ICES WGBOSV REPORT 2016

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Interim Report of the ICES/IOC/IMO Working Group on Ballast and Other Ship Vectors (WGBOSV)

14–16 March 2015

Olbia, Italy

ICES International Council for the Exploration of the Sea

CIEM Conseil International pour l'Exploration de la Mer

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Conseil International pour l'Exploration de la Mer

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Executive summary

The ICES/IOC/IMO Working Group on Ballast and Other Ship Vectors (WGBOSV) met at the Marine Protected Area of Tavolara Punta Coda Cavallo in Olbia, Italy, 14–16 March 2016, including a joint meeting on 16 March with the Working Group on Introductions and Transfers of Marine Organisms (WGITMO). The meeting was hosted by Anna Occhipinti and chaired by Sarah Bailey. The meeting was attended by 26 scientists in person, 5 by videoconference and 4 by correspondence representing 16 countries; 9 additional scientists representing 5 additional countries attended on the joint meeting day. The objective of the meeting was to discuss and address the six terms of reference (ToRs) in order to co-ordinate and advance research activities that reduce the risk of transporting non-native species via shipping activities.

This interim report provides a brief summary of progress achieved on all ToRs and the related work plan, with National Reports and Abstracts for all presentations appended as annexes. The approach taken at the meeting was for each country to provide an update on the status of shipping vector research in the form of a National Report, facilitating a thorough review of national activities to identify potential collaborations, advance research and address knowledge gaps (ToR a). Subsequently, individual ToRs were progressed through contributed presentations and group discussion. During the meeting, WGBOSV connected with the GloBal TestNet organization (a consortium of ballast water treatment system testing organizations working together to standardize test procedures) by videoconference, to identify areas of coordination and collaboration under ToR c. Jointly with WGITMO, WGBOSV responded to a direct request received from ICES Bureau regarding development of questions that could direct the development of demonstration advice on "risk management of nonindigenous species associated with shipping in the Arctic". In addition, jointly with WGITMO, WGBOSV identified key external researchers to invite to next year's meeting in order to expand expertise on biofouling issues.

Two recommendations were developed at the meeting: (i) to initiate discussion/coordination with other Arctic organisations (e.g. Arctic Council working groups on the Protection of the Arctic Marine Environment (PAME) and the Conservation of Arctic Flora and Fauna (CAFF)) with a view to jointly address non-native species issues in the Arctic; and (ii) to consider the following three questions as material for development of demonstration advice:

- How will climate change impact the risk of introduction, survival and/or establishment of marine non-native species in the Arctic?
- What management measures currently available in other marine environments are applicable for the Arctic?
- What future activities should be prioritized to manage marine NIS in the Arctic?

Next year, WGBOSV proposes to meet in Massachusetts, USA, 15–17 March 2017, with Judith Pederson (MIT Sea Grant) as host. A full-day joint meeting will be held with WGITMO on 15 March 2017.

1 Administrative details

Working Group name

Working Group on Ballast and Other Ship Vectors (WGBOSV)

Year of Appointment

2016

Reporting year within current cycle (1, 2 or 3)

1

Chair(s)

Sarah Bailey, Canada

Meeting venue

Sommerøy, Tromsø, Norway

Meeting dates

Olbia, Italy, 14–16 March 2016

2 Terms of Reference a) – z)

a) Conduct strategic planning (identify and develop collaborative activities, advance and standardize methods, etc.) to advance research and address knowledge gaps through review of national activities and to respond to new requests for advice;

b) Evaluate methods for collection and analysis of ballast water samples to inform national and/or international procedures for compliance testing of ballast water management systems;

c) Evaluate methods for, and outcomes of, type approval and operational testing of ballast water management systems to inform national and/or international procedures for type approval of such systems;

d) Investigate and evaluate climate change impacts on the establishment and spread of ship-mediated nonindigenous species, particularly with respect to the Arctic;

e) Investigate and evaluate methods/technologies to assess risks of, to minimize extent of, and to respond to vessel biofouling to inform national and/or international policies or guidelines;

f) Evaluate the current role/importance of shipping in relation to other invasion vectors/pathways globally.

3 Summary of Work plan

Year 1	Working on all ToRs, but with special focus on ToRs a, c, and d.
Year 2	Working on all ToRs, but with special focus on ToRs b, e, and f.
Year 3	Report on all ToRs

4 List of Outcomes and Achievements of the WG in this delivery period

- A thorough review of national activities was conducted to identify potential collaborations, advance research and address knowledge gaps.
- Multiple WGBOSV members have been involved in the development of a special issue in the Journal of Sea Research on advances in ballast water management, with special focus on methods for collection and analysis of ballast water samples.
- WGBOSV connected with the GloBal TestNet organization (a consortium of ballast water treatment system testing organizations working together to standardize test procedures) by videoconference, to identify areas of coordination and collaboration.
- Jointly with WGITMO, WGBOSV responded to a direct request received from ICES Bureau regarding development of questions that could direct the development of demonstration advice on "risk management of nonindigenous species associated with shipping in the Arctic".
- Jointly with WGITMO, WGBOSV identified key external researchers to invite to next year's meeting in order to expand expertise on biofouling issues.

5 Progress report on ToRs and work plan

ToR a) National Reports on ballast and other shipping research were submitted by eleven countries. Each report summarizes the status of shipping research in each country, as well as planned research for 2016–2018 and identifies research needs and gaps. Further, the reports highlight upcoming meetings of interest, recent publications and products and contact information for project leads. These were used as the basis to identify and develop collaborative activities within the Group. In addition, presentations were contributed to inform Group members about a framework for exemptions under the ballast water management convention; mesocosm approaches to characterize the risk-release relationship in the US; and to review genetic tools used for ballast water monitoring. In addition, participants reported on monitoring activities in the Orkney Islands (Scotland, UK); and the development and application of molecular methods for the early detection of marine aquatic invasive species in Spain. The Group discussed concerns about the scientific basis for granting of exemptions for ballast water management and the need to monitor related activities at the International Maritime Organization. The Group agreed that it could be advantageous to provide scientific input to that process, as required. The ToR Lead agreed to monitor developments at the International Maritime Organization and update WGBOSV accordingly, so that decisions could be taken about the need for action by the Group.

ToR b) Four presentations provided the Group with updates on research conducted to evaluate methods for the collection and analysis of ballast water samples related to compliance testing of ballast water management systems. Multiple WGBOSV members have been involved in the development of a special issue in the Journal of Sea Research on advances in ballast water management, with special focus on methods for collection and analysis of ballast water samples. In addition, the Group identified that it could be advantageous to provide information on such methods back to the International Maritime Organization formally. The ToR Lead agreed to explore avenues for future submission to the International Maritime Organization prior to the next meeting.

ToR c) WGBOSV connected with the GloBal TestNet organization (a consortium of ballast water treatment system testing organizations working together to standardize test procedures) by videoconference to review objectives of each group, and to identify areas of coordination and collaboration. Very few WGBOSV members are involved in such testing, and all of these are members in the GloBal TestNet. As a result, the broader WGBOSV relies on outside information to learn how ballast water management systems are developing, and to identify any scientific concerns related to biological efficacy or toxicity. Both Groups expressed interest to improve communication by coordinating meeting schedules and contributing to, or disseminating, each other's meeting reports. Given that WGBOSV already meets jointly with WGITMO, it would be difficult to arrange a joint meeting with Global TestNet, however, it was recommended that scientific interaction could be augmented through a theme session at a future relevant scientific conference. The Chairs of WGBOSV and GloBal TestNet agreed to contact each other directly to facilitate future interactions of the groups.

ToR d) WGBOSV began with presentations examining the biological introduction risks from shipping in a warming Arctic and a review of research and monitoring activities for ship-mediated nonindigenous species in the Canadian Arctic. In addition, the WGBOSV/WGITMO jointly discussed and developed questions that could direct the development of demonstration advice on "risk management of nonindigenous species associated with shipping in the Arctic", in response to a direct request received from ICES Bureau shortly before the meeting was held. The Groups reviewed recent activities at ICES related to the development of demonstration advice within strategic priority areas. Given that the ICES strategic plan commits to further develop its science and advisory capacity for the Arctic, and that multiple individual WGBOSV/WGITMO members have received requests for information directly from groups working on non-native species issues under the Arctic Council, the Groups jointly agreed to submit three questions for consideration as material for development of demonstration advice:

1) How will climate change impact the risk of introduction, survival and/or establishment of marine non-native species in the Arctic?

2) What management measures currently available in other marine environments are applicable for the Arctic?

3) What future activities should be prioritized to manage marine NIS in the Arctic?

A subset of members from both Groups expressed interest to draft a paper addressing these questions prior to the next meeting. Finally, the Groups reviewed the objectives of the Arctic Council working groups with interest in invasive species, discussed the lack of

coordination between the different international groups working on non-native species issues in the Arctic, and the uncertain role of WGBOSV/WGITMO experts that are feeding the same scientific input to multiple end-users. It was recommended that ICES leadership should initiate discussion/coordination with other Arctic organisations (e.g. Arctic Council working groups on the Protection of the Arctic Marine Environment (PAME) and the Conservation of Arctic Flora and Fauna (CAFF)) with a view to address non-native species issues in the Arctic jointly with all organisations active in this field.

ToR e) WGBSOV began with a review of the Guidelines and Guidance developed by the International Maritime Organization for control and management of ships' biofouling to minimize the transfer of aquatic non-native species by commercial ships and recreational boats. On the joint meeting day, an overview was presented of recent activities conducted to assess the risk of biofouling by recreational boats across Canada, and an update was given on related research in Italy. Finally, a presentation was contributed about marine infrastructures as corridors for non-native species and how changes in engineering of structures could serve to limit spread. Research activities under this ToR are limited within the current membership of WGBOSV. The Groups identified key external researchers to invite to next year's meeting in order to expand relevant expertise. The Groups noted that the International Maritime Organization highlighted research needs related to management of biofouling and that WGBOSV may be able to submit relevant information in the future. The ToR Lead agreed to contact researchers in Australia and New Zealand that may have already initiated submissions to the International Maritime Organization to see if WGBOSV members could assist or address any gaps. Seven WGBOSV members indicated interest to progress this ToR over the next year.

ToR f) Three presentations were contributed during the joint WGBOSV/WGITMO meeting that examined the relative importance of different vectors of aquatic non-native species in the Baltic and Mediterranean Seas; and the potential impacts of Japanese tsunami debris on ecosystems on the west coast of North America and Hawaii. The Group discussed how the relative importance of vectors has differed through time and by region, and how it could be valuable to conduct a global review on the topic. Concerns were raised about the lack of standardized data across regions, and the uncertainty surrounding the date of first report for introductions and the accurate assignment of responsible vectors. The Group noted that climate change and evolutionary responses of non-native species were important factors to consider when assessing future risk of new introductions. The ToR Lead agreed to develop an outline for a publication under this ToR, in consultation with a small number of WGBOSV/WGITMO members prior to next meeting.

6 Revisions to the work plan and justification

WGBOSV lacked the expertise to focus on ToR c (Evaluate methods for, and outcomes of, type approval and operational testing of ballast water management systems…) due to conflicting meeting dates with the GloBal TestNet. The situation was mediated by connecting the two meetings by videoconference. Given that GloBal TestNet has leading expertise on the topic, WGBOSV determined that it should not put effort into any research that may duplicate activities already underway. It was therefore recommended to amend the expected deliverable for ToR c to "Exchange information with other scientific

organizations examining such methods through a Theme Session at a relevant scientific conference".

7 Next meeting

Next year, WGIMT proposes to meet in Massachusetts, USA, 15–17 March 2017, with Judith Pederson (MIT Sea Grant) as host. A full-day joint meeting will be held with WGITMO on 15 March 2017.

Annex 1: List of participants

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Annex 2: Recommendations

RECOMMENDATION	ADRESSED TO
1. Initiate discussion/coordination with other Arctic organisations (e.g. PAME, CAFF) with a view to jointly address non-native species issues in the Arctic	SCICOM
2. Consider the following three questions as material for development of demonstration advice on risk management of nonindigenous species associated with shipping in the Arctic: • How will climate change impact the risk of introduction, survival and/or establishment of marine non-native species in the Arctic? • What management measures currently available in other marine environments are applicable for the Arctic? • What future activities should be prioritized to manage marine NIS in the Arctic?	SCICOM

Annex 3: Agenda

	MONDAY 14TH MARCH	
08.30	Set up Computers	.30
09.00	**Opening of the meeting**	
	Welcoming remarks: **Sarah Bailey** (Chair), **Anna Occhipinti** (Host)	.10
	Introduction of Participants	.15
	Update on ICES Activities – **Henn Ojaveer**	.15
	Discussion of 3-year ToRs and Interim Reporting requirements – **Sarah Bailey**	.15
	• Review WGBSOV Terms of Reference and Agenda	
10.00	**ToR a):** Conduct strategic planning (identify and develop collaborative activities, advance and standardize methods, etc.) to advance research and address knowledge gaps through review of national activities and to respond to new requests for advice. ***ToR lead: Sarah Bailey***	
	Review of National Activities (current + next 3 years)	
	• Belgium	.10
	• Canada	.10
	• Estonia	.10
10.30	**Morning break**	.30
11.00	• Finland	.10
	• France	.10
	• Germany	.10
	• Italy	.10
	• Lithuania	.10
	• Netherlands (*by correspondence*)	.10
	• Norway	.10
12.30	**Lunch break**	.60
13.30	• Sweden (*by videoconference*)	.10
	• UK	.10
	• USA	.10
	• Croatia (*by correspondence*)	
	Presentation: Framework for exemptions under the BWMC – **Henn Ojaveer**	.20
	Questions	.10
	Presentation: Mesocosm approaches to characterize the risk-release relationship – **Matthew TenEyck**	.20
	Questions	.10
15.00	**Afternoon break**	.30
15.30	Presentation: Genetic tools for ballast water monitoring – **John Darling**	.20
	Questions	.10

	Presentation: Monitoring activities in the Orkney Islands – **Jenni Kakkonen**	.10
	Questions	.5
	Presentation: Development and application of molecular methods for the early detection of marine aquatic invasive species – **Anais Rey**	.10
	Questions	.5
	Discussion, Gap Analysis and Strategic Planning under ToR a)	.30
16.30	**ToR b):** Evaluate methods for collection and analysis of ballast water samples to inform national and/or international procedures for compliance testing of ballast water management systems. ***ToR Lead: Lisa Drake***	
	Presentation: Comparative analysis of compliance methods on the RV METEOR – **Johanna Bradie** (*by videoconference*)	.20
	Questions	.10
	Presentation: Ballast Water Sample Collection Method - **Peter Stehouwer**	.20
	Questions	.10
17.30	**Close of Day 1**	

TUESDAY 15TH MARCH

08.30	Reconvene for Day 2 – Set Up Computers	.15
08:45	Presentation: Research on Sample Collection Ports and Compliance sampling methods – **Lisa Drake**	.30
	Questions	.10
	Presentation: Recommendations for Representative Ballast Water Sampling - Implications for Compliance Monitoring and Enforcement – **Stephan Gollasch**	.20
	Questions	.10
	Discussion, Gap Analysis and Strategic Planning under ToR b)	.30
10.30	**Morning break**	.30
11.00	Continue Discussion, Gap Analysis and Strategic Planning under ToR b) • Special Issue: *Recent Advances in Ballast Water Research and Management*	.30
11.30	**ToR e):** Investigate and evaluate methods/technologies to assess risks of, to minimize extent of, and to respond to vessel biofouling to inform national and/or international policies or guidelines. **ToR Lead: Cynthia McKenzie**	
	Presentation: Review of IMO biofouling guidelines – **Cynthia McKenzie**	.20
	Questions	.10
	Discussion, Gap Analysis and Strategic Planning under ToR e) – noting that work will continue on the joint day also	.30

12.30	**Lunch break**	.60
13.30	**ToR d):** Investigate and evaluate climate change impacts on the establishment and spread of ship-mediated nonindigenous species, particularly with respect to the Arctic. ***ToR Lead: Nathalie Simard***	
	Presentation: Biological introduction risks from shipping in a warming Arctic – **Anders Jelmert**	.20
	Questions	.10
	Presentation: Research and monitoring for ship-mediated nonindigenous species in the Canadian Arctic – **Kimberly Howland**	.20
	Questions	.10
	Discussion, Gap Analysis and Strategic Planning under ToR d) – noting that work will continue on the joint day also	.30
15.00	**Afternoon break**	.30
15.30	**ToR c):** Evaluate methods for, and outcomes of, type approval and operational testing of ballast water management systems to inform national and/or international procedures for type approval of such systems. ***ToR Lead: Stephanie Delacroix***	
	Videoconference with GloBal Test Net Meeting (Montreal)	
	Report on WGBOSV Mission, Objectives and Meeting ToRs – **Sarah Bailey**	.15
	Report on GloBal Test Net Mission, Objectives and Meeting ToRs – **Allegra Cangelosi**	.15
	General Discussion • Opportunities for Collaboration and Mutual Support • How can WGBOSV, GloBal Test Net, and IMO improve coordination in the future?	.30
	Discussion, Gap Analysis and Strategic Planning under ToR c)	.60
17.30	**Close of Day 2**	

WEDNESDAY 16TH MARCH
JOINT MEETING WITH WGITMO

08.30	Reconvene for Day 3 – Set Up Computers	.15
08.45	Welcoming remarks: **Sarah Bailey, Henn Ojaveer** (Co-Chairs), **Anna Occhipinti** (Host)	.10
	Introduction of Participants	.15
	Review joint WGBSOV/WGITMO Terms of Reference and Agenda	.10
09.30	**WGBSOV ToR e):** Investigate and evaluate methods/technologies to assess risks of, to minimize extent of, and to respond to vessel biofouling to inform national and/or international policies or guidelines / **WGITMO ToR d)** Continue investigating NIS associated with biofouling, incl. those on artificial hard structures in the marine environment and recreational boating. ***ToR Lead: Cynthia McKenzie***	

	Presentation: Canadian national risk assessment of biofouling by recreational boats – **Cynthia McKenzie**	.20
	Questions	.10
	Presentation: Challenges and opportunities of an ecologically-based design of marine infrastructures – **Laura Airoldi**	.20
	Questions	.10
10.30	**Morning break**	.30
11.00	**WGBOSV ToR f):** Evaluate the current role/importance of shipping in relation to other invasion vectors/pathways globally / **WGITMO ToR f):** Evaluate the role/importance of different bioinvasion vectors and pathways globally. ***ToR Leads: Sarah Bailey/Henn Ojaveer***	
	Short review of related activities – **Henn Ojaveer**	.10
	Short review of related activities – **Bella Galil**	.10
	Short review of related activities – **Tom Therriault**	.10
	Questions	.10
	Discussion, Gap Analysis and Strategic Planning under ToR f)	.45
12.30	**Lunch break**	.60
1.30	Location of next meeting and joint WGBOSV/WGITMO ToRs (2017-18)	.15
	Discussion of joint WGBOSV/WGITMO ToRs (2017-18)	.15
2.00	**New Item:** Develop ICES Demonstration Advice on Ballast Water in the Arctic. ***Lead: Andrea Sneekes***	
	Background About the Request to WGBOSV/WGITMO and ICES Advice – **Henn Ojaveer**	.10
	Presentation: DRAFT ICES Demonstration Advice on Ballast Water in the Arctic – **Andrea Sneekes**	.20
	Questions	.10
	Group Discussion/Revision/Strategic Planning to develop Draft Advice Document	.30
15.00	**Afternoon break**	.30
15.30	**WGBOSV ToR d):** Investigate and evaluate climate change impacts on the establishment and spread of ship-mediated nonindigenous species, particularly with respect to the Arctic / **WGITMO ToR c):** Continue identification and evaluation of climate change impacts on the establishment and spread of NIS. Finalize global review on salinity change effects on non-indigenous species. ***ToR Lead: Nathalie Simard***	
	Presentation: Arctic Council Objectives related to introduced species – **Peg Brady** (*by videoconference*)	.20
	Questions	.10
	Discussion, Gap Analysis and Strategic Planning under ToR d)	.30

16.30	Discuss any Issues Outstanding or Any Other Business	.60
17.30	**Close of Joint Day/End of WGBOSV**	

Annex 4: National Reports

Belgium

Report Prepared By:
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There is currently no work on ballast water or biofouling issues on vessels in Belgium. Belgium has on 7 March 2016 – just before the meeting of the SGBSOV - at last ratified the Ballast Water Management Convention. The Flanders Marine Institute (VLIZ) has issued a preliminary analysis of the distribution and the risk of target species in ports belonging to sailing routes for which companies want to obtain exemption. This study has now been published as a policy informing note 2015_002, and is online available via: http://www.vliz.be/nl/news?p=show&id=4474. None of the shipping routes where eligible for an exemption.

The work studying the fouling on the windmill farms is still ongoing. A range of species has been found, including non-natives and introduced species, especially in the intertidal zone.

Canada

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STATUS OF SHIPPING VECTOR RESEARCH

Canada has a long history of research and management concerning shipping vectors, especially regarding ballast water in the Laurentian Great Lakes where activity has been high since the late 1980s. Fisheries and Oceans Canada and Transport Canada both allocate funds annually to support research and monitoring of aquatic invasive species (including but not exclusively shipping vector activities), which recently has been in the range of $CAD 500–750K, depending on departmental priorities each year. Canada ratified the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004, in April 2010. Transport Canada is preparing to fully implement the Convention with the expectation that the Convention will enter into force in the near future.

The potential introduction of Asian carps into the Great Lakes from the Mississippi River basin is of high concern. Fisheries and Oceans Canada initiated an Asian Carp Program to prevent the introduction and establishment of four species of Asian carps (Grass, Bighead, Silver and Black carps). This 5-year program began in 2012 with a strong focus on early detection surveillance in the Canadian waters of the Great Lakes (approximately $CAD 875K annually). Additional activities include research

to support risk assessments, reduce spread of invasive fishes, and assess potential Asian carp containment options; funds for research in 2015/16 were $CAD 470K.

PLANNED RESEARCH

Planned research will focus on examining risk of shipping vectors to Canadian Arctic ports; developing protocols for collecting and analysing representative samples of ballast water; and evaluating efficacy of ballast water management systems for use in the Canadian environment.

RESEARCH NEEDS

- A baseline data set for Canadian Arctic plankton and benthos by marine ecoregions has been collated, but species records for different taxa should be incorporated into a consistent, standardized database format and ideally published/archived in a way that they can be made publicly available.

RESEARCH GAPS

- DNA barcode reference libraries to catalogue biodiversity of lower trophic level taxa. Such information will provide a basis for the use of new genetic tools for the detection of changes in biodiversity and detection of new species.
- Risk assessment and management strategies for biofouling on vessels arriving to Canadian waters, particularly Arctic ports
- Risk assessment for recreational boating as a vector of AIS to Arctic region
- Population genetics studies of cryptogenic species found in port surveys, to better understand origins (native versus introduced)
- Studies confirming environmental acceptability of treated ballast water discharged into recipient ecosystems, particularly Arctic ports

MEETINGS

- IMO-GloBallast R&D Forum, Montreal, Canada, 16-18 March, 2016
- 19th International Conference on Aquatic Invasive Species (ICAIS), Winnipeg, Canada, 10–14 April, 2016
- Marine & Freshwater Invasive Species: Ecology, Impact, and Management, Buenos Aires, Argentina, 2–4 May 2016
- International Conference on Marine Bioinvasions X , Argentina, October 16-18, 2018

PROJECT INFORMATION

1. Understanding ballast water as a pathway for introduction of aquatic invasive species (AIS) in the Canadian Arctic (2013–2016)

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Nathalie Simard, Fisheries and Oceans Canada: Nathalie.Simard@dfo-mpo.gc.ca

The primary objectives of this project are to: 1) Characterize diversity and propagule pressure of zooplankton and phytoplankton in the ballast of ships in Arctic Ports (Churchill and Deception Bay); 2) Evaluate seasonal changes in risks associated with ballast being brought into the Canadian Arctic; 3) Determine effectiveness of current

voluntary exchange practices for Arctic domestic ships. The project will provide analyses of species composition and abundance for both domestic and international shipping pathways, seasonal analyses of risks and recommendations regarding current voluntary exchange. Information from this study will improve our abilities to understand and manage ballast-mediated species introductions, help guide voluntary domestic ballast management practices by industry and feed into regulatory decisions by Transport Canada. Ballast samples of ships arriving in ports of Churchill and Deception Bay were collected in 2013–2015. Experimental testing of different exchange locations vs control (no exchange) was conducted on 3 voyages of the domestic ship MV Arctic in 2015. Sample analyses will be completed and first results will be published in 2016.

2. Evaluating ship biofouling as a potential pathway for the introduction and spread of aquatic invasive species (AIS) into the Canadian Arctic (2009–2018)

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The primary objectives of this project are: (1) To determine whether biofouling organisms on ships can survive voyages from temperate to Arctic ports in Canada. (2) To identify biofouling hotspots for ships operating in an Arctic environment. (3) To characterize biofouling extent and management practices of ships operating in Canadian Arctic waters.
(4) To evaluate the importance of ship biofouling as a pathway for the introduction and spread of AIS into the Canadian Arctic. The project will analyse data from hull SCUBA surveys of eight naval ships conducted before, during, and after voyages to the Canadian Arctic in the summers of 2009 to 2012. In addition, we have designed a questionnaire in line with the IMO Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species to collect information about voyage history, hull husbandry practices, and results from recent dry docking or in-water biofouling inspection/cleaning. Surveys were distributed it to all ships entering the Canadian Arctic in the summer of 2015 (will repeat in 2016) via the Canadian Coast Guard. Data from navy SCUBA surveys and questionnaires will be combined with published results of SCUBA surveys on commercial ship hulls to investigate the potential for ships to transport AIS to the Canadian Arctic via biofouling.

3. Study of plankton distribution in ballast tanks in order to collect a representative sample for compliance testing (2015–2017)

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Sarah Bailey, Fisheries and Oceans Canada: Sarah.Bailey@dfo-mpo.gc.ca

The primary objectives of this project are to determine: (1) if density distributions of plankton inside ballast tanks are heterogeneous and/or stratified, and if so, (2) the comparability of density estimates given by traditional net-haul vs. proposed in-line sampling using different estimation methods. Three extensive sampling trips (independent trials) were conducted in 2015 on a single operating vessel to examine the distribution of plankton in a single ballast tank, using traditional net-hauls and recently developed in-line sampling methods, augmented by stratified sampling

through tubing installed at different depths within the tanks. These samples are currently being counted for plankton densities. We will use stochastic models, such as non-homogeneous Poisson, to examine the spatial/temporal structure, heterogeneity, vertical stratification inside tanks, and temporal trends at discharge, of plankton densities. We will use method-comparison techniques to test whether density estimates given by net-haul and in-line sampling, using both traditional and our best-fit stochastic models, differ significantly, and also differ from those given by tube sampling, which exclusively captures the density variation by depth. We will investigate their relative accuracies, and how biases could be corrected analytically using mathematical/statistical models. We will also investigate the relationships between heterogeneity, spatial/temporal trends in densities with respect to environmental variability and other fixed and random factors using models such as GLMM.

4. Comparison of sampling devices and analytic methods for ballast water compliance monitoring (2015–2018)

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The primary objectives of this project are: (1) to examine whether there are differences in samples collected using traditional net sampling and in-line sampling skids (open and closed configurations), (2) to examine the accuracy and precision of analytic tools and to assess whether quick, indicative methods offer comparable results to standard, time-intensive testing methods (e.g. microscopy) and high-end scientific approaches, and (3) to examine whether there are differences between analytic devices in the detection of UV treatment events. To accomplish these objectives, a voyage was undertaken by 20 international researchers on board the German research vessel, RV Meteor, in June 2015. During this time 28 trials were conducted to evaluate three ballast sampling devices (plankton net and 2 sampling skids) and a number of analytic devices (>200µm: 1 technique, >50µm: 5 techniques, >10µm and <50µm: 10 techniques, bacteria: 6 techniques). Water samples were collected using paired sampling devices and analyzed in parallel by all analytic methods to determine whether results were similar between devices. Results are being analyzed using linear mixed models and method comparison models.

5. Development of community-based program for monitoring and early detection of aquatic invasive species in the Canadian Arctic – preparing for increased shipping related to resource development and climate change (2015–2018)

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Increased shipping in the Canadian Arctic associated with resource development and climate warming will inevitably result in unwanted species introductions. Preventative measures, such as ballast water exchange and treatment and reduction of vessel fouling, are key components for management of aquatic invasive species (AIS). However, these measures are not 100% effective. Thus, in addition to prevention, management should focus on strategies for monitoring and early detection, especially

where AIS have not yet established or population levels are still low, as in the Canadian Arctic. Monitoring improves the likelihood of detecting invasions at early stages when there is a greater chance for successful eradication, containment, or to prepare to adapt to the presence of a new species. Through this project we are developing a four stage approach for the development of a monitoring and early detection system in the Canadian Arctic. This includes the following elements and is extending current research efforts by DFO and the Canadian Aquatic Invasive Species Network (CAISN): 1) Updated analysis of shipping vectors to identify high risk pathways; 2) Identification and ranking of key ship-mediated AIS for early detection and monitoring, and geographic locations with highest probability for establishment; 3) Development of genetic early detection methodologies (e.g., environmental or eDNA) for AIS in high risk ports; 4) Establishment of a community based monitoring network/capacity. In 2015/16, collection of ballast samples and experimental work were conducted to provide updated information for use in future analyses of shipping vectors, identification and ranking of high risk NIS for follow-up modelling (year 2-3) was initiated and collection of port samples (including eDNA samples) and training programs were conducted in the Ports of Churchill and Iqaluit. Lab analysis of these samples is currently underway. In 2016, we plan to collect port samples in Pond/Milne Inlet and further subtidal benthic samples in Iqaluit. Additional lab work and identification/genetic analyses are also planned for the second year of this project.

6. An investigation of the risk posed by marine recreational boating as a vector in the introduction and spread of aquatic invasive species in Canada (2011–2016)

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A national marine recreational boating risk assessment was conducted in 2015 to assess the risk of this vector poses to marine systems on both the east and west coasts in Canada. The risk assessment includes information on the level of infestation of NIS in the different Canadian and international ecoregions, the probability that boat vectors will be fouled with NIS – based on extensive surveys and statistical models, information on boat movements, and environmental similarity of source and receiving ecoregions. This is combined with information on annual boat traffic to estimate the relative risk of NIS due to boating in the different Canadian marine ecoregions. This research document is presently in revision and will be published in 2016.

RECENT PUBLICATIONS AND PRODUCTS

Bailey SA. 2015. An overview of thirty years of research on ballast water as a vector for aquatic invasive species to freshwater and marine environments. Aquatic Ecosystem Health & Management 18: 261-268.

Briski E, S Gollasch, M David, RD Linley, O Casas-Monroy, H Rajakaruna and SA Bailey. 2015. Combining ballast water exchange and treatment to maximize prevention of species introductions to freshwater ecosystems. Environmental Science and Technology 49: 9566-9573.

Casas-Monroy O, RD Linley, JK Adams, FT Chan, DAR Drake and SA Bailey. 2015. Relative Invasion Risk for Plankton across Marine and Freshwater Systems: Examining Efficacy of Proposed International Ballast Water Discharge Standards. PLOS ONE 10(3): e0118267.

Chan FT, Bradie J, Briski E, Bailey SA, Simard N and MacIsaac HJ. 2015. Assessing introduction risk using species;' rank-abundance distributions. Proceedings of the Royal Society B – Bio-

logical Sciences 282: 1799.
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Drake DAR, O Casas-Monroy, MA Koops and SA Bailey. 2015. Propagule pressure in the presence of uncertainty: extending the utility of proxy variables with hierarchical models. Methods in Ecology and Evolution 6: 1363-1371.
DFO. 2015. Risk assessment of alternate ballast water exchange zones for vessel traffic to the eastern Canadian Arctic. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/019.
Gonzalez-Ortegon E, Sargent P, Pohle G and Martinez-Lage A. 2015. The Baltic prawn *Palaemon adspersus* Rathke, 1837 (Decapoda, Caridea, Palaemonidae): first record, possible establishment, and illustrated key of the subfamily Palaemoninae in northwest Atlantic waters. Aquatic Invasions 10: 299-312.
MacGillivary ML and Kaczmarska I. 2015. *Paralia* (Bacillariophyta) stowaways in ship ballast: implications for biogeography and diversity of the genus. Journal of Biological Research-Thessaloniki 22: 2.
MacIsaac HJ, Beric B, Bailey SA, Mandrak NE and A Ricciardi. 2015. Are the Great Lakes at risk of new fish invasions from trans-Atlantic shipping? Journal of Great Lakes Research 41:1172-1175.
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Paolucci EM, Hernandez MR, Potapov A, Lewis MA, and MacIsaac HJ. 2015. Hybrid system increases efficiency of ballast water treatment. Journal of Applied Ecology 52: 348-357.
Stewart DB, Nudds SH, Howland KL, Hannah CG and Higdon JW. 2015. An ecological and oceanographical assessment of alternate ballast water exchange zones in the Canadian eastern Arctic. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/037. vi + 75 p.
Sun Y and Wells MG. 2015. The application of life-history and predation allometry to population dynamics to predict the critical density of extinction. Ecological Modelling 312: 136-149.

Croatia

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STATUS OF SHIPPING VECTOR RESEARCH

Research regarding ballast water as a vector of introduction of non-native species in the Croatian part of the Adriatic Sea started in 1990s. The first such project has been conducted at the University of Dubrovnik in the period 1996 – 2007 and the work on this issue has been continued till today.

Croatia ratified the International Convention for the Control and Management of Ships' Ballast Water and Sediments (IMO, 2004) in June 2010. The first national Regulation on Management and Control of the Ballast Water has been enacted by Croatian Parliament in 2007. This Regulation was modified and improved in November 2012 (Official Gazette: NN 128/12). The Regulation enacts the principles and methods in managing and controlling of the ballast water in floating objects during their stay or voyage in Croatian part of the Adriatic Sea.

After several records of the blue crab *Callinectes sapidus* in the eastern Adriatic Sea, speciments were found at the mouth of the river Neretva in November 2009. Till today this species established population in this area competing native *Carcinus aestuarii*. Recently, three specimens of the adult blue crab were caught inside the Nature Park Vransko Lake in May 2013 (Župan *et al.* 2016). This is the first appearance of this species in the Mediterranean freshwater ecosystems thus further monitoring of the blue crab should gain more interest and support.

PLANNED RESEARCH

IPA CBC Adriatic Ballast water management system for Adriatic Sea protection (BALMAS) project, started in November 2013, is reaching its final this year. Project partners agreed to continue this important work within a new joint project after 2016. The new project should build up on the knowledge achieved in BALMAS and continue monitoring and improvement of ballast water management in the Adriatic Sea.

RESEARCH NEEDS

Experience and knowledge of BOSV members in species determination or ballast water management could be welcome and valuable during the project preparation and implementation.

RESEARCH GAPS

Systematic monitoring of introduced species in Croatian waters is still not established. This should be of high interest for Croatian scientific community as well as for economy in order to find the best practice in detection and control of introduced species (e.g. earlier mentioned Blue crab which continues to spread to new areas after first introduction in Croatia).

MEETINGS

No meetings planned for this period.

PROJECT INFORMATION

1. Ballast water management system for Adriatic Sea protection (BALMAS) (2013-2016)

Lead beneficiary: Institute for Water, Republic of Slovenia;
Final beneficiary: University of Dubrovnik, Marijana Pećarević, marijana.pecarevic@unidu.hr

Ballast water management system for Adriatic Sea protection – BALMAS (http://www.balmas.eu/) project includes partners from all Adriatic countries. The general BALMAS objective is to establish a common cross-border system linking all Adriatic research experts and national authorities to avoid the unwanted risks to the environment and humans from the transfer of HAOP, through the control and management of ships' BW and sediments. Adriatic countries recognised that BW related data (e.g. the presence and invasiveness of HAOP in Adriatic ports, BW uptake and discharge activities, sediment disposal, chemical pollution with BW) and knowledge (e.g. port baselines and monitoring, BW sampling for compliance control, risk as-

sessment, how to deal with non-compliant vessels, early warning system, effectiveness of BWM systems and measures) need to be shared in order to enable implementation of the BWM Convention requirements through a common BWM plan, and provide support to responsible authorities for faster and effective decision making with a decision support system (DSS). The goal of the project is preparation of a common Ballast Water Management (BWM) Plan for the Adriatic Sea area and implementation of the BALMAS BWM decision support system (DSS) including compliance control and enforcement (CME), compliant with the International Convention for the Control and Management of Ship´s Ballast Water and Sediments (BWM Convention) considering local specifics.

Estonia

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STATUS OF SHIPPING VECTOR RESEARCH

Monitoring, incl. port biological monitoring

The specifically dedicated and governmentally funded national alien species monitoring program, started in 2010, was continued in 2015. The alien species monitoring consists of three major sub-components: 1) monitoring of high risk areas of primary invasions; 2) tracking long-term performance of selected most important alien species and 3) evaluation of ecological and socioeconomic impacts caused by alien species. Monitoring of high risk areas of primary invasions – vicinity of ports – has been conducted in Port of Tallinn (since 2010) and Port of Sillamäe (since 2012), both located in the Gulf of Finland. Several stations were sampled in port vicinity and also in more distant localities called also as reference sites. Importantly, all data and annual reports are freely available, though unfortunately written in Estonian only (Anon. 2016).

Port biological monitoring (Muuga Harbour, Port of Tallinn) according to HELCOM protocol was added to the programme in 2014 with sampling being carried out in spring, summer and autumn. The monitoring included recording of key environmental conditions (incl. CTD profiles) and sampling of phytoplankton, zooplankton, benthic infauna, fouling communities and mobile epifauna.The samples taken both from the harbour area as well as adjacent localities confirm that spatio-temporally, the most stable and abundant populations were those of the cirriped *Amphibalanus improvisus* and the polychaete *Marenzelleria neglecta*, however, with substantial reduction in distribution area and abundance of the latter species during a few recent years (Anon. 2016).

Distribution of the round goby

Pan-Baltic modelling results show that the distribution of the round goby Neogobius melanostomus is primarily related to local abiotic hydrological conditions (wave

exposure). Furthermore, the probability of round goby occurrence was very high in areas in close proximity to large cargo ports. This links patterns of the round goby distribution in the Baltic Sea to shipping traffic and suggests that human factors together with natural environmental conditions are responsible for the spread of NIS at a regional sea scale. Thus, the models demonstrate clearly that the spatial distribution of the round goby in the Baltic Sea is a function of shipping intensity (distance to port, cargo traffic) and abiotic hydroclimatic environment (wave exposure). Although high frequency of release does not necessarily lead to successful invasions, the round goby seems not to have major environmental constraints in the Baltic Sea (Kotta *et al.* 2016).

Ballast Water Management Convention

As BWMC is expected to enter into force soon, shipping companies will start seeking exemptions for ballast water management in accordance with BWMC Regulation A-4. However,without scientifically robust risk assessment (RA) and consistent rules, the exemptions may introduce a new form of risk within a convention generally designed to reduce risks. To address this, a dedicated one week meeting was arranged in Pärnu (Estonia) with attendance of Sergej Olenin, Dan Minchin and Henn Ojaveer. As a result two documents were preapared:

1) Ojaveer *et al.* 2105. Proposal for IMO Ballast Water Management Convention A-4 Target Species selection criteria, submitted to the submitted to HELCOM Workshop on IMO BWMC target species, criteria and revision process (Tallinn, Estonia; 26 August 2015);

2) Olenin *et al.* 2016. Assessing exemptions under the ballast water management convention: preclude the Trojan horse. Marine Pollution Bulletin http://dx.doi.org/10.1016/j.marpolbul.2015.12.043

These documents describe an adaptive system for granting exemptions, consisting of six major components: target species selection procedure, port-to-port RA, monitoring, information support, administrative decision and review process. The systemis based on key principles defined in the IMO guidelines for RA and is designed to continuously accumulate evolving experience on granting exemptions. The ultimate goal is to contribute to the control of the spread of HAOPs, without placing an unnecessary burden on the shipping industry

Impacts

The range and density of the non-indigenous *G. tigrinus* is still increasing. Within a ten year of establishment the abundance of *G. tigrinus* showed no signs of decline with the invasive species exceeding about fifteen times the abundance values of native gammarids (Reisalu *et al.* 2016). Our recent experimental study demonstrated that the invasive *G. tigrinus* has higher reproductive potential compared to the native species (*Gammarus duebeni*, *Gammarus occanicus*, *Gammarus zaddachi*). Moreover, virtually all adult gammarids exerted a significant predation pressure on juvenile amphipods. Thus, the combined effect of predation on juvenile amphipods and large brood production of *G. tigrinus* could be plausible explanations describing increased abundance of *G. tigrinus* and decrease of local gammarid populations in the north-eastern Baltic Sea but plausibly in similar shallow water habitats in other seas (Jänes *et al.* 2015).

Our long-term data series analysis indicate that the late summer dynamics of the calanoid copepod *E. affinis* were explainable by a combination of positive SST effect and negative effect of *C. pengoi*. While these effects were for the younger stages independent of each other, we found for *E. affinis* adults indications of a control change. The TGAM suggested that SST has a positive effect only under low levels of *C. pengoi* abundances. At higher abundances of *C. pengoi*, reproductive processes governed by SST cannot counteract the predation pressure on *E. affinis*. On an average year, abundances of *C. pengoi* are above the threshold for entire July and August (data not shown). In contrast, abundances of *Acartia* spp. were not related to SST or abundances of *C. pengoi*, at least statistically (Klais *et al.* in prep.).

The Harris mud crab *Rhithropanopeus harrisii* was first found in Estonian waters in 2011. Further investigations in 2012 evidenced that the species has colonised whole Pärnu Bay and already occurring outside the area in the NE Gulf of Riga. There was an interactive effect between the presence of prey and crab population density with prey availability increasing the crab's affinity towards less favored habitats when population densities were low. Increased aggression between crab individuals increased their affinity towards otherwise less occupied habitats. Less favored habitats were typically inhabited by smaller individuals and presence of prey increased occupancy of some habitats for larger crabs. The experiment also demonstrated that the crab may inhabit a large variety of habitats with stronger affinity towards boulder fields covered with the brown macroalga *Fucus vesiculosus*. This implies stronger impact of crab in such habitats in the invaded ecosystem (Nurkse *et al.* 2015). *R. harrisii* significantly modifies meiobenthic communities and has by far the strongest effects on meiobenthos compared to any other environmental varible. The effects of *R. harrisii* varied among different habitats with the crab mostly modifying taxonomic composition and species abundances of meiobenthic communities mostly on unvegetated soft bottom sediments (Lokko *et al.* 2015).

PLANNED RESEARCH

As a direct outcome of the BWMC exemption research, analysis on seasonal port biological sampling carried out in Muuga Harbour (Port of Tallinn) will be undertaken. This will assist in not only defining the meaningful sampling frequency by various methods/organism groups, but also will help to evaluate the certainty of data obtained in those seasonal samplings

RESEARCH NEEDS

TBD

RESEARCH GAPS

TBD

MEETINGS

HELCOM Workshop on IMO BWMC target species, criteria and revision process (Tallinn, Estonia; 26 August 2015).

PROJECT INFORMATION

List individual projects of relevance to BOSV that will occur 2016-2018, using the format as below:

1. Project Title: Biodiversity changes – *investigating* causes, consequences and management implications (BONUS BIO-C3)
Contact information: https://www.bio-c3.eu/

BIO-C3 will investigate causes and consequences of changes in biodiversity, effects on ecosystem functioning, food web dynamics, productivity and assesses implications for environmental management and sustainable use of ecosystem goods and services. Planned biodiversity analyses will apply an integrated approach at species, genotype, population, community and ecosystem levels. Essential Baltic Sea features are low numerical species diversity, many recent immigrants, glacial relicts and simple food webs that nevertheless sustain goods and services of high economic and societal value. BIO-C3 will i) investigate genetic adaptation, eco-physiology, colonisation and role of native versus non-indigenous species, ii) advance understanding of functional links between biodiversity, external pressures and food-web interactions, and iii) improve future projections of trends in biodiversity. Biodiversity is dynamic, responding to various drivers that operate at different temporal and spatial scales. Spatio-temporal biodiversity responses will be analysed and evaluated by hindcasts and projections considering abiotic/biotic /anthropogenic drivers (climate change, eutrophication, species invasion, fisheries) and their interactions. Identified factors and processes will feed into impact assessments, guiding management policies to improve indicators of Good Environmental Status, efficacy and management of Marine Protected Areas and to conceptualise and design management evaluation frameworks.

2. Project Title Round goby in Estonian coastal waters: applied research for developmenting further action plan
Contact: Kristiina Nurkse, Estonian Marine Institute, University of Tartu. Email (kristiina.nurkse@ut.ee)

RECENT PUBLICATIONS AND PRODUCTS

Anon 2016. Operational monitoring of Estonian coastal sea. Estonian Marine Institute, University of Tartu. Final report, Tallinn.

Jänes, H.; Kotta, J.; Herkül, K. 2015. High fecundity and predation pressure of the invasive *Gammarus tigrinus* cause decline of indigenous gammarids. Estuarine Coastal and Shelf Science, 165, 185−189.

Kotta, J., Nurkse, K., Puntila, R., Ojaveer, H. (2016). Shipping and natural environmental conditions determine the distribution of the invasive non-indigenous round goby *Neogobius melanostomus* in a regional sea. Estuarine, Coastal and Shelf Science 169: 15-24.

Lokko, K., Kotta, J., Orav-Kotta, H., Nurkse, K., Pärnoja, M. (2015). Introduction of a functionally novel consumer to a low diversity system: Effects of the mud crab *Rhithropanopeus harrisii* on meiobenthos. Estuarine, Coastal and Shelf Science. doi:10.1016/j.ecss.2015.11.017

Nurkse, K., Kotta, J., Orav-Kotta, H., Pärnoja, M., Kuprijanov, I. (2015). Laboratory analysis of the habitat occupancy of the crab *Rhithropanopeus harrisii* (Gould) in an invaded ecosystem: The north-eastern Baltic Sea. Estuarine, Costal and Shelf Science 154: 152-157.

Ojaveer, H., Olenin, S., Minchin, D. and Boelens, R. 2015. Proposal for IMO Ballast Water Management Convention A-4 Target Species selection criteria. Document submitted to HELCOM Workshop on IMO BWMC target species, criteria and revision process (Tallinn, Estonia; 26 August 2015).

Olenin, S., Ojaveer, H., Minchin, D. and Boelens, R. 2016. Assessing exemptions under the ballast water management convention: preclude the Trojan horse. Marine Pollution Bulletin, http://dx.doi.org/10.1016/j.marpolbul.2015.12.043

Reisalu, G.; Kotta, J.; Herkül, K.; Kotta, I. (2016). The invasive amphipod *Gammarus tigrinus* Sexton, 1939 displaces native gammarid amphipods from sheltered macrophyte habitats of the Gulf of Riga. Aquatic Invasions, 11, in press.

Finland

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STATUS OF SHIPPING VECTOR RESEARCH

A national group to discuss and share knowledge on the implementation of the BWMC in Finland is an important forum and has been working efficiently durieng the past few years. It is led by the Finnish Trafic and Safety Agency, and the Finnish Environment Institute, Ministry of Environment, Ministry of Traffic and Communication and The Finnish Shipowners' Association as well as a representative from Auramarine (a company that has developped ballast water treatment technologies in Finland) take actively part to the meetings and discussions. The ratification of the IMO's BWM Convention by Finland has been delayed and will take place during winter-spring 2016. At present there is only one project ongoing related to shipping vectors. It concerns testing the Harmonised Procedure on granting exemptions from the ballast water treatment in the Baltic Sea and the North Sea that has been developped during the past few years in HELCOM and OSPAR cooperation. No other projects are ongoing related to the shipping vector or risk assesments at present but a few project proposals have been submitted or are under preparation in Baltic Sea cooperation.

PLANNED RESEARCH

The research will focus on minimising the risks of granting exemptions through a joint protocol and tool in the Baltic and North Seas, and on risks of new invasions and their management measures.

RESEARCH NEEDS

Biofouling issues; best practices to reduce biofouling, the importance of hull fouling

as a vector in the northern Baltic conditions.

PROJECT INFORMATION

1. A pilot study on granting exemptions for ships under the Ballast Water Management Convention regulation A-4, based on the operability of HELCOM & OSPAR Risk assessment tool and expert judgement

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Maiju Lehtiniemi, Finnish Environment Institute: Contact:
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A small project is ongoing 2016 to test the HELCOM/OSPAR tool to grant exemptions from the ballast water treatment. The study tests how well the tool and the target species criteria and list included in the tool works. As a test case a few shipping routes have been selected between a few ports in the Baltic Sea and in the North Sea. The study will be ready in mid-2016 and the results will be presented in HELCOM/OSPAR TG Ballast in June 2016.

2. INRISK Ecosystem impacts of invasive species in the Baltic Sea: Risks and management measures

Maiju Lehtiniemi, Finnish Environment Institute: Contact:
maiju.lehtiniemi@ymparisto.fi

The project proposal has been submitted to the EU Bonus call in March 2016. The project would study the risks of new invasions in the Baltic Sea, their ecological and sosio-economic impacts on the food web as well as cost efficiencies of hull fouling techniques and ballast water treatment. The project would start 2017 and last three years.

France

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STATUS OF SHIPPING VECTOR RESEARCH

A European consortium composed of ecologists and economists has examined the costs of putative non-indigenous species (NIS) mitigation measures directed towards fouling on commercial ships, at the European level (Fernandes *et al.* 2016). Their study used data from U.K. and France listing fouling NIS, some of which had been obtained in the course of the Interreg Marinexus project (WP3 – J. Bishop & F. Viard). Despite the limitations due to the scarcity of data that are available, Fernandes *et al.* (2016) suggest that NIS could have a higher impact than native species on fuel consumption. The reasons behind being some properties specific to NIS (life-history

traits and resistance to polluants and anti-fouling coating). The costs incurred may thus be viewed as positive investments if they prevent or mitigate the spread of NIS.
Other ongoing research is of a more technical nature. A study by Guilbaud *et al.* (2015) evaluated the techno-economic feasibility of using a microfiltration membrane process to remove high concentrations of microalgae from seawater. A recent paper by Tournadre (2015) used altimeter data to detect and monitor ship traffic through a method of analysis of echo waveform. The resulting ship traffic analysis shows a global fourfold increase in ship traffic between 1992 and 2012, with the largest increase being observed in the Indian Ocean and Chinese seas, thus reflecting changes in world trade.

In anticipation of the entry in force of the Ballast water Convention, new ballast water management plans aboard the research vessels (RV) of the French oceanographic fleet have begun. Although ballast water volumes pumped and released are small, these RVs carry out surveys in many different areas of the globe and as a result and are more likely to take on board and introduce NIS. The majority of the fleet is under the responsibility of the holding GENAVIR:

-"THALASSA": grosstonnage: 2803 UMS
-"POURQUOI PAS?": grosstonnage: 7854 UMS
-"ATALANTE": grosstonnage: 3559 UMS
-"EUROPE": grosstonnage:335 UMS
-"SUROIT": grosstonnage:946 UMS
-smaller vessels: "THALIA"(135 tons);"GWEN DREZ"(106 tons); "HALIOTIS" (6.28 tons); "ANTHEA" (571 tons); "ALIS" (for IRD; 207 tons)

Beginning with the RV "THALASSA », the solution retained is to use freshwater as ballast: the ship has a reverse osmosis desalination plant and a freshwater tank of 190 m3, for 187 m3 ballast water capacity. It is a question of changing the piping during the periodic refit operation of summer 2017, with sealed valves to prohibit saltwater use (except in an emergency). This is compatible with the G8 regulation, providing:

- IMO approval of the management plan
- sampling valves are installed in the piping system for port state controls

The suggestion to register ballast operations in an electronic logbook including GPS positions, for any further control was also made. If this system appears satisfactory at use and to the maritime authorities, the RVs "POURQUOI PAS" and "ATALANTE" will also be fitted with the same system. For the other smaller RVs, different solutions must be provided (i.e. commercially available physical or chemical treatment) bearing in mind that the ballast water capacity of those RVs are small and hence do not justify a costly treatment system.

RESEARCH NEEDS

Cooperation at an international level is essential and greatly facilitated by the WGBOSV and WGITMO groups. The gateway between scientific bodies and the port state control officers in charge of inspecting the implementation of the BWMC should be improved.

RESEARCH GAPS

- Biofouling studies of marinas, leisure craft and commercial vessels such as ferries
- DNA barcode reference libraries to catalogue biodiversity of lower trophic level taxa.
- Risk assessments of recreational boating as a vector of non-native species

MEETINGS

- 19th International Conference on Aquatic Invasive Species (ICAIS), Winnipeg, Canada, 10-14 April 2016
- Marine and Freshwater Invasive Species, Buenos Aires, Argentina, 2-4 May 2016
- Island Biology 2016, Terceira Island, Azores, 18-22 July 2016
- NEOBIOTA 2016 – 9th International Conference on Biological Invasions, Vianden, Luxembourg, 14-16 September

PROJECT INFORMATION

1. OCEANOMICS (2013 - ongoing)

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The OCEANOMICS project is building on the success of the Tara Oceans expedition, a public / private initiative that collected samples and eco-morpho-genetic data across 11 organism size fractions covering all planktonic communities - from viruses to animals - over more than 150 sites and 3 depths across the global oceans. OCEANOMICS offers a combination of high throughput sequencing and imaging protocols to extract information from this unique collection on several systemic levels: DNA, RNA and phenotypes. Comparisons of these new results with environmental metadata and new genomes and transcriptomes of strains/ reference planktonic organisms sequenced in the framework of the project will give access to a thorough taxonomic, metabolic, ecosystemic understanding of the structure, dynamics and evolution of plankton biodiversity.

2. EMODNET Atlantic Checkpoint (2015-2018)

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The purpose of the EMODnet checkpoints is to audit the value of marine data services to solve particular commercial and policy challenges with the development of the Blue Economy. With an increasing number of public marine data sources available, it is timely both to (a) support users in finding the right data products to solve their particular challenges and (b) examine how existing data services should be improved; including the content they offer and the way the service is delivered. The Atlantic Checkpoint considers eleven challenges of importance to the Blue Economy in the North East Atlantic, one of which concerns alien species. For each challenge a screening is undertaken to identify the data suitable to meet the challenge and an adequacy report produced on the data in actually solving the challenge. This adequacy report considers both the utility of the available data, but also what data gaps were found to exist. The alien species challenge aims to develop up to ten indicators on the impacts on ecosystems and economy of alien species, via a spatial analysis of

multiple data sets. Scientific partners: AZTI (lead), Ifremer, IPMA, CSIC.

Germany

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STATUS OF SHIPPING VECTOR RESEARCH

The German Federal Maritime and Hydrographic Agency (BSH) continues approving ballast water management systems (BWMS).

Completed projects:

During the Interreg IVB e-CME Ballast Water project an online training course for compliance monitoring and enforcement of ballast water management standards was developed. Training courses were successfully held and the training material is available online at the World Maritime University, Malmö, Sweden. For more information see http://elearning.e-cmeballastwater.eu/ or contact Josefin Madjidian, jam@wmu.se.

Notes:

As reported last year, a species of concern but not yet known from Germany is *Didemnum vexillum*. It is found in other European countries and it may be possible that this species becomes introduced to German waters with movements of living mussels and aquaculture gear or in the biofouling of vessels. Scientists involved in monitoring programmes were made aware of this species.

At the last meeting of the German "Platform for Information Exchange on Neobiota (NEOBIOTA)" (see below) it was noted that the newly opened port in Germany in 2012, i.e. the Jade-Weser-Port, only two years later became known as the area with the highest number of non-indigenous species in Lower Saxony. This may be due to the creation of new (hard-bottom) habitats and species introductions by ballast water and biofouling.

PLANNED RESEARCH

The German Federal State of Schleswig Holstein plans to initiate a study to document the non-indigenous species in the Kiel Canal (NEOBIOTA working group, pers. comm.).

The German Federal Ministry of Transport and Digital Infrastructure (BMVI) initiated a coordinated research effort to address early detection methods and management concepts for non-indigenous species introduction and spread by transport vectors. Further tasks are e.g. expanding the knowledge base for future exemptions from ballast water management requirements, identification of species introduction hot spots and introduction vectors as well as an improvement of the German authority network regarding non-indigenous species. Details of this planned 4 year initiative are currently developed (NEOBIOTA working group, Katja Broeg, pers. comm.).

RESEARCH AND COOPERATION NEEDS

National Reports to WGBOSV are seen as essential information to track species introductions. This in particular refers to our neighbouring countries as newly found spe-

cies there are taken as a warning signal because these may reach our waters in the near future. This highlights the need for international cooperation like contingency plans and common procedures for immediate report of new introductions to the respective stakeholders; e.g., information from National Reports on such new findings are made available to the experts conducting the German coastal monitoring programmes as kind of an early warning measure.
In contrast to ballast water, knowledge about biofouling as vector for species introduction and its management, especially after the ban of TBT as antifouling paint component, is limited. The probability that even after the BWMC comes into force, species introduction by maritime transport will not be stopped is high. In addition, fouling of leisure boats may act as important vector for secondary spread within a region. To address this vector, and to fill knowledge gaps, Germany stimulated regional discussion about a research programme on the development of biofouling management strategies for Baltic Sea maritime traffic and leisure boats at the third workshop of the EU-SBSR "Baltic Leadership Programme" (BLP) (annex1). These activities may be accompanied by the work of WGBOSV under ToR e.

RESEARCH GAPS

Chinese Mitten Crab

The trigger for the oscillating (massive) abundance increase of the Chinese mitten crab remains unknown. Fishermen reported in 2015 a decline in catchment records.

Introduction and spread

Role of offshore constructions as hot-spots of non-indigenous species and therefore as pathway for entry and spread.

Good Environmental Status (GES)

Several concepts to identify GES for the implementation of MSFD Descriptor 2 were discussed at a WSFD Workshop on Non-Indigenous Species (D2) at the Joint Research Centre, Italy in September 2015. It was concluded that this requires further work and needs further support. Ongoing activities will hopefully provide relevant experience and knowledge. It was therefore advised to involve the D2 expert group with the aim to implement MSFD Descriptor 2 in a harmonised and coherent way by addressing, e.g., monitoring, scales and aggregation as well as thresholds and reference points.
Germany currently discusses to base the GES evaluation on a trend indicator (number of new human-mediated species arrivals) and not on abundance and distribution because of the high monitoring effort needed to evaluate the latter.

EU Regulation 1143/2014 on Invasive Alien Species

This regulation enables provision of lists of "critical species" as species of Union-wide concern, species of regional concern and species of national concern. Species on the Union list will be published in early 2016. In a draft version of this list only one out of 37 species listed was a marine (catadromous) species, i.e. the Chinese mitten crab. All other species are freshwater or terrestrial. We see a possible research gap to in detail identify species selection criteria for these lists. Further, marine species should be considered as entrees on the Union list although these are possibly covered

by the IMO BWM Convention, IMO biofouling guidelines and EC instruments on aquaculture. Based on the IAS Regulation each Member State needs to report the presence and distribution of the species on this list also providing options for management and/or eradication. However, some species on the lists are so widely distributed that eradication efforts are meaningless. After consultation with WTO, the commercial trade with living organisms of these species will be prohibited. However, some issues remain, including what will be happening when organisms of these species are imported from non-EU Member States? May these parcels be opened for inspection (conflict with postal privacy)? In cases it was confirmed that these species were sent, can the donor be made known to authorities (for procecution)?

Discharge of treated ballast water
Some BWMS making use of active substances require the neutralization of the ballast water before discharge. However, it is largely unknown if there may be long-term accumulation effect of the neutralizers in use. Further, the treatment of ballast water may change the pH or other water parameters and it is unknown what effect this may have to the receipient environment. These points may especially be valid in enclosed ports with a limited water exchange.

MEETINGS
In order to develop and coordinate German monitoring efforts and other non-indigenous species related aspects, meetings of the national NEOBIOTA expert working group are anticipated, at least twice a year

Germany is actively contributing to ballast water and other maritime transport related meetings at IMO, HELCOM, and OSPAR, and regional and international meetings related to the implementation of the EU-MSFD.

PROJECT INFORMATION

1. Rapid-assessment of non-native species in German Coastal Waters including further development of the trend indicator
Christian Buschbaum, Alfred Wegener Institute:
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Dagmar Lackschewitz, Alfred Wegener Institute:
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The German alien species monitoring programmes continue with several sampling stations in ports along the Baltic and North Seas. The samplings are conducted annually between August and October with a focus on benthos and to a lesser degree on plankton. Recent monitoring activities in Germany filled geographical gaps in the network of coastal monitoring stations. Results of the rapid assessments indicate that the rate of newly recorded NIS is lower in the Baltic Sea compared to the North Sea.

2. Reliability of ballast water test procedures (ReBaT) Project
Susanne Heitmüller, Federal Maritime and Hydrographic Agency (BSH):
Susanne.Heitmüller@bsh.de
Katja Broeg, Federal Maritime and Hydrographic Agency (BSH):

Katja.broeg@bsh.de
Several ballast water sampling and sample processing/analytical methods were tested on a voyage of the research vessel Meteor when sailing between Cap Verde and Germany in June 2015. The voyage was attended by 19 scientists from 9 countries. (Ballast) water with low and high organism load was sampled and processed to challenge the methods used. The result report is in the making. The full report will be available by the end of February 2016.

3. Naturschutzfachliche Invasivitätsbewertungen für in Deutschland vorkommende gebietsfremde Wirbellose, Pilze und Pflanzen
(Nature protective invasion assessment for in Germany occurring non-indigenous invertebrates, fungi and plants)
Wolfgang Rabitsch, Umweltbundesamt GmbH, Vienna, Austria:
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The project is ongoing for Bundesamt für Naturschutz (BfN), Bonn, Germany. Fact sheets of aquatic non-indigenous invertebrates and algae in Germany were developed. This project continues with the aim to develop fact sheets for other non-indigenous aquatic and terrestrial species.

4. EU Verordnung zu invasiven Arten: Listungsvorschläge und Priorisierung der Einbringungspfade für invasive Arten von unionsweiter Bedeutung in Deutschland
(EU Regulation on Invasive Alien Species: Proposal for listing and prioritization of introduction pathways)
Stefan Nehring, Bundesamt für Naturschutz (BfN), Bonn, Germany:
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The project aims at refining and adopting the current methodology for the assessment of the invasive potential of species (http://www.bfn.de/fileadmin/BfN/service/Dokumente/skripten/skript401.pdf) to meet the requirements of the EU Regulation 1143/2014 on Invasive Alien Species concerning their definition as species of Union-wide concern. In addition, the pathways of species introductions are going to be prioritized.

5. Ballast water management for Adriatic Sea protection (BALMAS)
Matej David, Dr. Matej David Consult d.o.o.:
Matej.David@siol.net
Stephan Gollasch is involved as external expert in the BALMAS project. The project integrates all necessary activities to enable a long-term, environmentally efficient and financially and maritime transport sustainable implementation of ballast water management measures in the Adriatic Sea. BALMAS established a common cross-border system linking all Adriatic research, experts and national responsible authorities in order to avoid the unwanted risks to the environment and humans from the transfer of harmful aquatic organisms and pathogens through the control and management of ships' ballast waters and sediments.

6. Independent Laboratory
Cees van Slooten, Control Union Certifications:

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The Independent Laboratory consortium developed under the umbrella of the Dutch company Control Union was launched to meet the U.S. test requirements for BWMS. The U.S.-recognized consortium includes GoConsult and Dr. Matej David Consult d.o.o. and is currently planning land- and shipboard tests of BWMS.

7. GloBalTestNet

Allegra Cangelosi, North-East Mid-West Institute
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A formal group of test organizations involved in certification tests of BWMS was established as the "GloBal TestNet" to facilitate increased standardization and harmonization of test procedures and information exchange. The 2016 meeting of the group overlaps with the BOSV and ITMO meetings. Agenda items include the U.S. and IMO Guidelines G8 test requirements for BWMS versus testing realities. Currently Stephan Gollasch is the representative of the European test facilities.

8. Macro-invasion-ecology – towards understanding the global flows and distribution of alien species

Hanno Seebens, Biodiversity and Climate Research Centre (BiK-F)
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This project in a first step, will combine and analyse the currently most comprehensive databases of native and alien species distributions of various taxonomic groups. This unique data set will allow the establishment of networks of reported alien species flows between countries for each taxonomic group. In a second step, these reported invasion networks will be combined with existing comprehensive databases of invasion pathways and environmental conditions to simulate the global spread of alien species and to identify the relevant mechanisms to reliably predict alien species flows. The data will be inspected for inter-taxonomic variations in network topologies, important source regions, major introduction routes, hot spots of invasions and spatio-temporal variations.

9. BAllastwatertest QUality Assurance (BAQUA)

Dennis Binge, Katja Broeg, Federal Maritime and Hydrographic Agency (BSH):
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This project aims at developing BSH quality standards, ringtest facilities and performance for the validation of sampling- and analytical methods used in the framework of the type approval of ballast water management systems.

10. Helgoland Island sampling activities

Ralph Kuhlenkamp, PHYCOMARIN, Hamburg, Germany
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Registration of neobiota during standard long-term monitoring of coastal waters around Helgoland are conducted under the European Water Framework Directive and Marine Strategy Framework Directive implemented by the State Agency for Agriculture, Nature and Rural Areas (LLUR) of Schleswig-Holstein, Germany. Realization through qualitative and quantitative monitoring of the phytobenthos at one intertidal and one subtidal site, and of the macrozoobenthos at three sites: intertidal,

on *Laminaria*-rhizoids and in the Tiefe Rinne (near Helgoland) (Kuhlenkamp & Kind, PHYCOMARIN, pers. comm.).
Observation of species attached to floating algae (mainly *Himanthalia elongata*) of foreign origin (France or Great Britain): rare events of massive inputs of species from other European sites through long-distance transport via buoyant and drifting algae (see Kuhlenkamp & Kind 2013).
Sporadic investigation of neobiota in Helgoland: surveys of harbour constructions, buoys and pontoons etc. (Kuhlenkamp & Kind, PHYCOMARIN, pers. comm.).

11. Interreg IVB Project e-CME

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During this project an e-learning course for compliance, monitoring and enforcement of the Ballast Water Management Convention was developed and the e-CME course material is available at:
http://elearning.e-cmeballastwater.eu/
The course is free, but you need to register to open the files. The backbone of the course is narrated presentations and videos showing how to take ballast water samples and how to get them processed.

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Italy

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STATUS OF SHIPPING VECTOR RESEARCH

Research on ballast water is relatively recent in Italy. The first port baselines surveys were funded by the Italian Ministry of the Environment and conducted in 2006 by ISPRA in the ports of Trieste (NE Italy) and Milazzo (Sicily). After that, no systematic research on the ballast water issue has been carried out until 2013, when the EU IPA Adriatic Strategic Project 'BALMAS' (Ballast Water Management System for Adriatic Sea Protection; www.balmas.eu, budget 7,2 million euros) was started.

The project BALMAS is still on-going and is expected to end in September 2016. A documentary on the project activities, made by ISPRA, can be viewed at https://www.youtube.com/watch?v=B4_D2myKJHc

Activities such as Port Baseline surveys, ballast water sampling and analysis, development and test of an early warning system, data acquisition on ballast water operations and shipping patterns, have been carried out in 12 Adriatic Ports. In Italy, the Adriatic ports that have been investigated are Trieste, Venezia, Ancona and Bari. Non-indigenous species have been detected and scientific publications are in preparation. For example, the diatom *Didismosphenia geminata* was detected in the port of Venice. This species produces nuisance growths in freshwater rivers and streams of the northern hemisphere and is considered an invasive species in Australia, Argentina, New Zealand, and Chile. *D. geminata* threatens aquatic habitats, biodiversity and recreational opportunities, but does not pose risks to human health. The Pacific oyster *Crassostrea gigas* was found in the ports of Trieste, Venice and Ancona. The European Alien Species Information Network (EASIN) classifies *C. gigas* as alien species, with high impact on the environment mostly due to reduction of biodiversity. The species is included in the list of the 100 worst invasive species according to the Delivering Alien Invasive Species Inventories for Europe (DAISIE). Also, the Asian egg-carrying copepod *Pseudodiaptomus marinus* was found in the ports of Trieste and Venice. In 2007 and 2009, it was firstly detected in the Adriatic Sea, near Rimini and Trieste Monfalcone, but was not considered to be an established species. BALMAS findings suggest that this species is now established in the Adriatic Sea. European Alien Species Information Network (EASIN) classifies *P. marinus* as alien species. Its environmental impact is unknown.

Additional activities, not related to BALMAS, include scientific and technical support to Italian manufacturers of Ballast Water Treatment System for the achievement of the IMO Basic and Final Approval.

PLANNED RESEARCH

Project proposals to the EU on the ballast water issue are in preparation, in collaboration with Slovenia, Croatia and Greece. In 2015, national monitoring activities for the implementation of the EU Marine Strategy Framework Directive, Descriptor 2 (non-indigenous species), have started. Specifically, an assessment of abundance and taxonomic composition of plankton species in the main ports is being carried out by the Regional Environmental Agencies and is funded by the Italian Ministry of the Environment.

RESEARCH NEEDS

- Defining a transnational observatory for an effective alert system on new introductions of non-indigenous species and for their secondary diffusion, in particular invasive ones, between contiguous countries, also considering small ports and touristic moorings.
- Implementing studies focusing at the identification of vectors for alien species, particularly dealing with biofouling.
- Improving impact studies of non-indigenous species on native species, communities and ecosystems.
- Implementing DNA barcode libraries for rapid species identification through environmental DNA techniques.

RESEARCH GAPS

- DNA barcode libraries are not complete and therefore are not always available for rapid species identification
- Insufficient knowledge of response measures for containment of invasive species spread and mitigation of impacts
- Lack of sampling/monitoring, risk assessment and management strategies for biofouling on vessels arriving to Italian waters
- Insufficient knowledge of biofouling from the different vectors such as marine litter
- High level taxonomists and experts in marine invasions required at the national level – need for establishment of a National Focal Point for HAOP (Harmful Aquatic Organisms and Pathogens).

MEETINGS

- Training on identification of alien species from Mediterranean fouling, from 19 to 24 September 2016 at Lecce, Salento University: "Identification of hard bottom introduced invertebrate species in the Mediterranean basin and their ecological relevance: influence on fouling successional pattern" info at www.medalien.com.
- Conference "Alieni tra noi" 7 October 2016, Sala Riviera of the Congress Center of the Genova Exhibition in occasion of the 51th Boat Show of Genova. By Assonautica Provinciale of Genova, with the cooperation of the Marine Protected Area of Portofino
- 30 August-2 September 2016, University of the Studies of Milano Bicocca. 1st Unified National Congress SITE - UZI – SIB (Società Italiana di Ecologia, Unione Zoologica Italiana, Società Italiana di Biogeografia) "Biodiversity: concepts, new tools and future challenges"
- EuroMarine workshop: Management of bioinvasions in the Mediterranean Sea - the way forward. Ischia (Naples, Italy) 4-5 May 2016 Villa Dohrn-Benthic Ecology Center Hotel "Villa Maria"

PROJECT INFORMATION

1. BALMAS (Ballast Water Management for Adriatic Sea Protection)

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The general BALMAS objective is to establish a common cross-border system linking all Adri-

atic research experts and national authorities to avoid the unwanted risks to the environment and humans from the transfer of HAOP, through the control and management of ships' BW and sediments. Adriatic countries recognised that BW related data (e.g. the presence and invasiveness of HAOP in Adriatic ports, BW uptake and discharge activities, sediment disposal, chemical pollution with BW) and knowledge (e.g. port baselines and monitoring, BW sampling for compliance control, risk assessment, how to deal with non-compliant vessels, early warning system, effectiveness of BWM systems and measures) need to be shared in order to enable implementation of the BWM Convention requirements through a common BWM plan, and provide support to responsible authorities for faster and effective decision making with a decision support system (DSS). The goal of the project is preparation of a common Ballast Water Management (BWM) Plan for the Adriatic Sea area and implementation of the BALMAS BWM decision support system (DSS) including compliance control and enforcement (CME), compliant with the International Convention for the Control and Management of Ship´s Ballast Water and Sediments (BWM Convention) considering local specifics.

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Berto D., Castriota L., De Vendictis G., Magaletti E., Rak G., Romanelli G., Scarpato A., Silvestri C., Tornambè A., Trabucco B.. 2015. La gestione delle acque di zavorra delle navi tra disciplina internazionale e concreta attuazione. Strumenti allo studio con il progetto europeo BALMAS per il mare Adriatico. In: Tematiche in Primo Piano n. 60/2015, Capitolo 6 - Mare e Ambiente Costiero. ISPRA, 2015. Pp. 23-30.

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Norway

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Norway has ratified the BWC, and has implemented mandatory ballast water management (D1-Standard (Exchange)since 2010. Currently the relevant authorities is preparing for the BWC coming into force.

STATUS OF SHIPPING VECTOR RESEARCH
Harbour survey in Narvik (N68.43, E17.41) have not been repeated (last survey 2014 , may contribute to a baseline for future research).
Harbour survey at Melkøya (N70.69, E23.62) was not made in 2015, but is due in 2016 (or will eventually be made in 2017).
No sampling of ballast water or hull fouling in 2015.

PLANNED RESEARCH
Harbour surveys and BW + HF in sub-arcit/high boreal harbours will be made if funded

RESEARCH NEEDS
Exchange of check-lists, exchange of primers / sequences for relevant organism groups and target species

RESEARCH GAPS
Need for more efficacy testing for BWT techniques at low temperatures. Collection and eventually supplement existing species baseline for a) arctic proper, b) sub-arctic/ high boreal (The zones from which species transported into the arctic have the least range of adaption change to establish).

Need for information on robustness/sensitivity of dominant zooplankton and phytoplankton species from seawater/freshwater/brackishwater in different temperature zones for different physical and chemical water disinfection treatments

MEETINGS
Arctic Frontiers, 2016: http://www.arcticfrontiers.com/downloads/arctic-frontiers-2016
Arctic Frontiers 2017: http://www.arcticfrontiers.com/
Nor-shipping 2017: http://messe.no/en/nor-shipping/
IMO Ballast water conference, www.ballast2016.com

PROJECT INFORMATION
No planned project is currently funded for 2016-2018

2015: USCG approval of NIVA's ballast water testing facility; 2 years of experience with testing methods differences between IMO and USCG protocols regarding tem-

perature, salinity, TSS, DOC, sampling and analysis methods.
2016: Several ongoing projects at NIVA for land-based and shipboard testing of ballast water treatment systems according to both IMO and USCG requirements
2014-2017: Study on 10-50um organisms enumeration methods in UV treated ballast water
2015-2018: Study on water quality of discharged fish transport/ballast waters from wellboats

RECENT PUBLICATIONS AND PRODUCTS

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United Kingdom

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With contributions from:
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Leanne Page, Maritime and Coastguard Agency
Paul Stebbing, Cefas
Gabe Wynn, Natural Resources Wales

STATUS OF SHIPPING VECTOR RESEARCH

The U.K. has not ratified the Ballast Water Management Convention and is now likely to accede to the Convention when it enters into force. The U.K. plays an active role within the International Maritime Organization with regards to the Convention and currently holds the Co-Ordinator position for the BWM Guideline 8 review group that has been convened to discuss the amendments to the guidelines developed for the type approval of ballast water management treatment systems.

Orkney Islands Council continues to implement the Ballast Water Management Policy for Scapa Flow.
In order to maintain pristine environmental status in Scapa Flow the Orkney Islands Harbour Authority has developed an all-encompassing Ballast Water Management Policy that allows for this whilst exceeding international standards. As part of the Ballast Water Management Policy an annual non-natives species monitoring programme was implemented. The 2016 surveys will start in June 2016.

A large number of American lobsters (*Homarus americanus*) and Dungeness crab (*Metacarcinus magister*) were released off the south coast of England as part of a Buddhist religious ceremony in June 2015. Officials were notified only days after the event, and Cefas along

with the Marine Management Organisation (MMO) managed a rapid response process, where by local fishermen were tasked with laying pots in and around the release point in areas of suitable habitat with a view of capturing as many as possible to reduce the probability of a populations establishing.

PLANNED RESEARCH

The Orkney Islands Council continues to implement the Ballast Water Management Policy for Scapa Flow. The accompanying monitoring programme will continue annually with 2016 surveys starting in June 2016.

Cefas is developing a method by which molecular information on populations of NNS present in the UK, along with information regarding the potential pathways by which these species could have been introduced and spread, can be used to determine where the populations originated and the nature of their introduction.

RESEARCH GAPS

Technology gap with regards to compliance assessment technology. The development of portable ballast water assessment technologies should be encouraged, especially where analysis of treated water is a requirement for compliance verification and enforcement.

A stronger evidence base is needed to underpin future exemption decisions – it is currently unclear how exemptions will be granted or what evidence will support the exemptions. The Marine Industries Liaison Group (MILG) is planning to promote these issues.

MEETINGS

- Canadian Conference for Fisheries Research (Montréal, Canada; 6–8 January 2016); (www.uwindsor.ca/glier/ccffr/).
- 27th USDA Interagency Research Forum on Invasive Species (Annapolis, Maryland, USA; 12–14 January 2016).
- Mississippi River Basin Panel on Aquatic Nuisance Species Meeting (Gulfport, Mississippi, USA; 13–14 January 2016).
- Ninth International Conference on Marine Bioinvasions (Sydney, Australia; 19–21 January 2016)
- ICAIS 2016 – 19th International Conference on Aquatic Invasive Species (Winnipeg, Manitoba, Canada; 10–14 April 2016).
- Freshwater Invasives (FINS-II) – Networking for Strategy (University of Zagreb, Croatia; 11–14 July 2016).
- International Society of Limnology (SIL) – Alien species ecological impacts: from genomics to macroecology (Turi, Italy; 31 July– 5 August 2016).
- Neobiota 2016 – 9th European Conference on Biological Invasions: "Biological Invasions: interactions with environmental change" (Vianden, Luxembourg; 14–16 September 2016).

PROJECT INFORMATION

1. Ballast Water Management Policy for Scapa Flow, Orkney

Jenni Kakkonen, Orkney Islands Council: Contact Email jenni.kakkonen@orkney.gov.uk

Orkney Islands Council continues to implement the Ballast Water Management Policy for Scapa Flow (adopted in December 2013 by Orkney Islands Council).
http://www.orkneyharbours.com/pdfs/bwm/Ballast%20Water%20Management%20Policy%20for%20Scapa%20Flow%2010%20December%202013.pdf
In 2014 the taxonomic analysis of the samples from the monitoring surveys had not been fully completed in time for the report, this will cover the results for 2014 and 2015. During the 2014 monitoring surveys sixteen sites across Orkney Islands were surveyed and a total of thirteen non-native species were recorded. Out of these three were new records for Orkney Islands; Compass sea squirt (*Asterocarpa humilis*), Sideswimmer amphipod (*Gammarus tigrinus*) and red seaweed (*Neosiphonia harveyi*). During the 2015 monitoring surveys sixteen sites across Orkney Islands were surveyed and a total of ten non-native species were recorded, all of these species have been previously recorded in Orkney Islands. The current total number of marine and brackish water non-native species in Orkney Islands is twenty one. The monitoring programme will continue annually with 2016 surveys starting in June 2016.

2. Marine Pathways Group
Paul Stebbing, Cefas: Contact Email paul.stebbing@cefas.co.uk

The Marine Pathways Project which aimed to reduce the risk associated with pathways by which marine invasive non-native species may be introduced into the British Isles finished in 2015. The project, coordinated by Cefas, has had contributions from a number of organisations from across the U.K. and Republic of Ireland. Work conducted by the project has included the assessment of high risk location of introduction, the development of biosecurity advise for stakeholders, the development of monitoring and surveillance programmes and tools, including assessing the distribution of certain marine non-native species, in addition to examining control measures for certain marine invasive species. However, the project steering group which includes representatives from many organisations across the U.K. and Ireland will continue to share knowledge and experience and provide advice on Marine NIS to inform policy and management in an advisory capacity. Further work on the marine invasive non-native species is planned to be co-ordinated through the group in the future. Published reports, papers and other output are currently available, along with additional information on the project can be found at the projects website, further outputs will be placed on the website as they become available: http://www.nonnativespecies.org/index.cfm?pageid=545

3. Molecular Identification of Marine Invasive Species (MIMIS)
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Research and development of molecular tools continues at Cefas for the detection of non-native species, in particular the use of environmental DNA (e-DNA) and substratum scrapes. The eDNA approach, which has been submitted to a peer-reviewed journal for publication (Davison *et al.*) has been applied to assess to efficacy of an attempt to eradicate topmouth gudgeon (*Pseudorasbora parva*) from an angling pond. Using a robust sampling protocol, eDNA analysis of water samples from the pond revealed that topmouth gudgeon was still present, and subsequent intensive trapping at the detection locations

revealed a small number of specimens. Marine word has focused on the detection of target species relevant to the MSFD and WFD, and methods have been field validated. The marine-based DNA analysis of substratum scraps was finalised March 2015, and the work on inland still waters will be expanded in April 2016 to include the detection of non-native freshwater and diadromous fishes in running waters. Cefas is also developing a method by which molecular information on populations of NNS present in the UK, along with information regarding the potential pathways by which these species could have been introduced and spread, can be used to determine where the populations originated and the nature of their introduction.

4. NNS Monitoring and Surveillance Programme

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Cefas are continuing to develop a marine NNS monitoring and surveillance programme to cover the UK. This is based on the incorporation of NNS reporting into existing statutory marine monitoring programmes. This will be implemented from April 2016. Marine NNS monitoring and surveillance lists have also been developed and include high priority species currently present and those that are considered likely to arrive in the near future.

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United States

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STATUS OF SHIPPING VECTOR RESEARCH

Ballast Water and Hull Fouling Research

In the past year, research on ballast water as a *vector* of aquatic nuisance species (ANS) focused on the transport of organisms in the Arctic, while research on *biofouling* focused on evaluating methods for surveying vessels ships' and quantifying available surfaces for the transfer of organisms. Work on the *treatment of ballast water* proceeded in several areas: investigations of discharge toxicity associated with the neutralization of chlorine-treated ballast water, the appropriate collection of ballast water samples, the efficacy of combining open ocean exchange with ballast water treatment, and testing of ballast water management systems (BWMS) for U.S. type approval (TA). For example, at the Maritime Environmental Resource Center (MERC), two land-based TA tests were conducted aboard the MERC Mobile Test Platform, and two sets of shipboard tests were initiated. *Compliance testing of BWMS* was addressed by conducting validation testing of commercially available fluorometry-based tools and convening a workshop to explore the practicability and applicability of using adenosine triphosphate (ATP)-based compliance tools to determine the number of living organisms in discharged ballast water. Further, the suitability of using one size class of organisms to assess ships' compliance with the discharge standard was investigated. Regarding *ANS risk assessment*, a study continues to characterize the risk-release relationship of invasive species in the Great Lakes using meso-scale experiments and field surveys. *Economic assessments* were conducted during 2015 to collect and analyse information regarding the economics aspects of ballast water and hull fouling regulations and related technology markets. Finally, one new non-native species was reported in the U.S. this year, the polychaete *Branchiomma coheni*, which has been found in Tampa Bay Florida for several years.

Ballast Water Management Efforts

Ballast water management reporting and recordkeeping was amended and finalized and effective February 22, 2016. The U.S. "Coast Guard will require vessels with ballast tanks operating exclusively on voyages between ports or places within a single Captain of the Port Zone to submit an annual report of their ballast water management practices. This rule also simplifies and streamlines the ballast water report form. Finally, this rule will allow most vessels to submit ballast water reports after arrival at a port or place of destination, instead of requiring submission of such reports prior to arrival. This rule will reduce the administrative burden on the regulated population, while still providing the Coast Guard with the information necessary to analyze and understand ballast water management practices." (https://www.federalregister.gov/articles/2015/11/24/2015-29848/ballast-water-

management-reporting-and-recordkeeping).

The Coast Guard Marine Safety Center (MSC) denied four requests to approve a culture-based viability assay for organisms in the ≥10 μm and <50 μm size range as equivalent to the required test method (in the Environmental Technology Verification [ETV] Program Protocol). That the decision is under formal appeal.

The USCG is aware of 16 BWMS that are undergoing TA testing at independent laboratories (ILs), and with the Maritime Administration (MARAD), the USCG is organizing a workshop for ILs to discuss the challenges of testing BWMS (CAPT Scott Kelly, BWM Summit, Long Beach CA, 10-11 February 2016)

Recent or Anticipated Introductions (see the U.S. National report for the ICES Working Group on Introductions and Transfers of Marine Organisms for more detail)

Branchiomma coheni is a sabellid tubeworm that was described from the Pacific coast of Panama, near the mouth of the Panama Canal, and was reported in Florida last year. This worm occurs in rocky tide pools, marinas and docks, cultured oysters, and locks at the Pacific end of Panama Canal; its range extends north to the Gulf of California. In 2012 and 2014, it was found on fouling plates at one marina in Tampa, Florida. This worm was likely transported through the Panama Canal in ballast water or biofouling. Several species of sabellid and serpulid worms have been transported through the canal, between the two oceans, in both directions (Keppel *et al.* 2015).

The clinging jellyfish, *Gonionemus vertens* has been present since 1894, but it is now causing severe stings associated with the Pacific species and may be a new introduction. Genetic studies of two amphipod species, *Orchestia gammarellus* and *Corophium volutator* have been shown to be non-native in the Northwest Atlantic. Several recently introduced species (*Colpomenia peregrina* (moving south), *Palaemon macrodactylus*, *P. elegans*, and *Dasysiphonia japonica*) are expanding ranges; one the barnacle *Chthamalus fragilis* appears to be moving northward probably with increased temperatures.

The forthcoming book by Mathieson and Dawes will be a useful species list of seaweeds in the Northwest Atlantic. Here, 25 algal species found from Downeast Maine (Bay of Fundy) to Maryland are identified, and many species have not been previously reported although they have been present for many years.

> Mathieson, AC and Dawes CJ (in press) Seaweeds of the Northwest Atlantic; Botany / Environmental Studies, 000 pp., 00 illus., $00.00 paper, ISBN 978-1-62534-000-0, $90.00 hardcover, ISBN 978-1-62534-000-0. This book is expected to be published soon and can be found at www.umass.edu/umpress.

PLANNED RESEARCH

Investigations into the applicability and practicability of ballast water compliance tools will proceed, as will research to quantify the risk-release relationship, the efficacy of combining open ocean exchange with ballast water treatment, and hull fouling.

Testing of BWMS for TA will continue at the three U.S. test facilities: MERC, the Great Ships Initiative (GSI), and the Golden Bear Facility (GBF).

RESEARCH NEEDS

All of the above research topics will be strengthened by ongoing dialogue between U.S. researchers and ICES researchers conducting work along these lines.

RESEARCH GAPS

Climate change is not explicitly addressed in the above topics (although ANS research in the Arctic Ocean was spurred by climate-induced changes in the extent and duration of Arctic sea ice). Other groups at ICES are working in this area, and it will be useful to exchange of ideas. No research is being conducted on the colonization of artificial, submerged surfaces, such as wind turbines, and it would be useful to remain informed about that work through ICES.

MEETINGS

- The 10th International Conference on Marine Bioinvasions will be held October 16-18, 2018, in Puerto Madryn, Argentina.
- Mary Carman, the organizer of the International Invasive Sea Squirt Conference, announced the release of the final version of the special IISSC-V issue of MBI: http://www.reabic.net/journals/mbi/2016/Issue1.aspx.

PROJECT INFORMATION

1. Hull Fouling Cleaning Workshop

Mario Tamburri, MERC: tamburri@umces.edu
Lisa Drake, NRL: lisa.drake@nrl.navy.mil

A workshop will be convened to explore quantitative methods for determining efficacy of: (a) in-water fouling removal approaches (hull and niche areas), (b) capture of material released from vessel surfaces (particularly copper), and (c) effects of fouling removal approaches on vessel coating. It is planned to occur in July or August 2016.

2. Meeting to Explore Novel Techniques to Assess Biofouling

Lisa Drake, NRL: lisa.drake@nrl.navy.mil

A meeting will be convened to discuss novel and emerging technologies that can be used to quantify biofouling—specifically, large fouling organisms, such as barnacles and mussels—on the wetted surfaces of ships. The plan is to invite technical experts familiar with technologies designed for or adaptable to this purpose and to foster a discussion of the challenges and opportunities of the various technologies.

3. Efficacy of Open Ocean Exchange with Ballast Water Treatment

Lisa Drake, NRL: lisa.drake@nrl.navy.mil

A study is underway to examine the effectiveness of combining open ocean exchange with ballast water treatment to reduce the transport and delivery of potentially invasive species. Shipboard trials to compare the number of living organisms in ballast water that has undergone exchange and treatment vs. ballast water treatment alone. An assessment of the practicability of conducting exchange plus treatment is under-

way, and a literature review summarizing the biological efficacy of exchange has been completed and will be submitted for publication this spring.

4. Compliance Tools

Lisa Drake, NRL: lisa.drake@nrl.navy.mil
Mario Tamburri, MERC: tamburri@umces.edu
Allegra Cangelosi, GSI: acangelo@nemw.org

In 2015, the verification testing two variable fluorescent fluorometers was completed, and three more will be evaluated in 2016. That testing is underway, with laboratory and field trials conducted at one site. The effort to examine use of ATP kits for ballast water compliance monitoring, which began early this year, will continue.

5. Characterizing the Risk-Release Relationship for Aquatic Invasive Species in the Great Lakes

Allegra Cangelosi, GSI: acangelo@nemw.org

The overarching objective of the Risk-Release project is to define and implement experimental methods for parallel (1) mesocosm and (2) field survey approaches to characterizing the risk-release relationship for aquatic invasive species establishment in the Great Lakes. The mesocosm experiments assess cause and effect of establishment probability vs. inoculation densities. The objective of the field survey experimental approach is to determine the real-world relationship of propagule discharge concentrations and establishment of a second sentinel invader (the bloody-red mysid, *Hemimysis*) in specified harbors.

6. Economic Assessments

Mario Tamburri, MERC: tamburri@umces.edu

The assessments conducted during 2015 regarding the economics aspects of ballast water and hull fouling regulations and related technology markets resulted in several draft papers. They were not released last year because the U.S. EPA and IMO initiated reviews of ballast water treatment systems that could require modifying the analyses.

RECENT PUBLICATIONS AND PRODUCTS

Davidson IC, C Scianni, C Hewitt, R Everett, E Holm, GM Ruiz, and MN Tamburri. Differential strategies for ship biofouling assessments and management: examining the gaps between vessel performance and biosecurity. Biofouling, accepted

Drake LA, Moser CS, Wier TP, Grant JF (2015) Ballast Water Sample Ports, Sample Probes, and Sample Collection Devices: Recommendations for Standardization. Letter report 6130/1550 submitted to the U.S. Coast Guard on 03 November 2015 by the Naval Research Laboratory, Washington, DC

First MR, Robbins-Wamsley SH, Riley SC, and Drake LA (2015) Towards minimizing transport of aquatic nuisance species in ballast water: Do organisms in different size classes respond uniformly to biocidal treatment? Biological Invasions 18(3):647-660. DOI: 10.1007/s10530-015-1036-7

Holzer KK, JR Muirhead, GE Smith, KJ Carney, LA McKenzie, MN Tamburri, AW Miller, and GM Ruiz. Effect of trans-Arctic shipping on species dispersal and implications for invasion dynamics. Nature Climate Change, submitted

Keppel E, H Tovar, and G Ruiz (2015) First record and establishment of Branchiomma coheni (Polychaeta: Sabellidae) in the Atlantic Ocean and review of non–indigenous species of the

genus. Zootaxa 4058: 499-518

Moser CS, TP Wier, JF Grant, MN Tamburri, GM Ruiz, WA Miller, MR First and LA Drake (2015) Quantifying the total wetted surface area of the world fleet: A first step in determining the potential extent of ships' biofouling. Biological Invasions, DOI 10.1007/s10530-015-1007-z

Moser CS, TP Wier, JF Grant, MR First, MN Tamburri, GM Ruiz, AW Miller, and LA Drake. Quantifying the extent of niche areas – "Hot Spots" for biofouling – within the global fleet of commercial vessels. Biological Invasions, in preparation.

Wier TP, Moser CS, Grant JF, First MR, Riley SC, Robbins-Wamsley SH, and Drake LA (2015) Sample port design for ballast water sampling: Refinement of guidance regarding the isokinetic diameter. Marine Pollution Bulletin 98:148-155

Annex 5: Presentation Abstracts

ToR a)

Framework for exemptions under the BWMC

Henn Ojaveer

The International Maritime Organization (IMO) Ballast Water Management Convention (BWMC) is a powerful instrument aimed at reducing spread of harmful aquatic organisms and pathogens (HAOPs). As BWMC is expected to enter into force soon, shipping companies will start seeking exemptions for ballast water management in accordance with BWMC Regulation A-4. Regulation A-4 spells out the conditions under which such exemptions can b emade, i.e. when they are: a) granted to a ship or ships on a voyage or voyages between specified ports or locations; or to a ship which operetes exclusively between specified ports or locations; b) effective for a period of nomore than five years subject to intermediate review; and c) granted to ships that do not mix ballast water or sediments other than between the ports or locations specified above. However,without scientifically robust risk assessment (RA) and consistent rules, the exemptions may introduce a new form of risk within a convention generally designed to reduce risks. We propose and describe an adaptive system for granting exemptions, which consists of six interlinked major components: 1) target species selection procedure, 2) port-to-port RA, 3) monitoring, 4) information support, 5) administrative decision and 6) review process. The proposed system is based on key principles defined in the IMO guidelines for RA (effectiveness, transparency, consistency, comprehensiveness, risk management, precautionary, science based, continuous improvement) and is designed to continuously accumulate evolving experience on granting exemptions. The ultimate goal is to contribute to the control of the spread of HAOPs, without placing an unnecessary burden on the shipping industry. The final decisions regarding the acceptability of particular ballast water treatment procedures, as well as the acceptability of exemptions, are entirely a matter for administrators. With greater use of reliable information systems and improved RA procedures, and as experience in granting exemptions evolve, increasing confidence in the ballast water treatment exemption process is to be expected.

Olenin, S., Ojaveer, H., Minchin, D. and Boelens, R. 2016. Assessing exemptions under the ballast water management convention: preclude the Trojan horse. Marine Pollution Bulletin 103: 84-92

Mesocosm Approach to Test the Risk-Release Relationship, a Collaborative Project of the Northeast-Midwest Institute's Great Ships Initiative

A. Cangelosi, **M. TenEyck**, D. Branstrator, R. Aicher, E. Reavie, M. Aliff

There is general agreement that "density matters" in risk-release relationships (Lee *et al.*, 2013), but the bedrock scientific evidence describing the shape of the relationship or its relevance to ballast water management policy decisions is strikingly absent (NRC 2011). Our project designed methods and generated initial data describing the risk-release relationship for ship-mediated aquatic invasive species using 1000 L mesocosms and ambient water and biota from the Duluth-Superior Harbor in the Laurentian Great Lakes. Over the course of four trial events, each two weeks in duration, the project team filled 20 replicate mesocosm tanks simultaneously from a single intake stream to minimize water

quality heterogeneity across tanks. For each trial, ambient water quality factors, including background zooplankton and phytoplankton densities and composition, and several physiochemical parameters, were carefully measured and recorded across tanks. At the beginning of each trial, the project team inoculated sets of 5 tanks with Bythotrephes longimanus at four inoculum levels (1, 10, 20 and 40 organisms, controlled for life stage and gravidity) in a single inoculation event, and held the tanks in temperature and light controlled room for 2 weeks. At the end of the trial, test water from the mesocosms was completely drained through a sampling net and the age (as instar) and total number of Bythotrephes were determined. After four consecutive trials, there were N=20 mesocosm results for each inoculation level, and inoculation effects were tested across four different water quality conditions. There was a positive relationship between end population size and beginning inoculation size at the inoculations tested, but the relationship was not linear. The invader reached an average abundance of 5 m-3 at an inoculation density of 1 m-3 while it reached an average abundance of 50 m-3 at inoculation densities of 20 and 40 m-3. This plateau pattern observed at inoculum levels of 20 and 40 m-3 is indicative of density-dependent population growth. Results across trials also suggest that the magnitude of the growth response at inoculum levels of 20 and 40 m-3 is season-dependent, suggesting season-dependent environmental resistance. The highest average resulting abundance (70 m-3) was observed in the August trial, while the lowest average resulting abundance (20 m-3) occurred in the September trial. Mesocosm experiments allow for relatively rapid data collection to support modelling of the risk-release relationship shape and magnitude, and detection of important environmental variables which may influence establishment probability. However, the short-term nature of mesocosm experiments leads to inherent uncertainty about the fate of populations over time. As such, mesocosm experiments are best equipped to generate conservative (upper bound) estimates of the potential for establishment.

Nucleic acids-based tools for ballast water surveillance, monitoring, and research
John Darling

Understanding the risks of biological invasion posed by ballast water - whether in the context of compliance testing, routine monitoring, or basic research - is fundamentally an exercise in biodiversity assessment, and as such should take advantage of the best tools available for tackling that problem. The past several decades have seen growing application of genetic methods for the study of biodiversity, driven in large part by dramatic technological advances in nucleic acids analysis. Monitoring approaches based on such methods have the potential to increase dramatically the per sample cost effectiveness of biodiversity assessment, and to improve on the sensitivity, specificity, and taxonomic accuracy of traditional approaches. The application of targeted detection tools (largely focused on PCR but increasingly incorporating novel probe-based methodologies) has led to a paradigm shift in rare species monitoring, and such tools have already been applied for early detection in the context of ballast water surveillance. Rapid improvements in community profiling approaches based on High Throughput Sequencing (HTS) could similarly impact broader efforts to catalogue biodiversity present in ballast tanks, and could provide novel opportunities to better understand the risks of biotic exchange posed by ballast water transport—and the effectiveness of attempts to mitigate those risks. These various approaches still face considerable challenges to effective implementation,

depending on particular management or research needs. Compliance testing, for instance, remains dependent on accurate quantification of viable target organisms; while tools based on RNA detection show promise in this context, the demands of such testing require considerable additional investment in methods development. In general surveillance and research contexts, both targeted and community-based approaches are still limited by various factors: quantification remains a challenge (especially for taxa in larger size classes), gaps in nucleic acids reference databases are still considerable, uncertainties in taxonomic assignment methods persist, and many applications have not yet matured sufficiently to offer standardized methods capable of meeting rigorous quality assurance standards. Nevertheless, the potential value of these tools, their growing utilization in biodiversity monitoring, and the rapid methodological advances over the past decade all suggest that they should be seriously considered for inclusion in the ballast water surveillance toolkit.

Monitoring activities in the Orkney Islands
Jenni Kakkonen

Orkney Islands Council (OIC), Scotland, U.K. approved its new Ballast Water Management Policy on 10 December 2013. The policy can be downloaded from http://www.orkneyharbours.com/flotta_terminal.asp The Annex 4 of the policy contains 'The 'Monitoring and Recording System for Marine Invasive Non-Native Species; Scapa Flow and Loch of Stenness'. The baseline survey for marine non-native species in Scapa Flow and Loch of Stenness was conducted in 2013; the monitoring phase commenced in 2014 and will continue on annual basis.

The baseline survey and the monitoring programme include sixteen survey sites with several different sampling methods being used. The survey sites include rocky shores, navigation buoys, pier walls, benthic habitat and water column sites within Scapa Flow. Samples are collected using several methods; scrape samples are collected by scraping an area of 15x15cm and placing all material in a sampling bag; rapid assessments which are timed searches of distinct areas; correx settlement panels; infaunal benthic core samples; phytoplankton and zooplankton tow samples. All samples are identified by taxonomic specialists to the lowest taxonomic level possible.

During the baseline survey (2013) and first two years of monitoring (2014 and 2015) a total of nine marine non-native species have been recorded; Bonnemaisonia hamifera, Caprella mutica, Codium fragile subsp. fragile, Colpomenia peregrina, Corella eumyota, Dasysiphonia japonica, Gammarus tigrinus, Neosiphonia harveyi and Potamopyrgus antipodarum. From these marine non-native species two are new records for Orkney Islands; Gammarus tigrinus and Neosiphonia harveyi all other species have been previously recorded in Orkney Islands.

In addition to these surveys annual scrape samples have been collected from seventeen visitor yacht moorings (since 2012) and in 2014 all three Orkney marinas were included in the annual survey programme. From these sites an additional seven marine non-native species has been recorded; Asterocarpa humilis, Asparagopsis armata, Bugulina fulva, Bugulina simplex, Jassa marmorata, Schizoporella japonica and Tricellaria inopinata. From these marine non-native species one is new to Orkney Islands, the Asterocarpa humilis, all of the other species have been previously recorded in Orkney Islands.

A report on the marine non-native species monitoring programme is presented annually at the Orkney Marine Environment Protection Committee. The data is submitted to the local Orkney Biodiversity Records Centre as well as to the UK's National Biodiversity Network data base. It is also included in the UK's MSFD non-native species baseline maps.

Development and application of molecular methods for the early detection of marine Aquatic Invasive Species (AIS) in ballast water
Anaïs Rey, Naiara Rodriguez-Ezpeleta and Oihane Cabezas-Bazurko

The transportation of aquatic species by ships' ballast water is one of the most important vector by which Aquatic Invasive Species (AIS) are introduced to new aquatic ecosystems around the world. The aim of this PhD (2015–2018) is to develop and optimize DNA-based methods to early detect marine invasive species transferred by ballast water. By exploring how molecular tools could be implemented, we want to contribute to fill the gap between research and management in the early detection of AIS in ballast water. The first objective is to calibrate molecular methods with artificial communities of known composition to optimize (1) identification of early stages of macro-organisms, rare species, bacteria and viruses; (2) estimation of relative abundance of the species and (3) estimation of the living status of organisms. DNA or RNA metabarcoding and qPCR are the molecular tools considered in this study. The second objective is to get a first national overview of the ballast water activities and so, assess the risk level of potential AIS introduction and exportation by gathering data on the origin and the amount of loaded and discharged ballast water into major ports of Spain. Related to the Ballast Water Convention, representativeness of ballast water sampling and port risk assessment will be also conducted during this project. Ballast waters and ports sampling will be performed once appropriate molecular tools will be chosen and calibrated through the artificial communities approach.

This PhD is part of the project Aquainvad-ed (http://www.aquainvad-ed.com/) and has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No. 642197.

ToR b)

Comparative analysis of compliance methods on the RV METEOR
Johanna Bradie

Promising approaches for ballast water sample collection and analysis have been developed, but require further study in the field to examine their utility for compliance monitoring. To address this gap, a voyage was undertaken by 20 international researchers on board the RV Meteor, 4–15 June 2015. During this time 28 trials were conducted to evaluate three ballast sampling devices (plankton net and 2 sampling skids) and a number of analytic devices (>200µm: 1 technique, >50µm: 5 techniques, >10µm and <50µm: 10 techniques, bacteria: 6 techniques). Water samples were collected using paired sampling devices and analyzed in parallel by all analytic methods to determine whether results were similar between devices and whether quick, indicative methods offer comparable results

to standard, time-intensive testing methods (e.g. microscopy) and high-end scientific approaches.

For sample collection, differences were observed in the number of viable organisms collected by the various sampling devices (net, sampling skids in open and closed configurations), but these differences were not consistent across size classes. For sample analysis, several promising indicative methods were identified which showed high correlation with microscopy results but allow much quicker processing.

This study is the first to concurrently test a large number of analytic tools and multiple sampling devices under operational conditions. Results are useful to identify the benefits and drawbacks of each method in compliance monitoring.

Practical experiences in on board ballast water compliance sampling
Peter Stehouwer, Vladimiro Bonamin, Gerd Schneider

SGS has executed compliance sampling according to either the IMO or the U.S. VGP standards on several hundreds of ships. In this way we have gathered practical experiences on the challenges and limitations of these regulations.

Testing according to the IMO D-2 performance standard is a challenge due to the large sample volume for the >50 μm fraction and the requirement for representative sampling. Both of these issues are dealt with using the ballast water sampler developed by SGS. The IMO regulations do not require specific analysis methods to be used; this is in contrast to the VGP which has very strict requirements for analysis methods and sample holding times. These also pose the main challenge for these sampling events, a laboratory needs to be found that can perform the analysis according to the exact requirements and where the analysis of the samples can start within the holding time.

We also encountered general challenges, which included: inexperience of the crew, unsuitable sampling points and inaccessible sampling points.

Despite the challenges listed above, sampling and analysis according to both standards could be executed on board. However, efforts could be made by both regulators and ship owners to make the process easier.

Research on Sample Collection Ports and Compliance sampling methods
Lisa Drake

This summary discussed research in collecting representative samples as well as a validation study of compliance tools. Regarding sampling, by using an appropriate in-line sampling system, it is possible to obtain representative samples of ballast water from the main ballast line. An important parameter of the sampling port is its "isokinetic diameter" (D_{ISO}), which is the diameter calculated to determine the velocity of water in the sample port relative to the velocity of the water in the main ballast line. The guidance in the U.S. Environmental Technology Verification (ETV) Program Protocol suggests increasing the diameter from 1.0x D_{ISO} (in which velocity in the sample port is equivalent to velocity in the main line) to 1.5 – 2.0x D_{ISO}. In this manner, flow velocity is slowed—and mortality of organisms is theoretically minimized—as water enters the sample port. This

presentation described field and laboratory trials, as well as computational fluid dynamics modelling, to refine this guidance. From this work, a D_{ISO} of 1.0 – 2.0x (smaller diameter sample ports) is recommended.

Instruments designed to rapidly assess ballast water in shipboard environments are in development and (in many cases) production. The purpose of these instruments is to evaluate whether the sampled water complies with the national and international limits on the concentrations of organisms in ships' discharge. These instruments detect proximal characteristics of living organisms, such as the variable fluorescence of chlorophyll *a*. Whether results from these "compliance tools" correspond to time-consuming direct counts—performed by microscopy of organisms fluorescing after exposure to a set of vital fluorescent probes—is unclear. An initial, formal test of the relationship between several compliance tools and microscope counts began in summer of 2015 and continues. As part of this effort, field trials were conducted in freshwater, estuarine, and marine environments. These trials were designed to examine the fidelity of the relationship between the proximal measurements of compliance tools and the direct measurement of manual microscopy across different environments with different assemblages of organisms and water characteristics. Additionally, laboratory-based trials compared the compliance tools to the standard, microscopy-based approach using samples with two microalgal cultures (*Prorocentrum micans* and *Tetraselmis marina*). Several concentrations of the organisms were prepared and analysed. The laboratory studies included samples amended with dissolved and particulate matter as well as samples representative of water following treatment by hypochlorite. The integrity of a compliance monitoring system may rest upon the performance of the shipboard instrumentation. Consequently, the process for evaluating the compliance tools should be thorough, rigid, and effective.

BWMC Regulation D-1 and D-2 Ballast Water Sampling for Compliance Monitoring and Enforcement recommendations
Stephan Gollasch, Matej David

For D-1 compliance it is recommended to check the water salinity. The world ocean salinity is above 30 PSU which means that should the vessel have conducted BWE as required, the ballast water salinity should be above 30 PSU. Only small quantities like >50 ml of water are needed to do this measurement. However, our studies have shown that the water salinity inside a ballast tank is not homogenous when we measured the salinity in-tank from different depths and in-line during different times of a ballast water discharge. We therefore recommend for compliance checks with D-1 to take more than one sample with ~10 minute delay to identify if the salinity is changing through the discharge process. It is important to take the sample as soon as possible after the ballast water discharge has started to prevent possible discharges of non-compliant ballast water.

Sampling: Compliance checks with the D-2 standard may be done in an indicative and in a detailed analysis. Indicative sampling is recommended prior to detailed sampling to avoid any additional impact from possible non-compliant ballast water and in case tanks have direct discharge to the environment. For this analysis it is recommended to use in-tank sampling points to avoid discharge of ballast water and also as no in-line sampling points may be installed on a vessel. The sampling is also possible in-line after the ballast water discharge was started, the indicative test will still deliver result faster than a detailed test.

Sample processing: Considering the three organism groups addressed in the D-2 standard, phytoplankton indicative sample processing tools (Pulse-Amplitude Modulated - PAM – fluorometry based) are practical for on board use and need small water quantities. The indicative test may be followed/expanded to become a detailed test.

For detailed D-2 compliance control, sample representativeness is a key feature and refers to organism diversity, concentration and viability and requires a biological, statistical and shipping related compromise. Representativeness can be seen as of the whole discharge of ballast water from any single tank or any combination of tanks. Sample representativeness is related to the sampling point, sample timing (sampling start and end) and duration, number of samples and sample volume.

From our studies we recommend the following:

- Sample in-line (at discharge) as this represents discharge of organisms to the environment and D-2 is a discharge standard. To enable such a sampling, a sampling point needs to be installed on board;
- Do not start sampling during the first 5 minutes after the start of the ballast water discharge and do not sample in the last 5 minutes before end of discharge because at these times high patchiness of organisms occurs and more sediment is present in that sampling periods which may negatively affect organisms survival in the sample and also the sample processing;
- A sampling duration of ca. 10 minutes is recommended because longer sampling times negatively affect the survival of organisms ≥50 μm in minimum dimension, hence a sample is underestimating the "real" organisms concentration; and shorter sampling times are still representative for organisms in the group <50 and ≥10 μm in minimum dimension;
- Two or more sequential samples should be taken because the averaged biological content of two random samples has shown to be representative, alternatively a sample may be taken over the entire discharge time as appropriate;
- If more than one ballast water source is on the vessel, than at least one sample should be taken from each ballast source as sampling needs to be representative of the whole discharge;
- We suggest sample quantities which showed best results and the concentrated sample is easy to carry:
    - For organisms ≥50; 300 – 500 litres of sample, concentrated to ca. 5 litres for transport and concentrated further to 100 ml for analysis;
    - For organisms <50 and ≥10; 5 – 6 litres of a continuous drip sample during sampling, subsample of ca. 100 ml for transport;
    - For bacteria; 1 litre separated from the continuous drip sample for transport.

ToR c)

Overview of GloBal TestNet Activities
Allegra Cangelosi

The goal of the GloBal TestNet is to promote comparable and accurate test results on the performance of ballast water management systems for certification, through an open exchange of information, transparency in methodologies and advancing the science of

testing. Members of GloBal TestNet conduct biological effeciacy and toxicity testing of ballast water management systems at different scales (shipboard, land based and bench) and for different purposes (certification and research). Membership in GloBal TestNet has global reach with 16 different testing entities, 10 of which have certification to conduct testing according to U.S. Coast Guard requirements. More information about the network can be seen at www.globaltestnet.org.

ToR d)

Update on Biological introduction risks from shipping in a warming Arctic
Anders Jelmert, Chris Ware *et al.*

Seventeen ballast water samples from 8 vessels (two samples per ship plus one control sample), were collected at ports in Svalbard in 2011. Voyage length ranged from 7 to 22 days (mean 10.2, SE 1.7) Mean 1522 +- 335 SE individuals m^{-3}, predominately comprised of indigenous species. Non-indigenous coastal species were present in all except one of 17 ballast water samples (mean 144 +- 67 SE individuals m^{-3}) despite five of the eight ships exchanging ballast water *en route*. Operational Taxonomic Units and species identification by microscopy and molecular methods (mtDNA CO1 and 12S and 16S rDNA genes). Of a total of 73 taxa, 36 species including 23 non-indigenous species were identified. Of those 23, sufficient data permitted evaluation of the current and future colonization potential for eight widely known invaders. With the exception of one of these species, modelled suitability indicated that the coast of Svalbard is unsuitable presently; under the 2100 Representative Concentration Pathway (RCP) 8.5 climate scenario, however, modelled suitability will favour colonization for six species. We show that current ballast water management practices do not prevent non-indigenous species from being transferred to the Arctic. Consequences of these shortcomings will be shipping-route dependent, but will likely magnify over time: our models indicate future conditions will favour the colonization of non-indigenous species Arctic-wide.

Research and monitoring for ship-mediated nonindigenous species in the Canadian Arctic
Kimberly Howland, Philippe Archambault, Sarah Bailey, David Barber, Louis Bernatchez, Guillem Chust, Valérie Cypihot, Jesica Goldsmit, Anais Lacoursière, Frédéric Laget,George Liu, David Lodge, Jennifer Lukovich, Chris McKindsey, Ernesto Villarino, André Rochon, Nathalie Simard, Pascal Tremblay, Nathalie Simard, Gesche Winkler

The distribution of taxa along the Canadian Arctic coastline is poorly known, and the extent of non-indigenous species (NIS) incursions in the area is unknown. This lack of information makes it difficult to determine origins of new species and make predictions about impacts to native communities. Thus much of the research in the Arctic region has focused on obtaining a comprehensive baseline of current native and non-indigenous species diversity in high risk ports and species- specific predictive modelling/ecological risk assessment to identify taxa, geographic regions and pathways with high potential for introduction. Comparisons of recently collected samples from high risk ports with historical species lists indicated the presence of several new benthic marine species for the Canadian Arctic that are considered cryptogenic along with a number of taxa representing new records within the port regions surveyed or the more extended, adjacent surround-

ing regions. Although no known invasive species were detected in surveys, species distribution modelling under current environmental conditions predicted that at least three of eight candidate high risk benthic invasive species, have suitable habitat conditions for survival and reproduction in the Hudson Complex and Beaufort Sea regions of the Canadian Arctic. Under future environmental conditions (by mid-century), a northward extension of suitable habitat was predicted in the same regions for all the eight modelled species. These habitat suitability results are now being combined with shipping and habitat sensitivity in an ecological risk assessment framework to evaluate species-specific risk by pathway and year. Preliminary results show that although risk is temporally variable, discharge events from domestic vessels transiting to the Arctic generally pose a higher relative risk than international vessels for *Littorna littorea* and *Mya arenaria*, invasive species which are predicted to have suitable habitat under current Arctic conditions.

This ecological risk assessment is being complemented by ongoing experimental research on risks associated with domestic ballast (currently unregulated in Canada) and ballast sampling at high risk ports and new ports expected to have rapid increases in shipping due to resource development. Further research over the next 3 years will be aimed at developing a basis for a standardized monitoring and early detection program in the Canadian Arctic. The following objectives are designed to extend current research efforts by Fisheries and Oceans Canada and the Canadian Aquatic Invasive Species Network and are funded largely through Polar Knowledge Canada, ArcticNet and Nunavut Wildlife Management Board: 1) Identification and ranking of key ship-mediated AIS for early detection and monitoring, and geographic locations with highest probability for establishment; 2) Development of genetic early detection methodologies (e.g., environmental or eDNA) for AIS in high risk ports; 3) Establishment of a community based monitoring (CBM) network/capacity. The initial research and training through this study will provide the foundation for establishing an ongoing monitoring program in the Canadian Arctic that should ideally include: 1) research to continually improve monitoring approaches and update invasive species databases; 2) field surveys of existing native taxa, non-indigenous species, and environmental conditions through a combination of both community-based efforts that would be low intensity and regularly scheduled, and scientific efforts of episodic high intensity in key areas; and, 3) ongoing eDNA monitoring for high risk invasive species.

Arctic Council Invasive Species: an overview
Margaret M. (Peg) Brady

Arctic Council countries, Observers and Permanent Participants agreed to support the development of a strategy for the prevention and management of invasive species in the Arctic Region. The Arctic Marine Shipping Assessment (AMSA) Report: Recommendation II (E) provides:

- Arctic states should consider ratification of the IMO International BW Convention, as soon as practical.
- Arctic States should also assess the risk of introducing invasive species through ballast water and other means so that adequate prevention measures can be implemented.

Arctic Ocean Review (AOR) Final Report Recommendation 3:

- Arctic states should encourage ratification to enable entry into force and implementation of the BWM Convention and research into ballast water management systems that are effective in colder settings of polar regions.
- PAME-II 2015 adopted a ROD "inviting member governments to submit papers on how, within Arctic waters subject to their jurisdiction, they regulate ship ballast water." (PAME-I 2016)

Background: Currently two committees within the Arctic Council are addressing invasive spp. within the region:

- Protection of the Arctic Marine Environment (PAME) PAME is one of six Arctic Council working groups. Established under the 1991 Arctic Environmental Protection Strategy continued by the 1996 Ottawa Charter that established the Arctic Council. PAME is the focal point of the Arctic Council's activities: a) mandate is to address policy and non-emergency pollution prevention; and b) control measures related to the protection of the Arctic marine and environment from both land and sea-based activities.

- Conservation of Arctic Flora & Fauna (CAFF) - CAFF is the biodiversity working group of the Arctic Council and consists of National Representatives assigned by each of the eight Arctic Council Member States, representatives of Indigenous Peoples' organizations that are Permanent Participants to the Council, and Arctic Council observer countries and organizations. CAFF serves as a vehicle to cooperate on species and habitat management and utilization, shares information on management techniques and regulatory regimes, and facilitates more knowledgeable decision-making.

Next steps for PAME and CAFF

PAME following the PAME I-2016, February 2016 meeting. Record of decision and actions:

- U.S. to make a presentation at PAME II-2016 (September, 2016) to the Shipping Expert Group on Hazard Analysis Critical Control Point (HACCP) planning.
- PAME to partner with CAFF (see below) in its project to develop a strategy to prevent the introduction of alien and aquatic invasive species into Arctic ecosystems (Invasive Species Project).

CAFF:

- Committee members are populating a baseline template to summarize international agreements, national legislation and regulations relevant to invasive species (all taxa).
- CAFF Invasive Species Initiative Workshop: first face-to-face meeting of experts, Akureyri, Iceland, CAFF Secretariat Offices, 30 March -1 April 2016.
- CAFF Invasive Species Initiative Workshop Report (release date: tentative)

ToR e)

Review of IMO Guidelines on Biofouling
Cynthia McKenzie, Terri Wells and Haley Lambert

The IMO Adopted the 2011 Guidelines for Control and Management of Ships Biofouling to Minimize the Transfer of Invasive Aquatic Species. (Annex 26 Resolution MEPC.207 (62) Adopted 15 July 2011). Biofouling procedures should be effective, practical, cost efficient and environmentally safe. Measures outlined include:

1) Creation of a biofouling management plan and record book
2) Vessel surface preparation and use of an antifouling system (special attention to vessel niche areas)
3) Retention of biological, chemical and physical pollutants from cleaning and maintenance periods
4) In water inspections are recommended (dive or ROV)
5) New vessels should be designed to facilitate easy inspection and treatment
6) Ships should be provided with biofouling management information through the appropriate authority

The IMO Approved the Guidance for Minimizing the Transfer of Invasive Aquatic Species as Biofouling (hull fouling) for Recreational Craft (IMO, 2012, Annex MEPC.1/Circ.792, 12 November 2012).

The presentation also included a review of biofouling activities currently planned or in place particularly in Australia, New Zealand, the United States, Canada and Ireland. The Global Oil and Gas Industry Association for Environmental and Social Issues & International Association of Oil & Gas Producers (OPIECA/OGP) - London, U.K. also have guidelines for their industry which were discussed. Current biofouling response treatments or strategies include mechanical cleaning methods in water and on land, electrochemical/ electrical /powered methods as well as chemical treatments.

It was noted that the IMO Guidelines identify Research and Information needs related to biofouling management, such as the different types of anti-fouling systems and other biofouling management measures currently available, how they work and their performance under different operating conditions and situations.

Canadian National Risk Assessment of Biofouling by Recreational Boats
Cynthia McKenzie and Nathalie Simard

Fisheries and Oceans Canada conducted a National Risk Assessment to collect and provide scientific advice on the risk that recreational boating, as a vector for the introduction and spread of AIS, poses to Canadian fresh and marine waters. The objectives of the study were to determine: 1) The risk posed by recreational boating in Canadian marine waters on both the east and west coasts. a.) Characterization of movement patterns of recreational boats in marine waters within and between ecoregions and b) estimate potential risk to marine ecoregions considering vessel characteristics, their movements, environmental similarity, and AIS sources; 2) The ecological risk posed by recreational boating in the Great Lakes Basin. Quantify the characteristics of AIS spread by recrea-

tional boats within and among the Great Lakes proper, including an assessment of the relative probabilities of spread and establishment among different ports/marinas supporting boating activity. And finally, 3) The current state of knowledge about the ecological risk posed by recreational boating as a vector of overland AIS movement between inland lakes in Canada. Three research documents were produced and assessed at a meeting in Montreal in December 2015.

The first document was a "National Risk Assessment of Recreational Boating as a Vector for Marine Non-indigenous Species" by Simard, N., *et al.* 2016. National Risk Assessment of Recreational Boating as a Vector for Marine Non-indigenous Species. DFO Can. Sci. Advis. Sec. Res. Doc. 201X/nnn. vi + 114 p. Results of this assessment determined that primary introduction and secondary spread of NIS may result from recreational boating in all Canadian marine ecoregions, however only a small proportion have an intermediate or high risk. Although most ecoregions have lower risk they may still receive transient boats of a higher risk. High connectivity among marinas in all ecoregions and among ecoregions; these boats are very likely to transport NIS to other marinas. Final Ecoregion Invasion Risk scores were greater for the Pacific Region than the Atlantic Region. Regional differences greatly influenced by seasonality of boating activities (time in water, maintenance, boating activity) and sheer number of boats. This was a relative risk study and low risk does not indicate no risk.

The second document was "Ecological Risk Assessment of Recreational Boating as a Pathway for the Secondary Spread of AIS in the Great Lake Basin" by D.A.R. Drake, S.A. Bailey, N.E Mandrak. This assessment determined that a total of 11.8 Million recreational boating trips occur in the Great Lakes basin each year (3.8 M in Canada, 8.01 M in the United States). The sheer volume of boater activity allows for effective boater mediated spread of AIS in the GLB. When an invasive species is introduced to the GLB, modelling indicates that on-water boating activity can increase the rate of spread of species to new locations compared with natural dispersal. In some cases, this leads to new pathways of dispersal (i.e., to upstream locations) that would be unlikely to occur in the Great Lakes Basin, with presumed high ecological impact.

The final document was a review and addressed the "Overland Spread of Aquatic Invasive Species due to Recreational Boating in Canada" D.A.R. Drake. There is extensive literature pertaining to overland movement of AIS by freshwater recreational boats. Four themes emerged from the literature: contamination of vessels with aquatic species, predicting ecosystems at greatest risk of invasion, survival of species during overland transport, including effectiveness of physical decontamination, and the link between boater behaviours, educational campaigns, and spread management. A large number of boating trips occur through the overland, trailered movement of recreational boats among freshwater ecosystems in Canada each year (estimated at 21 Million). As a result of this large number, even low per-trip probabilities of introduction can lead to a high number of introduction events.

Recreational Boating as a vector of introduction of marine non-indigenous species in the Mediterranean Sea
Anna Occhipinti

A first estimate of the role of recreational marinas as hubs for marine NIS has been carried out in 2013-14 along the western coast of Italy, in the framework of a PhD project recently accomplished at University of Pavia, tutored by Anna Occhipinti and Agnese Marchini (PhD student: Jasmine Ferrario). The fouling assemblages in commercial harbours and recreational marinas were examined in five provinces of Liguria, Tuscany and Sardinia. Results indicated that marinas exhibit comparable (in a few cases higher) number of NIS than harbours, and NIS that do not occur in harbours, indicating that marina habitats represent high-risk sites of introduction of NIS, and deserve urgent attention from scientists and management. A survey on the habits (hull maintenance, travel history) of Italian recreational boaters was also performed, and allowed us to detect a low level of awareness about the problem of marine NIS.

A further PhD project is currently ongoing at University of Pavia, in collaboration with UPMC Paris and HCMR Crete, in the framework of the Doctoral Programme on Marine Ecosystem Health and Conservation MARES (PhD student: Aylin Ulman). This project includes analysis on fouling assemblages from marinas as well as recreational boat hulls at a Mediterranean-wide scale (France, Italy, Malta, Greece, Cyprus, Turkey).

ToR f)

Baltic Sea Pathways
Henn Ojaveer

In total, findings of 132 NIS and CS, with in total of 440 introduction events have been documented in the Baltic Sea. Germany has the highest (66) and Lithuania the lowest (33) number of recorded introductions. On average, 27 NIS/CS are currently established (with min/max of 20 and 42 species in Latvia and Germany, respectively) while 13 species have been unable to establish self-sustaining populations (Table 1).

Table 1. Status of non-indigenous and cryptogenic species in the Baltic Sea by countries until the end of 2015.

Country/region	Total/established
Denmark	39/25
Estonia	34/25
Finland	45/24
Germany	66/42
Latvia	40/20
Lithuania	33/22
Poland	56/32
Russia/Kaliningrad	43/26
Russia/St. Petersbourg	38/21
Sweden	49/31
Average	**44/27**

Benthic invertebrates strongly dominate both in terms of introductions recorded as well as established species (63 and 46 species, respectively). Despite relatively high introduction records of fish (32 species), only five of them (gibel carp *Cyprinus carpio*, rainbow trout *Onchorhyncus mykiss*, round goby *Neogobius melanostomus*, Chinese sleeper *Percottus glenii* and carp *Cyprinus carpio*) have been able to form self-sustaining populations in at least one Baltic country. The number of invaded species by all other organism groups (i.e., phytoplankton, phytobenthos, zooplankton, parasites) remains below ten species.

The most important introduction pathways (including both primary introductions and secondary spread) over time have been vessels (38.6%), then stocking (27.5%) and natural spread of NIS from neighbouring regions (24.8%). While vessel and natural spread mediated introductions have been important in most time-periods, the role of stocking (of several commercial fish such as for the sturgeons *Huso huso*, *Acipenser baeri*, *A. guldenstaedtii*, *A. stellatus* and *A. oxyrinchus*, and Pacific salmonids *Onchorhyncus keta*, *O. gorbusha*, *O. kisutch* and *O. tsawytscha*) clearly dominated during 1930–1989. This was also an important pathway prior to 1900 (introductions of *A. ruthenus*, *Carassius gibelio*, *Cyprinus carpio*, *Crassostrea virginica*, *Oncorhynchus mykiss*, *Orconectes limosus* and *Salvelinus fontinalis*). Notably, the role of canals has always been small (Figure 1), with the overall period mean of 5%. As most deliberate fish introductions have been unsuccessful, vessels and natural spread are the most important pathways for the currently established species.

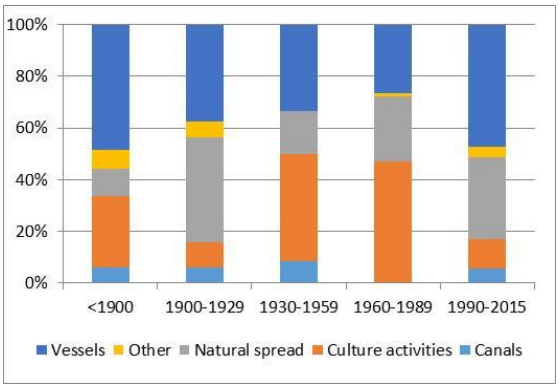


Figure 1. Relative importance of pathways (%) responsible for species invasions into the Baltic Sea over time.

The level of certainty in affiliating the responsible pathway for a primary introduction requires special attention. It appears that only in 14% of cases (29 out of the total of 214 primary introduction events) we know the introduction pathway with the highest level of confidence, i.e., there is a direct evidence. In 21% of the cases, the pathway could be assigned at a relatively high confidence level (very likely), while in the majority of cases (52%) only the possible pathway is known. In the case of 28 introduction events, the pathway remains unknown. During the first two time periods, confidence levels were lower (Figure 2).

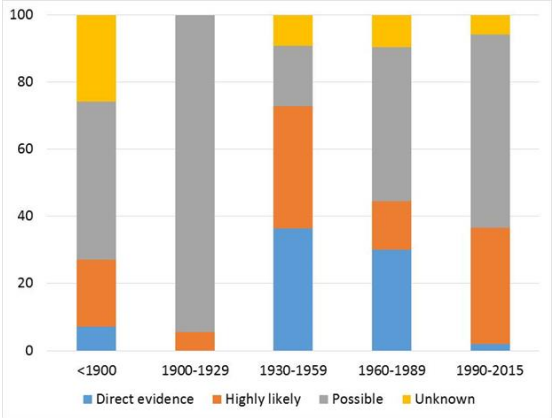


Figure 2. Relative level of certainty (%) in assigning pathways for primary introduction events into the Baltic Sea by five time-periods.

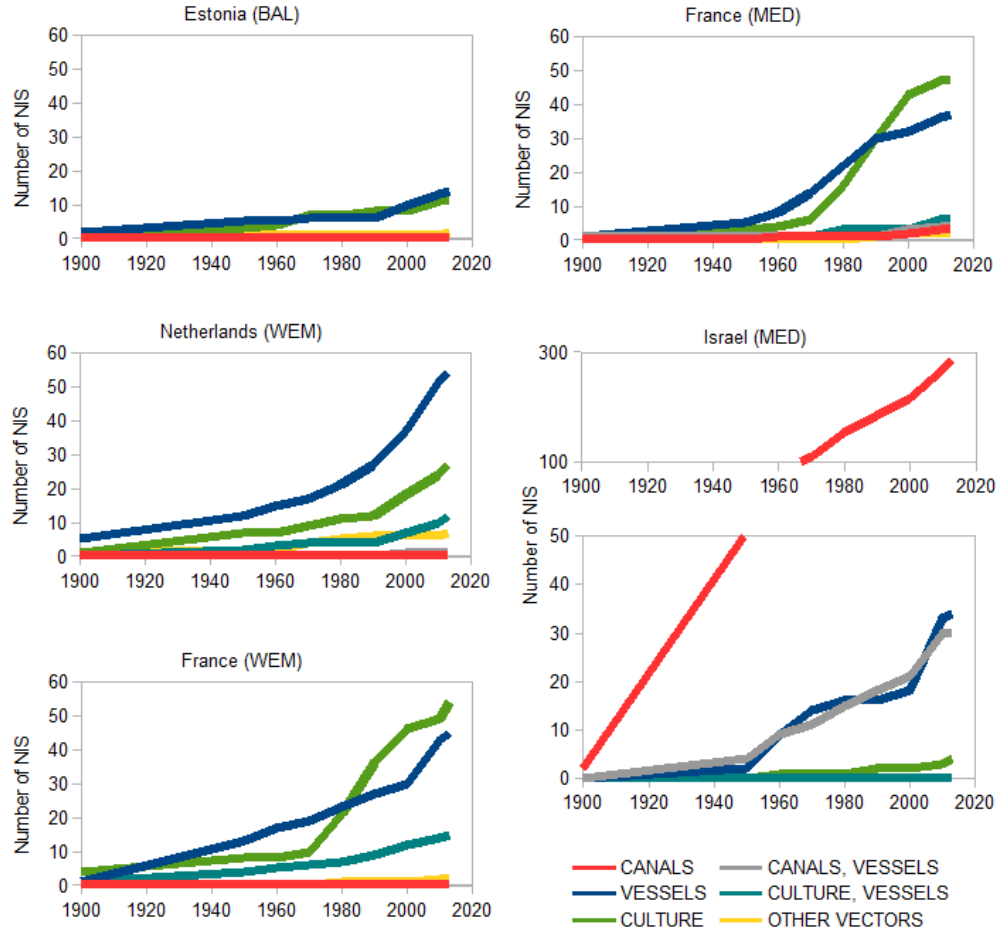
Source: Ojaveer, H., Olenin, S., Narščius, A., Florin, A.-B., Ezhova, E., Gollasch, S., Jensen, K.R., Lehtiniemi, M., Minchin, D., Normant-Saremba, M. and Strāke, S. Dynamics of biological invasions and pathways over time: a case study of a temperate coastal sea (in prep.)

Eyes wide shut – Shipping and the environmental impacts of the enlargement of the Suez Canal

Bella Galil

Non-indigenous species (NIS) richness differed among European seas, and was substantially greater for the Mediterranean than the Western European margin (WEM) or Baltic Sea, moreover, between 1970 and 2013, the number of recorded NIS has grown by 86, 173 and 204% in the Baltic, WEM and the Mediterranean, respectively (Galil *et al.* 2014). The most common vectors in the Baltic were likely culture (47%) and vessels (39%); in the WEM vessels (45%) and culture (35%); and in the Mediterranean, the Suez Canal (53%) and vessels (24%), though the relative importance of vectors varies among individual countries. A higher percentage of vessel-introduced NIS is noticeable among the most widespread NIS. Vectors determine the geographical origin and the introduced taxa: in a region where the Suez Canal is the main vector, most NIS are of tropical/ subtropical Indo-Pacific origin and comprise molluscs, fish and crustaceans, i.e. taxa actively spreading as adults or more passively transported as larvae. In regions where vessels and mariculture are the prevailing vectors, the taxonomic composition and native ranges of NIS are more diverse and depend on shipping routes and culture trades (Galil *et al.* 2016).

The Suez Canal is one of the most important waterways in the world, it is also the most potent corridor for invasions by marine species. The individual and cumulative impacts of these invasions adversely affect the conservation status of particular species and critical habitats, as well as the structure and function of ecosystems and the availability of natural resources. Some species are noxious, poisonous, or venomous and pose clear threats to human health (Galil *et al.* 2015). The recent enlargements of the Suez Canal increase the influx of NIS. While global trade and shipping are vital to society, there is an urgent need to minimize unwanted impacts and long term consequences affecting fisheries, tourism, human health and the wellbeing of the Mediterranean Sea and its biota.



Sources: Galil BS, Marchini A, Occhipinti-Ambrogi A, Minchin D, Narščius A, Ojaveer H, Olenin S. 2014. International arrivals: widespread bioinvasions in European seas. Ethology Ecology & Evolution 26(2-3): 152–171

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Effects of marine debris caused by the Great Tsunami of 2011

Thomas Therriault, Hideaki Maki, Nancy Wallace, Cathryn Clarke Murray and Alex Bychkov

The magnitude 9.0 Great East Earthquake in Japan on March 11, 2011, created a massive tsunami, which washed an estimated 5 million tons of debris out into the Pacific Ocean. According to estimates by the Government of Japan, 70% of that debris sank close to shore leaving at least 1.5 million tons floating in the Pacific Ocean. Japanese tsunami marine debris (JTMD) quickly reached the Hawaiian Islands and less than a year after the

earthquake tsunami debris started making landfall on the west coast of North America with debris expected to continue to arrive for years to come. The goal of this 3-year PICES project funded by the Ministry of the Environment of Japan starting in 2014 is to assess the potential impacts of Japanese tsunami debris on ecosystems on the west coast of North America and Hawaii, including the potential threat from nonindigenous species (NIS). In order to do this our project is focused around three major themes: modelling debris transport; surveillance and monitoring; and NIS research and risk assessment. Modelling efforts have focused on developing forecasts of JTMD distributions and timelines of its arrival on the US/Canada West Coast and in Hawaii by calibrating models using available observational reports. Lighter objects with more windage (e.g. Styrofoam) arrived quickly while heavier objects with less windage (e.g. docks, vessels) continue to arrive. Given vast and remote shorelines where JTMD could make landfall part of the surveillance and monitoring theme has focused on conducting aerial flights of coastal shorelines to identify potential JTMD collector beaches. Combined with monitoring efforts it has been possible to characterize debris landings attributable to the tsunami. In addition to the potential impacts of the debris itself, there is a possible threat due to NIS. Our project has been characterizing this unique invasion vector via direct sampling of JTMD items and using this information in both vector and screening-level risk assessments. To date, almost 300 invertebrate and more than 70 algal species have been found associated with JTMD arriving in North America and Hawaii. In addition, previous NIS work within PICES by WG-21 has proven invaluable, especially the database and Atlas that includes information on 747 NIS in the North Pacific.

Corridors for aliens but not for natives: challenges and opportunities of an ecologically-based design of marine infrastructures
Laura Airoldi

Urban sprawl has dramatically expanded across marine seascapes. Throughout history, marine infrastructures have expanded, shorelines have been developed and intertidal and shallow subtidal areas have been reclaimed and armoured to meet the growing societal needs of burgeoning coastal populations, and respond to greater threats from climate change, storm surges and sea level rise. These habitat modifications have altered the local to regional distribution of a number of species, including numerous aliens, which can thrive on these anthropogenic surfaces. Recent work has shown that artificial habitats can act as regional corridors for non-indigenous species, while not representing adequate substrata for many native species. I will discuss the structural and environmental factors promoting the colonisation of marine infrastructures by non-indigenous species, the seascape connections between artificial and natural habitats, and the potential of ecological engineering to mitigate some of these impacts. I will show that adequate substrates, transplantation techniques and sound management can be combined to design better constructions that favour the preferential use by native species over non-indigenous ones. I will also discuss the need to incorporate marine habitat enhancement in modern planning, policy and design of cities and waterfronts, where people would directly benefit from the ecological services provided by healthy marine ecosystems, and will introduce a conceptual framework for designing marine developments that provide multifunctional outcomes for the society.