Jenkins (Emeritus Professor of Civil and Environmental Engineering, University of California at Berkeley), Arleen Navarett (Senior Marine Biologist, Water Quality Bureau, City and County of San Francisco).
<b>Contact Details</b>	Dr Andrew Cohen San Francisco Estuary Institute 180 Richmond Field Station 1325 S 46 <sup>th</sup> Street Richmond, CA 94804 United States of America Tel: +1 510 231 9423 Fax: +1 510 231 9414 Email: acohen@sfei.org Web: www.sfei.org/invasion.html.
<b>Host Institution(s)</b>	<i>See Principal Researchers.</i>
<b>Location of Research</b>	Richmond Field Station, Richmond, CA.
<b>Funding Level</b>	Total of around US\$325,000 in received, obligated and pending funding.
<b>Funding Source(s)</b>	US Fish and Wildlife Service, California Sea Grant College System, Pollution Mitigation funds arranged through the San Francisco Bay Regional Water Quality Control Board.
<b>Timeframe of the Project</b>	Began in 1999 and is ongoing.
<b>Aims and objectives of the project</b>	To assess the potential and estimate the relative costs of treating ballast water discharges in onshore treatment plants, using either existing wastewater treatment plants or purpose-built treatment plants.
<b>Research Methods</b>	<ul style="list-style-type: none"> <li>• Benchtop tests and on-paper analyses of potential limitations on ballast water treatment in existing municipal wastewater treatment plants and the probable effectiveness of treatment of ballast water in existing municipal wastewater treatment plants, based in a variety of test organisms;</li> <li>• Design and on-paper analyses of probable effectiveness of treatment of ballast water in purpose-built, onshore ballast treatment plants;</li> <li>• Estimate costs of treatment in existing wastewater treatment plants and purpose-built treatment plants.</li> </ul>
<b>Results</b>	To be determined.

Name of Project	Inactivation of Human Pathogens through Photon Engineering
<b>Treatment options researched</b>	<i>UV light.</i>
<b>Principal Researcher(s)</b>	Fred C. Dobbs and Mounir Laroussi.
<b>Contact Details</b>	<p>Dr Fred C. Dobbs  Department of Ocean, Earth and Atmospheric Sciences  Old Dominion University  4600 Elkhorn Avenue  Norfolk, VA 23529-0276  United States of America  Tel: +1 757-683-5329  Fax: +1 757-683-5303  Email: fdobbs@odu.edu  Web: www.ocean.odu.edu/dobbs/dobbsnew.htm</p> <p>Dr Mounir Laroussi  Department of Electrical and Computer Engineering, Old Dominion University,  Applied Research Center Newport News, VA 23606  United States of America  Tel: +1 757-269-5640  Email: laroussi@jlab.org</p>
<b>Host Institution(s)</b>	Old Dominion University.
<b>Location of Research</b>	Old Dominion University, Norfolk, Virginia, USA.
<b>Funding Level</b>	US\$99,903.
<b>Funding Source(s)</b>	National Sea Grant College Program.
<b>Timeframe of the Project</b>	1 Oct 1999 - 31 March 2001.
<b>Aims and objectives of the project</b>	To design, construct, and develop a laboratory prototype UV reactor that will provide an effective second step, following filtration, to minimize microorganisms in ships' ballast waters.
<b>Research Methods</b>	Bench-top studies to test the efficacy of a UV lamp in killing bacteria and dinoflagellates and inactivating viruses in flowing water. Tests will proceed under various flow rates and with various repeated-pass scenarios.
<b>Results</b>	To be determined.

<b>Name of Project</b>	<b>West Coast Regional Applied Ballast Management Research and Demonstration Project</b>
<b>Treatment options researched</b>	<i>Cyclonic Separation and UV (Optimar Ballast System).</i>
<b>Principal Researcher(s)</b>	Maurya B. Falkner, California State Lands Commission, Marine Facilities Division with Nick Welschmeyer, Ph.D., Moss Landing Marine Laboratories, San Jose State University Foundation and Stephen Bollens, Ph.D., Romburg Tiburon Center for Environmental Studies, San Francisco State University
<b>Contact Details</b>	Maurya B. Falkner California State Lands Commission Marine Facilities Division 200 Oceangate, Suite 900 Long Beach, CA 90802 Tel: +1 562-499-6312 Fax: +1 562-499-6317 Email: falknem@slc.ca.gov
<b>Host Institution(s)</b>	California State Lands Commission. Marine Facilities Division.
<b>Location of Research</b>	California State Lands Commission, Moss Landing Marine Laboratories and Romberg-Tiburon Center, San Francisco State University.
<b>Funding Level</b>	Approximately US \$300,000.
<b>Funding Source(s)</b>	U.S. Fish & Wildlife Service and Port of Oakland.
<b>Timeframe of the Project</b>	September 2000 - December 2002.
<b>Aims and objectives of the project</b>	Provide cost estimates and ballast water treatment options to the maritime industry. Conduct applied research, in cooperation with California State Water Resources Control Board, U.S. Coast Guard, the maritime industry and technology vendors on ballast water treatment.
<b>Research Methods</b>	Utilize full-scale engineering designs to install the Optimar Ballast System on two vessels, the <i>Sea Princess</i> and the <i>R.J. Pfeiffer</i> . Conduct shipboard biological and operational evaluations of these systems under normal vessel conditions. Biological efficacy testing includes sampling of treatment and control tanks. Samples will be evaluated for zoo- and phytoplankton, bacteria and virus removal and inactivation.
<b>Results</b>	To be determined.

Name of Project	<b>Ballast and Oily Water Treatment System (BOWTS)</b>
<b>Treatment options researched</b>	<i>Extending a proven, in-use treatment system that removes oils/fuels/heavy metals from bilges to bar similar contaminants and aquatic nuisance species from contaminating harbors. Methodology is to treat ballast water via a series of stages that include mechanical separation and filtration, chemical attachment and stripping, and ultraviolet microbial sanitation.</i>
<b>Principal Researcher(s)</b>	Several and various corporate and alliance members
<b>Contact Details</b>	Martin Fox Director, Emerging Technology Division Santa Barbara Applied Research Incorporated 1925 N. Lynn Street, Suite 1102 Arlington, VA 22209 United States of America Tel: +1 703 526 0022 Fax: +1 703 526 0222 Email: martinfox@sbar.com
<b>Host Institution(s)</b>	Santa Barbara Applied Research Incorporated.
<b>Location of Research</b>	California, USA and Chesapeake Tidewater Area, USA.
<b>Funding Level</b>	Under discussion.
<b>Funding Source(s)</b>	Internal R&D ... seeking institutional/government partners.
<b>Timeframe of the Project</b>	Initial feasibility exploration < 1 year. Establishment of treatment criteria to be determined.
<b>Aims and objectives of the project</b>	1. Prove scalability of existing system to permit increased flow rates and filtration levels appropriate to economic treatment of large capacity ballast.  2. Exploration of the level of ballast water treatment (how clean of what species) that will help establish reasonable criteria, both biologic and economic, for the use of government regulators.
<b>Research Methods</b>	Empirical.
<b>Results</b>	To be determined.

<b>Name of Project</b>	<b>Onboard Ballast Water Treatment/Management with Ozone &amp; Sonics</b>
<b>Treatment options researched</b>	<i>Filtration, low frequency sonics and ozone</i>
<b>Principal Researcher(s)</b>	Thomas L. Maddox
<b>Contact Details</b>	T.L. Maddox Companies 16149 Westwoods Business Park Ellisville, MO 63021-4505 United States of America Tel: +1 636 394 8161 Fax: +1 636 394 6776 Email: tlm@tlmcos.com Web: www.zebra-mussels.com http://invasions.si.edu
<b>Host Institution(s)</b>	United States Department of Commerce. National Oceanic & Atmospheric Administration (NOAA). National Sea Grant Program.
<b>Location of Research</b>	Lab work in USA.
<b>Funding Level</b>	US\$175,000.
<b>Funding Source(s)</b>	National Sea Grant College Program NA96RG0478.
<b>Timeframe of the Project</b>	Phase I: October 1, 1999 – September 30, 2000.
<b>Aims and objectives of the project</b>	Develop a ballast treatment system which treats only the ballast water actually being discharged at any given point in time @ 5,000GPM . This system would kill bacteria, phytoplankton, zooplankton, dinoflagellates, etc. All of this to occur without producing any byproducts. This system would also be: compact, quiet, safe, user friendly, reliable, durable, low maintenance, environmentally friendly, PLC controlled and monitored, use off-the-shelf components, flexible and scalable for use on any size, age, and type of ship, economical to operate, and have no moving parts.
<b>Research Methods</b>	Phase I - Demonstrate the effectiveness of combining the use of filtration and a low-frequency sonic contact reactor with ozone.  Phase II - Demonstrating the unit dockside at several locations @ 500 GPM.  Phase III - Incorporate the findings from early work into an operable, shipboard system @ 5,000 GPM.  The method uses a mechanically driven acoustic transducer operating at low-frequency to promote intimate mixing of gases, liquids, and solids to improve the contact between the organisms in ballast water and ozone bubbles, resulting in greater mortality at small dosing rates. The processes produce high-intensity acoustic compression and rarefaction waves which are propagated throughout the reactor. The intense pressure and turbulence induced shear caused by these waves will stress and traumatize the organisms, increasing their vulnerability to the ozone.  For details of lab methods used to evaluate the effectiveness of these techniques, see next section.
<b>Results</b>	Phase I Final Report available upon request. Also available are the lab results by Dr. Robert A. Andersen at Provasoli-Guillard National Center for Culture of Marine Phytoplankton, Bigelow Laboratory for Ocean Sciences, West Boothbay Harbor, ME 04575 USA.

<b>Name of Project</b>	<b>The Feasibility of Biocide Application in Controlling the Release on Nonindigenous Aquatic Species from Ballast Water</b>
<b>Treatment options researched</b>	<i>Biocide treatment of ballast water using glutaraldehyde.</i>
<b>Principal Researcher(s)</b>	Dr Michael Parsons, Dr Peter Landrum, Ms Larissa Sano, Lt Curtiss C. Potter, Ms Ann Krueger.
<b>Contact Details</b>	Dr Michael Parsons 236A NA&ME Bldg., Room 2145 Ann Arbor, MI 48105 United States of America Tel: +1 734 763 3081 Fax: +1 734 936 8820 E-mail: parsons@engin.umich.edu
<b>Host Institution(s)</b>	Cooperative Institute for Limnology and Ecosystems Research (University of Michigan, College of Engineering) and the Great Lakes Environmental Research Lab (National Oceanic and Atmospheric Association).
<b>Location of Research</b>	Ann Arbor, Michigan.
<b>Funding Level</b>	US\$306,000.
<b>Funding Source(s)</b>	Great Lakes Fishery Trust Fund.
<b>Timeframe of the Project</b>	March 1998 – February 2001.
<b>Aims and objectives of the project</b>	To investigate the potential for biocide treatment in helping reduce the number of nonindigenous species released into Great Lakes' waters.  Components of this objective are to establish the concentrations of glutaraldehyde required to achieve 90% mortality rates (LC90) in 24-hour water-only exposures using a range of representative aquatic organisms; Determine the effect of sediments on glutaraldehyde efficacy in 24-h water-sediment exposures; Measure degradation rates of glutaraldehyde under conditions similar to those found in ballast tanks; Determine the concentrations of glutaraldehyde that may pose a risk to organisms exposed in receiving waters; Conduct a field trial of glutaraldehyde treatment using a foreign NOBOB (no ballast on board) vessel transiting from the Baltic area to the Great Lakes.
<b>Research Methods</b>	Laboratory testing, which included a 24-hour acute lethal toxicity bioassays, chronic toxicity bioassays, degradation experiments and shipboard application (still in development).
<b>Results</b>	To be determined.

<b>Name of Project</b>	<b>Electrochemically Generated Ozone for On-Board Control of Nonindigenous Invasive Species in Ballast Water</b>
<b>Treatment options researched</b>	<i>Electrochemically generated ozone.</i>
<b>Principal Researcher(s)</b>	Dr. Tom D. Rogers, Principal Investigator, Dr. Dalibor Hodko (Lynntech, Inc.) Associate Investigator, Capt. Phil Jenkins, Jenkins and Associates Ltd, Fonthill, Ontario, Canada (Subcontractor).
<b>Contact Details</b>	Lynntech, Inc 7610 Eastmark Dr College Station, TX 77840 United States of America Tel: +1 979 693 0017 Fax: +1 979 764 7479 Email: trogers@lynntech.com Web: www.lynntech.com.
<b>Host Institution(s)</b>	Lynntech, Inc.
<b>Location of Research</b>	College Station, Texas and Ontario, Canada.
<b>Funding Level</b>	US\$200,000.
<b>Funding Source(s)</b>	U.S. Department of Commerce (Sea Grant).
<b>Timeframe of the Project</b>	1 September 2000 – 31 August 2002.
<b>Aims and objectives of the project</b>	<p>Evaluate:</p> <ul style="list-style-type: none"> <li>• Methods of on-board use of ozone (i.e., intake pulse treatment, in-tank contacting).</li> <li>• Various factors pertaining to corrosion when using ozone.</li> <li>• Dose-rate requirements for ozone related to various water qualities typical of representative ports and waterways.</li> <li>• Requirements for system integration into specific types of ships.</li> <li>• Safety requirements for on-board use of ozone.</li> <li>• Cost estimates for scale-up of technology and systems to meet on-board implementation.</li> </ul>
<b>Research Methods</b>	Laboratory and pilot scale tests will be performed to meet tasks defined within the scope of the project as presented to the U.S. Department of Commerce.
<b>Results</b>	To be determined.



Name of Project	Pacific Ballast Water Treatment Pilot Project
<b>Treatment options researched</b>	<i>Various.</i>
<b>Principal Researcher(s)</b>	Scott Smith.
<b>Contact Details</b>	Washington State Aquatic Nuisance Species Coordinator Washington Department of Fish and Wildlife 600 Capitol Way N. Olympia, WA 98501 United States of America Tel: +1 360 902 2724 Fax: +1 360 902 2845 Email: smithsss@dfw.wa.gov.
<b>Host Institution(s)</b>	Washington Department of Fish and Wildlife, USGS Biological Resources, US Fish and Wildlife Services, Hyde Marine, Velox, California State Lands Commission, University of Washington.
<b>Location of Research</b>	Marrowstone Marine Field Station, WA, USA.
<b>Funding Level</b>	US\$330,000 plus in-kind contributions.
<b>Funding Source(s)</b>	US Fish and Wildlife Service, USGS Biological Resources, Velox Technologies, Hyde Marine.
<b>Timeframe of the Project</b>	Phase I (Project Planning, Organisation and Funding): April 2000-October 2000.  Phase II (All project deliverables completed. Final report submitted within six months): October 2000-June 2001.
<b>Aims and objectives of the project</b>	This project aims to recommend a standard for the discharge of treated ballast water and recommend a sampling/monitoring protocol to verify an adequate ballast water exchange. The final report will be made available for distribution in the US.
<b>Research Methods</b>	Laboratory and on-board tests.
<b>Results</b>	To be determined.

Name of Project	Clean Ballast Water
<b>Treatment options researched</b>	<i>Innovative application of high frequency ultrasound</i>
<b>Principal Researcher(s)</b>	Dr. Christopher Sullivan
<b>Contact Details</b>	Dr. Christopher Sullivan Oceanit Laboratories, Inc. 1001 Bishop Street Pacific Tower, Suite 2970 Honolulu, Hawaii 96813 United States Tel: +1808 531 3017 Fax: +1 808 531 3177 Email: Csullivan@oceanit.com
<b>Host Institution(s)</b>	
<b>Location of Research</b>	Honolulu, Hawaii.
<b>Funding Level</b>	US \$350,000.
<b>Funding Source(s)</b>	U.S. Department of Commerce. U.S. Department of Transportation/Coast Guard. High Technology Development Corp.
<b>Timeframe of the Project</b>	Through 2002.
<b>Aims and objectives of the project</b>	To design, build and demonstrate an effective ballast water treatment system that cleans ballast water of marine organisms by utilizing a unique high-frequency ultrasound technology.
<b>Research Methods</b>	Use innovative application of high-frequency ultrasound, with unique treatment vessel configurations, to produce a viable ultrasonic ballast water treatment system.
<b>Results</b>	To be determined. Initial results are very promising.

Name of Project	<b>Field Tests on Alternatives to Ballast Exchange</b>
<b>Treatment options researched</b>	<i>Self Cleaning Screens, Hydrocyclones, UV radiation.</i>
<b>Principal Researcher(s)</b>	Dr Thomas D Waite.
<b>Contact Details</b>	College of Engineering University of Miami Coral Gables, FL 33124 United States of America Tel: +1 305 284 3467 Fax: +1 305 284 2885 Email: <a href="mailto:twait@miami.edu">twait@miami.edu</a> Web: <a href="http://www.eng.miami.edu">www.eng.miami.edu</a> .
<b>Host Institution(s)</b>	University of Miami.
<b>Location of Research</b>	University of Miami School of Marine Science, Biscayne Bay, Miami, FL.
<b>Funding Level</b>	Approx. US\$400,000.
<b>Funding Source(s)</b>	US Coast Guard.
<b>Timeframe of the Project</b>	August 2000 – July 2001.
<b>Aims and objectives of the project</b>	To determine treatment effectiveness of the unit processes described above.
<b>Research Methods</b>	This is a dockside pilot facility operating at 300 cubic meters per hours. It is currently under construction, and testing will commence in September 2000. Samples will be evaluated for both zoo- and phytoplankton removal and inactivation before and after treatment.
<b>Results</b>	To be determined.

Name of Project	<b>Large Scale Treatment of Ballast Water With Screens, Hydrocyclones and UV, at Variable Turbidity and Color</b>
<b>Treatment options researched</b>	<i>50 micron screen, Hydrocyclone, UV, Media Filter</i>
<b>Principal Researcher(s)</b>	Thomas D. Waite, Junko Kazumi
<b>Contact Details</b>	<a href="mailto:twait@miami.edu">twait@miami.edu</a> , <a href="mailto:jkazumi@miami.edu">jkazumi@miami.edu</a>
<b>Host Institution(s)</b>	University of Miami, Coral Gables, FL 33124 (USA).
<b>Location of Research</b>	Miami, Florida (USA).
<b>Funding Level</b>	Approx. US\$0.5M (two years).
<b>Funding Source(s)</b>	U.S. Coast Guard.
<b>Timeframe of the Project</b>	September 2000 – September 2002.
<b>Aims and objectives of the project</b>	Evaluate effects of turbidity and color effects on the unit processes of screening, hydrocyclones, and UV radiation at large scale (300 m <sup>3</sup> /Hr).
<b>Research Methods</b>	Bacteria, phytoplankton, zooplankton, ATP, protein changes due to treatment under the influence of variable parameters.
<b>Results</b>	Effects of turbidity on treatment efficiency finished and report (interim) with the U.S. Coast Guard. Studies of treatment efficiency studies as a function of color are underway. Paper describing results has been submitted to <i>Marine Ecology Progress Series</i> .

<b>Name of Project</b>	<b>RJ Pfeiffer (Panamax containership)</b>
<b>Treatment options researched</b>	<i>OptiMar Ballast System (Separation and UV)</i>
<b>Principal Researcher(s)</b>	Nick Welschmeyer and Steve Bollens
<b>Contact Details</b>	
<b>Host Institution(s)</b>	Moss Landing Marine Laboratories and Romberg-Tiburon Center, San Francisco State University.
<b>Location of Research</b>	West coast of USA.
<b>Funding Level</b>	
<b>Funding Source(s)</b>	California State Lands Commission and California State Water Resources Control Board.
<b>Timeframe of the Project</b>	Spring/Summer 2002.
<b>Aims and objectives of the project</b>	Verify effectiveness of the OptiMar System.
<b>Research Methods</b>	On board sampling.
<b>Results</b>	To be determined.

<b>Name of Project</b>	<b>Sea Princess and Star Princess (Cruise ships)</b>
<b>Treatment options researched</b>	<i>OptiMar Ballast System (Separation and UV)</i>
<b>Principal Researcher(s)</b>	Nick Welschmeyer and Steve Bollens
<b>Contact Details</b>	
<b>Host Institution(s)</b>	Moss Landing Marine Laboratories and Romberg-Tiburon Center, San Francisco State University.
<b>Location of Research</b>	West coast of USA.
<b>Funding Level</b>	
<b>Funding Source(s)</b>	California State Lands Commission and California State Water Resources Control Board.
<b>Timeframe of the Project</b>	Spring/Summer 2002.
<b>Aims and objectives of the project</b>	Verify effectiveness of the OptiMar System.
<b>Research Methods</b>	On board sampling.
<b>Results</b>	To be determined.

**Appendix One:  
Template for Submissions to be  
Included in the Directory**



<b>Name of Project</b>
<b>Treatment options researched</b>
<b>Principal Researcher(s)</b>
<b>Contact Details</b>
<b>Host Institution(s)</b>
<b>Location of Research</b>
<b>Funding Level</b>
<b>Funding Source(s)</b>
<b>Timeframe of the Project</b>
<b>Aims and objectives of the project</b>
<b>Research Methods</b>
<b>Results</b>









## More Information?

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