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

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International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Editor

Lisa Drake

Authors

Allegra Cangelosi • Afra Asjes • Amelia Curd • Anders Jelmert • Ana Amorim • April Blakeslee • Astrid Hoogstraten • Carolyn Tepolt • Cátia Bartilotti • Cato C. ten Hallers-Tjabbes • Chris Brown • Cynthia McKenzie • Dan Minchin • Dennis Binge • Elena Ezhova • Elizabeth Cottier-Cook • Francis Kerckhof • Frédérique Viard • Greta Srebaliene • Henn Ojaveer • Iveta Matejusova • Jenni Kakkonen • Joanna Hegele-Drywa • Judith Pederson • John Darling • Jorge Lobo Arteaga • Katja Broeg • Kimberly Howland • Lena Granhag • Lisa Drake • Louisa Wood • Mario Tamburri • Mariusz Zabrocki • Matthew First • Miina Karjalainen • Monika Normant-Saremba • Nathalie Simard • Okko Outinen • Paula Chainho • Peter Stehouwer • Sabine Reuland • Sarah Bailey • Sergej Olenin • Solvita Strake • Stacey Clarke • Stephan Gollasch • Stephanie Delacroix • Tanya Zervoudaki • Thomas Therriault

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

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i Executive summary

The goal of the International Council for the Exploration of the Seas/ Intergovernmental Oceanographic Commission/ International Maritime Organization Working Group on Ballast and Other Ship Vectors (ICES/IOC/IMO WGBOSV) is to provide scientific support to the development of international measures aimed at reducing the risk of transporting non-native species via shipping activities. This report summarizes the key findings and outcomes in 2019–2021.

A notable product of the group's work is a comprehensive review paper examining spatial and temporal trends in the transport of aquatic, non-native species over a 50-year period. On average, a new detection occurred every 8.4 days, highlighting the importance of this issue.

WGBOSV developed and submitted four papers to the IMO. These papers provided scientific underpinnings to the discussions at IMO on two of the group's ToRs: ballast water management (specifically, the verification of compliance monitoring devices, CMDs) and biofouling management. The synthesis report on biofouling that was submitted to IMO also served as the underlying scientific evidence for the first ICES Viewpoint: "Biofouling on vessels – what is the risk, and what might be done about it?". Further, four peer-reviewed papers offered insight into ballast water management by: proposing a verification protocol of CMDs, considering exceptions and exemptions to ballast water management, and evaluating the availability and suitability of sampling ports on ships. ICES science highlights were published to amplify the findings from two of these papers.

Regarding the term of reference on climate change, three peer-reviewed manuscripts that benefitted from discussions at meetings were published regarding the risk of invasions in the Arctic.

Finally, addressing the term of reference on the utility of molecular tools—an emerging approach for reliably identifying and quantifying non-native organisms—a manuscript was published. Here, the utility of using high throughput sequence metabarcoding in the context of invasion species was demonstrated. A workshop has been planned to harness the knowledge of international experts on this topic. The proposed future work will carry on these five priorities and clarify emerging, topical issues within them.

ii Expert group information

Expert group name	Joint ICES/IOC/IMO Working Group on Ballast and Other Ship Vectors (WGBOSV)
Expert group cycle	Multiannual fixed term
Year cycle started	2019
Reporting year in cycle	3/3
Chair(s)	Lisa Drake, USA
Meeting venue(s) and dates	3-5 March 2021, online meeting (43 participants)
	2-4 March 2020, Gdynia, Poland (32 participants)
	6-8 March 2019, Weymouth, UK (42 participants)

1 Introduction

This report summarizes the work of the International Council for the Exploration of the Seas/ Intergovernmental Oceanographic Commission/ International Maritime Organization Working Group on Ballast and Other Ship Vectors (ICES/IOC/IMO WGBOSV) during 2019–2021. Specifically, the progress made toward each of the five terms of reference (ToRs) is detailed in the following sections. The output of various member countries is presented in Annex 3.

2 ToR a) National reports

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

Following the national reports, wide-ranging discussions occurred. Common themes and research gaps emerged: in-water cleaning and capture of biofouling, environmental deoxyribonucleic acid (eDNA) research, ballast water "same risk area" assessments, the disconnect between the scientific community and regulators (and concern about new legislation that had been recently passed), and the validation of ballast water compliance tools. Once identified, some of these topics were further investigated under other ToRs. The results were to draft papers or plan future discussions (see the outputs of the other ToRs below).

When national reports were presented, the AquaNIS database/dataset was also discussed (www.corpi.ku.lt/databases/index.php/aquanis). It is a main repository of new data on non-native species, with each country updating the database annually. Geo-referenced data can now be stored, and interactive tools for data inquiry have been added. The value of AquaNIS was illustrated as data were collected and collated for the review paper discussed in Section 2.1).

2.1 Historical perspective on introductions of non-native species

In an ambitious project led by WGBOSV and in collaboration with the Working Group on Introductions and Transfer of Marie Organisms (WGITMO), temporal and spatial trends in the introduction of aquatic, non-native species were analyzed over a 50-year period (1965–2015). In total, >2200 records of detection across 49 aquatic ecosystems were analyzed. The 29 co-authors concluded that, on average, a new detection occurred every 8.4 days. Given that many introductions are not reported, this value is surely an underestimate, and the authors highlighted the urgent need for standardized detection methods to be employed over long time scales. The results of this study can be used to inform management decisions. Limited resources must be allocated to reduce the transport, release, and spread of non-native species, which occur via multiple pathways. Additionally, this 50-year perspective provides an important lens through which the effects of regulatory measures can be assessed over time.

Reference

Bailey SA, Brown L, Campbell ML, Canning-Clode J, Carlton JT, Castro N, Chainho P, *et al.* 2020. Trends in the detection of aquatic non-indigenous species across global marine, estuarine and freshwater ecosystems: A 50-year perspective. Diversity and Distributions, 26: 1780-1797. https://doi.org/10.1111/ddi.13167

3 ToR b) Ballast water management

Evaluate test conditions, methods for collection of ballast water, or analysis of samples to inform national and/or international procedures for type approval and compliance testing of ballast water management systems

Across the three annual meetings, a variety of topics was discussed: compliance monitoring devices (CMDs); national, regional, and international ballast water management; characterizing the relationship between release of species and the risk of invasion; measurement error at ballast water test facilities; field monitoring programs; sample ports, probes and collection devices; standard operating procedures that will be used by researchers during the IMO Experience Building Phase (document PPR 5/5/2 previously submitted by ICES); long-term data from testing ballast water management systems (BWMS), testing of total residual oxidant (TRO) sensors to be used for BWMS; and biological community composition in samples after BWMS treatment vs. those after ballast water exchange.

Because many members were concerned with the lack of specific guidance on ballast water compliance testing that was provided by the IMO, two papers were drafted by the group to provide input to IMO on the topic of verifying ballast water CMDs. Here, a framework for verification was suggested. A peer-reviewed paper that summarized the IMO papers was published, and an ICES Highlight was written and circulated to announce the manuscript. Another peer-reviewed paper was published on shipboard "sample ports" that are used to collect ballast water samples. This paper benefitted from discussions at ICES/IOC/IMO WGBOSV annual meeting. A third peer-reviewed paper to analyze alternatives to ballast water management was conceived at an annual meeting, written by ICES/IOC/IMO WGBOSV members, and later published. It, too, was accompanied by an ICES Highlight.

3.1 Verification of ballast water compliance monitoring devices

Based on the group's expertise and other documents submitted to the IMO, members of ICES/IOC/IMO WGBOSV drafted a paper proposing a protocol for validating CMDs (PPR 7/21). The framework suggested an experimental design of laboratory and shipboard measurements, and it included minimum recommendations for accuracy, precision, detection limits, and reliability. The paper was discussed informally at the 7th meeting of the IMO Pollution Prevention and Response (PPR) sub-committee. Afterwards, to progress this work at IMO, ICES worked informally and by correspondence to update PPR 7/21 to reflect the discussions. The result was document PPR 8/11. Both of these documents substantially contributed to the discussion about CMDs at IMO.

This topic is of critical important as the IMO International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention) is implemented by port States. That is, if port State control Officers take ballast water samples and analyse them using CMDs, the CMDs must have been be validated to demonstrate that they produce reliable, accurate results. The proposed protocol was codified as a peer-reviewed paper, which was published in the ICES TIMES journal (Tamburri *et al.* 2020). Afterwards, the publication was announced with an ICES Highlight.

The IMO has convened a correspondence group to finalize the IMO protocol for the verification of CMDs. Members of ICES/IOC/IMO WGBOSV—under ICES' status as an Intergovernmental Organization having an agreement with IMO—are providing input to the correspondence group.

References

Canada, Denmark, Germany, and ICES. 2020. Revised proposed protocol for the verification of ballast water compliance monitoring devices. Submitted by Canada, Denmark, Germany, and ICES to PPR 8 as document PPR 8/11. International Maritime Organization. pp. 1-13

Drake LA, Bailey SA, Brydges T, Carney KJ, Ruiz GM, Bayly-Stark J, Drillet G, Everett RA. 2021. Design and installation of ballast water sample ports: Current status and implications for assessing compliance with discharge standards. Marine Pollution Bulletin 167 https://doi.org/10.1016/j.marpolbul.2021.112280

IOC-UNESCO, ICES, and ISO. 2019. Proposed protocol for the verification of ballast water compliance monitoring devices. Submitted by IOC-UNESCO, ICES, and ISO to PPR 7 as document PPR 7/21. International Maritime Organization. pp. 1-12.

Tamburri MN, Bailey SA, Everett RA, First MR, Gollasch S, Outinen O, Drake LA. 2020. Protocol for the Verification of Ballast Water Compliance Monitoring Devices. ICES Techniques in Marine Environmental Science, Volume 63 13 pp http://doi.org/10.17895/ices.pub.5465

ICES Science Highlight: Protocol for the Verification of Ballast Water Compliance Monitoring Devices https://www.ices.dk/news-and-events/news-archive/news/Pages/TIMES63.aspx

3.2 Exceptions and exemptions for ballast water management

The BWM Convention has set regulations for ships to utilize "Exceptions" (Regulation A-3) and "Exemptions" (Regulation A-4) from ballast water management under specific circumstances. While the IMO has issued guidelines to apply these procedures, in practice, many questions remain. This desk study evaluated local and regional risk assessment case studies to provide clarity for situations where ships could be excepted or exempted from ballast water management (without subjecting recipient locations to the risk of new introductions of non-native species).

The study concluded that exceptions based on the same location concept under Regulation A-3.5 should be confined to the smallest feasible areas within a harbour. Exemptions under Regulation A-4 must be based on scientifically robust risk assessments indicating an acceptable low risk for each shipping route. Additionally, exceptions and exemptions should not be considered as common alternatives for ballast water management.

References

Outinen O, Bailey SA, Broeg K, Chasse J, Clarke S, Daigle RM, Gollasch S, Kakkonen JE, Lehtiniemi M, Normant-Saremba M, Ogilvie D, Viard F. 2021. Exceptions and exemptions under the ballast water management convention – Sustainable alternatives for ballast water management? Journal of Environmental Management 293 https://doi.org/10.1016/j.jenvman.2021.112823

ICES Science Highlight: Sustainable Alternatives to Exceptions and Exemptions for Ballast Water Management https://www.ices.dk/news-and-events/news-archive/news/Pages/Sustainable-alternatives-to-exceptions-and-exemptions-for-ballast-water-management.aspx?gmc=rjc3emSRHk&gm=302&gml=vsmq3V0bRu&gmv=0

4 ToR c) Climate change

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

Presentations considered various aspects of this ToR: suitable habitats for non-native species, eDNA in ballast water and biofouling on an ice-breaking research vessel, variation in eDNA in an Arctic commercial port, the acceleration of invasions in the Arctic, and harmful algal blooms in the Arctic.

Three peer-reviewed papers were published that benefited from (and acknowledged) presentations and surrounding discussions at annual meetings of ICES/IOC/IMO WGBOSV and WGITMO. Collectively, the papers roadmap the risks of invasions in Arctic and provide predictions for invasions. Using the semi-quantitative Canadian Marine Invasive Screening Tool (CMIST), the distribution of species that may pose the highest risk for invasion was determined.

References

Chan FT, Stanislawczyk K, Sneekes AC, Dvoretsky A, Gollasch S, Minchin D, David M, *et al.* 2019. Climate change opens new frontiers for marine species in the Arctic: Current trends and future invasion risks. Global Change Biology, 25: 25-38 https://doi.org/10.1111/gcb.14469

Goldsmit J, McKindsey CW, Shlegel RW, Stewart DB, Archambault P, Howard KL. 2020. What and where? Predicting invasion hotspots in the Arctic marine realm. Global Change Biology 26:4752-4771 DOI: 10.1111/gcb.15159

Goldsmit J, McKindsey CW, Stewart B, Howard KL. 2021. Screening for High-Risk Marine Invaders in the Hudson Bay Region, Canadian Arctic. Frontiers in Ecology and Evolution https://doi.org/10.3389/fevo.2021.627497

5 ToR d) Biofouling

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

Updates on biofouling research or regulations were provided on the UNDP-GEF-IMO GloFouling Partnerships project, as well as on the regional level (i.e., the Baltic, via Project COMPLETE), and the national level. Additionally, presentations were given on the topics of: copper leakage from coated panels, monitoring programs and sampling techniques, regional programs to detect biofouling on merchant or regional ships, and the evaluation of in-water cleaning and capture systems and in-water grooming systems.

In an effort led by WGITMO—and in collaboration with members of ICES/IOC/IMO WGBOSV—the report forming the underlying scientific evidence for the first ICES Viewpoint ("Biofouling on vessels – what is the risk, and what might be done about it?") was published. The purpose of Viewpoint is to provide unsolicited advice on topical issues, in this instance, on the management of ships' biofouling. The following recommendations were made (Galil *et al.* 2019):

- Update the current IMO guidelines on biofouling (Resolution MEPC.207(62)) to provide information for specific ship types and to urgently implement the updated guidelines;
- Incorporate the reduction of biofouling in ships' designs;
- Have all vessels (commercial, recreational, inoperable) follow to a standard to control and manage biofouling;
- Assess the efficacy of management practices.

This significant paper was accompanied by a longer, supporting document that provided a fulsome background and references for the Viewpoint. These papers were subsequently submitted to the IMO (PPR 7/7 and PPR 7/INF.2), which is undertaking a review of the existing Biofouling Guidelines. Members of ICES/IOC/IMO WGBOSV and WGITMO—under the ICES delegation at IMO—are providing input to the correspondence group that is updating the Guidelines.

References

Galil BS, McKenzie C, Bailey S, Campbell M, Davidson I, Drake L, Hewitt C, Occhipinti-Ambrogi A, Piola R. 2019. ICES Viewpoint background document: Evaluating and mitigating introduction of marine non-native species via vessel biofouling. ICES Ad Hoc Report 2019. 17 pp. https://doi.org/10.17895/ices.pub.4680

ICES. 2019. Additional actions to minimize biofouling introductions. Submitted by ICES to PPR 7 as document PPR 7/7. International Maritime Organization. pp. 1-3.

ICES. 2019. ICES VIEWPOINT: Biofouling on vessels – what is the risk, and what might be done about it? In *Report of the ICES Advisory Committee, 2019, vp.2019.01.https://doi.org/10.17895/ices.advice.4687*

ICES. 2019. References to inform additional actions to evaluate and minimize biofouling introductions. Submitted by ICES to PPR 7 as document PPR 7/INF.2. International Maritime Organization. pp. 1-23.

6 ToR e) Molecular tools

Evaluate the development of DNA- and RNA-based molecular tools for surveillance and monitoring of ship-borne invasive species

Presentations were delivered to highlight issues with molecular tools as they relate to the working groups' aims and needs. Other presentations were given on the topics of: regional connectivity of non-native species, detecting rapid differentiation in marine invaders, challenges and possibilities of genome-editing technology, using metabarcoding to assess the risk of non-native species introductions via ballast water, the persistence and extinction of eDNA signals, and differences in detecting organisms in marinas using traditional methods vs. metabarcoding.

At the WGBOSV/ WGITMO joint meeting in 2019, it was agreed that a workshop was needed to address the use of eDNA and metabarcoding for detecting and monitoring invasive species (i.e., a workshop to review and provide guidance on the utilization of these tools). ToRs for the workshop were subsequently developed. The workshop will be held in conjunction with the 11th International Conference on Marine Bioinvasions (ICMB XI, https://www.marinebioinvasions.info/). Initially, the conference was to be held in 2021, but due to the COVID-19 pandemic, the conference was delayed until 2022. The workshop will go forward then.

A peer-reviewed paper that benefitted from discussions on the joint day with WGITMO was published. Using field samples, the utility of using high throughput sequence metabarcoding to characterize ballast water communities was demonstrated, and differences in the effort required to estimate diversity across receiving ports was revealed.

Reference

Darling JA, Martinson J, Pagenkopp-Lohan K, Carney KJ, Pilgrim E, Banerji A, Holzer KK, Ruiz GM. 2020. Metabarcoding quantifies differences in accumulation of ballast water borne biodiversity among three port systems in the United States. Science of the Total Environment 749:141416

7 Next steps

Many scientific questions remain pertaining to the introduction of non-native species via ballast water and other ship-based vectors.

During the 2021 virtual meeting, the working group agreed there are multiple research/policy needs that WGBOSV is uniquely suited to address—and given the expertise in the group—*should* address. Further, the group is a good mix of long-term and medium-term contributors who are leaders in this field, as well as new members who are early career researchers. To lead the important work of the group, a new Chair was elected: Mr. Okko Outinen, Finland. To frame and guide the work, and new set of ToRs and deliverables for 2022–2024 was developed by ICES/IOC/IMO WGBOSV members.

Annex 1: List of participants

Name	Institute	Country (of institute)
Allegra Cangelosi	Penn State Behrend	USA
Afra Asjes	Wageningen University & Research	The Netherlands
Amelia Curd	Ifremer	France
Anders Jelmert	Institute of Marine Research	Norway
Ana Amorim	Universidade de Lisboa	Portugal
April Blakeslee	East Carolina University	USA
Astrid Hoogstraten	Marine Eco Analytics	The Netherlands
Carolyn Tepolt	Woods Hole Oceanographic Institution	USA
Cátia Bartilotti	Instituto Português do Mar e da Atmosfera (IPMA)	Portugal
Cato C. ten Hallers-Tjabbes	Royal Netherlands Institute for Sea Research	The Netherlands
Chris Brown	California State University Maritime Academy	USA
Cynthia McKenzie	Fisheries and Oceans Canada	Canada
Dan Minchin	Unaffiliated	Ireland
Dennis Binge	Bundesamt für Seeschifffahrt und Hydrographie	Germany
Elena Ezhova	Russian Academy of Science	Russian Federation
Elizabeth Cottier-Cook	Scottish Association for Marine Science	United Kingdom
Francis Kerckhof	Royal Belgian Institute of Natural Sciences (MUMM)	Belgium
Frédérique Viard	Institute of Evolutionary Sciences of Montpellier (ISE.M)	France
Gary Chew	International Maritime Organization	N/A
Greta Srebaliene	Marine Research Institute of the Klaipeda University	Lithuania
Henn Ojaveer	University of Tartu	Estonia
Iveta Matejusova	Marine Scotland Science	UK
Jenni Kakkonen	Orkney Islands Council, Marine Services	UK
Joanna Hegele-Drywa	University of Gdansk	Poland
John Alonso	International Maritime Organization	N/A
Judith Pederson	MIT Sea Grant College Program	USA
John Darling	Environmental Protection Agency	USA
Jorge Lobo Arteaga	Instituto Português do Mar e da Atmosfera (IPMA)	Portugal
Katja Broeg	Bundesamt für Seeschifffahrt und Hydrographie	Germany
Kimberly Howland	Fisheries and Oceans Canada	Canada
Lena Granhag	Chalmers University of Technology	Sweden
Lisa Drake (Chair)	SGS Marine Field Services & Monitoring	USA

Louisa Wood	Centre for Environment, Fisheries and Aquaculture Science	UK
Mario Tamburri	Center for Environmental Science	USA
Mariusz Zabrocki	Bundesamt für Seeschifffahrt und Hydrographie	Germany
Matthew First	U.S. Naval Research Laboratory	USA
Megan Jensen	International Maritime Organization	N/A
Miina Karjalainen	Project COMPLETE	Finland
Monika Normant-Saremba	University of Gdansk	Poland
Nathalie Simard	Fisheries and Oceans Canada	Canada
Okko Outinen	Finnish Environment Institute (SYKE)	Finland
Paula Chainho	University of Lisbon	Portugal
Peter Stehouwer	SGS Marine Field Services & Monitoring	Germany
Sabine Reuland	Bundesamt für Seeschifffahrt und Hydrographie	Germany
Sarah Bailey	Fisheries and Oceans Canada	Canada
Sergej Olenin	Marine Research Institute of the Klaipeda University	Lithuania
Solvita Strake	University of Latvia	Latvia
Stacey Clarke	Centre for Environment, Fisheries and Aquaculture Science	United Kingdom
Stephan Gollasch	GoConsult	Germany
Stephanie Delacroix	NIVA	Norway
Tanya Zervoudaki	Hellenic Centre for Marine Research	Greece
Theofanis (Teo) Karayannis	International Maritime Organization	N/A
Thomas Therriault	Fisheries and Oceans Canada	Canada

Annex 2: WGBOSV Resolution

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

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2019	6-8 March	Weymouth, UK		
Year 2020	2–4 March	Gdynia, Poland		
Year 2021	3–5 March	Online meeting	Final report by 1 May to SCICOM	

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	Evaluate test conditions, methods for collection of ballast water, or analysis of samples to inform national and/or international procedures for type approval and compliance testing of ballast water management systems.	The Convention for the Control and Management of Ships' Ballast Water and Sediments, (2004) (BWMC) aims to minimize the transfer of harmful aquatic organisms with the ballast water from ships. It is imperative that the BWMC is implemented in a scientifically valid and standardized way globally. There are science and advisory requirements related to validated methods and procedures.	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 evaluate climate change impacts on the establishment and spread of ship-mediated nonindigenous species, particularly with respect	This work will be carried out jointly with WGITMO. Contributes to SICCME and ICES high-priority action area 'Arctic research'.	2.1; 2.5; 4.4	3 years	Contribution to a peer-reviewed manuscript (with WGITMO as the lead).

	to the Arctic.				
d	Investigate and evaluate methods/technologies to assess risks of, to minimize extent of, and to respond to vessel biofouling to inform national and/or international policies or guidelines.	This work will be carried out jointly with WGITMO. Ships' biofouling is, with ballast water, a primary bioinvasion vector. As management of invasion vectors is the only effective way to reduce risks of new invasions, addressing biofouling issues is of high priority in bioinvasions management.	2.7; 6.1; 6.4	3 years	Strengthen ties to the IMO GloFouling partnerships through meeting participation and increased discussion of research aims; report to ICES.
e	Evaluate the development of DNA- and RNA-based molecular tools for surveillance and monitoring of ship-borne invasive species.	Considering the complexity of the taxonomic groups to which invasive species belong, the decline in taxonomic expertise, the need for robust monitoring efforts, and the need for 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 methods. Although some challenges remain, these methods warrant close scrutiny.	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 or peer-reviewed manuscript.

Summary of the Work Plan

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

Supporting information

Priority	The work of the Group forms the scientific basis for essential advice related to the movement of invasive 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 some 25-35 members and guests, but has more than 65 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. Potential or occasional linkage with WGBIODIV, WGHABD, 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: Completed ToRs - Detailed summary by country

High-level summary

All the ToRs are completed. The progress is summarized the below table.

ToR	ToR Description	Progress in relation to ToR
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.	Useful discussions occurred as the national reports from 14-16 countries were given at each meeting. Common themes and research gaps were identified: in-water cleaning and capture of biofouling, eDNA research, ballast water "same risk area" assessments, the disconnect between the scientific community and regulators (and concern about new legislation that had been recently passed), and the validation of ballast water compliance tools. Given the breadth of the information presented in the national reports, it was acknowledged that this three-year report at the end of the term (as well as future reports) would be unwieldy if they contained all of the information presented. It was agreed that a more succinct—but complete—way to capture all of this information would be for member countries to list their work relevant to each ToR in tabular form. A template was circulated and filled out. See Annex 3 for the completed tables.
b	Evaluate test conditions, methods for collection of ballast water, or analysis of samples to inform national and/or international procedures for type approval and compliance testing of ballast water management systems.	This ToR solicited the most presentations, papers, and discussions. Two (2) papers were drafted by the group to provide input to IMO on the topic of verifying ballast water compliance monitoring devices: PPR 7/21 and PPR 8/11. A peer-reviewed paper was published on the topic (Tamburri *et al.* 2020), and another was published on shipboard data collected on sample ports used to collect samples (Drake *et al.* 2021).
c	Investigate and evaluate climate change impacts on the establishment and spread of ship-mediated nonindigenous species, particularly with respect to the Arctic.	Given time constraints and the interest of the group, the least amount of time was allocated to this ToR. At the annual meeting in 2020, on the joint day with WGITMO, the two groups were joined by members of the Working Group on Harmful Algal Bloom Dynamics (WGHABD). This session focused on presentations regarding harmful algal blooms in the Arctic. Three (3) peer-reviewed papers benefited from presentations and surrounding discussions in WGBOSV and WGITMO (Chan *et al.* 2019, Goldsmit *et al.* 2020 and 2021).
d	Investigate and evaluate methods/technologies to assess risks of, to minimize extent of, and to respond to vessel biofouling to inform national and/or international policies or guidelines.	This ToR was shared with WGITMO, and along with members of WGBOSV, two (2) papers were submitted to IMO, as it undertakes a review of the existing biofouling guidelines: PPR 7/7 and PPR 7/INF.2. Additionally, presentations were made on the joint day of the annual meetings to discuss in-water cleaning and capture.

ToR	ToR Description	Progress in relation to ToR
e	Evaluate the development of DNA- and RNA-based molecular tools for surveillance and monitoring of ship-borne invasive species.	Presentations were delivered by members of WGBOSV, WGITMO, or WGHABD (the latter at the meeting in 2020) to highlight issues with molecular tools as they relate to the working groups' aims and needs. Following the recommendation of the WGBOSV-WGITMO joint meeting in 2019 that a workshop was needed to address these pressing issues, ToRs for the workshop were developed. The workshop will be held in conjunction with the 11th International Conference on Marine Bioinvasions (ICMB XI, delayed from 2021 to 15-19 MAY 2022).

Detailed summary by country

At the 2020 annual meeting, it was decided that the final, three-year report should capture accomplishments related to the ToRs in more detail than could practicably be included in the body of the report. Thus, a template was provided to organize this information. The information is summarized, by members' countries in the below tables.
In all tables, 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** = Evaluate test conditions, methods for collection of ballast water, or analysis of samples to inform national and/or international procedures for type approval and compliance testing of ballast water management systems
- **c** = Investigate and evaluate climate change impacts on the establishment and spread of ship-mediated nonindigenous species, particularly with respect to the Arctic (joint ToR with the Working Group on Introductions and Transfers of Marine Organisms [WGITMO])
- **d** = Investigate and evaluate methods/technologies to assess risks of, to minimize extent of, and to respond to vessel biofouling to inform national and/or international policies or guidelines (joint ToR with WGITMO)
- **e** = Evaluate the development of deoxyribonucleic acid (DNA)- and ribonucleic acid (RNA)-based molecular tools for surveillance and monitoring of ship-borne invasive species

Summary of outputs by members from Canada

ToR	Canada – Updates
a	• Bailey SA, L Brown, ML Campbell, J Canning-Clode, JT Carlton, and 24 others. 2020. Trends in the detection of aquatic non-indigenous species across global marine, estuarine and freshwater ecosystems: A 50-year perspective. Diversity and Distributions 26: 1780-1797. https://doi.org/10.1111/ddi.13167
b	• Casas-Monroy O, H Rajakaruna and SA Bailey. 2020. Improving estimation of phytoplankton abundance and distribution in ballast water discharges. Journal of Applied Phycology 32:1185-1199. https://doi.org/10.1007/s10811-019-02034-x • Tamburri, M.N., Bailey, S.A., Everett, R.A., First, M.R., Gollasch, S., Outinen, O., and Drake, L.A. 2020. Protocol for the verification of ballast water compliance monitoring devices. ICES Techniques in Marine Environmental Sciences, Vol. 63. 13 pp. http://doi.org/10.17895/ices.pub.5465

ToR	Canada – Updates
	• Macintyre, H.L., Cullen, J.J., Whitsitt, T.J., and Petri, B. 2018. Enumerating viable phytoplankton using a culture-based Most Probable Number assay following ultraviolet-C treatment. Journal of Applied Phycology 30(2): 1073-1094. doi:10.1007/s10811-017-1254-8
c	• Goldsmit J, McKindsey CW, Schlegel RW, Archambault P, Howland KL. 2020. What and where? Predicting invasion hotspots in the Arctic marine realm. Glob Change Biol 26:4752-4771 doi: 10.1111/gcb.15159 https://doi.org/10.1111/gcb.15159 • Iacarella, J.C., Lyons, D.A., Burke, L., Davidson, I.C., Therriault, T.W., Dunham, A. and DiBacco, C., 2020. Climate change and vessel traffic create networks of invasion in marine protected areas. Journal of Applied Ecology, 57(9), pp.1793-1805. https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2664.13652 • Chan FT, Stanislawcyzk K, Sneekes AC, Dvoretsky A, Gollasch S, Minchin D, David M, Jelmert A, Albretsen J and SA Bailey. 2019. Climate change opens new frontiers for marine species in the Arctic: current trends and future invasion risks. Global Change Biology 25:25-38. https://doi.org/10.1111/gcb.14469
d	• Galil, B.S., McKenzie, C., Bailey, S., Campbell M., Davidson, I., Drake, L., Hewitt, C., Occhipinti-Ambrogi, A., and Piola, P. 2019. ICES Viewpoint background document: Evaluating and mitigating introduction of marine non-native species via vessel biofouling. ICES Ad Hoc Report 2019. 17 pp. https://doi.org/10.17895/ices.pub.4680
e	• Sevellec M, Lacoursière-Roussel A, Bernatchez L, Normandeau E, Solomon E, Arreak A, Fishback L, Howland K. 2020. Detecting community change in Arctic marine ecosystems using the temporal dynamics of environmental DNA. Environmental DNA 3:155. doi: 10.1002/edn3.155 https://doi.org/10.1002/edn3.155

Summary of outputs by members from Estonia

ToR	Estonia – Updates
a	• Bailey, S.A., Brown, L., Campbell, M., Canning-Clode, J., Carlton, J.T., Castro, N., Chainho, P., Chan, F.T., Creed, J.C., Curd, A., Darling, J., Fofonoff, P., Galil, B.S., Hewitt, C.L., Inglis, G.J., Keith, I., Mandrak, N.E., Marchini, A., McKenzie, C.H., Occhipinti-Ambrogi, A., Ojaveer, H., Pires-Teixeira, L.M., Robinson, T.B., Ruiz, G.M., Seaward, K., Schwindt, E., Son, M.O., Therriault, T.W. and Zhan, A. 2020. Trends in the detection of aquatic non-indigenous species across global marine, estuarine and freshwater ecosystems: A 50-year perspective. Diversity and Distributions 26:1780–1797, https://doi.org/10.1111/ddi.13167 • Tsiamis, K., Azzurro, E., Bariche, M., Cinar, M.E., Crocetta, F., De Clerck, O., Galil, B., Gomez, F., Hoffman, R., Jensen, K.R., Kamburska, L., Langeneck, J., Langer, M.R., Levitt-Barmats, Y., Lezzi, M., Marchini, A., Occhipinti-Ambrogi, A., Ojaveer, H., Piraino, S., Shenkar, N., ... Cardoso, Ana Cristina. 2020. Prioritizing marine invasive alien species in the European Union through horizon scanning. Aquatic Conservation: Marine and Freshwater Ecosystems, 30: 794–845. http://doi.org/10.1002/aqc.3267 • Tsiamis, K., Palialexis, A., Stefanova, K., Gladan, Z.N., Skejić, S., Despalatović, M., Cvitković, I., Dragičević, B., Dulčić, J., Vidjak, O., Bojanić N., Žuljević, A., Aplikioti, M., Argyrou, M., Josephides, M., Michailidis, N., Jakobsen, H.H., Staehr, P.A., Ojaveer, H., Lehtiniemi, M., Massé, C., Zenetos, A., Castriota, L., Livi, S., Mazziotti, C., Schembri, P.J., Evans, J., Bartolo, A.G., Kabuta, S.H., Smolders, S., Knegtering, E., Gittenberg, A., Gruszka, P., Kraśniewski, W., Bartilotti, C., Tuaty-Guerra, M., Canning-Clode, J., Costa, A.C., Parente, M.I., Botelho, A.Z., Micael, J., Miodonski, J.V., Carreira, G.P., Lopes, V., Chainho, P., Barberá, C., Naddafi, R., Florin, A., Barry, P., Stebbing, P.D., Cardoso, A.C. 2019. Non-indigenous species refined national baseline inventories: A synthesis in the context of the European Union's Marine Strategy Framework Directive. Mar Pol Bul 145: 429-435 https://doi.org/10.1016/j.marpolbul.2019.06.012
b	• Gollasch, S., David, M., Broeg, K., Heitmüller, S., Karjalainen, M., Lehtiniemi, M., Normant-Saremba, M., Ojaveer, H., Olenin, S., Ruiz, M., Helavuori, M., Sala-Pérez, M., Strake, S., 2020.

	Target species selection criteria for risk assessment based exemptions of ballast water management requirements, Ocean & Coastal Management, 183(105021) 10.1016/j.ocecoaman.2019.105021 • Contribution to the proposed Baltic Sea Biofouling Management Roadmap (https://balticcomplete.com/publications/project-reports/320-proposal-for-a-regional-baltic-biofouling-management-roadmap)

Summary of outputs by members from Finland

ToR	Finland – Updates
a	NIS monitoring • Konstantinos, T., Palialexis, A., Stefanova, K., Gladan, Z.N., Skejić, S., Despalatović, M., Cvitković, I., Dragičević, B., Dulčić, J., Vidjak, O., Bojanić N., Žuljević, A., Aplikioti, M., Argyrou, M., Josephides, M., Michailidis, N., Jakobsen, H.H., Staehr, P.A., Ojaveer, H., Lehtiniemi, M., Massé, C., Zenetos, A., Castriota, L., Livi, S., Mazziotti, C., Schembri, P.J., Evans, J., Bartolo, A.G., Kabuta, S.H., Smolders, S., Knegtering, E., Gittenberg, A., Gruszka, P., Kraśniewski, W., Bartilotti, C., Tuaty-Guerra, M., Canning-Clode, J., Costa, A.C., Parente, M.I., Botelho, A.Z., Micael, J., Miodonski, J.V., Carreira, G.P., Lopes, V., Chainho, P., Barberá, C., Naddafi, R., Florin, A., Barry, P., Stebbing, P.D., Cardoso, A.C. 2019. Non-indigenous species refined national baseline inventories: A synthesis in the context of the European Union's Marine Strategy Framework Directive. Mar Pol Bul 145: 429-435 https://doi.org/10.1016/j.marpolbul.2019.06.012 • Lehtiniemi, M., Outinen, O., Puntila-Dodd, R. 2020. Citizen science provides added value in the monitoring for coastal non-indigenous species. Journal of Environmental Management, 267, 110608. 10.1016/j.jenvman.2020.110608 • Outinen, O., Forsström, T., Yli-Rosti, J., Vesakoski, O., Lehtiniemi, M. 2019. Monitoring of sessile and mobile epifauna – Considerations for non-indigenous species. Mar Pol Bul 141: 332-342. https://doi.org/10.1016/j.marpolbul.2019.02.055 • Outinen, O., Puntila-Dodd, R., Barda, I., Brzana, R., Hegele-Drywa, J., Kalnina, M., Kostanda, M., Lindqvist, A., Normant-Saremba, M., Scibik, M., Strake, S., Vuolamo, J., & Lehtiniemi, M. 2021.The role of marinas in the establishment and spread of non-indigenous species in Baltic Sea fouling communities. Biofouling.
b	Ballast water management • Gollasch, S., David, M., Broeg, K., Heitmüller, S., Karjalainen, M., Lehtiniemi, M., Normant-Saremba, M., Ojaveer, H., Olenin, S., Ruiz, M., Helavuori, M., Sala-Pérez, M., Strake, S., 2020. Target species selection criteria for risk assessment based exemptions of ballast water management requirements, Ocean & Coastal Management, 183(105021) 10.1016/j.ocecoaman.2019.105021 • Outinen, O., Bailey, S., Broeg, K., Chasse, J., Clarke, S., Daigle, R. M., Gollasch, S., Kakkonen, J. E., Lehtiniemi, M., Normant-Saremba, M., Ogilvie, D., & Viard, F. Exceptions and exemptions under the Ballast Water Management Convention – Sustainable alternatives for ballast water management? (submitted). J. Env. Man. • Outinen, O., Lehtiniemi, M., 2019. Indicative ballast water analysis testing for port State control purposes (Online report), Traficom Research Reports 32/2019. Finnish Transport and Communications Agency, Helsinki. https://www.traficom.fi/sites/default/files/media/publication/Indicative%20ballast%20water%20analysis%20testing%20for%20port%20State%20control%20purposes_Traficom_32_2019.pdf • Tamburri, M. N., Bailey, S. A., Everett, R. A., First, M. R., Gollasch, S., Outinen, O., and Drake, L. A. (2020) Protocol for the verification of ballast water compliance monitoring devices. ICES TIMES, 63. https://www.ices.dk/news-and-events/news-archive/news/Pages/TIMES63.aspx

Summary of outputs by members from France

ToR	France - Updates
a	Strategic planning • May 2019 cross-border information exchange on IAS Biosecurity in Aquatic Environments co-organised by the LIFE RAPID project and the Centre de ressources espèces exotiques envahissantes (summary report available here: http://especes-exotiques-envahissantes.fr/wp-content/uploads/2019/05/32486_ofb_rencontres-vf-vang-biosecu-et-prevention-invasion_en_bd-1.pdf) • The Atlantic Blue Port Services (@BluePorts) - Interreg Atlantic Area (2017-2020) Project main objective was to improve port-based services for the treatment of ship effluents. It was led by the Brittany Chamber of Commerce and Industry. The InvaSave mobile port UV-based treatment unit developed by Damen Green was tested with port reception facility (PRF) operators, users and policy makers, in five different ports across Europe.
b	Analysis informing compliance testing • Drillet, G. *et al.* Commissioning Testing of Ships' Ballast Water Management Systems: Lessons Learned from 350 Tests. *In prep.*
c	Ocean warming and acidification impact on microfouling • Dobretsov, S., Coutinho, R., Rittschof, D., Salta, M., Ragazzola, F. and Hellio, C., 2019. The oceans are changing: impact of ocean warming and acidification on biofouling communities. *Biofouling*, *35*(5), pp.585-595
d	Anti-biofouling bioactive compounds • Alemán-Vega, M., Sánchez-Lozano, I., Hernández-Guerrero, C.J., Hellio, C., Quintana, E.T., 2020. Exploring Antifouling Activity of Biosurfactants Producing Marine Bacteria Isolated from Gulf of California. *International Journal of Molecular Sciences* 21, 6068. https://doi.org/10.3390/ijms21176068 • Report Finistère 360°, Tourisme, Nautisme & Territoires - Etude : Antifouling et Environnement. https://professionnels.ofb.fr/index.php/fr/doc/antifouling-environnement-en-sommes-nous Biofouling in ports and marinas • Charles, M., Faillettaz, R., Desroy, N., Fournier, J., Costil, K., 2018. Distribution, associated species and extent of biofouling "reefs" formed by the alien species *Ficopomatus enigmaticus* (Annelida, Polychaeta) in marinas. Estuarine, Coastal and Shelf Science 212, 164–175. https://doi.org/10.1016/j.ecss.2018.07.007 • Leclerc, J.-C., Viard, F., González Sepúlveda, E., Díaz, C., Neira Hinojosa, J., Pérez Araneda, K., Silva, F., Brante, A., 2018a. Non-indigenous species contribute equally to biofouling communities in international *vs* local ports in the Biobío region, Biofouling 34, 784–799. https://doi.org/10.1080/08927014.2018.1502276 • Leclerc, J.-C., Viard, F., 2018b. Habitat formation prevails over predation in influencing fouling communities. Ecology and Evolution 8, 477–492. https://doi.org/10.1002/ece3.3654 • Leclerc, J. C., Viard, F., González Sepúlveda, E., Díaz, C., Neira Hinojosa, J., Pérez Araneda, K., Silva, F. & Brante, A., 2020. Habitat type drives the distribution of non-indigenous species in fouling communities regardless of associated maritime traffic. Diversity and Distributions 26:62-75. DOI: 10.1111/ddi.12997 • Leclerc, J.-C., Brante, A., Viard, F., 2021. Rapid recovery of native habitat-builders following physical disturbance on pier pilings offsets colonization of cryptogenic and non-indigenous species in a Chilean port. Marine Environmental Research 163, 105231. https://doi.org/10.1016/j.marenvres.2020.105231 • Salamon, M., Lévêque, L., Ballenghien, M., Viard, F., 2020. Spill-back events followed by self-sustainment explain the fast colonization of a newly built marina by a notorious invasive seaweed. Biological Invasions. https://doi.org/10.1007/s10530-019-02193-5
e	Molecular tools for surveillance • Couton, M., Comtet, T., Le Cam, S., Corre, E., Viard, F., 2019. Metabarcoding on planktonic larval stages: an efficient approach for detecting and investigating life cycle dynamics of benthic aliens. *Management of Biological Invasions* 10, 657–689. https://doi.org/10.3391/mbi.2019.10.4.06

	• Couton, M., Baud, A., Daguin-Thiébaut, C., Corre, E., Comtet, T. & Viard, F. (in press) High-Throughput Sequencing on preservative ethanol is effective at jointly examining infra-specific and taxonomic diversity, although bioinformatics pipelines do not perform equally. Ecology and Evolution. • Guzinski, J., Ballenghien, M., Daguin-Thiébaut, C., Lévêque, L., Viard, F., 2018. Population genomics of the introduced and cultivated Pacific kelp *Undaria pinnatifida* : Marinas-not farms-drive regional connectivity and establishment in natural rocky reefs. Evolutionary Applications 11, 1582–1597. https://doi.org/10.1111/eva.12647 • Simon, A., Arbiol, C., Nielsen, E. E., Couteau, J., Sussarellu, R., Burgeot, T., Bernard, I., Coolen, J. W. P., Lamy, J., Robert, S., Skazina, M., Strelkov, P., Queiroga, H., Cancio, I., Welch, J. J., Viard, F., & Bierne, N., 2019. Replicated anthropogenic hybridisations reveal parallel patterns of admixture in marine mussels. Evolutionary Applications, eva.12879. https://doi.org/10.1111/eva.12879 • Pearman, J.K., Ammon, U., Laroche, O., Zaiko, A., Wood, S.A., Zubia, M., Planes, S., Pochon, X., 2021. Metabarcoding as a tool to enhance marine surveillance of nonindigenous species in tropical harbors: A case study in Tahiti. Environmental DNA 3, 173–189. https://doi.org/10.1002/edn3.154 • Turon, X., Casso, M., Pascual, M., Viard, F., 2020. Looks can be deceiving: *Didemnum pseudovexillum* sp. nov. (Ascidiacea) in European harbours. Mar. Biodivers. 50, 48. https://doi.org/10.1007/s12526-020-01083-7 • Viard, F., Roby, C., Turon, X., Bouchemousse, S., Bishop, J., 2019. Cryptic Diversity and Database Errors Challenge Non-indigenous Species Surveys: An Illustration With *Botrylloides* spp. in the English Channel and Mediterranean Sea. Frontiers in Marine Science 6, 615. https://doi.org/10.3389/fmars.2019.00615

Summary of outputs by members from Germany

ToR	Germany – Updates
a	• A German shipping related regulation (paragraph 18, SeeUmwVerhV 2014, last updated 2019) requires also to manage ballast water in domestic shipping and national responsibilities in this regard are regulated by a law (SeeAufgG 2019). This may especially be of interest to all countries with coastlines along two seas or large marine ecosystems (LMEs). • A new online service is available to get a ballast water discharge permit for the Port of Hamburg. In accordance with Articles 8, 10, 13 and 18 of the "Gesetz zur Ordnung des Wasserhaushalts" (Federal Water Act) in conjunction with the "Hamburgisches Wassergesetz (HWaG)" (Hamburg Water Act) and the "Hafenverkehrsordnung" (Port Traffic Regulations) Article 41 a-c, a permit is required before you may start discharging ballast water. In this online tool a ballast water discharge permit may be applied for and your request is automatically sent to the competent authority. There are specific questions to apply for this permit, including to indicate who you are, vessels specifics, planned vessel berth in Hamburg, water origin (North Sea, Baltic Sea or outside), was ballast water management conducted to meet the D-1 or D-2 standard and the amount of water intended to be discharged. (https://serviceportal.hamburg.de/HamburgGateway/Service/Entry/BallastWaE). • Bock G, Lieberum C 2016. Neobiota in schleswig-holsteinischen Ostsee-Häfen. Project code LLUR AZ 0608.451614. Landesamt für Landwirtschaft, Umwelt und länd-liche Räume Schleswig-Holstein. 43 pp. • Bick A, Bastrop R, Kotta J, Meißner K, Myeyer K, Syomin V (2018) Description of a new species of Sabellidae (Polychaeta, Annelida) from fresh and brackish waters in Europe, with some remarks on the branchial crown of Laonome. • Holst S, Laakmann S (2018) First record of the stalked jellyfish Haliclystus tenuis Kishi-nouye, 1910 (Cnidaria: Staurozoa) in Atlantic waters. Marine Biodiversity https://doi.org/10.1007/s12526-018-0888-3 • Meßner U, Zettler ML (2018) The conquest (and avoidance?) of the brackish environ-ment by Ponto-Caspian amphipods: A case study of the German Baltic Sea. Bio-Invasions Records 7 • Rabitsch W, Heger T, Jeschke J, Saul W-C, Nehring S (2018) Analysis and prioritisation of pathways of unintentional introduction and spread of invasive alien species in Germany in accordance

ToR	Germany – Updates
	with Regulation (EU) No 1143/2014. BfN-Skripten 490. 103 pp. Bundesamt für Naturschutz, Bonn, Germany. DOI 10.19217/skr490 • Schiller J, Lackschewitz D, Buschbaum C, Reise K, Pang S, Bischof K (2018) Heading northward to Scandinavia: Undaria pinnatifida in the northern Wadden Sea. Bo-tanica Marina 61(4): 365-371. • Wranik W, Malaquias MAE (2018) Zum Auftreten der Kopfschilschnecke Haminoea solitaria (Say 1822) im Bereich der deutschen Ostseeküste. Mitt. Dtsch. malako-zool. Ges. 99, 1-20. • Klunder L, Lavaleye M, Schaars LK, Dekker R, Holthuijsen S,van der Veer HW (2019) Distribution of the dwarf surf clam *Mulinia lateralis* (Say, 1822) in the Wadden Sea after first introduction. BioInvasions Records 8(4): 818–827, https://doi.org/10.3391/bir.2019.8.4.10 • Kraberg AC, Widdicombe CE, Beckett R, Rick J, Rooks P, van Wezel R (2018) Further records of a new diatom species in the English Channel and North Sea: the importance of image-referenced data. Marine Biodiversity Records, 11:21. https://doi.org/10.1186/s41200-018-0155-0. • Jaspers C, Huwer B, Weiland-Bräuer N, Clemmesen C (2018) First record of the non-indigenous jellyfish *Blackfordia virginica* (Mayer, 1910) in the Baltic Sea. Helgol Mar Res 72: 13. https://doi.org/10.1186/s10152-018-0513- • Rabitsch W, Heger T, Jeschke J, Saul W-C, Nehring S (2018) Analysis and prioritisation of path-ways of unintentional introduction and spread of invasive alien species in Germany in accordance with Regulation (EU) No 1143/2014. BfN-Skripten 490. 103 pp. Bundesamt für Naturschutz, Bonn, Germany. DOI 10.19217/skr490 • Schanz, A., Nestler, S., Hoffmann, F., von Duerselen, C-D (2018) Assessment of Non-Indigenous Species (NIS) in the Ports of Hamburg and Kiel, Scientific Report 2017. BMVI Expertennetzwerk & Bundesamt für Seeschifffahrt und Hydrographie (BSH), 141pp. • Schanz A, Nestler S, von Duerselen C-D (2020) Assessment of Non-indigenous Species (NIS) in the Port of Cuxhaven and JadeWeserPort. Scientific Report 2018. BMVI Expertennetzwerk & Bundesamt für Seeschifffahrt und Hydrographie (BSH), 168 pp. • Lackschewitz D, Buschbaum C (2019) Mitteilungen an die Neobiota Fach AG, Hamburg (01.2019): Neobiota Monitoring 2018. • Zettler A, Zettler ML 2020a. Status und Verbreitung der Gebiets-fremden Arten (Neobiota) in den deutschen Küstengewässern der Ostsee Ergebnisse des Rapid Assessments 2019. Erstellt im Rahmen des Projektes: Erfassung, Bewertung und Kartierung benthischer Arten und Biotope (AWZ-P4, Benthos). Bundesamt für Naturschutz. 26 pp. • Zettler A, Zettler ML 2020b. Status und Verbreitung der Gebiets-fremden Arten (Neobiota) in den deutschen Küstengewässern der Ostsee. Ergebnisse des Rapid Assessments 2020. Version 1. Leibniz Institut für Ostseeforschung Warnemünde für Bundesamt für Naturschutz. 30 pp. • Kazmierczak F, Leitinger J, Schüler L, Pomrehn S (2020) Erfassung und Bewertung nicht einheimischer Arten -Neobiota- in Küstengewässern Mecklenburg-Vorpommerns Endbericht 2019. IfAÖ Institut für Angewandte Ökosystemforschung GmbH, Neu Broderstorf. 49 pp. • Nehring S, Skowronek S (2020) Die invasiven gebietsfremden Arten der Unionsliste der Verordnung (EU) Nr.1143/2014 – Zweite Fortschreibung 2019 – BfN-Skripten 574. Bundesamt für Naturschutz (BfN), Bonn. 190 pp. DOI 10.19217/skr574. • Nigmann U, Nehring S (eds) (2020) Erster nationaler Bericht Deutschlands gemäß Artikel 24 der Verordnung (EU) Nr.1143/2014 über invasive Arten für den Berichtszeitraum 2015-2018. BfN-Skripten 567. Bundesamt für Naturschutz (BfN), Bonn. 143 pp. DOI 10.19217/skr567. • Vilizzi L, Copp GH, Hill GE, et al (195 co-authors) 2021. A global-scale screening of non-native aquatic organisms to identify potentially invasive species under current and future climate condi-tions. Science of The Total Environment, 788:147868. doi: 10.1016/j.scitotenv.2021.147868 • Gollasch S, Hewitt CL, Bailey S, David M (2019) Introductions and transfers of species by ballast water in the Adriatic Sea. Marine Pollution Bulletin (Special Issue) 147, 8-15. https://doi.org/10.1016/j.marpolbul.2018.08.054. • Tsiamis K, Palialexis A, Connor D (et al) 2021 Marine Strategy Framework Directive- Descriptor 2, Non-Indigenous Species, Delivering solid recommendations for setting threshold values for non-indigenous species pressure on European seas, EUR 30640 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-32257-3, doi:10.2760/035071, JRC124136.
b	• Results of a study to evaluate how to take representative ballast water samples was published in a peer review journal (Gollasch & David 2017). Gollasch, S., David, M., 2017. Recommendations for

ToR	Germany – Updates
	representative ballast water sampling. J Sea Res 123 (Special Issue Ballast Water Management), 1-15. http://dx.doi.org/10.1016/j.seares.2017.02.010. • Evaluations of compliance monitoring and enforcement devices continued (Peperzak *et al.* 2018) and during COMPLETE a workshop was held to use these tools in the laboratory and on board also addressing methods for representative sampling. Peperzak, L., Zetsche, E.-M., Gollasch, S., Artigas, L.F., Bonato, S., Creach, V., de Vré, P., Dubelaar, G.B.J., Henneghien, J., Hess-Erga, O.-C., Langelaar, R., Larsen, A., Maurer, B., Mosselaar, A., Reavie, E.D., Rijkeboer, M., Tobiesen, A., 2018. Comparing Flow Cytometry and Microscopy in the Quantification of Vital Aquatic Organisms. Journal of Mechanical Engineering and Technology (JMET). 10 pp. DOI: 10.1080/20464177.2018.1525806 • Biological results and abiotic parameters of nearly 100 control water tests conducted during the last >10 years of BWMS performance tests with ballast water uptakes and corresponding discharges were summarized to, e.g., compare the IMO challenge water criteria with these parameter values in nature. Gollasch, S., David, M., 2021. Abiotic and biological differences in ballast water uptake and discharge samples. Marine Pollution Bulletin 164, 112046. https://doi.org/10.1016/j.marpolbul.2021.112046 • Gollasch S, David M. (2018) Ballast Water Management Convention Implementation Challenges. In: Chircop A, Coffen-Smout S, McConnell M (eds.) Ocean Yearbook 32. 456-476. • David M, Gollasch S, Penko L. (2018) Identification of ballast water discharge profiles of a port to enable effective ballast water management and environmental studies. Journal of Sea Research 133, 60–72. http://dx.doi.org/10.1016/j.seares.2017.03.001 • David M, Gollasch S 2018. Ballast water and harmful aquatic organism mobilities. 119-137. In: Monios J, Wilmsmeier (eds) Maritime Mobilities. Routledge Studies in Transport Analysis. Routledge, Oxon, New York. 224 pp. ISBN: 978-1-138-23280-8. • Gollasch S, David M. 2018. Algae viability over time in a ballast water sample. J Sea Res 123 (Special Issue Ballast Water Management), 112-114. http://dx.doi.org/10.1016/j.seares.2017.04.005 • David M, Gollasch S (2018). How to approach ballast water management in European seas. Estuarine, Coastal and Shelf Science 201, 248-255. http://dx.doi.org/10.1016/j.ecss.2016.10.018 • Magaletti E, Garaventa F, David M, Castriota L, Kraus R, Luna Gian M, Silvestri C, Forte C, Bastianini M, Falautano M, Maggio T, Rak G, Gollasch S. 2018. Developing and testing an Early Warning System for Non Indigenous Species and Ballast Water Management. J Sea Res 123 (Special Issue Ballast Water Management), 100-111. http://dx.doi.org/10.1016/j.seares.2017.03.016 • David M, Gollasch S (2019) Risk assessment for ballast water management – learning from the Adriatic Sea case study. Marine Pollution Bulletin (Special Issue), 147, 36–46. https://doi.org/10.1016/j.marpolbul.2018.02.003. • Rak G, Zec D, Markovičić Kostelac M, Joksimović D, Gollasch S, David M (2019) The implementation of the ballast water management convention in the Adriatic Sea through States' cooperation: The contribution of environmental law and institutions. Marine Pollution Bulletin (Special Issue), 147, 245–253. https://doi.org/10.1016/j.marpolbul.2018.06.012. • Gollasch S, David M. (2020) Chapter 5. Ballast water. Cambridge University Press Book "Environmental Impact of Ships". • Gollasch S, David M 2019. Ballast Water: Problems and Management. In: Sheppard C, World Seas: An Environmental Evaluation. 2nd Edition. Volume III: Ecological Issues and Environmental Impacts. Academic Press, London, United Kingdom. 666 pp. DOI: 10.1016/B978-0-12-805052-1.00014-0. • Gollasch S, David M. (2018) Ballast Water Management Convention Implementation Challenges. 456-476. In: Chircop A, Coffen-Smout S, McConnell M (eds.) Ocean Yearbook 32, Koninklijke Brill NV, Leiden, The Netherlands. 841 pp. DOI: 10.1163/9789004367005_018 • Maas J, Tegtmeier S, Quack B, Biastoch A, Durgadoo JV, Rühs S, Gollasch S, David M 2019. Simulating the spread of disinfection by-products and anthropogenic bromoform emissions from ballast water discharge in Southeast Asia. Ocean Sci., 15, 1–14. https://doi.org/10.5194/os-15-1-2019 • Dock A, Linders J, David M, Gollasch S, David J, Ziegler G (2020) Are workers on board vessels involved with chemicals from treated ballast water sufficiently protected? e A decadal perspective and risk assessment. Chemosphere 247, 125824. https://doi.org/10.1016/j.chemosphere.2020.125824.

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	• Dock A, Linders J, David M, Gollasch S, David J (2019) Is human health sufficiently protected from chemicals discharged with treated ballast water from vessels worldwide? - A decadal perspective and risk assessment. Chemosphere 235, 194-204. https://doi.org/10.1016/j.chemosphere.2019.06.101. • David M, Linders J, Gollasch S, David J (2018) Is the aquatic environment sufficiently protected from chemicals discharged with treated ballast water from vessels worldwide? A decadal environmental perspective and risk assessment. Chemosphere 207, 590-600. https://doi.org/10.1016/j.chemosphere.2018.05.136 • Outinen, O., Bailey, S., Broeg, K., Chasse, J., Clarke, S., Daigle, R. M., Gollasch, S., Kakkonen, J. E., Lehtiniemi, M., Normant-Saremba, M., Ogilvie, D., & Viard, F. 2021. Exceptions and exemptions under the Ballast Water Management Convention – Sustainable alternatives for ballast water management? J. Env. Man. 293 (2021) 112823. https://doi.org/10.1016/j.jenvman.2021.112823. • Gollasch, S., David, M., Broeg, K., Heitmüller, S., Karjalainen, M., Lehtiniemi, M., Normant-Saremba, M., Ojaveer, H., Olenin, S., Ruiz, M., Helavuori, M., Sala-Pérez, M., Strake, S., 2020. Target species selection criteria for risk assessment based exemptions of ballast water management requirements, Ocean & Coastal Management, 183(105021) 10.1016/j.ocecoaman.2019.105021 • Tamburri, M.N., Bailey, S.A., Everett, R.A., First, M.R., Gollasch, S., Outinen, O., Drake, L.A., 2020. Protocol for the verification of ballast water compliance monitoring devices. ICES Techniques in Marine Environmental Sciences, Vol. 63. 13 pp. http://doi.org/10.17895/ices.pub.5465
c	• It is expected that due to climate change a larger number of NIS native in warmer waters may become established here, especially this NIS which did previously not survive the winter conditions. This refers to both, primary introductions as well as secondary spreading species. More and more “warm-water” species were found in the southern German Bight and these were considered as range expansions from the NE Atlantic, which are likely sup-ported by climate change. • One example is *Goneplax rhomboides*, a decapod native to the NE Atlantic and Mediterranean Sea, which had until recently rarely been reported from the North Sea, with no evidence of sustainable populations. However, recent surveys documented an increasing abundance of this species in the area since 2000 (Neumann *et al.* 2013) and very recently more than 80 individuals were caught at 50 sampling stations so that the crab is now considered to occur with a self-sustaining population. It seems that low winter temperatures affect the species survival. Neumann, H., de Boois, I., Kröncke, I., Reiss, H., 2013. Climate change facilitated range expansion of the non-native angular crab *Goneplax rhomboides* into the North Sea. Mar Ecol Prog Ser 484:143-153. https://doi.org/10.3354/meps10299 • In summer 2018 a mass development of *Diadumene lineata* was observed in Kiel, Marinehafen (Hoffmann pers. comm.) and this may be climate related as 2018 was an extraordinary warm summer. • Chan *et al.* (2018) published a review of Arctic NIS and addressed also climate change. Key conclusions were that the number of NIS is expected to increase due to the expected growth in human activities that accompany continuing climate change, which may create more hospitable conditions supporting the establishment of temperate NIS in the Arctic. Chan, F.T., Stanislawcyzk, K., Sneekes, A.C., Dvoretsky, A., Gollasch, S., Minchin, D., David, M., Jelmert, A., Albretsen, J., Bailey, S.A., 2018. Climate change opens new frontiers for marine species in the Arctic: current trends and future invasion risks. Global Change Biology 25:25-38. https://doi.org/10.1111/gcb.14469
d	• Research and information efforts continue and biofouling as species introduction pathway became more in focus compared to previous years by e.g.: • Establishment of the German Round Table Biofouling as platform for knowledge transfer between stakeholders • Discussions on requirements for in-water cleaning within the German competent authorities • Development of a Best Practice Guide Biofouling Management for the Baltic Sea as part of the proposal for a Baltic Sea Biofouling Management Roadmap (https://balticcomplete.com/publications/project-reports/320-proposal-for-a-regional-baltic-biofouling-management-roadmap) • Development of a Database Biofouling Management (https://biofouling(https://biofouling--database.bsh.de/)database.bsh.de/) • Submission of a commenting paper to PPR 8 to support the review of the IMO Biofouling Guidelines (PPR 8/4/1)

ToR	Germany – Updates
	• Co-Chair of HELCOM/OSPAR TG Ballast and Biofouling • Chair of GESAMP WG44 on Biofouling and NIS • Sampling and analysis of biofouling in marinas and leisure boats • National discussions on the use of biocides in AFS • Proposal for a ZIM innovation network Antifouling Systems at the German Ministry for the Economy • Information on AFS, biofouling management as well as map on fouling pressure in German waters in German available under https://www.umweltbundesamt.de/themen/chemikalien/biozide/biozidprodukte/antifouling-mittel/bewuchsatlas-start. • Lastly, the project "Completing management options in the Baltic Sea Region to reduce risk of invasive species introduction by shipping" (COMPLETE). It tackled several gaps in ballast water and biofouling knowledge and resulted in the development of operational frameworks and actual tools, e.g., a proposal for a biofouling roadmap (see above); effective risk assessment procedures and tools as basis for ballast water management exemptions; an early warning system for NIS introductions; an integrated regional NIS monitoring system and surveillance for compliance control with ballast water management standards. https://www.balticcomplete.com/.
e	• Several metabarcoding and eDNA projects are underway to evaluate these technologies for the (rapid) identification of (non-indigenous) species. • Project GBOL - German Barcode of Life: Inventory and genetic characterization of animals, plants and fungi in Germany The GBOL project aims at capturing the genetic diversity of animals, fungi and plants in Germany. The genetic inventory of these organisms is based on their DNA barcodes. Germany has taken a leading role in an international consortium of natural history museums, zoos, herbaria, research organizations and government institutions to jointly establish the "DNA barcode library of life". • Mass sequencing of environmental samples for the development of future techniques for the identification of diatoms in water quality assessment R. Jahn, BGBM, Freie Universität Berlin - Zentraleinrichtung Botanischer Garten und Botanisches Museum Berlin-Dahlem. • PhD Research Training Group "The ecology of molecules" („EcoMol") in the framework of research topics in biodiversity and marine science at the University of Oldenburg Work package 7: Following migration of animals in the North Sea by environmental DNA (eDNA) (Gerlach, Schupp, Dittmar). • Identification of Invasive Seaweeds by Metabarcoding (NGS) S. Steinhagen, GEOMAR, Kiel. • Development of an e-DNA-based method for the detection of crayfish plague *Aphanomyces astaci* in water samples C. Wittwer, C. Nowak, Senckenberg; M. Thines, Biodiversität und Klima Forschungszentrum (BiK-F). • eDNA and metabarcoding A project is ongoing analysing Dogger Bank and German Bight samples with eDNA and metabarcoding approaches for non-indigenous species. First results indicate the presence of non-indigenous species which have not been found during the monitoring campaigns. Further analysis suggests that, e.g., *Hemigrapsus penicillatus* and *H. takanoi* should be considered as one species (Martinez pers. comm.). Pedro Martinez, Senckenberg, pmartinez@senckenberg.de

Summary of outputs by members from Lithuania

ToR	Lithuania – Updates
a	• AquaNIS. Editorial Board, 2021. Information system on Aquatic Non-Indigenous and Cryptogenic Species. World Wide Web electronic publication. www.corpi.ku.lt/databases/aquanis. Version 2.36+. Accessed 2021-03-02. AquaNIS stores and disseminates information on NIS introduction histories, recipient regions, taxonomy, biological traits, impacts, and other relevant documented data. Currently it contains data on 1984 species involved in 6203 introduction events worldwide,

ToR	Lithuania – Updates
	including species which introduction is associated with ballast water and other ship vectors. In 2019-2021 online courses were arranged for users and data contributors of AquaNIS. • Srėbalienė, G., Olenin, S., Minchin, D., & Narščius, A. (2019). A comparison of impact and risk assessment methods based on the IMO Guidelines and EU invasive alien species risk assessment frameworks. PeerJ, 7, e6965. https://doi.org/10.7717/peerj.6965 • Cheng, M., Liu, T.K., Olenin, S. and Su, P.X., 2019. Risk assessment model based on expert's perspective for ballast water management. Ocean & coastal management, 171, pp.80-86. https://doi.org/10.1016/j.ocecoaman.2019.01.009
b	• Gollasch, S., David, M., Broeg, K., Heitmüller, S., Karjalainen, M., Lehtiniemi, M., Normant-Saremba, M., Ojaveer, H., Olenin, S., Ruiz, M., Helavuori, M., Sala-Pérez, M., Strake, S., 2020. Target species selection criteria for risk assessment based exemptions of ballast water management requirements, Ocean & Coastal Management, 183(105021) 10.1016/j.ocecoaman.2019.105021 • An early warning system (EWS) on introduction of Harmful Aquatic Organisms and Pathogens (HAOP) is being developed under the EU INTERREG COMPLETE (www.balticcomplete.com) project. The EWS is functionally connected to AquaNIS, using the stored data to support decision-making to issue a warning signal in the event of a HAOP detection for environmental authorities, seafarers and port authorities. An online workshop was arranged to present the EWS and its implementation to potential users in January, 2021.
c	• Solovjova, S., Samuilovienė, A., Srėbalienė, G., Minchin, D., & Olenin, S. (2019). Limited success of the non-indigenous bivalve clam *Rangia cuneata* in the Lithuanian coastal waters of the Baltic Sea and the Curonian Lagoon. Oceanologia, 61(3), 341-349 https://doi.org/10.1016/j.oceano.2019.01.005 • Minchin, D., Arbačiauskas, K., Daunys, D., Ezhova, E., Kotta, J., Olenin, S. *et al.* (2019). Rapid expansion and facilitating factors of the Ponto-Caspian invader *Dikerogammarus villosus* within the eastern Baltic Sea. Aquatic Invasions, 14(2). 10.3391/ai.2019.14.2.02 • Vilizzi, L., Copp, G.H., Hill, J.E., Adamovich, B., Aislabie, L., Akin, D., Al-Faisal, A.J., Srėbalienė, G., Olenin, S. *et al.*, 2021. A global-scale screening of non-native aquatic organisms to identify potentially invasive species under current and future climate conditions. Science of the Total Environment, 788, p.147868. https://doi.org/10.1016/j.scitotenv.2021.147868
d	• Kotwicki, L., Weslawski, J.M., Włodarska-Kowalczuk, M., Mazurkiewicz, M., Wenne, R., Zbawicka, M., Minchin, D. and Olenin, S., 2021. The re-appearance of the Mytilus spp. complex in Svalbard, Arctic, during the Holocene: The case for an arrival by anthropogenic flotsam. Global and Planetary Change, 202, p.103502
e	• The COMPLETE project contributed to the development of molecular methods that allow quick and accurate identification of target species, i. e. species, which "may impair or damage the environment, human health, property or resources and are defined for a specific port, State or biogeographic region" (IMO, 2007. Guidelines for Risk Assessment Under Regulation A-4 of the BWM Convention) at any stage of life (https://www.balticcomplete.com/news/316-dna-barcoding-library-for-detection-of-target-non-indigenous-species-gets-new-data)

Summary of outputs by members from Poland

ToR	Poland – Updates
a	• Normant-Saremba, M., Hegele-Drywa, J., Marszewska, L., 2020. Sampling native and non-native mobile epifauna with baited traps and habitat collectors – Port of Gdynia case study (southern Baltic Sea, Poland). Oceanological and Hydrobiological Studies 49 (3): 319-327. https://doi.org/10.1515/ohs-2020-0028 • Outinen, O., Puntila-Dodd, R., Barda, I., Brzana, R., Hegele-Drywa, J., Kalnina, M., Kostanda, M., Lindqvist, A., Normant-Saremba, M., Scibik, M., Strake, S., Vuolamo, J., & Lehtiniemi, M. 2021. The role of marinas in the establishment and spread of non-indigenous species in Baltic Sea fouling communities. (submitted). Biofouling.
b	• Gollasch, S., David, M., Broeg, K., Heitmüller, S., Karjalainen, M., Lehtiniemi, M., Normant-Saremba, M., Ojaveer, H., Olenin, S., Ruiz, M., Helavuori, M., Sala-Pérez, M., Strake, S., 2020. Target species selection criteria for risk assessment based exemptions of ballast water management requirements, Ocean & Coastal Management, 183(105021) 10.1016/j.ocecoaman.2019.105021 • Outinen, O., Bailey, S., Broeg, K., Chasse, J., Clarke, S., Daigle, R. M., Gollasch, S., Kakkonen, J. E., Lehtiniemi, M., Normant-Saremba, M., Ogilvie, D., & Viard, F. Exceptions and exemptions under the Ballast Water Management Convention – Sustainable alternatives for ballast water management? J. Env. Man. 293. https://doi.org/10.1016/j.jenvman.2021.112823
d	• Contribution to the proposed Baltic Sea Biofouling Management Roadmap by assessment of biofouling potential on merchant ships and leisure boats as well as mapping of the risky areas for arrival and spreading of non-indigenous species (https://balticcomplete.com/publications/project-reports/320-proposal-for-a-regional-baltic-biofouling-management-roadmap)

Summary of outputs by members from Portugal

ToR	Portugal – Updates
a	• Afonso I., Berecibar E., Castro N., Costa J.L., Frias P., Henriques F., Moreira P., Oliveira P., Silva G., Chainho P. (2020). Assessment of the colonization and dispersal success of non-indigenous species introduced in recreational marinas. *Ecological Indicators*, 113: 106147. https://doi.org/10.1016/j.ecolind.2020.106147 • Gestoso I., Ramalhosa P., Cacabelos E., Ferrario J., Castro N., Monteiro J., Chainho P., Pham C.K., Castro J.J., Canning-Clode J. (2019). A new methodology for the study of biological invasions on coastal communities. *Frontiers in Marine Sciences*. Conference Abstract: XX Iberian Symposium on Marine Biology Studies (SIEBM XX). doi: 10.3389/conf.fmars.2019.08.00137 • Lobo-Arteaga J., Tuaty-Guerra M., Gaudêncio M. (2019). The marine brachyuran crab *Pyromaia tuberculata* (Lockington, 1877) reached Europe. *Rapp Comm Int Mer Médit* 42:183 http://ciesm.org/online/archives/abstracts/pdf/42/CIESM_Congress_2019_Cascais_article_0183.pdf • MM (2020) Reavaliação do Estado Ambiental e Definição de Metas: Parte D, Subdivisão do Continente. Estratégia Marinha, Relatório do 2º Ciclo. Ministério do Mar, República Portuguesa, p. 458 [in Portuguese] (Marine Strategy Framework Directive report). • Santos M., Oliveira P., Moita M.T., David H., Caeiro M.F., Zingone A., Amorim A., Silva A. (2019). Occurrence of *Ostreopsis* in Two Temperate Coastal Bays (SW Iberia): Insights from the Plankton. *Harmful Algae* 86: 20–36. https://doi.org/10.1016/j.hal.2019.03.003
b	• Costa E.G., Paulino C.D., Singer J.M. (2021). Verifying compliance with ballast water standards: a decision-theoretic approach. *SORT* - Statistics and Operations Research Transactions, 45 (1): 19-32. https://doi.org/10.2436/20.8080.02.107. • Costa E.G., Paulino C.D., Singer J.M. (2021). Sample size for estimating organism concentration in ballast water: A Bayesian approach. Brazilian Journal of Probability and Statistics, 35 (1), 158-171. https://doi.org/10.1214/20-BJPS470
d	• Ferrario J., Gestoso I., Ramalhosa P., Cacabelos E., Duarte B., Caçador I., Canning-Clode J. (2020) Marine fouling communities from artificial and natural habitats: comparison of resistance to

ToR	Portugal – Updates
	chemical and physical disturbances. *Aquatic Invasions* 15 (2): 196-216. https://doi.org/10.3391/ai.2020.15.2.01 • Ramalhosa P., Gestoso I., Duarte B., Caçador I., Canning-Clode J. (2019). Metal pollution affects both native and non-indigenous biofouling recruitment in a subtropical island system. *Marine Pollution Bulletin* 141: 373-386. https://doi.org/10.1016/j.marpolbul.2019.02.072
e	• Duarte, S., Vieira, P.E., Costa, F.O. (2020). Assessment of species gaps in DNA barcode libraries of non-indigenous species (NIS) occurring in European coastal regions. Metabarcoding and Metagenomics, 4: e55162. https://doi.org/10.3897/mbmg.4.55162 • Duarte S., Parente M.I., Costa A.C., Costa F.O. (2019). Species gap analysis in DNA barcode reference libraries of marine non-indigenous species in the Azores archipelago. *Frontiers in Marine Science.* Conference Abstract: XX Iberian Symposium on Marine Biology Studies (SIEBM XX). https://doi.org/10.3389/conf.fmars.2019.08.00170 • Duarte, S., Vieira, P.E., Lavrador, A.S., Costa, F.O. (2021). Status and prospects of marine NIS detection and monitoring through (e)DNA metabarcoding. Science of the Total Environment, 751, 141729. https://doi.org/10.1016/j.scitotenv.2020.141729 • Lavrador, A.S., Amaral, F.G., Vieira, P.E., Costa, F.O., Duarte, S. (2021). Surveillance of non-indigenous invertebrate species through DNA metabarcoding in recreational marinas in the North and Center of Portugal. ARPHA Conference Abstracts, 4, e64900. https://doi.org/10.3897/aca.4.e64900

Summary of outputs by members from Sweden

ToR	Sweden - Updates
d	Biofouling and hull cleaning • Oliveira D and Granhag L (2020) Ship-hull in water cleaning and its effect on fouling- control coatings. Biofouling 26:1-19 DOI: 10.1080/08927014.2020.1762079 Biofouling and antifouling • Lagerström M, Yngsell D, Eklund B and Ytreberg E (2019) Identification of commercial and recreational vessels coated with banned organotin paint through screening of tin by portable XRF, Journal of Hazardous Materials https://doi.org/10.1016/j.jhazmat.2018.09.038 • Lagerström M, Ytreberg E, Eklund A-K and Granhag L (2020) Antifouling paints leach copper in excess – study of metal release rates and efficacy along a salinity gradient. Water research 186: 116383 DOI: 10.1016/j.watres.2020.116383 • Ytreberg E, Lagerström M, Nöu S and A-K E Wiklund (2021) Environmental risk assessment of using antifouling paints on pleasure crafts in European Union waters. Journal of Environmental Management 281 111846
e	Molecular tools for monitoring of marine NIS • Obst M *et al.*, 45 authors (2020) A Marine biodiversity observation network for genetic monitoring of hard-bottom communities (ARMS-MBON) Front. Mar. Sci., 30 November 2020 | https://doi.org/10.3389/fmars.2020.572680

Summary of outputs by members from the United Kingdom

ToR	United Kingdom – Updates
a	• RAPID LIFE was a three-year project (2017-2020) piloting innovative approaches to Invasive Alien Species (IAS) (i.e. invasive NNS) management in freshwater aquatic, riparian and coastal environments across England. The goal of the project was to embed a coordinated, strategic and evidence-based approach to managing Invasive Alien Species (IAS) across England.
b	• The Orkney Islands Council Harbour Authority continues to implement the Ballast Water Management Policy for Scapa Flow. Ballast water samples are collected from every vessel wishing to discharge ballast water into Scapa Flow. A non-native species (NNS) monitoring programme is carried out in conjunction with the ballast water sampling programme. A baseline for the NNS monitoring programme was completed in 2013 and it continues annually.
c	• A recent study applied a modelling framework to examine the role temperature as a driver of Pacific oyster population dynamics (Teixeira Alves M, Taylor NGH, Tidbury HJ (2021) Understanding drivers of wild oyster population persistence. *Scientific Reports* 11:7837).
d	• In collaboration with the Orkney Harbour Authority and Solway Firth Partnership, Marine Scotland Science investigated the use of settlement panels to capture biofouling and carried out comparisons between traditional rapid assessments followed by morphology-based identification of biofouling and high throughput sequencing (HTS) outputs.
e	• 2017-2021 saw the development of a UK Non-native Species eDNA Technical Group and a UK Marine DNA Technical Group, which include representatives from academia and regulators, and aim to share knowledge to bridge the gap between research and routine monitoring applications. These groups fall under the umbrella of the UKEOF DNA Working Group. https://www.ukeof.org.uk/our-work/ukdna • In March 2019, the Defra DNA Centre of Excellence was launched. This brings together UK government agencies with shared interests in developing molecular methods, with non-native species detection recognized as one of the group's priorities. • Cefas, Natural England and Marine Scotland are developing targeted PCR assays for prioritized high-risk species, for a Defra DNA Centre of Excellence project (2019-2022). • eDNA tools have been applied to the monitoring of NNS, including *Didemnum vexillum* and in Scotland • Cefas are participating in the Interreg GEANS project 'Genetic Tools for Ecosystem Health Assessment in the North Sea Region' (2019-2023), which aims to improve sequence databases for North Sea invertebrates (including non-native species) and develop robust survey methodology. https://northsearegion.eu/geans/ • As part of Interreg ECOSTRUCTURE project a metabarcoding approach for environmental DNA was tested at coastal sites in North Wales and Ireland as a tool for early warning of non-native species introductions.

Summary of outputs by members from the United States

ToR	United States – Updates
a	Strategic planning • Prihoda *et al.* (2020) Great Lakes ballast water research and development plan, Great Waters Research Collaborative [GWRC] https://www.uwsuper.edu/lsri/gwrc/gllcisp/upload/MARAD_Great-Lakes-Ballast-Water-RD-Plan_v4_FINAL_NoAppendix.pdf
b	Evaluating test conditions • Cangelosi *et al.* (2018) Great Lakes Ship Ballast Monitoring Project Technical Report, GWRC https://www.uwsuper.edu/lsri/publications/upload/LSRI-GWRC-TR-GLSBM-1_FINAL-FOR-RELEASE_31May2018_2_ForSignature.pdf Methods for collection of ballast water • Drake *et al.* (2021) Design and installation of ballast water sample ports: Current status and implications for assessing compliance with discharge standards. Marine Pollution Bulletin Volume 167 https://doi.org/10.1016/j.marpolbul.2021.112280 • Moser *et al.* (2018) Design and validation of a ballast water compliance sampling device for shipboard use. Management of Biological Invasions [MBI] 9:497-504 https://doi.org/10.3391/mbi.2018.9.4.12 Analyses informing type approval • Alliance for Coastal Technology [ACT] (2020) Performance verification testing for total residual oxidant analyzers. https://www.act-us.info/evaluations.php • First *et al.* (2020) Measurement uncertainty in determining concentrations of living organisms. MBI 11: 493–511 https://doi.org/10.3391/mbi.2020.11.3.10 • Nelson *et al.* (2019) Identifying and classifying Great Lakes ship transits using a state machine approach. Journal of Great Lakes Research 45:384-389 https://doi.org/10.1016/j.jglr.2019.01.012 • Petersen *et al.* (2019) Ballast water treatment and bacteria: Analysis of bacterial activity and diversity after treatment of simulated ballast water by electrochlorination and UV exposure. Science of the Total Environment 648:408-421 https://doi.org/10.1016/j.scitotenv.2018.08.080 Analysis informing compliance testing • First *et al.* (2018) A test of the framework designed to evaluate compliance monitoring devices for ballast water discharge. 9:505-513 https://doi.org/10.3391/mbi.2018.9.4.13 • Polkinghorne *et al.* (2020) Bench-scale technical report: Freshwater verification of the B-QUA quick ballast water monitoring kit. GWRC http://digital.library.wisc.edu/1793/80297 • Polkinghorne *et al.* (2020) Bench-scale technical report: Tests of the Nano Bubble ozone technology (2.5 HP unit), GWRC http://digital.library.wisc.edu/1793/80441 • Polkinghorne *et al.* (2020) Bench-scale technical report: Tests of the Kria Ionizer Superoxide Generator bench-scale ballast water treatment technology, GWRC http://digital.library.wisc.edu/1793/79994 • SGS (2020) Commissioning Testing of Ballast Water Management Systems (white paper) https://www.sgs.com/en/white-paper-library/commissioning-testing-of-ballast-water-management-systems • Soler-Figueroa *et al.* (2020) Characteristics of global port phytoplankton and implications for current ballast water regulations. Marine Pollution Bulletin [MPB] 155:111165 https://doi.org/10.1016/j.marpolbul.2020.111165 • Tamburri *et al.* (2020) Protocol for the verification of ballast water compliance monitoring devices. ICES Techniques in Marine Environmental Sciences, 63:1-13 https://doi.org/10.17895/ices.pub.5465 • Ziegler *et al.* (2018) Long-term algal toxicity of oxidant treated ballast water. MPB 133:18-29
d	In-water cleaning evaluation • ACT (2020) Test plan for evaluations of the Jotun Hull Skating Solution: A proactive biofouling in-water cleaning solution. • Tamburri *et al.* (2020) In-water cleaning and capture to remove ship biofouling: An initial evaluation of efficacy and environmental safety. Frontiers in Marine Science 7:437 https://doi.org/10.3389/fmars.2020.00437 Inspection and quantification of biofouling

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