JOINT ICES/IOC/IMO WORKING GROUP ON BALLAST AND OTHER SHIP VECTORS (WGBOSV)

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Contents

i Executive summary

The Working Group on Ballast and Other Ship Vectors under the International Council for the Exploration of the Sea, Intergovernmental Oceanographic Commission of UNESCO, and International Maritime Organization (ICES/IOC/IMO WGBOSV) aims to provide scientific support to international decision-making to reduce the risk of spread and establishment of non-native species via maritime transport. The work contributes to ICES Strategic Plan by improving understanding between anthropogenic activities and marine ecosystems. This report outlines the achievements during 2022–2024. The work of the group consisted of reporting on national actions; collaborative research, and management actions on shipping vectors; as well as advancing the use of novel monitoring approaches and studying species dispersal mechanisms associated with maritime transport.

Concerning ballast water, several members of the group collated a dataset of treated ballast water samples from ships and published a peer-reviewed article addressing ships' compliance to the ballast water performance standard of IMO. The study concluded that compliance testing should be increased globally with periodic testing to ensure that ballast water management systems remain operational after commissioning.

The group has provided impartial and evidence-based recommendations to the Marine Environment Protection Committee (MEPC) and Sub-Committee on Pollution Prevention and Response (PPR) of IMO in ballast water and biofouling-related matters. The most significant contribution to IMO included two submissions to the 10th session of PPR in 2023; 1) guidelines for testing ship biofouling in-water cleaning systems to assess the efficacy of these systems, and 2) a commenting paper to provide clarifications and avoid subjective wording in the revised Biofouling Guidelines of IMO.

Several research elements provided new information on tracking the movement of ships potentially translocating species between distinct biogeographic regions. This work further highlighted the importance of relatively pristine areas, such as the Arctic and Antarctic region, and identified biogeographic barriers limiting natural spread of organisms within distinct coastal regions. Regarding molecular methods, an important achievement was a workshop following the International Conference on Marine Bioinvasions XI (ICMB XI) 2023, to provide recommendations to the end-users of these tools, which may help monitoring activities to identify newly introduced species.

ii Expert group information

Expert group name	Joint ICES/IOC/IMO Working Group on Ballast and Other Ship Vectors (WGBOSV)
Expert group cycle	Multiannual
Year cycle started	2022
Reporting year in cycle	3/3
Chair	Okko Outinen, Finland
Meeting venues and dates	2-4 May 2022, online meeting (55 participants)
	8-10 March 2023, Athens, Greece (50 participants)
	4-6 March 2024, Seville, Spain (57 participants)

1 Introduction

This report outlines the most recent advancements in scientific collaboration and work conducted within the International Council for the Exploration of the Sea/ Intergovernmental Oceanographic Commission/ International Maritime Organization Working Group on Ballast and Other Ship Vectors (ICES/IOC/IMO WGBOSV) from 2022 to 2024. The work of the group has been conducted in five terms of references (ToRs), and progress made for each ToR is summarized in the following sections. Summaries of the national activities of the member countries throughout the three years are presented in Annex 3.

2 ToR a) National reporting

Conduct strategic planning (identify and develop collaborative activities, advance and standardize methods, etc.) to advance research and address knowledge gaps by reviewing national activities and responding to new requests for advice

In total, national reports were provided on behalf of 14 countries throughout the three-year term, focusing mainly on national and regional research projects. Country representatives reported not only common themes in ongoing research activities, such as use of molecular tools and measuring water quality parameters during monitoring campaigns, but also concerning gaps on a national level, such as the lack of national compliance monitoring for the ballast water performance standard of the Ballast Water Management Convention. Furthermore, national, and regional regulations and guidance on the management of shipping vectors were included to the national reporting format to exchange information on initiatives that can be activated under national and/or regional cooperation.

Several members of the group also contributed to Greater North Sea Ecosystem Overview (ICES, 2022). The Ecosystem Overview summarized that shipping vectors have been responsible for more than half of the non-indigenous species introductions to the Greater North Sea region, and this contribution to the unintentional spread of organisms has remarkably increased over the past few decades.

References

ICES. 2022. Greater North Sea ecoregion – Ecosystem overview. In Report of the ICES Advisory Committee, 2022. ICES Advice 2022, Section 7.1, https://doi.org/10.17895/ices.advice.21731912

3 ToR b) Ballast water management

Provide support to the IMO Ballast Water Management Convention (2004, BWMC) Experience-Building Phase (EBP) by providing input on the validation of compliance monitoring devices, the use of indicative or detailed analysis tools (including the quantification of harmful/target species), or other aspects of the EBP

The discussions and presentations on ballast water management included a wide range of topics throughout the three-year term, including commissioning testing of ballast water management systems, compliance monitoring of ships ballast water using indicative compliance monitoring devices, as well as total residual oxidant testing for ballast water management systems that utilize active substances.

Additionally, latest developments at IMO in relation to the implementation of the Ballast Water Management Convention, and the Convention Review Plan of the ballast water experience-building phase initiated a lot of discussion. Priority issues associated with the implementation of the Convention have been drafted at IMO, and ships' compliance to the ballast water performance standard, as well as challenges with ballast water treatment when ships are operating at ports with challenging water qualities were reported among the high priority issues. Several members of the group worked together and gathered data from commissioning testing and compliance monitoring events to compile a dataset covering a broad range of samples, eventually conducting statistical and trend analyses on ballast water compliance. A peer-reviewed article resulted from this cooperation, concluding that compliance testing should be made mandatory for at least the next few years to improve common understanding on the effectiveness of the Convention.

3.1 Biological testing of ships' ballast water compliance

Commissioning testing of ballast water management systems and operational compliance monitoring of ballast water aim at minimizing the ballast water-related spread of organisms. A joint study compiled treated ballast water samples collected and analysed from 228 ships during 2017–2023. The samples were collected for enumeration of living organism concentrations in the categories of ≥50μm and <50 to ≥10μm -sized organisms (in minimum dimension), as well as indicator microbes in comparison to the ballast water performance standard (D-2 Standard) of IMO. Several ship-specific factors were statistically analysed to infer potential factors affecting compliance rates.

The main findings included that nearly half of all samples exceeded the compliance limit for the ≥50μm -sized organisms. Compliance rate concerning ships with an operational ballast water management system did not improve significantly over time, yielding a recommendation that compliance testing should be increased in frequency to ensure that these systems remain operational after commissioning testing. Furthermore, the study outcomes promote further research on the efficiency of filter mesh sizes and different filtration units associated with ballast water management systems, to improve mechanical removal of larger organisms.

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4 ToR c) Shipping, climate change and biodiversity

Investigate and evaluate the potential effects of shipping on biodiversity in a world transformed by climate change, and provide recommendations regarding the dispersal of organisms by ships, particularly in areas of high biological value (e.g., the Arctic, Baltic, and Mediterranean Seas)

The sessions under this ToR included several presentations and discussions on shipping impacts in areas of high biological value, such as work done under the Arctic Council on potential risk areas within the region. In addition, spread of species naturally and anthropogenically via shipping were demonstrated by several presentations, both globally, and to a more remote biogeographic regions, including Arctic and Antarctic regions.

One specific deliverable for this ToR was hosting a theme session on "The Spread of Non-native Species in a Changing World: Climate and Vector Change" at the International Conference on Aquatic Invasive Species in Halifax, Canada (12–16 May 2024). Six talks covered wide-ranging topics, including assessing habitat suitability, climate projections and pathway analyses to predict future translocation of species, potential biofouling pressure from commercial ships in the Baltic Sea region, and extreme weather events as a potential source of new introductions. The work conducted under this ToR, including contributed talks, has revealed interesting aspects concerning the natural movement of species under changing climate and altering shipping scenarios, and one of the key aspects for future work will be determining how specific ship movements and shipping routes may pose certain areas under risks of new species introductions. Further, it has become evident that climate change, including the increased frequency and intensity of extreme events, is facilitating the success of specific invaders in areas of high biological diversity and efforts should be made to determine which species pose the greatest risk to these areas so that management options can be identified.

4.1 The Spread of Non-native Species in a Changing World: Climate and Vector Change

The session on "The Spread of Non-native Species in a Changing World: Climate and Vector Change" was convened partially as a contribution to ToR c. The first presentation noted that in the US there is concern that climate change is causing invaders from the south to move further north and more work is needed identify management and policy stakeholders that should be alerted by this information. One tool that is commonly used to predict the potential distribution of a species is species distribution modeling but determining how best to represent climate change can be difficult and relies on many assumptions. However, by engaging a wide range of stakeholders has helped improve projections for many species, especially those that are on the doorstep of a new area. The next speaker used the spread of European Green Crab on the North American west coast as a test case of how this high-risk invader has genetically demonstrated adaptations that are facilitating natural dispersal northwards. Further, events like marine heatwaves are enhancing larval survival and contributing to the Salish Sea invasion that otherwise would have proceeded along a different trajectory if at all. Thus, identifying those invaders that have these adaptive abilities will be essential to understand who the most successful invaders will be in a future climate which will allow targeted management efforts on these species. One presenter showcased a study in the Baltic Sea where they compared wetted surface area of various ship types for biofouling propagule pressure of the studied vessels. Roll-on/Roll-off vessels

posed the greatest risk, especially those sailing only within the Baltic Sea. Thus, management efforts can be tailored to better mitigate the specific risks posed by these vessels. Another case study highlighted a potential high-risk invader to the Canadian arctic believed to have been introduced via commercial shipping. However, given the massive extent of the region in conjunction with limited to no sampling, establishing taxonomic confidence in this potentially invasive worm has proven challenging. Another presenter used a well-known tunicate invader to highlight how laboratory studies can help inform invasive species management. The tunicate was exposed to conditions that are expected to be encountered during a ship's voyage to better understand transit locations and/or life history stages that could be susceptible and hence pose a reduced risk. The final speaker made the case for hurricanes as a new invasion vector. It was demonstrated that invasive plants benefitted more than native ones from a real-life hurricane, and with expected changes in both the frequency and severity of extreme events one should expect the invaders to have the advantage. Thus, management needs to increasingly pay attention to how to incorporate extreme events in risk assessment and mitigation efforts.

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5 ToR d) Biofouling management

Investigate and evaluate relatively understudied aspects of vessel biofouling, such as the effect of microfouling (including species contributing to microbially induced corrosion [MIC]), the release of organisms (including larval stages) from ships during normal operations, and biofouling on recreational or fishing vessels

Biofouling management and various aspects associated with biofouling of ship hulls and niche areas have received increased attention over the past few years, and many presentations, project updates and discussions touched several topics during the three-year term. The sessions included presentations on experimentational research, in-water cleaning technologies, and increasingly on policy aspects concerning the testing of in-water cleaning systems, biofouling management for ships with extended lay-up periods, as well as the review of the IMO Biofouling Guidelines.

Several members of the working group were involved in a project that produced guidelines for testing ship biofouling in-water cleaning systems under the coordination of the Alliance for Coastal Technologies (ACT) and Maritime Environmental Resource Center (MERC). The guidelines provide detailed procedures to test in-water cleaning systems and produce the data needed to assess the efficacy and other measures of these systems. The testing guidelines were submitted to the 10th Session of Pollution Prevention and Response (PPR 10) Sub-Committee of the IMO (Document PPR 10/5). In addition, the group prepared another submission to PPR 10 clarifying concerns related to the review of the Biofouling Guidelines. The submission highlighted that subjective wording and phrases open to various interpretations should be avoided in the revised Biofouling Guidelines. It was noted that biofouling ratings and inspection frequency intervals for ships have not been standardized and are not evidence-based at this time. Therefore, such additions should not be included to the revised Guidelines. Members of this working group, as part of ICES delegation, participated in PPR 10, further explaining the content of these documents, which helped IMO to finalize the revised Biofouling Guidelines during the session.

These efforts nicely followed the ICES Viewpoint on Biofouling that was drafted and finalized during the previous three-year term, concluding that IMO guidelines on Biofouling must be updated.

5.1 Testing of in-water cleaning systems

In-water cleaning of biofouling is a known approach to increase ship performance between drydockings. Such cleaning systems typically involve the use of diver- or remotely- operated cleaning units that remove biofouling from ship surfaces. While in-water cleaning can improve ship operations and provide biosecurity benefits, incomplete capture of the cleaning debris by the unit or release of untreated effluent from debris processing may result in a biosecurity risk. The aim of the proposed testing guidelines was to provide standardized, evidence-based test procedures that produce the data needed to assess applications of in-water cleaning systems. The guidelines describe how to measure and report efficiency and safety of in-water cleaning systems for the capture and disposal of cleaning debris. The guidelines are mainly intended for cleaning service providers, ship operators, and port State control authorities. Detailed and rigorous procedures are described for the independent performance testing of all forms of in-water cleaning systems and for all types of external ship surfaces.

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ICES. 2023b. Comments on the report of the Correspondence Group on Review of the Biofouling Guidelines. PPR 10/5/5. International Maritime Organization, London.

6 ToR e) Molecular methods

Evaluate the development of DNA- and RNA-based molecular tools for surveillance and monitoring of ship-borne non-native species, including harmful species

A workshop on the effective and operational use of molecular tools for non-indigenous species monitoring and management was scheduled to be held for several years already, and finally after several years of restrictions due to the COVID-19 pandemic, the session occurred in 2023 during the 11th International Conference on Marine Bioinvasions (ICMB XI, https://www.marinebioinvasions.info/). This workshop focused on the use of molecular tools for non-indigenous species management, and discussions pointed to the key messages and recommendations to be delivered to the end-users of these tools, focusing on member States conducting monitoring.

Further, presentations under this ToR addressed several aspects related to DNA, such as its use to detect non-indigenous species from ports and fouling communities; this included work targeting recreational boats, an unregulated vector of spread of non-indigenous species, as well as large vessels coming into Arctic ports. Other presentations showed how these methods can be applied to study the genetics of various invertebrates. For instance, DNA studies allow the discovery of new ecotypes of mussels confined to ports that arose following shipping-mediated introductions of non-indigenous species. Other work showed how genomics of a species can aid to understand the sources and pathways of spread, for instance for the mitten crab. These presentations demonstrate that numerous countries are using genetic-based methods for species identification (confirmation) or developing tools, notably based on metabarcoding, as part of surveillance and monitoring programs in ports.

7 Next steps

Several scientific questions remain unanswered in relation to shipping-mediated spread of non-native species. Implementation of the Ballast Water Management Convention has reached the Convention Review stage at IMO, where new priority issues such as ballast water management in ports with challenging water qualities have emerged. In addition, ship biofouling has received increased attention over the past years, and more scientific work is needed on several biofouling management aspects, such as categorization of biofouling ratings and how that relates to the risk of spreading non-native species on ship surfaces. Furthermore, secondary spread mechanisms of species via ocean currents under changing climate conditions in combination with trans-oceanic shipping, as well as the standardization of the use of molecular methods across different countries and institutions remain understudied.

During the 2024 meeting, the group agreed to continue working on the abovementioned topics, and Mr. Okko Outinen, Finland, was re-elected to chair the group in 2025–2027. New ToRs and deliverables for 2025–2027 were developed by ICES/IOC/IMO WGBOSV members to guide the work of the group.

Annex 1: List of participants

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Annex 2: WGBOSV resolution

The **ICES/IOC/IMO Working Group on Ballast and Other Ship Vectors** (WGBOSV), chaired by Okko Outinen, Finland, will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2022	2-4 May	Online meeting		Meeting in association with WGITMO
Year 2023	8-10 March	Athens, Greece		Meeting in association with WGITMO
Year 2024	4-6 March	Seville, Spain	Final report by 16 June to SCICOM	Meeting in association with WGITMO

ToR descriptors

ToR	Description	Background	Science Plan Codes	Duration	Expected Deliverables
a	Conduct strategic planning (identify and develop collaborative activities, advance and standardize methods, etc.) to advance research and address knowledge gaps by reviewing national activities and responding to new requests for advice.	ICES strategic plan Goal 2: understand the relationship between the impact of human activities (e.g., shipping) and marine ecosystems to estimate pressures and impacts and develop science-based sustainable pathways	2.1, 2.5, 4.4	3 years	Report to ICES. Respond to advice requests, as applicable.
b	Provide support to the IMO Ballast Water Management Convention (2004, BWMC) Experience-Building Phase (EBP) by providing input on the validation of compliance monitoring devices, the use of indicative or detailed analysis tools (including the quantification of harmful/target species), or other aspects of the EBP.	The BWMC aims to minimize the transfer of harmful aquatic organisms with the ballast water from ships. To assess the Convention's implementation, the EBP is underway. In addition to gauging the logistics of the implementation, there are science needs related to the validation of methods and tools that need to be addressed.	2.7, 4.1	3 years	Input on the general applicability or otherwise of such conditions or methods to IMO or national regulators through meeting participation, correspondence group and/or technical paper or peer-reviewed manuscript.
c	Investigate and	This work will	2.1, 2.5, 4.4	3 years	Contribution to

	evaluate the potential effects of shipping on biodiversity in a world transformed by climate change, and provide recommendations regarding the disperal of organisms by ships, particularly in areas of high biological value (e.g., the Arctic, Baltic, and Mediterranean Seas)	contribute to the ICES/PICES Strategic Initiative on Climate Change Impacts on Marine Ecosystems (SICCME); address the Convention on Biological Diversity (CBD) and priority actions identified in the Arctic Council Arctic Invasive Alien Species (ARIAS) Strategy and Action Plan; and be relevant to the ICES high-priority action area of 'Arctic research'.			symposium or conference, and a peer-reviewed manuscript.
d	Investigate and evaluate relatively understudied aspects of vessel biofouling, such as the effect of microfouling (including species contributing to microbially induced corrosion [MIC]), the release of organisms (including larval stages) from ships during normal operations, and biofouling on recreational or fishing vessels.	This work will be carried out jointly with WGITMO. Ships' biofouling is, with ballast water, a primary vector of non-native species. As management of such vectors is the only effective way to reduce risks of new introductions, addressing biofouling issues is of high priority in non-native species management.	2.7, 4.1, 4.4	3 years	Strengthen ties to the IMO GloFouling partnerships through meeting participation and increased discussion of research aims, report to ICES, and/or publish a technical paper or peer-reivewed manuscript.
e	Evaluate the development of DNA- and RNA-based molecular tools for surveillance and monitoring of ship-borne non-native species, including harmful species.	This work will be carried out jointly with WGITMO. Robust monitoring efforts for vessel-borne biodiversity (including non-native species) is critically important, as is the application of reliable and accurate methods to assess compliance to regulations (e.g., BWMC). RNA- and DNA-based molecular tools have been proposed as complementary approaches to traditional monitoring and compliance	1.6, 4.4	3 years	Input on the general applicability or otherwise of such methods to IMO or national regulators through meeting participation, correspondence group and/or technical paper, peer-reviewed manuscript, or workshop.

	testing methods, and although some challenges remain, these tools warrant close scrutiny.

Summary of the Work Plan

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

Supporting information

Priority	The work of the Group forms the scientific basis for essential understanding of the movement of non-native aquatic organisms and pathogens via ballast water and other shipping vectors. As a joint working group, it also follows and supports related work within the IMO and IOC.
Resource requirements	The research programmes which provide the main input to this group are already underway, with resources provided by national governments and scientific funding agencies. The additional resources required to undertake activities in the framework of this group are negligible.
Participants	The Group is normally attended by 40-60 members and guests, but has 91 members in total.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	The group will serve as primary respondent to incoming advice requests on various issues related to ship-mediated introductions.
Linkages to other committees or groups	There is a very close working relationship with WGITMO and regular linkage to WGSHIP. Potential or occasional linkage with WGBIODIV, WGHABD, WGPDMO, WGIMT, WGPME and WGZE.
Linkages to other organizations	International Oceanographic Commission (IOC), International Maritime Organization (IMO), North Pacific Marine Science Organization (PICES). In addition, the outcomes are relevant to other national and international organizations involved in the development of regulatory policies.

Annex 3: National contributions

National contributions to the ToRs of the ICES/IOC/IMO WGBOSV during 2022–2024 are summarized in the sections below. For all country-specific sections, the ToRs are defined as:

- a = Conduct strategic planning (identify and develop collaborative activities, advance and standardize methods, etc.) to advance research and address knowledge gaps by reviewing national activities and responding to new requests for advice.
- b = Provide support to the IMO Ballast Water Management Convention (2004, BWMC) Experience-Building Phase (EBP) by providing input on the validation of compliance monitoring devices, the use of indicative or detailed analysis tools (including the quantification of harmful/target species), or other aspects of the EBP.
- c = Investigate and evaluate the potential effects of shipping on biodiversity in a world transformed by climate change, and provide recommendations regarding the dispersal of organisms by ships, particularly in areas of high biological value (e.g., the Arctic, Baltic, and Mediterranean Seas)
- d = Investigate and evaluate relatively understudied aspects of vessel biofouling, such as the effect of microfouling (including species contributing to microbially induced corrosion [MIC]), the release of organisms (including larval stages) from ships during normal operations, and biofouling on recreational or fishing vessels.
- e = Evaluate the development of DNA- and RNA-based molecular tools for surveillance and monitoring of ship-borne non-native species, including harmful species.

Summary of contributions by members from Canada

ToR	Canada
a	International vessels arriving at Canadian ports must submit ballast water reporting forms to demonstrate compliance with Canadian ballast water regulations. These forms contain valuable data for scientific research, risk assessment, and trend analysis. However, historically, the manual entry of these forms into a database led to a backlog due to limited resources, rendering the data inaccessible. To address this issue, a modern repository called the Ballast Water Information System is being developed. This system aims to automate the data entry and standardization of ballast water reporting forms, facilitating compliance assessment and scientific analysis. Additionally, a centralized data analytics system is being developed to aggregate and analyze these data, enabling the reporting of trends in ballast water activities and management practices in Canada. Canada also cooperates on a variety of other studies to evaluate spread, impacts and risks associated with nonindigenous species (NIS) moved through shipping activities (listed below and in ToR b-e). • Bradie JN, Bailey SA (2021). A decision support tool to prioritize ballast water compliance monitoring by ranking risk of non-indigenous species establishment. Journal of Applied Ecology, 58(3): 587-595. https://doi.org/10.1111/1365-2664.13822 • DFO (2021). Science advice on risk assessment methods for granting ballast water management exemptions. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/039. https://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2021/2021_039-eng.html • Etemad M, Soares A, Mudroch P, Bailey SA, Matwin S (2022). Developing an advanced information system to support ballast water management. Management of Biological Invasions, 13(1): 68-80, https://doi.org/10.3391/mbi.2022.13.1.04 • Ogilvie D, Daigle R, Chassé J, Bailey SA (2021). Evaluation of existing risk assessment methods for granting ballast water management exemptions. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/061. vi + 29 p. https://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2021/2021_039-eng.html
b	Canada has been evaluating if ballast water discharges from ships using different ballast water management systems (BWMS) meet the viable organism limits specified in the Ballast Water Management Convention. This evaluation involves assessing paired uptake and discharge samples, preserving specimens for taxonomic analysis, and monitoring water quality parameters during uptake. Simultaneously, Canada has been leading projects to assess commercially available compliance monitoring devices' accuracy in detecting viable organisms in both regulated size classes (≥50µm and ≥10µ - ≤50µm), using ballast water samples and laboratory tests. Canada has implemented additional measures (exchange plus treatment) for management of ballast water releases into freshwater areas and in their largest Arctic port to help mitigate risks associated with inoperable or partially functioning ballast water management systems (BWMS). They have been investigating these risks and evaluating mitigation strategies, such as ballast water exchange (BWE) , considering factors like voyage routes and uptake concentrations. • Bailey SA, Brydges T, Casas-Monroy O, Kydd J, Linley RD, Rozon RM, and Darling JA (2022). First evaluation of ballast water management systems on operational ships for minimizing introductions of nonindigenous zooplankton. Marine Pollution Bulletin 182, 113947. https://doi.org/10.1016/j.marpolbul.2022.113947 • Bailey, S. A., Casas-Monroy, O., Kydd, J., Ogilvie, D., Rozon, R. M., and Yardley, S. 2023. Efficacy of ballast water management systems operating within the Great Lakes and St. Lawrence River (2017 – 2022). Can. Data Rep. Fish. Aquat. Sci. 1376: vii + 24 p. • Bradie JN, Drake DAR, Ogilvie D, Casas-Monroy O, Bailey SA. 2021. Ballast water exchange plus treatment lowers species invasion rate in freshwater ecosystems. Environmental Science & Technology, 55 (1): 82-89. http://dx.doi.org/10.1021/acs.est.0c05238 • Bradie, J., Rolla, M., Bailey, S.A. and MacIsaac, H.J., 2023. Managing risk of non-indigenous species establishment associated with ballast water discharges from ships with bypassed or inoperable ballast water management systems. Journal of Applied Ecology, 60(1), pp.193-204. https://doi.org/10.1111/1365-2664.14321

	• Casas-Monroy O, Bailey SA (2021). Do Ballast Water Management Systems Reduce Phytoplankton Introductions to Canadian Waters? Frontiers in Ecology and Evolution, 19 August. https://doi.org/10.3389/fmars.2021.691723 • Casas-Monroy, O, T Brydges, J Kydd, D Ogilvie, RM Rozon and SA Bailey. 2023. Examining the performance of three ballast water compliance monitoring devices (CMD) for quantifying live organisms in both regulated size classes (≥ 50 μm and ≥ 10 – < 50 μm). Journal of Plankton Research 45: 540–553. https://doi.org/10.1093/plankt/fbad014 • Casas-Monroy O, Kydd J, Rozon RM, Bailey SA. 2022. Assessing the performance of four indicative analysis devices for ballast water compliance monitoring, considering organisms in the size range ≥10 and <50 μm. Journal of Environmental Management 317, 115300. https://doi.org/10.1016/j.jenvman.2022.115300 • Outinen O, Bailey SA, Casas-Monroy O, Delacroix S, Gorgula S, Griniene E, Kakkonen J and G Srebaliene. 2024. Commissioning and compliance testing of ships' ballast water indicate challenges for the implementation of the Ballast Water Management Convention. Frontiers in Marine Science 11:1334286. https://doi.org/10.3389/fmars.2024.1334286 • Peperzak L, Casas-Monroy S and S Bailey. 2024. Validation of an adenosine triphosphate (ATP) model for 10-50 μm plankton. Marine Pollution Bulletin 200: 116066. https://doi.org/10.1016/j.marpolbul.2024.116066 • Rolla M, MR Hernandez, J Bradie, SA Bailey and HJ MacIsaac. 2023. Ballast water management systems protect the Great Lakes from secondary spread of non-indigenous species. Biological Invasions https://doi.org/10.1007/s10530-023-03182-5 • Song, R., Tavakoli, Y., Bailey, S.A. and Soares, A. 2023. A temporal assessment of risk of non-indigenous species introduction by ballast water to Canadian coastal waters based on environmental similarity. Biological Invasions 25: 1991-2005 http://dx.doi.org/10.21203/rs.3.rs-1304354/v1
c	To assess effects of shipping under climate change, Canada is expanding research in the Arctic to better understand impacts of treated ballast water discharges at Milne Inlet Port, the largest Arctic port in Canada. Objectives of this study include exchanging knowledge with local communities, providing training for indigenous participation in sampling, developing standardized monitoring protocols for assessing compliance with D-2 standard, identifying key risk factors for introducing NIS via ballast water discharges, and creating a risk assessment tool for targeting high-risk ships. This research builds on previous ballast water research efforts in the Arctic region and complements recent studies to evaluate risks of NIS, as well as hotspots and barriers for their introduction and potential for spread under climate change. Canada is expanding studies initially focused on species and shipping pathways of concern for the Canadian Arctic to evaluate risks at a PanArctic scale by integrating species and pathway-specific approaches. • Deb J., and Bailey, S.A. 2023. Arctic marine ecosystems face increasing climate stress. Environmental Reviews 31(3) https://doi.org/10.1139/er-2022-0101 • Dhifallah, F., Rochon, A., Simard, N., McKindsey, C., Gosselin, M., and Howland, K. 2022. Dinoflagellate communities in high-risk Canadian Arctic ports. Estuar. Coast. Shelf Sci. 266 107731 https://doi.org/10.1016/j.ecss.2021.107731 • Goldsmit, J., Clark, H.A., McKindsey, C.W., Stewart, D.B. and Howland, K.L. 2023. Screening for high-risk marine invaders in the Hudson Bay Region, Canadian Arctic: Compilation of background information, rationale, and references used to answer questions with the Canadian Marine Invasive Species Tool (CMIST). Can. Data Rep. Fish. Aquat. Sci. 1373: vi + 344 p. https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/41117591.pdf • Goldsmit, J., McKindsey, C.W., Deslauriers, D., Schegel, R. and Howland, K.L. 2024. Predicted shifts in suitable habitat of interacting benthic species in a warmer and invaded Canadian Arctic. Elementa: Science of the Anthropocene 12(1): 00018 https://doi.org/10.1525/elementa.2023.00018 • Goldsmit J, McKindsey CW, Stewart DB, Howland K. 2021. Screening for High-Risk Marine Invaders in the Hudson Bay Region, Canadian Arctic. Frontiers in Ecology and Evolution 9: 627497 https://www.frontiersin.org/articles/10.3389/fevo.2021.627497/full • Krumhansl, K., Gentleman, W., Lee, K., Ramey-Balci, P., Goodwin, J., Wang, Z., Lowen, B., Lyons, D., Therriault, T.W., and DiBacco, C. 2023. Permeability of coastal biogeographic

	barriers to marine larval dispersal on the east and west coasts of North America. Global Ecology and Biogeography 32: 945-961.
d	Canada has identified biofouling as a key vector for introducing aquatic NIS that threaten Canadian ecosystems. The Department of Fisheries and Oceans (DFO) is conducting assessments of biofouling levels across various Canadian regions, ship types, hull/niche areas; including evaluating the performance of different epoxy resin to prevent biofouling of ships hulls. Preliminary findings indicate higher biofouling risks on the Atlantic and Pacific coasts compared to the Great Lakes-St. Lawrence and Arctic regions. In 2023, sampling efforts across eastern, western, and Great Lakes regions were conducted to update existing datasets, accounting for factors such as shipping patterns, paint age, and vessel history. Canada is also collaborating under the Canada-Inuit Nunangat-United Kingdom Arctic Shipping Risks Project, where Inuit youth and experts are receiving training in environmental DNA (eDNA) sampling and remotely operated vehicle (ROV) operation in Arviat and Pond Inlet, Nunavut and conducted sampling in 2023. This baseline data on coastal marine communities and detection of NIS, complemented with ROV surveys and eDNA sampling in close proximity to vessel hulls and niche areas, are documenting biofouling levels on arriving ships. By evaluating Arctic biofouling risks associated with increased shipping activities driven by climate change, the project expects to support Inuit-determined marine governance strategies. • Brinklow TR, Chan FT, Etemad M, Deb JC, and Bailey SA. 2022. Vessel Biofouling as a Vector for Nonindigenous Species Introductions in Canada. DFO Canadian Science Advisory Secretariat Research Document 2022/072. iv + 48p. • Chan FT, Ogilvie D, Sylvester F, Bailey, SA. 2022. Ship biofouling as a vector for non-indigenous aquatic species to Canadian Arctic coastal ecosystems: A survey and modeling-based assessment. Frontiers in Marine Science, 9:808055. https://doi.org/10.3389/fmars.2022.808055 • DFO. 2022. Science advice on vessel biofouling as a vector for nonindigenous species introductions in Canada. DFO Can. Sci. Advis. Sec. Science Advisory Report 2022/048. • Ferrario, F., Araújo, C.A.S., Bélanger, S., Bourgault, D., Carrière, J., Carrier-Belleau, C., Dreujou, E., Johnson, L.E., Juniper, S.K., Mabit, R., McKindsey, C.W., Ogston, L., Picard, M.M.M., Saint-Louis, R., Saulnier-Talbot, É., Shaw, J.-L., Templeman, N., Therriault, T.W., Tremblay, J.-E., and Archambault, P. 2022. Holistic environmental monitoring in ports as an opportunity to advance sustainable development, marine science, and social inclusiveness. Elementa: Science of the Anthropocene 10(1): 00061. • Riley C, Drolet D, Goldsmit J, Hill JM, Howland KL, Lavoie M-F, McKenzie CH, Simard N, McKindsey CW. 2022. Experimental analysis of survival and recovery of ship fouling mussels during transit between marine and freshwaters Front. Mar. Sci. 8:808007 http://doi.org/10.3389/fmars.2021.808007
e	Canada is conducting a program that aims to develop a foundation for the development of a monitoring and early detection system in the Canadian Arctic. This includes the following elements and extends past research efforts by DFO and the Canadian Aquatic Invasive Species Network (CAISN): 1) Identification and ranking of key ship-mediated NIS for early detection and monitoring, and geographic locations with highest probability for establishment via Environmental Niche Modeling; 2) Building capacity for ongoing community-based monitoring; 3) Testing and development of genetic early detection methodologies (environmental or eDNA to evaluate optimal sampling strategies for biodiversity including NIS detection in marine and estuarine Arctic ports including: a) comparing metabarcoding (COI, 18S rRNA) of eDNA water samples with standard invertebrate species collection methods at various spatial scales and depths, b) evaluating the potential of eDNA to detect temporal transitions in marine Arctic port communities, c) evaluating interactive effects of tide and depth on detected biodiversity; d) exploring effects of sampling effort on biodiversity patterns and NIS detection. • Abbott C, Coulson M, Gagné N, Lacoursière-Roussel A, Parent GJ, Bajno R, Dietrich C, May-McNally S. 2021. Guidance on the use of targeted environmental DNA (eDNA) analysis for the management of aquatic invasive species and species at risk. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/019. iv + 42 p. https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2021/2021_019-eng.html • Andrés, J., Czechowski, P., Grey, E., Mandana, S., Andres, K., Brown, C., Chawla, N., Corbett, J.J., Brys, R., Cassey, P., Correa, N., Deveney, M.R., Egan, S.P., Fisher, J.P., van den

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Summary of contributions by members from Finland

ToR	Finland
a	A national indicator assessment for marine non-indigenous species (NIS) according to the European Union Marine Strategy Framework Directive was completed in 2024, summarizing the status, trends and impacts of marine NIS in Finland. In addition, several other studies in national and regional cooperation have contributed to studying impacts and spread of marine NIS. • Anttila-Huhtinen, M. and Könönen, K., 2022. Ensihavainnot uudesta vieraslajista, japaninkuuppaäyriäisestä Nippoleucon hinumensis (Gamô 1967) (Crustacea: Cumacea, Leuconidae) Suomen rannikolla. LUOMUS SAHLBERGIA, p.12. DOI: https://luomus.fi/sites/default/files/files/sahlbergia_28_1_2022.pdf#page=13 • Gagnon, K., Herlevi, H., Wikström, J., Nordström, M.C., Salo, T., Salovius-Laurén, S. and Rinne, H., 2022. Distribution and ecology of the recently introduced tanaidacean crustacean Sinelobus vanhaareni Bamber, 2014 in the northern Baltic Sea. Aquatic Invasions, 17(1), 57–71. DOI: https://doi.org/10.3391/ai.2022.17.1.04 • Jormalainen, V., Kiiskinen, E., Hauhia, V. and Merilaita, S., 2023. Functionally novel invasive predator eradicates herbivores of a littoral community. Aquatic Invasions, 18(3), 313–329. DOI: https://doi.org/10.3391/ai.2023.18.3.103350 • Ojaveer H, Einberg H, Lehtiniemi M, Outinen O, Zaiko A, Jelmert A, Kotta J., 2023. Quantifying impacts of human pressures on ecosystem services: Effects of widespread non-indigenous species in the Baltic Sea. Science of The Total Environment, 858, 159975. DOI: https://doi.org/10.1016/j.scitotenv.2022.159975 • Outinen, O., Katajisto, T., Nygård, H., Puntila-Dodd, R., and Lehtiniemi, M., 2024. National assessment on the status, trends and impacts of marine non-indigenous species for the European Union marine strategy framework directive. Ecological Indicators, 158, 111593. DOI: https://doi.org/10.1016/j.ecolind.2024.111593 • Zenetos A, Tsiamis K, Galanidi M, Carvalho N, Bartilotti C, Canning-Clode J, Castriota L, Chainho P, Comas-González R, Costa AC, Dragičević B, Dulčić J, Faasse M, Florin A-B, Gittenberger A, Jakobsen H, Jelmert A, Kerckhof F, Lehtiniemi M, Livi S, Lundgreen K, Macic V, Massé C, Mavrič B, Naddafi R, Orlando-Bonaca M, Petovic S, Png-Gonzalez L, Carbonell Quetglas A, Ribeiro RS, Cidade T, Smolders S, Stæhr PAU, Viard F, Outinen O. 2022. Status and Trends in the Rate of Introduction of Marine Non-Indigenous Species in European Seas. Diversity, 14(12):1077. DOI: https://doi.org/10.3390/d14121077
b	Finland co-sponsored a document MEPC 78/4/10 'Next steps in the experience-building phase associated with the BWM Convention' that was submitted to MEPC 78 in 2022. The document proposed the development of a Convention Review Plan for the implementation of the BWMC to establish a clear scope for a feasible BWMC Review and identify priority issues associated with the implementation of the Convention. In addition, Finland participated to a study that collated treated ballast water samples from 2017 to 2023 and assessed their compliance to the D-2 standard. • IMO, 2022. Next steps in the experience-building phase associated with the BWM Convention. MEPC 78/4/10. International Maritime Organization, London. • Outinen O, Bailey SA, Casas-Monroy O, Delacroix S, Gorgula S, Griniene E, Kakkonen J and G Srebaliene. 2024. Commissioning and compliance testing of ships' ballast water indicate challenges for the implementation of the Ballast Water Management Convention. Frontiers in Marine Science 11:1334286. https://doi.org/10.3389/fmars.2024.1334286
d	Finland co-sponsored two documents that were submitted to the IMO by several delegations. The document PPR 9/6 suggested modifications to the guidelines of the AFS Convention concerning inspections, sampling, and certification of AFS on ships, and document PPR 9/INF.9 provided further information on these aspects. In addition, new national restrictions for biocidal antifouling products for leisure craft are under preparation and will be published in 2024. There will be several restrictions for biocidal products, such as the length of the boats which are allowed to be painted with biocidal products, prohibition of in-water cleaning concerning boats painted with biocidal products, prohibition to release untreated boat washing effluents into the environment and decrease in the copper release rate of the products.

	• IMO, 2021. Proposal to revise the Guidelines for brief sampling of anti-fouling systems on ships, the Guidelines for survey and certification of anti-fouling systems on ships and the Guidelines for inspection of anti-fouling systems on ships. PPR 9/6, pre-session public release. International Maritime Organization, London. • IMO, 2022. Information on possible revision of the Guidelines for brief sampling of anti-fouling systems on ships, the Guidelines for survey and certification of anti-fouling systems on ships and the Guidelines for inspection of anti-fouling systems on ships. PPR 9/INF.9, pre-session public release.
e	Port monitoring for aquatic NIS introductions, and the use of eDNA methods has been ongoing in 2022–2024 in five largest ports in Finland in terms of export tonnage. Also, updates and potential improvements to the JHP port survey protocol and HELCOM/OSPAR target species lists are being developed by a correspondence group coordinated by Finland and Spain in JTG BALLAST & BIOFOULING in 2024.

Summary of contributions by members from France

ToR	France
a	Fourteen new introductions, all unintentional, are reported to have been introduced through shipping vectors into France, either as first country records or for new biogeographic regions. In 2022 an updated inventory of non-indigenous species (NIS), along with their pathway of introduction, was carried out for the three metropolitan biogeographic regions of France. The pathway analysis in this study showed that 68% of the 342 recorded NIS are likely to have been introduced through ballast waters (29%) or hull fouling (37%). • Massé, C., Viard, F., Humbert, S., Antajan, E., Auby, I., Bachelet, G., Bernard, G., Bouchet, V.M.P., Burel, T., Dauvin, J.-C., Delegrange, A., Derrien-Courtel, S., Droual, G., Gouillieux, B., Goulletquer, P., Guérin, L., Janson, A.-L., Jourde, J., Labrune, C., Lavesque, N., Leclerc, J.-C., Le Duff, M., Le Garrec, V., Noël, P., Nowaczyk, A., Pergent-Martini, C., Pezy, J.-P., Raoux, A., Raybaud, V., Ruitton, S., Sauriau, P.-G., Spilmont, N., Thibault, D., Vincent, D., Curd, A., 2023. An Overview of Marine Non-Indigenous Species Found in Three Contrasting Biogeographic Metropolitan French Regions: Insights on Distribution, Origins and Pathways of Introduction. Diversity 15, 161. https://doi.org/10.3390/d15020161
b	A national group to discuss and share knowledge on the implementation of the BWMC in France has been in place for four years now. It is led by the French Ministry of the Sea, and convenes approximately twice a year prior to MEPC and PPR meetings of the IMO to prepare national opinion on the documents. Nevertheless, at present, very few analyses informing compliance testing are carried out on French vessels. Despite France being on the flag states mandating commissioning testing, <2% of SGS's commissioning tests worldwide were conducted in France (Drillet *et al.* 2023), and comprehensive data on the number of compliance tests performed nationally remain unavailable.
c	BIOcean5D (2022-2026 https://www.biocean5d.org/) is a major interdisciplinary project designed to better understand the impact of human activity on Europe's seas and coastlines. Within its WP5, "Monitoring human impacts on marine biodiversity and modelling future ocean health." this project will use a set of tools (e.g. trait-based modelling, species distribution models, multivariate analyses) to identify how invasion success varies depending on biotic and abiotic settings to ultimately predict future invasion success depending on climate change scenarios.
d	2023 saw the creation of a national "thematic research network" on aquatic biofilms and biofouling. This network, initiated by biotechnology laboratories, encourages exchanges between academics and industry in order to promote the emergence of innovative cross-disciplinary environmental biofouling projects. Several green chemistry studies have made advances on the antifouling properties of various marine invertebrates, seaweeds and bacteria. In addition, several research projects examined biofouling and the contribution of NIS in ports or on vessels. New regional citizen science projects, targeting NIS, were developed in France ("Réseaux Alien"); these include the Normandy region (Alien Mer Normandie)[1], which includes harbour monitoring, Corsica (Réseau Alien Corse)[2] as well as the Occitanie region (Sentinelles de la Mer Occitanie)[3]. The latter has a program dedicated to recreational boat monitoring (2021-2023) that was renewed in 2023 for an additional three years. • Cahill, P.L., Moodie, L.W.K., Hertzer, C., Pinori, E., Pavia, H., Hellio, C., Brimble, M.A., Svenson, J., 2024. Creating New Antifoulants Using the Tools and Tactics of Medicinal Chemistry. Acc. Chem. Res. 57, 399–412. https://doi.org/10.1021/acs.accounts.3c00733 • Davis, R.A., Cervin, G., Beattie, K.D., Rali, T., Fauchon, M., Hellio, C., Bodin Åkerlund, L., Pavia, H., Svenson, J., 2023. Evaluation of natural resveratrol multimers as marine antifoulants. Biofouling 39, 775–784. https://doi.org/10.1080/08927014.2023.2263374

[1] https://biologie.ffessm.fr/reseau-alien-mer-normandie

[2] https://www.ffessm-corse.com/signalement-especes-reseau-alien-corse

[3] https://www.sentinellesdelamer-occitanie.fr/le-reseau-presentation-2/

	• Gauff, R. P. M., Joubert, E., Curd, A., Carlier, A., Chavanon, F., Ravel, C., & Bouchoucha, M., 2023. The elephant in the room: Introduced species also profit from refuge creation by artificial fish habitats. Marine Environmental Research, 185, https://doi.org/10.1016/j.marenvres.2022.105859 • Quémener, M., Kikionis, S., Fauchon, M., Toueix, Y., Aulanier, F., Makris, A.M., Roussis, V., Ioannou, E., Hellio, C., 2021. Antifouling Activity of Halogenated Compounds Derived from the Red Alga *Sphaerococcus coronopifolius*: Potential for the Development of Environmentally Friendly Solutions. Marine Drugs 20, 32. https://doi.org/10.3390/md20010032
e	A number of research programs detailed in the French national report have examined ecological and evolutionary processes in biofouling communities found in ports, marinas and on recreational boat hulls. Within the BIOcean5D project, work has started on gathering eDNA metabarcoding data in ca. 15 ports across European seas, and developing indicators for non-indigenous invasive species, through a combination of molecular and modelling approaches. Several national workshops dedicated to the use of eDNA for NIS surveillance including in ports were carried out. Other research projects focused, or are focusing, on 1) the effectiveness of eDNA methods for detecting non-native species, including on ship hulls, 2) combining molecular and modelling approaches in order to develop indicators for non-indigenous invasive species, and 3) whether eco-engineering of marine infrastructures and marine restoration initiatives are efficient in limiting opportunistic and invasive alien species. • Couton, M., Lévêque, L., Daguin-Thiébaut, C., Comtet, T., and Viard, F., 2022. Water eDNA metabarcoding is effective in detecting non-native species in marinas, but detection errors still hinder its use for passive monitoring. Biofouling 38(4), 367-383. doi: 10.1080/08927014.2022.2075739 • Hammel, M., Touchard, F., Burioli, E. A. V., Paradis, L., Cerqueira, F., Chailler, E., . . . Bierne, N., 2024. Marine transmissible cancer navigates urbanized waters, threatening spillover. Proceedings of the Royal Society B: Biological Sciences, 291(2017), 20232541. https://doi.org/10.1098/rspb.2023.2541 • Touchard, F., Cerqueira, F., Bierne, N. & Viard, F., 2024. Adaptive alien genes are maintained amid a vanishing introgression footprint in a sea squirt. Evolution Letters. Accepted https://doi.org/10.1093/evlett/qrae016 (BioRXiv: https://doi.org/10.1101/2023.09.21.558831)

Summary of contributions by members from Germany

ToR	Germany
a	The European Marine Strategy Directive (MSFD) aims to achieve a Good Status of the marine Environment (GES). As part of the required review and update (2016 – 2022) of the national marine strategy, the introduction rate into the North and Baltic Sea was reassessed. The pressures on biodiversity and ecosystem caused by non-indigenous species (NIS) remained too high. With 12 newly recorded NIS in the German North Sea, the introduction rate fell, but is still well above the threshold of the maximum of one to two species per assessment period. In the same assessment period 9 newly introduced NIS were recorded in the Baltic Sea. Here, the introduction rate remained also high and the Baltic threshold value of a maximum one NIS per assessment period was clearly exceeded. The calculation of the Trend Indicator/Introduction Rate (D2C1) is based on constant monitoring efforts (eRAS) including time, costs and established monitoring web at the North and Baltic Sea (in total 21 stations). In addition, to minimize the introduction and spread of newly introduced NIS, the so-called "Round Table Biofouling" has been launched in 2019 and organized by Bundesamt für Seeschifffahrt (BSH), Hamburg and the German Shipowners Association annually since then. The round table is an important tool for MSFD proceedings to support the implementation of the IMO Biofouling Guidelines and the further development of the IMO in-water cleaning guidelines. An additional round table biofouling will be organized with an exclusive focus on the recreational boating sector. A concept of a national early warning system including a chain of communication, as well as decision support tool are being further developed for immediate actions, as described in the MSFD framework to avoid and control the spread of NIS. With the entry into force of the EU Regulation (Regulation (EU) No. 1143 /2014) in 2015 and listing of marine NIS in the "List of IAS of Union concern", additional measures and strategies to prevent introductions of NIS have to be developed. In the scope of the national BMDV Network of Experts, a Neobiota Information System (NIS) is being further developed as a web-based data management tool at BSH. This application allows for data quality and management, as well as standardisation between the German coastal states for monitoring NIS. Once data are uploaded (within a standardized excel data sheet), the application automatically checks the data for consistency and plausibility. For the future, it is desirable to check and structure all German NIS data (collected after the MSFD protocol) equally and consistently to enable comparability, completeness and efficacy of collected data for public visibility and retrieval. Various studies have indicated that the research results and knowledge must be tailored to the target groups As an awareness campaign, a ca. 4 minute scribble-movie: "Alien species and importance of biofouling for the aquatic environment" was jointly prepared by BSH and NIS experts. The movie addresses several biofouling issues and can be found here: https://www.youtube.com/watch?v=Thg3pnK1Zgk A book, including all known introduced species into German coastal waters has been published in 2023 (English and German language). Each species is described in detail, as well as the location of origin and suspected transport vector. • Karsten Reise, Dagmar Lackschewitz, Strangers at the German Shores – Fremd an den deutschen Küsten. 2023, ISBN: 978-3-96194-209-1
b	Germany has decided to join the pilot implementation of a regionally harmonized Early Warning System (EWS) on the detection of harmful aquatic organisms and pathogens (HAOP) within the HELCOM area in 2023. In 2024, the 2nd Edition of the earlier published book on ballast water management was published to address new developments in this field of work since the 1st Edition came out in 2015.

	• David, M., and Gollasch, S., 2024. Global Maritime Transport and Ballast Water Management: Issues and Solutions. Invading Nature – Springer Series in Invasion Ecology. 2nd edition. Springer Nature, Switzerland. https://doi.org/10.1007/978-3-031-48193-2
d	Germany is working to finalize the draft Biofouling Management Guidance for recreational craft to be submitted to the HELCOM IC Maritime 3-2024 meeting in September 2024. Additionally the Draft Guidance for the control and management of ship's biofouling in the HELCOM and OSPAR region will be also finalized in 2024. In the framework of NEAS 2030 (North East Atlantic Strategy) Germany is involved in the development of coordinated management strategies to minimize the number of NIS introduced via human activities. A biofouling parameter has been developed for the climate change fact sheet and submitted for final approval to the HELCOM GEAR meeting in 2024.
e	Genetic methods (eDNA, metabarcoding) as part of the surveys in the Port of Rostock were completed in 2022. From the perspective of administration both genetic methods have strengths and weaknesses.

Summary of contributions by members from Lithuania

ToR	Lithuania
a	Considering national activities on NIS in Lithuania, project INVA (Assessment of the status of invasive and alien species is new stage of biodiversity research in Lithuania) is implemented, which aim to identify and explore 100 EU and Lithuanian invasive and alien species in the country, determine their population status, spread, threats descriptions, and development of distribution maps. • Report on preliminary project results: https://cdn.biip.lt/inva-wp/app/uploads/Invazines-rusys-Lietuvoje_Trumpa-vykdyto-tyrimo-apzvalga_V.-Rasomavicius.pdf Lithuania was coordinator and developer of the Early Warning System (EWS) for Ballast water management convention, and the EWS was launched in 2022 (HELCOM). Countries involved in the pilot implementation were Denmark, Finland, Latvia and Lithuania, from 2024 request from Germany was initiated. • Report on EWS and application and functions. https://www.balticcomplete.com/attachments/article/324/COMPLETE+Early+Warning+System+online+workshop.pdf In addition, several other studies with international cooperation have contributed to studying history of impacts and spread of marine NIS. • Arbačiauskas, K., Smith, C., & Audzijonyte, A. (2022). Does the Ice Age legacy end in Central Europe? The shrinking distributions of glacial relict crustaceans. *bioRxiv*, 2022-11. • Katsanevakis, S., Olenin, S., Puntila-Dodd, R., Rilov, G., Stæhr, P. A., Teixeira, H., ... & Tidbury, H. J. (2023). Marine invasive alien species in Europe: 9 years after the IAS Regulation. *Frontiers in Marine Science*, *10*, 1271755.
b	New National Guidelines of the procedure for granting exemptions for the voyage of a ship under regulation A-4 of the 2004 International Convention on ships' ballast water and sediment control and cleaning is under consideration by Ministry of Environment. The guidelines will describe the process of exemptions for vessels, and responsibilities of controlling institutions. Considering the IMO Ballast Water Management Convention (2004, BWMC) Experience-Building Phase (EBP) national cooperation with stakeholders workshop on knowledge transfer for Klaipeda port state control on ballast water management, ballast sampling and analysis were given. Lithuania participated in a study that collated treated ballast water samples from 2017 to 2023 and assessed their compliance to the D-2 standard. • Outinen, O., Bailey, S. A., Casas-Monroy, O., Delacroix, S., Gorgula, S., Griniene, E., ... & Srebaliene, G. (2024). Biological testing of ships' ballast water indicates challenges for the implementation of the Ballast Water Management Convention. *Frontiers in Marine Science*, *11*, 1334286.
d	Activities considering the biofouling for research was done 2022- 2023. Inspecting the leisure boats in two marinas (Dreverna, Smyltinė), pontons and navigational buoys. After samples and photographs was analysed, based on visual expertise possible specimen of *Ficopomotus spp.* was found. Additional analyses are planned to make genetic analysis in order to identify species.
e	For port national monitoring, hull biofouling and ballast water monitoring eDNA methods are not applied for national monitoring, but the research on possible application of eDNA for NIS is developing in Lithuania, protocol and sampling guidelines. • Copilaş-Ciocianu, D., Rewicz, T., Sands, A. F., Palatov, D., Marin, I., Arbačiauskas, K., ... & Audzijonyte, A. (2022). A DNA barcode reference library for endemic Ponto-Caspian amphipods. *Scientific reports*, *12*(1), 11332.

	• Zaiko, A. Samuilovienė, A., Olenin, S. 2021. eDNA sampling protocol for hull biofouling and ballast water monitoring, and guidelines for the monitoring of target non-indigenous species using molecular methods https://www.balticcomplete.com/attachments/article/326/COMPLETE%20O2_1%20report%20FINAL.pdf

Summary of contributions by members from Norway

ToR	Norway
a	A national monitoring program for non-indigenous marine species (NIMS) in Norway has been suggested and will probably start up in 2025. Methods for monitoring have been tested out (including genetic tools) and analysis of ships traffic into Norwegian ports has been conducted to identify high risk areas. Furthermore, e-DNA methods for targeted organisms, such as *Didemnum vexillum*, *Homarus americanus* and *Neogobius melanostomus* have been used in specific mapping programs. A new risk assessment of NIMS and doorknockers in Norway was published in 2023. Several methods to limit the spread of the invasive ascidian *D. vexillum* have been tested in lab and field experiments and a given rise to advice to management. • Artsdatabanken (2023). Fremmede arter i Norge – med økologisk risiko 2023. https://www.artsdatabanken.no/lister/fremmedartslista/2023 • Fossøy F, Sivertsgård R, Ambjørndalen VM, Brandsegg H, Andersskog IPØ, Husa V, Forsgren E. 2022. Kartlegging av den fremmede marine arten havnespy Didemnum vexillum ved hjelp av miljø-DNA. En rask respons undersøkelse. NINA Rapport 2092. Norsk institutt for naturforskning. • Fossøy, F., Husa, V, Andersskog, I.P.Ø., Brandsegg, H., Sivertsgård, R., Legrand, E., Svensen, Ø., Dahle Øverby, L., Husby E. 2023. Kartlegging av den fremmede marine arten havnespy Didemnum vexillum ved hjelp av miljø-DNA og visuell inspeksjon. Oppfølgende undersøkelser i 2022-23. NINA Rapport 2278. Norsk institutt for naturforskning. • Husa V, Agnalt A-L, Falkenhaug T, Fossøy F, Forsgren E, Grefsrud ES, Hansen F, Jelmert A, Mortensen S. 2022. Alien marine species in Norway. Mapping, monitoring and assessment of vectors for introductions. Rapport fra Havforskningen.Vivian Husa, Ann-Lisbeth Agnalt, Tone Falkenhaug (HI), Elisabet Forsgren (NINA), Frode Fossøy (NINA), Ellen Sofie Grefsrud (HI), Frank Hanssen (NINA), Anders Jelmert og Stein Mortensen (HI) • Husa V, Fossøy F, Davey M, Agnalt A-L, Bransegg H, Bruntveit L, Eilertsen M, Falkenhaug T, Forsgren E, Grefsrud ES, Taraldset Haugland B, Aaserud Olsen S, Olssøn R, Svensen R, Svensen Ø. 2024. Monitoring marine alien species in Norway- A pilot study for implementing a national program. Rapport fra Havforskningen 2024-1. • Legrand E, Escobar Lux RH, Mengede M, Aaserud Olsen S, ParsonsA, Husa V. 2024. Efficacy of lime, hydrogen peroxide and azamethiphos as potential control treatments against the proliferation of the invasive ascidian Didemnum vexillum. Management of Biological invasions 15.
c,d,e	A pilot study started up in 2024 to test the potential for use of e-DNA and metabarcoding on biofouling and water samples collected during in-sea cleaning operations of vessel with suction of waste. This work will also include microorganisms in biofilm.

Summary of contributions by members from Poland

ToR	Poland
a	State biological monitoring of the Polish Marine Areas was carried out under the coordination of Chief Inspectorate for Environmental Protection. Additionally, samples of ichthyofauna were also collected in transitional waters (according to EU Water Framework Directive). In 2023 Port of Gdynia and in 2024 port of Gdańsk were surveyed for the presence of non-indigenous species (NIS) according to the Joint Harmonised Procedure for the Contracting Parties of HELCOM and OSPAR on the granting of exemptions under International Convention for the Control and Management of Ships' Ballast Water and Sediments, Regulation A-4. • Dobrzycka-Krahel A., 2023. Movement of Southern European Aquatic Alien Invertebrate Species to the North and South. Water, 2023, 15(14), 2598; https://doi.org/10.3390/w15142598 • Dobrzycka-Krahel A., Stepien C.A., Nuc Z., 2023. Neocosmopolitan distributions of invertebrate aquatic invasive species due to euryhaline geographic history and human-mediated dispersal: Ponto-Caspian versus other geographic origins. Ecological Process 12 (2). https://doi.org/10.1186/s13717-022-00412-x • Ewers C., Normant-Saremba M., Keirsebelik H., Schoelynck J., 2023. The temporal abundance-distribution relationship in a global invader sheds light on species distribution mechanisms. Aquatic Invasions 18(2), 179-197. http://dx.doi.org/10.3391/ai.2023.18.2.105548 • Gruszka P., Brzeska-Roszczyk P., Pełechaty M., 2023. Alien or endangered? Historical development of Chara connivens in the Baltic coastal waters and its implication for the species management. Journal for Nature Conservation 73, 126416 https://doi.org/10.1016/j.jnc.2023.126416 • Homberger L., Xu J., Brandis D., Chan T.-Y., Keirsebelik H., Normant-Saremba M., Schoelynck J., Hou Chu K., Ewers-Saucedo C., 2022. Genetic and morphological evidence indicates the persistence of Japanese mitten crab mitochondrial DNA in Europe for over 20 years and its introgression into Chinese mitten crabs. NeoBiota 73, 137-152. • Spich K., Witalis B., Gromisz S., Szymanek L., Woźniczka A., Non-native shrimps in Polish coastal waters: first record of Palaemon longirostris H. Milne Edwards, 1837 and new sites for P. macrodactylus Rathbun, 1902. 2024, (in-review), Oceanologia • Witalis B., Hegele-Drywa J., Gromisz S., Nowak A., First record of brush-clawed shore crab Hemigrapsus takanoi (Asakura and Watanabe, 2005) in the Gulf of Gdańsk (southern Baltic Sea). 2024, (submitted), Oceanologia
b	Institute of Nuclear Chemistry and Technology (INCT) in cooperation with Remontowa Shiprepair Yard S.A. designed and tested a complete system, based on an application of electron beam irradiation, dedicated to ballast water treatment in the shipyard dock. • Rogowski M., Zimek Z., Chmielewska- Śmietanko D., Gryczka U., Smoliński T., Woźniak H., Romanowski P., Kozdra A., Chmielewski A.G., 2022, Electron accelerator based technology for ballast water treatment at floating dock. 2nd International Conference on Applications of Radiation Science and Technology (ICARST-2022), CN-290, Vienna, Austria; 22-26 August 2022.
d	• Hegele-Drywa J., Normant-Saremba M., Wójcik-Fudalewska D., Small sea with high traffic - what is the biofouling potential of commercial ships in the Baltic Sea, 2024, Biofouling, 1–10. https://doi.org/10.1080/08927014.2024.2353025
e	Participation in updating and potential improvements to the Joint Harmonised Procedure (JHP) port survey protocol and Baltic Sea and North-East Atlantic Ocean target species lists by a correspondence group co-coordinated by Finland and Spain in the HELCOM/OSPAR Joint Task Group on BALLAST & BIOFOULING in 2024.

Summary of contributions by members from Portugal

ToR	Portugal
a	In the scope of the Marine Strategy Framework Directive (MSFD), the updates of Article 11 - Monitoring Programme (MoP), and Article 13 - Programme of Measures (PMe), for descriptor 2 – non-indigenous species, were presented and approved under public consultation. MoP includes a sub-programme dedicated to NIS in hotspot areas, namely ports, harbors and marinas, according with the recommended methodology for ports, i.e. the HELCOM/OSPAR Joint Harmonised Procedure (JHP; 2013), and for harbors and marinas the extended Rapid Assessment Survey (eRAS, EC 2020). PMe aims to identify areas with high NIS introduction risk. • In January 2022, in the scope of the Marine Strategy Framework Directive (MSFD), it was published the 2020 update of the Monitoring Programme for Portugal (article 11) - https://www.dgrm.pt/documents/20143/532604/Relatorio_PMo_Parte+B_FINAL_Jan.2022.pdf/0cc15184-b895-f7ec-e46d-34292f53e1bd • In January 2023, also, in the scope of the MSFD, the Programme of Measures was updated for Portugal (article 13) - https://www.dgrm.pt/documents/20143/532604/PARTE+B_Fichas_final.pdf/15d4685b-70be-05ed-1502-edb021c70d5b The action plan for the priority pathways for the introduction of Invasive Alien Species in mainland Portugal, addressing biofouling (hull fouling in boats and ships), was approved. Resolution of the Council of Ministers Nr 45/2023 of 22nd may – Action plan for the priority pathways of unintentional introduction of Invasive Alien Species in mainland Portugal.
e	Research developed in universities and state institutions on NIS monitoring and surveillance using DNA- and RNA-based molecular tools to provide strategic planning, policy development, and operational processes. **Publications** • Amaral FG, Lavrador AS, Duarte S, Costa FO, Vieira PE. 2022. Detection and monitoring of invertebrate non-indigenous species through DNA metabarcoding in a recreational marina of the Northwest of Portugal. ARPHA Conference Abstracts 5: e87557. https://doi.org/10.3897/aca.5.e87557 • Carvalho S, Shchepanik H, Aylagas E, Berumen ML, Costa FO, Costello MJ, Duarte S, Ferrario J, Floerl O, Heinle M, Katsanevakis S, Marchini A, Olenin S, Pearman JK, Peixoto RS, Rabaoui LJ, Ruiz G, Srėbalienė G, Therriault TW, Vieira PE, Zaiko A. 2023. Hurdles and opportunities in implementing marine biosecurity systems in data-poor regions. BioScience 73: 494–512. https://doi.org/10.1093/biosci/biad056 • Duarte S, Simões L, Costa FO. 2023. Current status and topical issues on the use of eDNA-based targeted detection of rare animal species. Science of the Total Environment 904: 166675. https://doi.org/10.1016/j.scitotenv.2023.166675 • Lavrador AS, Amaral FG, Moutinho J, Vieira PE, Costa FO, Duarte S. 2024. DNA metabarcoding-based detection of non-indigenous invertebrates in recreational marinas: influence of sample type and seasonal variation. bioRxiv 2024.01.25.577180, https://doi.org/10.1101/2024.01.25.577180 • Lavrador AS, Fontes JT, Vieira PE, Costa FO, Duarte S. 2023. Compilation, revision, and annotation of DNA barcodes of marine invertebrate non-indigenous species (NIS) occurring in European coastal regions. Diversity 15: 174. Article Editor's choice. https://doi.org/10.3390/d15020174 • Moutinho J, Carreira-Flores D, Gomes PT, Costa FO, Duarte S. 2023. Assessing seasonal and spatial dynamics of zooplankton through DNA metabarcoding in a temperate estuary. Animals 13: 3876. https://doi.org/10.3390/ani13243876 • Moutinho J, Lavrador AS, Vieira PE, Costa FO, Duarte S. 2022. Assessing the seasonal dynamics of zooplankton in a recreational marina of the northwest of Portugal through multi-marker DNA metabarcoding. ARPHA Conference Abstracts 5: e87492. https://doi.org/10.3897/aca.5.e87492

- Pawlowski J, Bruce K, Panksep K, Aguirre FI, Amalfitano S, Apothéloz-Perret-Gentil L, Baussant T, Bouchez A, Carugati L, Cermakova K, Cordier T, Corinaldesi C, Costa FO, Danovaro R, Dell'Anno A, Duarte S, Eisendle U, Ferrari BJD, Frontalini F, Frühe L, Haegerbaeumer A, Kisand V, Krolicka A, Lanzén A, Leese F, Lejzerowicz F, Lyautey E, Maček I, Sagova-Marečková M, Pearman JK, Pochon X, Stoeck T, Vivien R, Weigand A, Fazi S. 2022. Environmental DNA metabarcoding for benthic monitoring: A review of sediment sampling and DNA extraction methods. Science of the Total Environment 818: 151783. https://doi.org/10.1016/j.scitotenv.2021.151783

Theses

- Jorge Moutinho. 2022. DNA metabarcoding monitoring of zooplankton for the detection of non-indigenous species (NIS): a seasonal study in a recreational marina of the northwest of Portugal. MSc in Biodiversity, Ecology and Global changes, University of Minho, Braga, Portugal.
- Fábio Amaral. 2022. Optimization of molecular tools for non-indigenous species monitoring in coastal regions of the North of Portugal. MSc in Ecology, University of Minho, Braga, Portugal.
- Ana Sofia Lavrador. Optimization of DNA metabarcoding for the early detection and improved monitoring of non-indigenous species (NIS) in Portuguese coastal ecosystems (UI/BD/150871/2021). PhD in Molecular and Environmental Biology (PBDMA), Universidade do Minho, Braga, Portugal, *ongoing*.

Communications in Scientific events

- Amaral FG, Lavrador AS, Vieira PE, Costa FO, Duarte S. Detection and monitoring of invertebrate non-indigenous species through DNA metabarcoding in a recreational marina of the Northwest of Portugal. Poster communication in the International Conference on DNA Barcoding and Biodiversity (ICDBB), Sofia, Bulgaria, May 25-27, 2022.
- Azevedo MM, Saraiva E, Duarte S. Early detection of invasive species in coastal ecosystems through DNA barcoding. Activity with basic school students. Poster communication in "Encontro Ciência 2023", Aveiro, Portugal, July 5-7, 2023.
- Duarte S. Catch me if you can: the use of environmental DNA-based tools for the detection and monitoring of invasive species. Invited oral communication in the advanced course "Invasions Biology", Department of Biology, University of Minho, Braga, Portugal, March 23, 2023.
- Duarte S, Lavrador AS, Amaral FG, Vieira PE, Costa FO. Developing and implementing DNA-based tools for detecting and monitoring non-indigenous species (NIS) in Portuguese coastal ecosystems. Invited oral communication in the Workshop "Monitoring Marine Non-Indigenous Species Through Introduction Sites". Central Fisheries Research Institute, Trabzon, Turkey, July 18-19, 2023.
- Duarte S. Catch me if you can: the use of eDNA-based tools to detect rare species. Invited oral communication in the advanced course "Next generation sequencing in environmental monitoring", Department of Biology, University of Minho, Braga, Portugal, June 25, 2022.
- Lavrador AS. Early detection of non-indigenous invertebrates in recreational marinas of the North of Portugal through DNA metabarcoding. Invited oral communication in the advanced course "Next generation sequencing in environmental monitoring", Department of Biology, University of Minho, Braga, Portugal, June 23, 2022.
- Lavrador AS. NIS-DNA: Early detection and monitoring of non-indigenous species (NIS) in coastal ecosystems based on high-throughput sequencing. Poster communication in the Mirpuri Foundation Ocean Award 2022. Honorable mention. https://mirpurifoundation.org/mirpuri-news/sailing-trophy/2022-mirpuri-foundation-ocean-award/
- Lavrador AS, Amaral FG, Moutinho J, Vieira PE, Costa FO, Duarte S. Detection and monitoring of non-indigenous invertebrate species in recreational marinas through DNA metabarcoding of zooplankton communities in the North of Portugal. Poster communication in the "ICES Annual Science Conference 2022, Dublin, Ireland, September 23, 2022.
- Lavrador AS, Amaral FG, Moutinho J, Vieira PE, Costa FO, Duarte S. Detection of non-indigenous invertebrate species in recreational marinas of North of Portugal using DNA metabarcoding: impact of season and sample type. Poster communication in the I CBMA

	OPEN DAY & II PhD|Bio SYMPOSIUM, University of Minho, Braga, Portugal, February 2, 2024. 3rd prize. • Lavrador AS, Amaral FG, Moutinho J, Vieira PE, Costa FO, Duarte S. Seasonal variation of non-indigenous invertebrate species in recreational marinas in the Northwest of Portugal using DNA metabarcoding: impact of sample type. Oral communication in the IV International Meeting of the Portuguese Society of Genetics (IMPSG), Braga, Portugal, October 19-20, 2023. • Lavrador AS, Amaral FG, Moutinho J, Vieira PE, Costa FO, Duarte S. Seasonal variation of non-indigenous invertebrate species in recreational marinas in the north of Portugal using DNA metabarcoding: impact of substrate selection. Oral communication in the ICES Annual Science Conference 2023, Bilbao, Spain, September 11-14, 2023. • Lavrador AS, Fontes JT, Vieira PE, Costa FO, Duarte S. Compilation, revision, and annotation of DNA barcodes of marine invertebrate non-indigenous species (NIS) occurring in European coastal regions. Poster communication in the I PhD|Bio SYMPOSIUM, University of Minho, Braga, Portugal, 2023. • Moutinho J, Carreira-Flores D, Gomes PT, Costa FO, Duarte S. Assessing seasonal and spatial dynamics of zooplankton communities in a temperate estuary through DNA metabarcoding. Poster communication in the I CBMA OPEN DAY & II PhD|Bio SYMPOSIUM, University of Minho, Braga, Portugal, February 2, 2024. • Moutinho J, Lavrador AS, Vieira PE, Costa FO, Duarte S. Assessing the seasonal dynamics of zooplankton in a recreational marina of the northwest of Portugal through multi-marker DNA metabarcoding. Poster communication in the International Conference on DNA Barcoding and Biodiversity (ICDBB), Sofia, Bulgaria, May 25-27, 2022. • Moutinho J, Lavrador AS, Vieira PE, Costa FO, Duarte S. DNA metabarcoding monitoring of zooplankton for the detection of non-indigenous species (NIS): a seasonal study in a recreational marina of the northwest of Portugal. Poster communication in the "XVIII Encontro Nacional de Biologia Evolutiva (ENBE)", Braga, Portugal, December 15-16, 2022.

Summary of contributions by members from Sweden

ToR	Sweden
a	A nordic network for aquatic IAS, initiated by county board Västra Götaland, swedish westcoast, started January 2024. The forum has approximately 40 participants with representatives from environmental agencies, coastal county boards in Sweden, Norway, Denmark and academia.
b	Five ferries in traffic between Sweden and Denmark (Helsingborg-Helsingör) has exemption from Ballast Water Treatment. Exemptions granted by Swedish Transport Agency September 2021 (with advice from Swedish Authority for Marine and Water Management and Swedish Meterological and Hydrological Institute) and is valid for five years, with interim survey. Research ongoing to develop methodology for viability assessment in eggs and larval stages of aquatic invertebrates in ballast water. A combination of different staining methods is being tested together with various treatments enhancing the penetrability of the stains through the shells and integument. Collaboration between Stockholm University (Sweden) researchers and MicroWISE company (Denmark) to improve ballast water control.
d	The Guidelines for in-water cleaning of recreational boats are currently (2024) being revised by Swedish Authority for Marine and Water Management (SwAM). Several research projects (Chalmers University of Technology) target to evaluate different antifouling coatings and to develop a support tool for sustainable hull maintenance strategies. • Oliveira, D.R., Lagerströ̈m, M., Granhag, L., Werner, S., Larsson, A.I., Ytreberg, E., 2022. A novel tool for cost and emission reduction related to ship underwater hull maintenance. Journal of Cleaner Production, Vol 356, 131882 https://doi.org/10.1016/j.jclepro.2022.131882 • Lagerströ̈m, M., Wrange, A.-L., Oliveira, D. R., Granhag, L., Larsson, A., & Ytreberg, E. 2021 Are silicone foul-release coatings a viable and sustainable alternative to biocidal antifouling coatings in the Baltic Sea region? Preprint (Version 1) available at Research Gate DOI: http://dx.doi.org/10.13140/RG.2.2.27758.54080/1 • Granhag L, Javadi M and Ytreberg E (2023) Best practice for cleaning of ship hulls (report for SwAM by Chalmers) https://research.chalmers.se/publication/535739
e	Port sampling for marine NIS in Sweden is conducted under a national monitoring program and based on the HELCOM guidelines for monitoring of NIS by extended Rapid Assessment Survey (eRAS). Twenty ports, including North Sea and Baltic Sea, are sampled with 6-year intervals. From 2022 also sampling to include comparison between eRAS and molecular methods were added.

Summary of contributions by members from United Kingdom

ToR	United Kingdom
a	The UK acceded to the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention) on the 26th May 2022. The UK domestic regulations entered into force on the 29th July 2022 and implement the Convention requirements. In doing so they establish standards and procedures for the management and control of ships' ballast water and sediments, establish a survey and certification regime for ships and prescribe technical requirements relating to ballast water management systems installed on ships. The Maritime and Coastguard Agency has also published MSN 1908 and MGN 675. MSN 1908 provides the detailed technical requirements of the obligations contained in the Regulations and MGN 675 provides guidance on certain aspects of the Regulations. Documents can be accessed here: • The Merchant Shipping (Control and Management of Ships' Ballast Water and Sediments) Regulations 2022 • MSN 1908 • MGN 675 UK national indicator assessment and thematic summary for marine NIS, which complements the OSPAR QSR 2023 NIS assessment, is being finalised and will be published in 2024. Scottish invasive non-native species horizon scanning workshop was held in 2021 with the report published in 2023. • Alves, M.T. and Tidbury, H.J. (2022). Invasive non-native species management under climatic and anthropogenic pressure: application of a modelling framework. Management of Biological Invasions, 13(2), p.259. https://doi.org/10.3391/mbi.2022.13.2.01 • Dauvin, J. C., Gofas, S., Raoux, A., Bouchet, V. M. P., Pavard, J. C., & Pezy, J. P. (2022). The American protobranch bivalve Yoldia limatula (Say, 1831) in European waters. BioInvasions Records, 11(2), 473–481. https://doi.org/10.3391/BIR.2022.11.2.20 • Dodd, J.A., Copp, G.H., Tidbury, H.J., Leuven, R.S., Feunteun, E., Olsson, K.H., Gollasch, S., Jelmert, A., O'Shaughnessy, K.A., Reeves, D. and Brenner, J. (2022). Invasiveness risks of naked goby, Gobiosoma bosc, to North Sea transitional waters. Marine Pollution Bulletin, 181, p.113763. https://doi.org/10.1016/j.marpolbul.2022.113763 • Mann D. G. (2022). Determining geographical range and alien status in diatoms: three instructive case histories of species newly recorded in the British Isles, including a non-native marine species from the Pacific, Diademoides luxuriosa, Diatom Research, https://doi.org/10.1080/0269249X.2022.2078428 • Palero, F., Ferrer-Mateu, I., Wray, B., Hughes, R., Morritt, D., Lepage, M., Kotterman, M., van der Meer, M., Tate, M., Kamanli, S.A., Smith, L., Llewellyn-Hughes, J., & Clark, P.F. (2022). Presence of a second Eriocheir species in Europe as confirmed by molecular and morphological data. Aquatic Invasions, 17(3), 374–392. https://doi.org/10.3391/ai.2022.17.3.03 • Scottish Government (2023). Provision of horizon scanning and analysis of pathways of spread of invasive species into Scotland. https://www.gov.scot/publications/provision-horizon-scanning-analysis-pathways-spread-invasive-species-scotland/ • Stæhr, P.A.U., Carbonell, A., Guerin, L., Kabuta, S.H., Tidbury, H. and Viard, F. (2023). Trends in New Records of Non-Indigenous Species (NIS) Introduced by Human Activities. https://doi.org/10.1007/s10530-021-02467-x • Taylor, J.G, Wood, C.A., Bishop, J.D.D. (2022). Mapping Invasive Alien Species in intertidal habitats within Natura 2000 sites in the Solent. Natural England and The Marine Biological Association Joint Publication JP042. Mapping Invasive Alien Species in intertidal habitats within Natura 2000 sites in the Solent - JP042 (naturalengland.org.uk) • Want, A., Matejusova, I., & Kakkonen, J.E. (2023). The establishment of the invasive non-native macroalga Sargassum muticum in the north of Scotland. Journal of the Marine Biological Association of the United Kingdom, 103, E69. https://doi.org/10.1017/S0025315423000577
b	Orkney Islands Council continues to implement the Ballast Water Management Policy for Scapa Flow (adopted in December 2013 by Orkney Islands Council). UK members are part of a study on

	biological testing of ship's ballast. A manuscript has been published which includes discussion of challenges associated with the implementation of the Ballast Water Management Convention. • LuminUltra (2022). BQUA Plus test kit evaluation for a local port authority ballast water policy. https://www.luminultra.com/resource/bqua-pluse-valuation-for-a-local-port-case-study/ • Outinen, O., Bailey, S.A., Casas-Monroy, O., Delacroix, S., Gorgula, S., Griniene, E., Kakkonen, J.E., and Srebaliene, G. (2024). Biological testing of ships' ballast water indicates challenges for the implementation of the Ballast Water Management Convention. Frontiers in Marine Science, 11, p.1334286. https://doi.org/10.3389/fmars.2024.1334286
c	Work has been undertaken looking at the persistence, prevalence and management of species associated with shipping vectors under future climate change scenarios. • Alves, M.T. and Tidbury, H.J. (2022). Invasive non-native species management under climatic and anthropogenic pressure: application of a modelling framework. Management of Biological Invasions, 13(2), p.259.
d	eDNA based surveillance of fouling organisms has been trialed. Biofouling monitoring through Rapid Assessment Surveys have been conducted at Ports and Marinas. • Wood, C.A., Tidbury, H., and Bishop, J.D.D (2024). Comprehensive marine Non-Native Species (NNS) survey for England and Wales. Defra Report. Project code MRD375.
e	A number of studies evaluating and applying NIS molecular monitoring methods are being conducted across the UK. • Fonseca, V.G., Davison, P.I., Creach, V., Stone, D., Bass, D. and Tidbury, H.J., 2023. The Application of eDNA for Monitoring Aquatic Non-Indigenous Species: Practical and Policy Considerations. Diversity, 15(5), p.631.

Summary of contributions by members from USA

ToR	USA
a	**Ongoing Research and Development** • (2020-2024) **Evaluating Effectiveness of Ballast Water Management Practices, Filters**. Lake Superior Research Institute (LSRI) is continuing a study to determine if current filtration technologies are suitable for ballast water management in the Great Lakes, specifically cold water that potentially contains ice. • (2020-2027) **Shipboard Ballast Water Management System Evaluation**. A long-term study is underway, led by the LSRI with the goal of understanding technical challenges related to the use of ballast water management systems on the Great Lakes. • (2023-2027): **Characterizing Challenging Conditions in Great Lakes Ports and Harbors**. LSRI is leading a study of water quality conditions in Great Lakes ports and harbors. Data will eventually be available in a public database that will support data queries by location/parameter/season. **Policy Updates** • **US Ballast Water and other vessel discharges.** The US Environmental Protection Agency (EPA) continues to work on rulemaking for commercial vessels in US waters. See https://www.epa.gov/vessels-marinas-and-ports/commercial-vessel-discharge-standards for details. **Publications** • Ashton, GV; Freestone, AL; Duffy, JE; Torchin, ME; Sewall, BJ; Tracy, B; Albano, M; Altieri, AH; Altvater, L; Bastida-Zavala, R; Bortolus, A; Brante, A; Bravo, V; Brown, N; Buschmann, AH; Buskey, E; Barrera, RC; Cheng, B; Collin, R; Coutinho, R; De Gracia, L; Dias, GM; DiBacco, C; Flores, AAV; Haddad, MA; Hoffman, Z; Erquiaga, BI; Janiak, D; Campean, AJ; Keith, I; Leclerc, JC; Lecompte-Perez, OP; Longo, GO; Matthews-Cascon, H; McKenzie, CH; Miller, J; Munizaga, M; Naval-Xavier, LPD; Navarrete, SA; Otalora, C; Palomino-Alvarez, LA; Palomo, MG; Patrick, C; Pegau, C; Pereda, SV; Rocha, RM; Rumbold, C; Sanchez, C; Sanjuan-Munoz, A; Schloder, C; Schwindt, E; Seemann, J; Shanks, A; Simoes, N; Skinner, L; Suarez-Mozo, NY; Thiel, M; Valdivia, N; Velez-Zuazo, X; Vieira, EA; Vildoso, B; Wehrtmann, IS; Whalen, M; Wilbur, L; Ruiz, GM (2022) Predator control of marine communities increases with temperature across 115 degrees of latitude. Science, 376:1215 http://dx.doi.org/10.1126/science.abc4916 • Ashton, GV; Zabin, CJ; Davidson, IC; Ruiz, GM (2022) Recreational boats routinely transfer organisms and promote marine bioinvasions. Biological Invasions 24:1083–1096 http://dx.doi.org/10.1007/s10530-021-02699-x • Calder, DR; Carlton, JT; Keith, I; Ashton, GV; Larson, K; Ruiz, GM; Herrera, E; Golfin, G (2022) Biofouling hydroids (Cnidaria: Hydrozoa) from a Tropical Eastern Pacific island, with remarks on their biogeography. Journal of Natural History, 56:565-606 http://dx.doi.org/10.1080/00222933.2022.2068387 • Castro, N; Carlton, JT; Costa, AC; Marques, CS; Hewitt, CL; Cacabelos, E; Lopes, E; Gizzi, F; Gestoso, I; Monteiro, JG; Costa, JL; Parente, M; Ramalhosa, P; Fofonoff, P; Chainho, P; Haroun, R; Santos, RS; Herrera, R; Marques, T; Ruiz, GM; Canning-Clode, J (2022) Diversity and patterns of marine non-native species in the archipelagos of Macaronesia. Diversity and Distributions 28:667–684 http://dx.doi.org/10.1111/ddi.13465 • Cheng, BS; Blumenthal, J; Chang, AL; Barley, J; Ferner, MC; Nielsen, KJ; Ruiz, GM; Zabin, CJ (2022) Severe introduced predator impacts despite attempted functional eradication. Biological Invasions 24:725¬–739 http://dx.doi.org/10.1007/s10530-021-02677-3 • Donelan, SC; Miller, AW; Muirhead, JR; Ruiz, GM (2022) Marine species introduction via reproduction and its response to ship transit routes. Frontiers in Ecology and the Environment 20:581–588, http://dx.doi.org/10.1002/fee.2551 • Drake L, Drillet G, Gianoli C, Zacharopoulou E (2022) The Importance of Ongoing Testing of Ballast Water Management Systems. The Maritime Executive 22 March 2022 https://www.maritime-executive.com/editorials/the-importance-of-ongoing-testing-of-ballast-water-management-systems

	• Drake, L; Lodato, D; Drillet, G (2023) 2022: a year of ballast water testing. Riviera Maritime, January 2023. https://www.rivieramm.com/news-content-hub/news-content-hub/2022-and-a-year-of-ballast-water-testing-74381 • Fanberg LM, Nagel MA, Polkinghorne CN, TenEyck MC (2023). Presence of zooplankton, eggs, and resting stages in ballast water samples from the Laurentian Great Lakes Presence of zooplankton, eggs, and resting stages in ballast water samples from the Laurentian Great Lakes. Journal of Great Lakes Research 102275. https://doi.org/10.1016/j.jglr.2023.102275 • First, MR; Robbins-Wamsley, SH; Riley, SC; Grant, JF; Molina, V; Wier TP (2022) None detected: What "zero" indicates in direct counts of aquatic microorganisms in treated ballast water. Frontiers Marine Science 1034386:1-8. https://doi.org/10.3389/fmars.2022.1034386 • Pagenkopp Lohan, KM; Darling, JA; Ruiz, GM (2022)International shipping as a potent vector for spreading marine parasites. Diversity and Distributions 28:1922–1933, http://dx.doi.org/10.1111/ddi.13592 • Ruiz, GM; Galil, BS; Davidson, IC; Donelan, SC; Miller, AW; Minton, MS; Muirhead, JR; Ojaveer, H; Tamburri, MN; Carlton, JT (2022) Global marine biosecurity and ship lay-ups: intensifying effects of trade disruptions. Biological Invasions 24:3441-3446 http://dx.doi.org/10.1007/s10530-022-02870-y • Smith JM Jr., Klein ZB, Steffen C (2022) Documentation of invasive rusty crayfish Faxonius rusticus (Girard, 1852) in Kansas. BioInvasions Records 11: 766–775, https://doi.org/10.3391/bir.2022.11.3.18 • Smith JM Jr., Klein ZB, Steffen C (2022) Documentation of invasive rusty crayfish Faxonius rusticus (Girard, 1852) in Kansas. BioInvasions Records 11: 766–775, https://doi.org/10.3391/bir.2022.11.3.18 • Tamburri, MN; Soon, ZY; Scianni, C; Øpstad, CL; Oxtoby, NS; Doran, S; Drake LA (2022) Understanding the potential release of microplastics from coatings used on commercial ships. Frontiers in Marine Science https://doi.org/10.3389/fmars.2022.1074654 **Reports** • Toward Development of a Great Lakes Relevant BWMS Testing Protocol: Assessment of Environmental Accessibility of Treated Ballast Water Upon Discharge https://minds.wisconsin.edu/handle/1793/84115 • Toward Development of a Great Lakes Relevant BWMS Testing Protocol: Use of Stains to Assess Viability of Resting Stages https://minds.wisconsin.edu/handle/1793/84116 • Land Based Evaluation of the Effectiveness of the Optimarin DN100 and DN150 Ballast Systems in the Great Lakes https://minds.wisconsin.edu/handle/1793/84040 • Bench-Scale Tests of the Newman Zone OS Ballast Water Deoxygenation Treatment https://minds.wisconsin.edu/handle/1793/83984 • The Great Waters Research Collaborative (GWRC). Land-based evaluation of the Nanobubble Ozone/Oxygen Water Cleaning System (NBOT 2x7.5 HP-60 units) developed by the NanoClear Group Inc. of Rockville, Maryland, USA http://digital.library.wisc.edu/1793/82503 • GWRC; LSRI. Lake Superior Research Institute (LSRI) Freshwater verification tests evaluating the performance of the MicroWISE BallastWISE compliance monitoring device. http://digital.library.wisc.edu/1793/81745 • GWRC; LSRI. Freshwater verification tests evaluating the performance of the Satake Ballast Eye Viable Organism Analyzer VOA1000K compliance monitoring device. http://digital.library.wisc.edu/1793/81857 • GWRC;LSRI. Bench-scale verification tests evaluating the performance of the FastBallast compliance monitoring device in freshwater. http://digital.library.wisc.edu/1793/81831 • GWRC; LSRI, Land-based evaluation of the Optimarin Ballast System, Model 334/340FX2. http://digital.library.wisc.edu/1793/82759 **Popular Media** • Protecting our oceans: Environmental issues affecting the shipping industry (13 October) SGS interview. https://www.youtube.com/watch?v=zfkBvEMfyq8&feature=youtu.be
b	**Ongoing R&D**

	• (2024-2025): **Implementation of ISO 3725: Evaluating Compliance Monitoring Devices (CMDs).** This effort is led by the U.S. Naval Research Laboratory and will perform a field-test of the newly published ISO standard related to evaluating CMDs. **Publications** • Pagenkopp Lohan KM, Aguilar R, DiMaria R, Heggie K, Tuckey TD, Fabrizio MC, Ogburn MB (2023) Juvenile Striped Bass consume diverse prey in Chesapeake Bay tributaries. Marine and Coastal Fisheries, 15:e10259 https://doi.org/10.1002/mcf2.10259 • Wassick A, Hunsucker KZ, Swain G (2022) A baseline survey to document the distribution and abundance of native and non-native barnacle species in Port Canaveral, Florida. BioInvasions Records 11: 710-720 https://doi.org/10.3391/bir.2022.11.3.13
d	**Standards Development** • (2022-2024) **Development of ISO standards for Evaluation In-Water Cleaning Technology**. University of Maryland Center for Environmental Sciences (UMCES, Dr. Mario Tamburri) is leading the development of an ISO standard to facility the testing of in-water cleaning technologies. **Ongoing R&D** • (2022-2025) **Evaluation of an autonomous, proactive in-water cleaning system for ship biofouling** & **Evaluation of ship in-water cleaning system performance and safety**. Projects are led by UMCES (Dr. Mario Tamburri). • (2023-2024) **Investigating the Fate, Behavior, and Bioavailability of Microplastics Released from Ship Antifouling Coatings**. A project relevant to biofouling and antifouling coatings is underway and led by UMCES (Dr. Mario Tamburri). **Publications** • Braga CR, Richard KN, Gardner H, Swain G, Hunsucker KZ (2023) Investigating the impacts of UVC radiation on natural and cultured biofilms: an assessment of cell viability. Microorganisms 11:1348 https://doi.org/10.3390/microorganisms11051348 • First MR, Riley SC, Islam KA, Hill V, Li J, Zimmerman RC, Drake LA (2021) Rapid quantification of biofouling with an inexpensive, underwater camera and image analysis. Management of Biological Invasions 12(3): 599–617, https://doi.org/10.3391/mbi.2021.12.3.06 • Georgiades ET, Scianni C, Davidson I, Tamburri MN, First MR, Ruiz GM, Ellard K, Deveney M, and Kluza D (2021) The Role of Vessel Biofouling in the Translocation of Marine Pathogens: Management Considerations and Challenges. Front. Mar. Sci., 28 April 2021, https://doi.org/10.3389/fmars.2021.660125 • Georgiades E, Scianni C, Tamburri MN (2023) Biofilms associated with ship submerged surfaces: Implications for ship biofouling management and the environment. Frontiers in Marine Science 10:1197366 https://doi.org/10.3389/fmars.2023.1197366 • Krause LMK, Manderfeld E, Gnutt P, Vogler L, Wassick A, Richard K, Rudolph M, Hunsucker KZ, Swain GW, Rosenhahn A (2023) Semantic segmentation for fully automated macrofouling analysis on coatings after field exposure. Biofouling 39:64-79 https://doi.org/10.1080/08927014.2023.2185143 • Ralston E, Pringle S (2023) The use of tuneable encapsulation for long-term fouling control. Journal of Marine Science and Engineering 11:1947 https://doi.org/10.3390/jmse11101947 • Ralston E, Swain G (2023) The effect of husbandry and original location on the fouling of transplanted panels. Journal of Marine Science and Engineering 11:478 https://doi.org/10.3390/jmse11030478 • Scianni C, Georgiades E, Mihaylova R, Tamburri MN (2023) Balancing the consequences of in-water cleaning of biofouling to improve ship efficiency and reduce biosecurity risk. Frontiers in Marine Science 10:1239723 https://doi.org/10.3389/fmars.2023.1239723 • Scianni C, Lubarsky K, Ceballos-Osuna L, Bates T (2021) Yes, we CANZ: initial compliance and lessons learned from regulating vessel biofouling management in California and New Zealand. Management of Biological Invasions 12(3): 727–746, https://doi.org/10.3391/mbi.2021.12.3.14 • Tamburri MN, Georgiades ET, Scianni C, First MR, Ruiz GM, Junemann CE (2021) Technical Considerations for Development of Policy and Approvals for In-Water Cleaning

	of Ship Biofouling. Front. Mar. Sci., 15 December 2021, https://doi.org/10.3389/fmars.2021.804766 • Wassick A, Hunsucker KZ, Swain G (2023) Measuring the recruitment and growth of biofouling communities using clear recruitment panels. Biofouling 39:643-660 https://doi.org/10.1080/08927014.2023.2243236
e	• Andrés J, Czechowski P, Grey E, Saebi M, Andres K, Brown C, Chawla N, Corbett JJ, Brys R, Cassey P, Correa N, Deveney MR, Egan SP, Fisher JP, Vanden Hooff R, Knapp CR, Leong SCY, Neilson BJ, Paolucci EM, Pfrender ME, Pochardt MR, Prowse TAA, Rumrill SS, Scianni C, Sylvester F, Tamburri MN, Therriault TW, Yeo DCJ, Lodge DM (2023) Environment and shipping drive environmental DNA beta-diversity among commercial ports. Molecular Ecology https://doi.org/10.1111/mec.16888