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Study on Ports Perspectives regarding Biofouling Management

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Building Partnerships to Assist Developing Countries to Minimize the Impacts from Aquatic Biofouling (GloFouling Partnerships) is a collaboration between the Global Environment Facility (GEF), the United Nations Development Programme (UNDP) and the International Maritime Organization (IMO). The project aims to develop tools and solutions to help developing countries to reduce the transfer of aquatic invasive species through the implementation of the IMO Guidelines for the control and management of ships' biofouling.
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IMO - the International Maritime Organization – is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships.
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TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

AFC – Anti-fouling Coating

AFS – Anti-fouling system

AIS – Aquatic invasive species

BES – The British Ecological Society

BFMP – Biofouling management plan

BFRB – Biofouling record book

BIMCO – Baltic and International Maritime Council

Bioinvasao Brasil – Plataforma Brasileira de Bioinvasao

BSH – Bundesamt für Seeschifffahrt und Hydrographie

CABI – Centre for Agriculture and Biosciences International

CIESM – Mediterranean Science Commission Atlas of Exotic Species

CO_2 – Carbon dioxide

COMBINA – Coastal Ocean Marine Biosecurity Integrated Network for the Americas

COMPLETE – Completing management options in the Baltic Sea Region to reduce risk of invasive species introduction by shipping

CRMS – Craft Risk Management Standard (New Zealand)

CSI – Clean Shipping Index

CSLC – California State Lands Commission

DAFF – Department of Agriculture, Fisheries and Forestry

DAISIE – Delivering Alien Invasive Species Inventories for Europe

DCBD – Dutch Caribbean Biodiversity Database

DFO – Department of Fisheries and Oceans Canada

DHI – Previously the Danish Hydraulic Institute

DPRID – Department of Primary Industries and Regional Development (Western Australia)

EASIN – European Alien Species Information Network

EC – European Commission

EEPL – National Priority List of Exotic Environmental Pests, Weeds and Diseases

EMODnet – European Marine Observation and Data Network

ESG – Environmental, social and governance

ESI – Environmental Ship Index

Especies MMA – Inventario Nacional de Especies de Chile

GB NNSS – Great Britain Non-Native Species Secretariat

GBIF – Global Biodiversity Information Facility

GEF – Global Environment Facility

GESAMP – Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

GHG – Greenhouse gas

GIA – Global Industry Alliance

GISD – Global Invasive Species Database

GLANSIS – Great Lakes Aquatic Non-indigenous Species Information System

GRIIS – Global Register of Introduced and Invasive Species

IAS – Invasive aquatic species (used in the IMO Biofouling Guidelines and throughout this document)

ICES – International Council for the Exploration of the Sea

iDigBio – Integrated Digitized Biocollections

IMO – International Maritime Organization

INVEMAR – Especies Marinas Costeras Introducidas en Colombia

IOC – Intergovernmental Oceanographic Commission

ISO – International Organization for Standardization

IWC – In-water cleaning

KIOST – Korea Institute of Ocean Science and Technology

KOMERI – Korea Marine Equipment Research Institute

LNV – Dutch Ministry of Agriculture, Nature and Food Quality

MAMIAS – Marine Mediterranean Invasive Alien Species

MARLIN – Marine Life Investigator

MGPS – Marine growth prevention system

MMA – Ministerio del Medio Ambiente

MPI – Ministry for Primary Industries (New Zealand)

MGPS – Marine growth prevention systems

NAS – Non-indigenous Aquatic Species database

NEMESIS – National Estuarine and Marine Exotic Species Information System

NIMPIS – National Introduced Marine Pest Information System

NISIC – National Invasive Species Information Center

NIWA – National Institute of Water and Atmospheric Research

NNS – Non-native species

NNSS – Great Britain Non-native Species Information Portal

NOBANIS – European Network on Invasive Alien Species

NO_x – Nitrogen oxide

NSF – National Science Foundation

OBIS – Ocean Biodiversity Information System

PICES – North Pacific Marine Science Organization

QAN – Quarantine Area Notice

REMPEC – Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea

RWS – Rijkswaterstaat (Dutch Ministry of Infrastructure and Water Management)

SAS – Static artificial structures

SERC – Smithsonian Environmental Research Center

SIG – Special Interest Group

SO_x – Sulphur oxide

STRI – Smithsonian Tropical Research Institute

UHI – University of the Highlands and Islands (Scotland)

UMCES – University of Maryland Center for Environmental Science

UNDP – United Nations Development Programme

WA – Western Australia

WG – Working group

WGBOSV – (ICES/IOC/IMO) Working Group on Ballast and Other Ship Vectors

WGITMO – (ICES) Working Group on Introductions and Transfers of Marine Organisms

WGSHIP – (ICES) Working Group on Shipping Impacts in the Marine Environment

WHOI – Woods Hole Oceanographic Institution

WRiMS – World Register of Introduced Marine species

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EXECUTIVE SUMMARY

Ports are focal points for managing the potential spread of invasive aquatic species (IAS) via ships' biofouling. By ensuring having clear plans and guidance for managing biofouling on vessels and port infrastructure, port operators can contribute to the reduction of the global transfer of IAS. Given their centrality to the issue, a study was conducted to investigate biofouling management within ports using a variety of approaches: a legal review, a literature review, surveys and interviews of stakeholders, and a survey of researchers and test-facility operators.

It was determined that the maritime community is well-positioned to implement a robust, global management programme. Several international guidelines already exist, although implementation of policies aligned with these are required in many countries. Several nations, regions, ports and terminals, however, have developed legal frameworks or strategies to implement the International Maritime Organization (IMO) Biofouling Guidelines, and some are enforcing regulations. The result of this action is two-fold. On one hand, it highlights the importance of managing biofouling, and it provides direction to stakeholders, whether they are shipowners who must effectively manage biofouling on their ships or in-water cleaning (IWC) service providers who will need approval to provide their services in ports. On the other hand, while these early adopters are moving the field forward, without a clear, unified approach, the regulations can, in some cases, be confusing and unclear. Thus, there is an urgent need for a well-defined, transparent and globally consistent approach at all scales, that is, to implement national frameworks following the existing IMO Biofouling Guidelines. Should a mandatory regime be developed and adopted, then the national frameworks should already be in place. At the same time, international standards for IWC are being developed with stakeholder input by the International Organization for Standardization (ISO), and additional guidance on IWC is under development at the time of publishing by IMO (with a target date of completion in 2025).

Finally, because research on biofouling is siloed and difficult to aggregate, a global database that collates and houses research results would be of use. Such a tool would facilitate communication across research and groups, thus speeding work on technical issues related to biofouling management. The resulting cohesive, international approach will serve stakeholders well and protect marine environments.

INTRODUCTION

Marine biofouling refers to the accumulation of aquatic organisms on submerged surfaces in general. More specifically, it is defined as "the accumulation of aquatic organisms such as microorganisms, plants and animals on surfaces and structures immersed in or exposed to the aquatic environment. Biofouling can include pathogens" (IMO 2023a). Biofouling is a natural process, and when it occurs on a surface that is moved, such as ships' hulls, organisms can be transported to a new location. Indeed, the basin-wide transfer of such communities – potential IAS[1], including pathogens – is well documented (e.g., Carlton, 1985; Coutts et al., 2003; Coutts and Taylor, 2004; Drake et al., 2005). It should be noted that the potential translocation of pathogens is a particular concern with respect to aquaculture facilities (e.g., the Shanghai Declaration Food and Agriculture Organization 2021, Subasinghe et al., 2023). This is especially striking because approximately 90% of the world's aquaculture production occurs in Asia (Karisa, 2023), which is home to many of the world's busiest ports (e.g., Nilson, 2024).

With regard to marine operations, biofouling can have dramatic, negative impacts. For example, increased hydrodynamic drag occurs even from thin slime layers (biofilms) (Schultz and Swain, 2000), leading to increased fuel consumption (e.g., Schultz, 2007; Schultz et al., 2011), which in turn results in increased greenhouse gas (GHG) emissions (e.g., Davidson et al., 2016; Farkas et al., 2021). Other effects can include the impaired manoeuvrability of vessels, corrosion of marine structures and additional operational costs due to hull cleaning and coating (e.g., Visscher, 1923; Schultz et al., 2011). While these physical consequences of biofouling are important, Davidson et al. (2016) caution the industry to focus also on the biosecurity aspects of biofouling, including on "niche" areas, which tend not to incur a fuel penalty. Niche areas are structurally complex areas, such as rudder posts, which may be more prone to biofouling than flat surfaces, such as hulls (Davidson et al., 2013).

Biofouling begins with the formation of a conditioning film (dissolved organic matter that adheres to the submerged surface), and a complex, multispecies biofilm forms on top of the organic layer as a thin layer of microorganisms (such as bacteria, fungi, microalgae and protozoans). This layer is also referred to as "microfouling" or a "slime layer" (IMO 2023a). Over time, larger organisms such as barnacles, mussels, hydroids and seaweed attach themselves to this biofilm in a dynamic process, leading to a more complex fouling community (e.g., Callow and Callow, 2011).

IMO, recognizing the important biosafety implications of marine biofouling, adopted guidelines for its management and control in 2011. They were updated in 2023. The 2023 Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species (IMO Biofouling Guidelines) recommend practices for regular hull cleaning, use of anti-fouling systems (AFS), and thorough checks for biofouling on ships' surfaces below the waterline (IMO 2023a). These guidelines aim to reduce the risks associated with biofouling, promoting environmental protection. By improving ships' hydrodynamic performance, they may also increase energy (fuel) efficiency.

Increasingly, it is recognized that IWC of ships' submerged surfaces may unintentionally translocate IAS to new ports as well as liberate pollutants from ships' coatings such as heavy metals (e.g., Morrisey et al., 2013; Scianni and Georgiades, 2019; Tamburri et al., 2021) and microplastics (Tamburri et al., 2022). These submerged surfaces may include the hull as well as niche areas. Cleaning taken as a corrective action to remove biofouling is referred to as "reactive" cleaning. There is also concern that biofilms cleaned on a periodic basis to remove microfouling ("proactive" cleaning) may also represent a biosecurity risk of introducing IAS (e.g., Georgiades et al., 2023). In response (at the time of writing), IMO is developing separate guidelines (with a planned completion date during 2025), and concurrently, the ISO is developing two standards on IWC[2]. Additionally, some Administrations, regions and ports have put in place guidelines or regulations to address these concerns.

[1] *IAS are defined as "non-native species to a particular ecosystem which may pose threats to human, animal and plant life, economic and cultural activities and the aquatic environment" (IMO 2023a). While different stakeholders and researchers use varying terminology that carries different meanings, for example, non-native species, alien species, etc., "IAS" is used here to align with IMO documents. Note that this term is also used by Blackburn et al. (2011), who propose a "unified framework for biological invasions".*

[2] *ISO 6319 on Conducting and Documenting In-Water Cleaning of Ships' Biofouling and ISO 20679 on conducting In-Water Cleaning Testing of Ship Biofouling In-Water Cleaning Systems*

Ports are focal points for biofouling management, whether by making IWC available for ships or by managing biofouling on port infrastructure. Given this centrality, this study investigates ports' biofouling management using a number of approaches: a legal review, a literature review, surveys and interviews of stakeholders, and a survey of researchers and test facility operators. First, the methods are described. Next, the results are presented. The results section is the bulk of the report, and it begins with a consideration of biofouling regulations, which proceeds from a global level to regional and then national levels, culminating in a gap analysis. Afterwards, the potential negative impacts on ports are discussed, followed by best practices that can minimize the risk of IAS. Last – because biofouling management is an evolving topic driven by technical advances – ongoing biofouling research, IAS databases and IWC test facilities are catalogued.

METHODOLOGY

Literature and legal reviews were conducted to address an array of aspects related to ports' biofouling management. Additionally – and critically – to gather the most (and highest quality) information from the broadest, global array of stakeholders, surveys were sent to relevant groups: port managers and regulators, stakeholders associated with IWC of ships' biofouling and researchers.

2.1 SURVEY – PORTS' BIOFOULING PRACTICES

To catalogue ports' biofouling regulations and identify best practices, a survey was circulated by the study team and SGS colleagues around the world. It was sent to 170 representatives of Administrations, regional managers, independent consultants on matters related to biofouling, and local ports to assess current and planned regulations, practices and training on biofouling[3]. Additionally, the survey was posted on the GloFouling LinkedIn site and sent directly to 146 stakeholders. The full set of questions is included in Annex 1.

It should be noted that questions on anti-fouling (AF) regulations were also included to ensure that respondents did not confuse the two topics (see Section 3.1.1).

2.2 SURVEY – GIA MEMBERS AND OTHER STAKEHOLDERS

To collect observations and input on ports' biofouling practices, individual members of the Global Industry Alliance (GIA) for Marine Biosafety were contacted (by email, then by phone). The GIA for Marine Biosafety was created in 2020 as part of the GEF-UNDP-IMO GloFouling Partnerships Project. Its aim is to support improved biofouling management, which in turn addresses two IMO objectives: protecting marine biodiversity and advancing decarbonization in the shipping industry.

To also include the views of other experts who are currently active in biofouling management, additional stakeholders were contacted, and they also kindly agreed to be interviewed. In total, 16 GIA members or stakeholders provided information via interviews or by correspondence. Between them, all commercial facets of biofouling management were represented: classification societies, coatings manufacturers, IWC providers, shipowners and trade associations. The interview questions are shown in Annex 2. It should be noted that all these stakeholders are early movers in the field of biofouling management, and as such, their views may be more informed regarding regulations than other stakeholders' views.

Some of the stakeholders are commercial competitors. With these circumstances in mind, all interviewees were reassured that their responses would be confidential. To honour that commitment, the detailed responses are not included in this report, and instead, where applicable, input from the group is knitted into the report.

2.3 SURVEY – DATA AVAILABLE ON BIOFOULING, IAS AND IWC

To catalogue studies on biofouling, and more broadly, research on IAS in general, a request was sent to the research and testing communities to solicit information about:

1. ongoing biofouling studies;
2. databases or websites of current IAS research;
3. IAS registries; and
4. test facilities for IWC equipment.

The survey was submitted to members of research and testing working groups (outlined in Annex 3). Across all of these groups, the survey was sent to a total of 202 researchers, some of whom forwarded it to other colleagues. Additionally, the survey was sent to other stakeholders known to the study team.

[3] *To ensure the greatest possible response rate, the survey was posted on a private company website rather than a commercial website, because commercial survey sites sometimes cannot be accessed by government officials.*

RESULTS

The following sections describe critical aspects related to ports' biofouling management. These results, analysis and subsequent conclusions are based on the literature and legal reviews, and, where applicable, the surveys' results. Detailed results from the surveys to port stakeholders and researchers are shown in Annexes 4[4] and 5 respectively. The top-level results are summarized and discussed below, starting with regulations at all levels. Next, the potential negative impacts on ports are considered, followed by best practices that can minimize the risk of IAS. Finally, the conclusions from the survey to researchers and testing organizations are provided.

3.1 REGULATORY ASPECTS

3.1.1 Regulatory Background – International Agreements

Often, national and local regulations to protect the marine environment are based on rights and obligations derived from multilateral environmental agreements, for example, international conventions. Although countries can enact local and national regulations without a multilateral agreement, ideally, a multilateral agreement is in place to promulgate national and regional regulations and provide an overarching framework to prevent a patchwork of regulations. This is particularly important in the maritime industry, where ships, platforms and equipment can visit multiple countries, each with their own regulations in place, in a matter of days. However, there is no international convention that regulates biofouling management. At present, there are only (voluntary) international guidelines and industry standards that are relevant to biofouling management. This list is shown in Annex 6.

At this time, the only international legal framework that regulates IAS associated with shipping focuses not on biofouling, but on ballast water: the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (BWM Convention). It sets out obligations to "prevent, minimize, and ultimately eliminate the risks of introduction of harmful aquatic organisms and pathogens" through the control and management of ships' ballast water and sediment (IMO 2004). This pathway, of course, differs widely from biofouling.

Another important distinction to make regarding biofouling-specific agreements is with the International Convention on the Control of Harmful Anti-fouling Systems on Ships, 2001 (AFS Convention, IMO 2001). The objective of the AFS is to reduce or eliminate adverse effects on the marine environment and human health caused by AFS, for example, coatings on ships' hulls. Thus, the AFS Convention does not aim to prevent the introduction of IAS but rather to prevent the adverse impacts from the use of AFS and the biocides they may contain, specifically, by banning certain compounds used in AFS. The AFS Convention thus deals with a different subject, namely the toxicity of the active components of AF paints and coatings.

It was evident from the survey responses that it is important to clearly differentiate biofouling management and obligations derived from the AFS Convention, because occasionally, respondents submitted AFS information as biofouling management measures. For this small number of respondents who erroneously referred to AF regulations when biofouling questions were asked, and vice versa, their responses were changed accordingly (in three instances, from a total of 79 respondents, each answering up to all seven questions provided in the survey). Regardless, it is also important to consider the AFS Convention, since it is relevant during IWC operations, as caution must be given to the removal of AFS and capturing of associated waste.

3.1.2 Regional and national biofouling management strategies

Often regulatory frameworks (in this instance, frameworks to manage biofouling) are preceded by strategies setting out a shared vision, mission and objectives to manage biofouling. Currently, several regions have established dedicated Regional Task Forces that are tasked to adopt and implement a regional strategy and action plan to manage biofouling. These RTFs also liaise and engage with relevant National Task Forces to consider the work undertaken towards developing national strategies.

[4] *Due to the large amount of information available for Canadian ports and the governance structure which provides for different procedures and regulations regarding In-water cleaning in different ports and territories, an overview of In-water Cleaning inclusion in Practices and Procedures of Canadian Ports and Legislation and Regulations relevant to In-water Cleaning in the Provinces/Territories of Canada are provided in Annex 7.*

The Mediterranean Sea Region is an example of such a region, as it has a ballast water management strategy (Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) 2022) that includes reference to biofouling management. In the Baltic Sea Region, the "COMPLETE project" (Completing management options in the Baltic Sea Region to reduce risk of invasive species introduction by shipping) aimed to reduce the risk of IAS invasions from ballast water and biofouling by developing monitoring tools, early warning approaches and other tools (BalticComplete 2018). In Southeast Asia and South America, regional strategies and action plans to manage biofouling have also been adopted. Other regions working towards regional strategies include the Pacific, the Red Sea, the Gulf of Aden and South Asia.

Various national strategies and action plans on Biofouling Management to minimize the introduction of IAS are also underway (e.g., through the GEF-UNDP-IMO GloFouling Partnerships Project). It is intended that these national strategies will pave the way for national regulatory frameworks that will include national and local regulations, and ideally, they will address liability aspects for ports to manage biofouling.

3.1.3 Applicable national and local regulations

From the survey to port stakeholders (defined in section 2.1), 79 responses were received from stakeholders in 39 countries and two regions. Among the respondents' countries, the acknowledgement of the IMO Biofouling Guidelines was widespread: 20 countries (51%) of countries recommend their use. However, far fewer have training programmes in place or planned: seven countries, which represent 18% of respondents' countries.

Figure 1. Respondents to the survey sent to port stakeholders

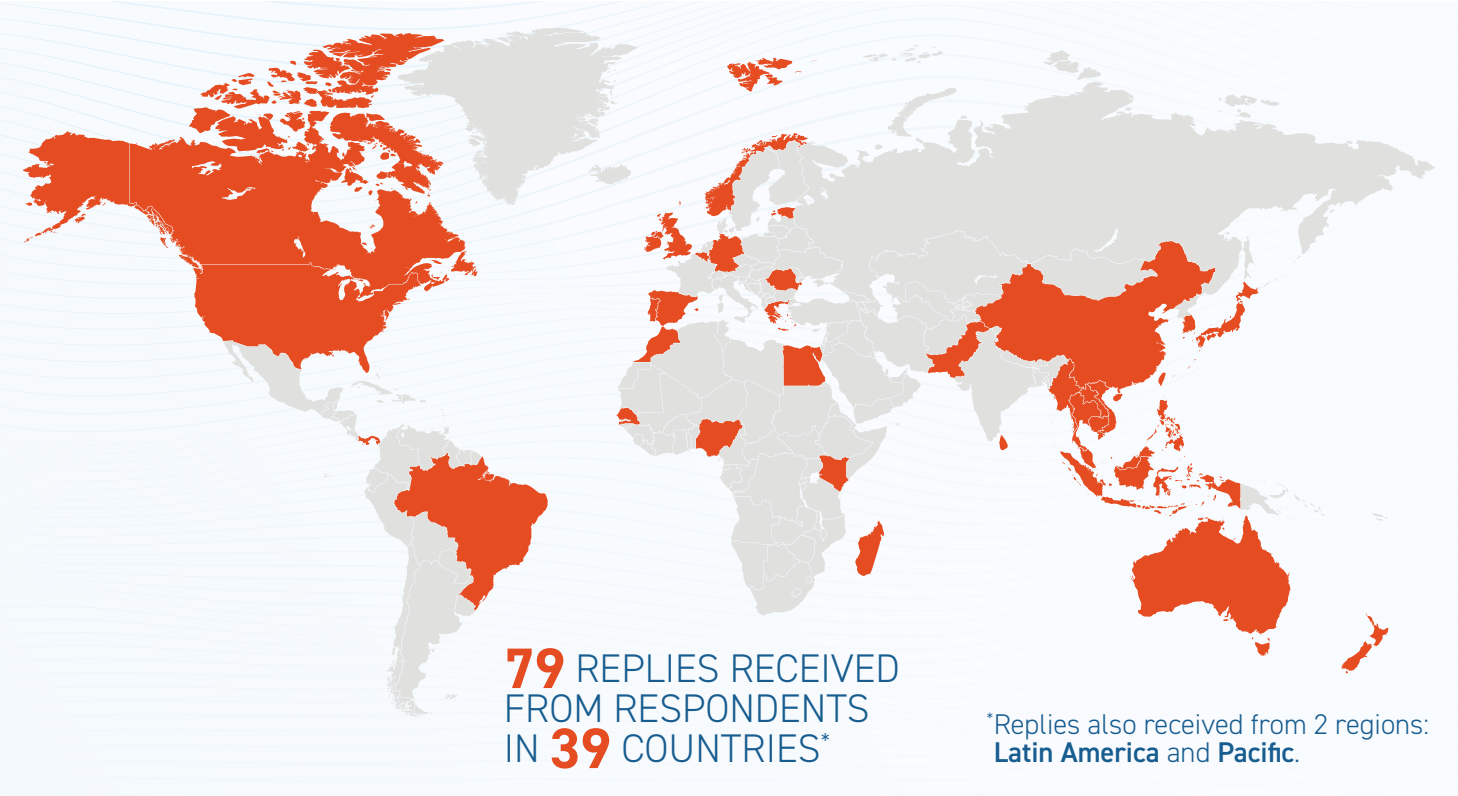
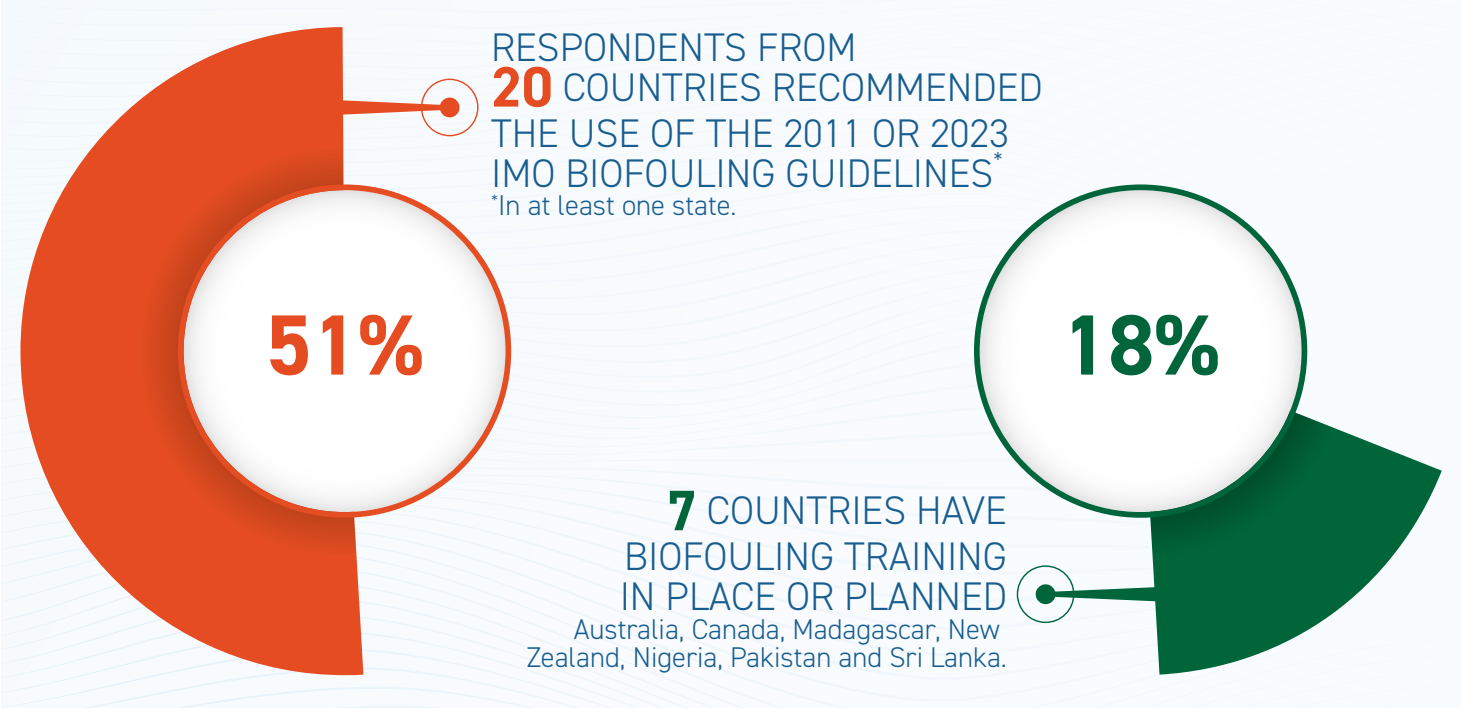


Figure 2. Use of IMO Biofouling Guidelines and biofouling training programmes



While it is not the purpose of this report to analyse national policies and/or strategies, the survey results correspond with a recent report (GEF-UNDP-IMO, 2022), which found that only a few national biofouling management regulations or policies are in place globally (that are currently publicly available). The report identified only four countries (Australia, New Zealand, South Africa and the United States) as having mandatory frameworks in place. Some countries, however (e.g., Chile), have voluntary guidelines. It is, however, important to mention that without mandatory frameworks in place, ports will not have any enforcement mechanisms to rely on, and it will be very difficult – if not nearly impossible – to address liability aspects.

This ambiguity in the existing (few) regulations was noted by most (69%) of the respondents to the survey. This uncertainty can exist at very small scales. Astonishingly, the requirements of a privately owned terminal may differ from its host port's regulations. Some survey respondents also indicated that while regulations could be challenging (e.g., New Zealand, Australia), they were clear and set coherent requirements to implement, which was appreciated. It was noted that current regulations in New Zealand, Australia and the U.S. state of California (which differ from the U.S. national regulations) are underpinned by science, which is desirable.

Consistent enforcement of regulations is critical, both to provide clarity to the industry and to encourage compliance. New Zealand, for example, refused entry to non-compliant cruise ships, and 6% of all international arrivals between January 2020 and September 2022 needed to address biofouling (Frost, 2023). This sent a strong, clear signal to the shipping industry that compliance would be required.

3.1.4 Biofouling Management Plans and Record Books

The creation and maintenance of ship-specific Biofouling Management Plans (BFMPs) and Biofouling Record Books (BFRBs) are central tenets of the IMO Biofouling Guidelines, and from the survey results above, they are widely used. The State of California is an example of a jurisdiction that has a mandatory framework in place. The California Biofouling Regulations include sections on the BFMP and BFRB, which empower the California State Lands Commission (CSLC) staff to carry out onboard inspections to verify documentation and regulatory compliance (CSLC 2017). Other countries have voluntary BFMP and BFRB guidelines.

3.1.5 In-water cleaning regulations

While multiple IWC regulations and provisions exist, they vary, with several ports prohibiting IWC. The survey feedback intimated that the majority of these regulations and provisions that attempt to reduce environmental risks are not perceived as comprehensive. Additionally, multiple layers of approval for cleaning may be needed. For example, Australia's process for approving IWC or treatment was referred to or perceived as "complex", because state and territory governments have additional regulations; thus, "sufficient time" must be allowed for regulatory review (Commonwealth of Australia, 2023a). Helpfully, links to the various regions are available on the country-wide website (Commonwealth of Australia, 2023b).

Canada has published Voluntary Guidance for Relevant Authorities on In-Water Cleaning of Vessels (Transport Canada 2022). This guidance applies to relevant authorities that manage port operations, including Canada Port Authorities, municipalities and public and private ports, and aligns with the IMO Biofouling Guidelines. The guidance outlines best practices to assist these authorities in making the decision whether to allow an IWC service provider to operate in the waters under the jurisdiction of the authority, and whether a ship should be allowed to undertake cleaning in waters under the jurisdiction of the authority using a pre-approved service provider. These guidelines must be read in conjunction with relevant legislation. In the absence of federal regulations, the Canada Marine Act allows Canada Port Authorities, for example, the Montreal Port Authority, to establish their own practices and procedures to promote environmental protection in its waters, including biofouling; here, hull cleaning is prohibited (Montreal Port Authority 2023). Currently, some Canada Port Authority Practices and Procedures do not explicitly mention IWC, while others ban it or require a permit[5].

In a handful of locations, IWC is permitted subject to a permit being issued. For example, in terms of the Port Rules of South Africa, IWC providers must apply for a permit every three years (Transnet National Ports Authority, 2010), fulfilling various permit requirements and conditions. One such condition being that IWC is only allowed in certain port areas (Republic of South Africa, 2005). Flemish ports are an example of a jurisdiction where IWC is allowed if the service provider obtains a permit issued by ports following laboratory and field testing, which is attended by at least one representative of the port (Port of Antwerp-Bruges, 2019). The Flemish port policy is also the only jurisdiction that makes a provision to identify specific, independent testing bodies to analyse water samples.

A model of collaboration between industry and regulators can be seen in the Netherlands and Belgium. In both locations, the ports' approach has been to partner with IWC companies to define the best available technology and how to improve it. Representatives in the Netherlands (via the executive branch of the Dutch Ministry of Infrastructure and Water Management, Rijkswaterstaat (RWS)) and in Belgium (ports of Antwerp, Port of Bruges-Zeebrugge, Ghent, Ostend and Genk) go on ships to witness IWC technologies in service. In the same manner, regulators in New Zealand have regular conversations with IWC stakeholders. These types of collegial partnerships foster trust, generate objective data to base decisions on, and, from survey feedback, invite progress by encouraging innovation.

On a practical note, in some cases, regulations or practices can be difficult to find in many pages of regulations or biofouling may not be referenced specifically. For example, feedback from surveys showed that information about a port's biofouling can be tucked into sections of port tariffs with unrelated topics, such as nuclear waste. While this placement is seemingly illogical, it can be due to lawmakers' lack of familiarity with the topic, resulting in such a circuitous path. Even worse, regulations are sometimes not posted publicly at all and are communicated by phone or email when information is solicited. Equally confusing, stakeholders can hold multiple meetings with specific regulators only to learn that they have no decision-making authority in this area, or different regulators within a region can provide conflicting views on activities permitted in a given area. Interestingly, some regions or areas focus on IAS, while others are more concerned about pollution (biocides and heavy metals liberated from coatings during cleaning).

The IMO Biofouling Guidelines recognize that IWC is a "complex activity to manage appropriately" (IMO 2023a). In fact, this practice is so pivotal that work to create international standards for IWC may continue, culminating in a separate document to accompany the guidelines (paragraph 9.3, IMO 2023a). This need was also recognized in a previous study that noted most policies that require independent verification and approval of IWC systems do not identify approved independent experts (GloFouling Partnerships Project, 2022). Indeed, the lack of identified, independent experts as well as standards for the approval of IWC systems creates problems for all involved, namely IWC providers, shipowners, regulators and, in particular, port authorities. From a port's perspective, it means that authorities cannot rely on independent testing results. Once criteria are in place for experts, however, a number of groups could potentially conduct testing on IWC.

[5] *More information is provided in Annex 7.*

Two ISO standards are in development with the goal of addressing technical details of this gap. ISO standard 20679 "Testing ship biofouling in-water cleaning systems", will provide methods for testing vendors' claims for the performance of IWC equipment; reports may be submitted to Administrations, port authorities, and other regulators to approve their use. ISO standard 6319 "Conducting and documenting in-water cleaning of ships' biofouling" will provide guidance on conducting IWC activities after equipment has been approved. In addition, IMO is developing guidance on IWC to complement the 2023 Biofouling Guidelines.

It should be noted that within the IWC community (and beyond), a concern is that regulators and scientists are seen as proposing a cleaning standard so high that it is nearly impossible for any technology to achieve and implement. In reality, while some technologies are capable of removing and managing biofouling material on uniform areas of the hull to satisfy fuel consumption and GHG emission needs, at present, it is nearly impossible to achieve the proposed cleaning standards in niche areas for marine biosecurity needs, and few IWC equipment can clean niche areas (from discussions with stakeholders). This illustrates the need for IWC stakeholders, particularly those with field experience, to be included in the development of practicable standards.

Until regulations are consistent globally, and universal standards for IWC are established, banning IWC will continue, which may push cleaning outside of ports (e.g., to anchorages) or to locations with less stringent environmental controls (especially regarding IAS management or waste management). Such concerns were voiced by multiple respondents to the GIA survey (38%). Indeed, some shipowners/operators are turning to port States, such as the Pacific Islands, some of which lack the regulatory capability or resources to manage IWC, thus risking that these areas risk becoming dumping grounds for AF coatings and IAS (A. Coutts, pers. com.). A critical aspect of this paradigm is the added danger posed to divers. Operational safety is paramount in the IWC community, and conducting operations in anchorages or the open sea also increases the risk of accidents for divers (e.g., by exposing divers to more severe weather). Other undesirable outcomes would be that illegal IWC is carried out or pressures are placed on areas where cleaning is permitted.

3.1.6 Considerations for biofouling waste management

From this study, it appears that the requirements for IWC are very rarely posted in port or national documents, and thus the disposal processes are not specified, either. Cleaning material from ships with biocidal coatings may be considered hazardous waste and thus disposed of following local, state and national regulations. In fact, efforts to turn biofouling waste into fuel pellets have been hitherto unsuccessful, in part, because the waste could not be transported across country borders due to national regulations.

Many studies have been conducted in New Zealand to determine the risk of IWC cleaning, including chemical contamination (e.g., Morrisey et al., 2013). Here, modelling showed that copper released during cleaning could exceed acceptable levels. Combining modelling results and biological risks estimated by expert judgement, cleaning was recommended (or not) in scenarios based on vessel type, level of fouling and whether the vessel's coatings contained copper biocide. As IWC standards are being developed, this and other research is available to guide the development of quantitative measures for liberated chemical constituents (e.g., Scianni and Georgiades, 2019, Tamburri et al., 2021).

3.1.7 Regulatory gaps and related issues observed in ports

A main observation is the lack of an international convention to manage biofouling management. Previous surveys also concluded that the lack of an international convention is a barrier to biofouling management policy implementation. A further challenge to complying with biofouling requirements is the lack of consistency in biofouling policy, where it does exist (GEF-UNDP-IMO GloFouling Partnerships Project and GIA for Marine Biosafety, 2022).

In sum, the legal review and survey results identified the following common gaps and issues related to ports' biofouling management:

- Varying biofouling management policies and practices: the lack of international mandatory obligations to manage biofouling and the (current) voluntary nature of the IMO Biofouling Guidelines – and in turn, the lack of national obligations to manage biofouling – can lead to varying biofouling management policies and practices as well as ambiguity.
- Varying nature of existing policies: the nature of existing policies varies, between voluntary or mandatory, or in certain cases, a combination of voluntary and mandatory measures.
- Lack of biofouling-specific provisions in existing legislation and policies: in most jurisdictions where there is existing legislation and policy that address invasive species, clean water, port rules, etc., provisions specific to biofouling are not included.

- Inconsistent biofouling management: existing policies and practices can give rise to inconsistent biofouling management between ports, and in some instances, existing regulations are inconsistent with best practices set out by national departments.
- Lack of understanding of biofouling management measures: the port stakeholder and GIA surveys also showed that in some instances, regulators and port authorities do not understand biofouling management measures.
- Lack of data and standardization regarding IWC practices: the lack of a universal approval process for IWC equipment is problematic, not only for the shipping industry but also for regulators and port operators to develop and implement IWC policies (where they do exist). Similarly, a measurable standard to ensure biological material and contaminants associated with IWC are well managed is lacking; standard guidance for IWC providers is lacking; and information available to regulators and port operators to understand the environmental risks associated with IWC is lacking.
- Awareness of biofouling management is lacking at multiple levels: information specific to biofouling regulations and IWC can sometimes be hard to find, as it is a relatively new parameter that is controlled. Of course, a lack of transparency can lead to confusion and potentially reduce biosecurity. Likewise, training for regulators and port operators is lacking.

3.2 NEGATIVE EFFECTS OF BIOFOULING IN PORTS

Biofouling negatively affects ports in a variety of ways. In an often-visible reminder, biofouling physically colonizes port surfaces, necessitating maintenance. Pollutants evolved during IWC operations, on the other hand, are often microscopic (microplastics) or dissolved (biocides and other chemical constituents). From a financial perspective, a port or marina colonized by IAS can realize lost revenue and increased costs resulting from remediation efforts, and idle vessels can increase the odds of colonization.

3.2.1 Impact of biofouling on port equipment and infrastructure

A common, direct and ongoing impact of biofouling in ports (and marinas) is that it requires extra maintenance for pontoons and mooring lines. For instance, most marinas encountered with old (more than 20 years old) pontoons engage divers every 6 to 12 months to remove the heavy accumulation of biofouling (A. Coutts, pers. com.) to prevent them sinking under the weight. To address this issue, manufacturers have created pontoons that are "fouling rated" and offer superior buoyancy, and this engineering design adjustment has been widely adopted (A. Coutts, pers. com.). These pontoons are rated to accumulate a carrying capacity of biofouling and do not require cleaning as often.

3.2.2 Impact on the local environment from biofouling waste

If a ship's coating containing biocides is damaged during cleaning, as particles sink to the seabed, the biocide levels can render the sediments contaminated. The cost and logistical challenges with disposing large volumes of spoils from dredging operations become cost-prohibitive.

A pollutant that has received relatively new global attention, microplastics, is also a concern during IWC. At present, little is known about the evolution of microplastics from ships' hulls during cleaning or underway, and at a more basic level, the terminology used to describe the sizes of microplastics is not globally agreed upon (Tamburri et al., 2022). In a modelling study, the volume of micro- and nanoplastics was calculated for self-polishing AF paint (approximately 90% of the world fleet) and hard AF paint (approximately 10% of the world fleet) to be approximately 6,500 tonnes per year (IMO 2023b).

From the perspective of IAS, in Hobart, Australia, the huge recruitment of mussels (Mytilus spp.) on port infrastructure is routinely removed (also relevant in section 3.2.1), and mussels fall to the seabed, where they are eaten by the invasive northern Pacific sea stars, helping them sustain high abundances.

3.2.3 Implications for ports

If an IAS is established, and it prompts the federal and/or state government to declare the port a quarantine area, the impact on a port (and businesses supported by it) can be financially disastrous (at least temporarily). Such a case occurred in 1999 in Darwin, Australia, when the first recorded marine pest in tropical Australian waters was identified by research divers. Following the detection of Mytilopsis sallei (the black-striped mussel), the Northern Territory Government quarantined and treated the three infected marinas (Commonwealth of Australia, 2000). As a result, no commercial fishing boats, tourist boats or recreational yachts could enter or leave the marina for approximately four weeks (Commonwealth of Australia, 2000) with the operation costing an estimated AU$2.2 million (Livingstone, 2023).

In another example, the non-native carpet sea squirt (Didemnum vexillum) was detected on marine infrastructure in Western Australia (WA) for the first time in Henderson in 2023. Subsequently, the Department of Primary Industries and Regional Development (DPIRD) issued a Quarantine Area Notice (QAN) at the Australian Marine Complex, Southern Harbour in Henderson, WA from 26 February 2024 until 15 March 2025 (DPIRD, 2024). Its goal is to limit the risk of vessels transporting Didemnum vexillum to other ports in WA. To do so, the QAN outlines biofouling management controls: Vessels in the quarantine area may be required to undergo a risk assessment and subsequent inspection, and if Didemnum vexillum is detected, vessels must be treated to remove it (capturing all material more than 50 µm that is released from wet areas while undergoing treatment). Finally, treated vessels must be inspected, with the accompanying report provided to DPIRD.

Here, the burden (and cost) of managing IAS falls on the port managers, who will most likely lose customers during the quarantine period. Going forward, they may need to implement a more stringent biofouling monitoring programme to prevent future IAS from colonizing the port infrastructure. The burden also falls to vessels that visit the port, since they may need to organize and pay for inspections and treatment from third parties. These incidents illustrate the real-world consequences of IAS at a local level.

Taking a broader view, an important future consideration is the issue of liability aspects of ports. Often ports are limited liability companies and are responsible for the well-being of ports. If an IAS established in a port incurs great economic or health-related harm, ports could be held liable for the environmental and human health impacts, and potentially, claims from nearby aquaculture or tourism industries.

3.2.4 Implications for vessels idle periods in port areas

It has long been recognized that a longer time in ports allows for more biofouling to accumulate vs being underway. Furthermore, most ports are located in coastal areas with high biological productivity (relative to the open ocean), so surfaces more readily accumulate biofouling when they are idle and in productive waters. Additionally, when vessels with fouling-release coatings are in port, they are not underway, and layers of coating (and associated biofouling) are not sloughed off. These lay-ups and long waiting times can act as "super-spreader" events for IAS. The density of organisms increases on ship surfaces, allowing reproduction (and local colonization) by translocated organisms as well as potentially allowing IAS to hopscotch across ships tightly grouped in a stationary fleet (Ruiz et al., 2022).

In a practical demonstration of this effect, experimental panels submerged in coastal areas on the U.S. East and West coasts were evaluated for biofouling cover during long stationary durations mimicking lay-ups, namely 28, 45 and 60 days. Between 10 and 28 days of static immersion, the results were striking: there was a 13 to 25 times difference in biofouling between the shorter and longer time (Davidson et al., 2020).

The recent Covid-19 pandemic vividly showed how unexpected events can affect ships' operational profiles. For more than two years, thousands of ships were idle, particularly cruise ships (Ruiz et al., 2022). These lay-ups were typically in coastal, tropical and sub-tropical areas, which have warm temperatures, which can lead to high growth rates and high biofouling accumulation rates. Containerships, too, have experienced longer-than-usual waiting times at ports, a function of pandemic-induced supply chain disruption, and, in a more localized event, the days-long blockage of the Suez Canal when the container ship Ever Given ran aground.

As mentioned in section 3.2.3, it is in ports' best interest to manage biofouling risks so no reactive regulatory action (such as quarantine) is needed due to IAS. Thus, when vessels are inactive for long periods, it is valuable to ensure best practices are used. If the port can offer consistent inspections (i.e., good water clarity and minimal tidal currents), with environmentally responsible IWC, this would be particularly valuable.

3.3 BEST PRACTICES FOR PORTS' BIOFOULING MANAGEMENT

Best practices start with prevention at the ship level, namely rigorously following the advice in the IMO Biofouling Guidelines. Beyond this level, risk assessment tools complement ship actions to aid ports in determining what, if any, actions are needed for arriving ships. From a business view, incentive programmes and sustainable practices can benefit the port owners, and awareness is needed to ensure successful management of this environmental issue.

3.3.1 Best practices that can contribute to minimize biofouling risks

Prevention is the key. Therefore, as outlined in the IMO Biofouling Guidelines, selecting a suitable AF coating, using and maintaining marine growth prevention systems (MGPS), and managing topside immersible equipment

are the foundation of minimizing the transfer of IAS. Furthermore, a robust, global implementation of the IMO Biofouling Guidelines will help to ensure that ships adopt effective biofouling management plans (and accompanying record books) that are realistic, achievable and effective. Of course, it is also vital to inspect and monitor the performance of the coating, MGPS, internal seawater systems, etc., on a continuing basis. Finally, environmentally responsible IWC is necessary so that debris liberated during cleaning operations (potential IAS and particles of coatings with chemical pollutants or microplastics) is effectively captured.

Two novel approaches to provide port infrastructure with a level of defence to IAS are worth mentioning. The first is the use of bubbles to mitigate the accumulation of biofouling on marina infrastructure, for example, seawalls, also called static artificial surfaces (SAS) (Hopkins et al., 2021, 2023). In laboratory and field trials, macroscopic biofouling on SAS is reduced by diffusers, but long-term deployment of this technology will need additional development, as the diffusers themselves become fouled.

The second is changes to human-made infrastructure in ports. The addition of "enhancements", known in some locations as "living seawalls" can protect the underlying structure and also, under optimum conditions, promote the recruitment of native species (e.g., Dafforn, 2017, Schaefer et al., 2023). Such efforts are underway in Singapore and Australia.

3.3.2 Vessel inspections and risk assessment

Two national programmes are notable in this context, from Australia and New Zealand (described below). Additionally, to help shipowners, regulators and service providers reduce the risk of IAS from biofouling, a number of software program packages and frameworks (flow charts) are available (listed in Annex 7). As noted in Green Marine (2018), risk assessments should focus on ship-specific parameters, for example, operational profile, previous ports that were visited, etc.

In June 2022, Australia's Biosecurity Amendment (Biofouling Management) Regulations 2021 entered into force. It requires mandatory pre-arrival information to be sent to the first port of arrival in Australia. Biosecurity officers may conduct a vessel inspection on arrival at an Australian port to assess and manage potential biosecurity risks. Additional details are described in the next section, as they apply to incentive programmes.

In New Zealand, and in accordance with the Craft Risk Management Standard (CRMS) for Vessels (2023), all arriving vessels must provide evidence of biofouling management prior to their arrival. As of October 2023, all vessels need documentation to prove that biofouling requirements were met by undertaking one of the following actions:

1. undertaking continual hull maintenance using best practices (only applicable to vessels staying up to 28 consecutive days in New Zealand, namely "short-stay" vessels);
2. inspecting and, if necessary, cleaning the hull and niche areas to remove all biofouling less than 30 days before arrival in New Zealand;
3. booking an appointment for the vessel to be hauled out and cleaned by a Ministry for Primary Industries (MPI)-approved treatment supplier within 24 hours of arrival; or
4. treating the ship upon arrival following an MPI-approved treatment (which does not include a haul-out facility (New Zealand, 2023).

Vessels that are not able to meet the New Zealand standards by using one of these measures may develop a craft management plan that details alternate but equivalent measures to manage biofouling.

3.3.3 Incentive-based programmes and business models

Australia has adopted an incentive approach for the current biofouling management guidelines, which were phased in from 15 June 2022 to 15 December 2023 (using an "education-first" approach). The country rewards ships that comply with "less intervention".

Vessel operators will receive less intervention for biofouling if they comply with one of the following three accepted biofouling management practices:

1. Implementation of an effective biofouling management plan;
2. Hull and niche areas cleaned of all biofouling within 30 days prior to arriving in Australian territory; or
3. Implementation of an alternative biofouling management method pre-approved by the department.

A vessel operator that has not applied one of these three accepted biofouling management practices will be "subject to further questions and assessment of the biosecurity risk

associated with biofouling on the vessel" (Commonwealth of Australia, 2022). In this manner, ships are incentivized to avoid further scrutiny and action by regulators when they adhere to an accepted biofouling management practice.

In a broader context, a certification scheme, similar to the Marine Stewardship Council certification of sustainable fisheries, could be applicable to ports. For instance, when vessel operators have periods of inactivity, they will try to avoid high-risk ports where IAS are known to occur (A. Coutts, pers. com.). In this scenario, ports able to demonstrate that they pose a low risk – or offer environmentally responsible IWC – will have a competitive advantage.

While it does not address biofouling directly, the Environmental Shipping Index (ESI) is a voluntary incentive programme offering all seagoing vessels an enticement to reduce air pollutants, carbon dioxide (CO2), and noise. At participating ports around the globe (with a focus in Europe), fees are lowered for ships with a good ESI score (ESI 2024a). Scores are based on self-declaration. Currently, the score is calculated based on:

- two air pollutants (nitrogen oxide (NOX) and sulphur oxide (SOX));
- GHG (as CO2);
- the capacity to conduct operations in port without combustion (e.g., with an on-shore power supply); and
- airborne noise measurements; the formula is in the process of being updated (ESI 2024b).

This programme also helps ports meet their environmental and environmental, social and governance (ESG) goals. While biofouling management is not directly measured in the ESI score, it is indirectly measured in the accounting of GHG; that is, low GHG emissions are due, in part, to little biofouling, which is a reflection of good biofouling management.

In another example, the Clean Shipping Index (CSI) assesses vessels' environmental performance that goes beyond complying with regulations. A CSI score is calculated based on: SOx, NOx, CO2, chemical use, water and waste control, and particulate matter (Clean Shipping Index, 2024). Higher scores result in reduced fees in participating ports, currently in Sweden, Canada and Finland. In this programme, data must be verified by a third party to obtain rebates on Swedish fairway dues and some port fees, in addition to the CSI performance label. As in the ESI, biofouling management is not directly measured.

3.3.4 Added value for ports from sustainable biofouling management

Given the recent focus in shipping on environmental issues, particularly decarbonization, 57 green corridors have been established to accelerate the use of carbon-neutral fuels (DNV, 2024). In the same way, ports are developing green corridors, which will likely increase business (and elevate ESG scores), having sustainable biofouling management will augment a port's existing services as well as its environmental profile.

3.3.5 Awareness and communication aspects

Outreach at a global level has been formalized, of course, via the GEF-UNDP-IMO GloFouling Partnership Project (2018–2025). The many efforts under the project deliver broad outreach (and build awareness) as well as specifically building capacity in 12 Lead Partnering Countries. A biofouling e-learning course is available free of charge at https://www.glofouling.imo.org/elearning-course-biofouling.

A compelling approach to national awareness was used in New Zealand: stakeholder meetings were convened before the biofouling management requirements were finalized, so stakeholders had input and, therefore, some degree of ownership of the outcome. In 2018, the CRMS (as updated in 2023) requirements became mandatory. A four-year lead preceded it, during which time, compliance was voluntary (although the MPI did have the right to take measures if ships represented an acute biosecurity risk; Georgiades et al., 2020). By the time the standard was mandatory (in 2018), stakeholders were not only aware of the regulations, but the maritime industry had time to develop biofouling management practices. The regulations were prominently circulated, both nationally and internationally.

At an individual level, citizens can greatly promote biosecurity by identifying invasive species in biofouling communities. Such programmes are not uncommon, for example, the US state of Oregon (Western Regional Panel on Aquatic Nuisance Species, 2021) and in Australia (Commonwealth of Australia, 2024a). Outreach programmes intended for speciality divers, however, appear to be limited, other than in New Zealand (Marine Biosecurity Toolbox, 2022) and Australia (Commonwealth of Australia, 2024b). It is important to engage this segment of the biofouling stakeholder community, as divers can initially identify invasive species on surfaces of vessels arriving to their ports.

3.4 DATA AVAILABLE ON BIOFOULING, IAS AND IWC

To catalogue the ongoing research on biofouling, ongoing research on IAS, and facilities that test IWC equipment, responses to the research survey were collated.

3.4.1 Support or participation in scientific research

Currently, there are dozens (if not hundreds) of biofouling studies ongoing. Much of the research is unknown (even to colleagues in the field) until results are published in peer-reviewed literature or unless conversations at conferences reveal work that is underway. That said, from the survey to researchers as well as outreach to other stakeholders about ongoing research on biofouling, a broad view of the current research was developed.

The topic of IAS research is expansive, as it not only includes a consideration of biofouling and biofouling management, but it also includes vectors such as ballast water transfers, aquarium releases and intentional species releases. Furthermore, individual studies may focus on a range of topics, for example, from a single species (e.g., their temperature and salinity tolerances) to IAS risk assessment to pre- and post-invasion management efforts. The best source of up-to-date knowledge (at this time) appears to be proceedings from conferences, outputs from national or regional networks of researchers, and outputs from relevant scientific and technical working groups (outputs are reports, presentations, notes from technical discussions, etc.). To that end, Table 8-2 lists conference proceedings, networks and working groups that have (or will likely have) voluminous lists of research papers or projects.

3.4.2 Data on sampling/registry of information

In producing this report, a total of 35 IAS databases were identified (see Annex 5). Many are data repositories for nations or regions; some are global databases. It should be noted that some databases do not have a review process to vet the quality of the data, so errors in identification can be common. This is concerning on its own, but there is also a decades-long global lack of taxonomists who can conclusively identify organisms using morphology. Molecular tools are part of the solution, but a visual identification is still needed. When molecular tools are used to initially identify specimens, the assignment is typically confirmed by taxonomy. This is for two reasons. First, global sequence databases, for example, GenBank, have a number of misidentifications. Second, most species are not registered on GenBank. Finally, given the lack of molecular information and taxonomists in particular groups, for example, sponges and hydroids, there are big gaps in our knowledge of their transfer as IAS.

3.4.3 Test facilities for in-water cleaning equipment of ships' biofouling

It was noted through the production of this report that, at present, four biofouling test facilities have been built, located in Denmark, South Korea, Sweden and the United States, and their capabilities range from laboratory testing, to ship-scale tank testing, to field testing in open water. Additional details are available in Annex 4. It should be noted, however, that other organizations may have the capacity to conduct this type of testing in other pre-existing facilities.

In summary, while these highlights provide a good overview of current work, there is no centralized, global accounting for IAS research in general (and biofouling research more specifically), so this outreach effort cannot present a fully complete view of ongoing work. Thus, the most important conclusion from this analysis is that a centralized site to house IAS research results is needed. Furthermore, national and regional networks of experts will speed the exchange of information, which in turn will quicken the pace of solving this global environmental problem.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RECOMMENDATIONS AND CONCLUSIONS

From the legal review, the literature review, and from the results of multiple surveys to over a hundred stakeholders, a number of points became clear. In some cases, legislation or procedures are already in place or planned to address current gaps, and these paradigms can serve as "bright spots" (Heath and Heath, 2010) to show that success is possible. They can be duplicated to frame, build or apply solutions at the relevant scale. The lessons learned are summarized below.

Overwhelmingly, there is a need for clear, standardized international obligations to manage ships' biofouling. Should there be development and adoption of an international convention, signatory countries would have the obligation to incorporate these provisions into national legislation. This will also ensure that legislation is coherent and harmonized, and it will avoid a situation where different jurisdictions and ports have varying obligations. Some GIA interviewees remarked that while national regulations in some locations are onerous, they are clear and implementable.

Overall, a model for transparent, robust biofouling management at multiple scales would have the following elements:

- clear international obligations;
- clear national regulations that flow from the international obligation, are transparent and readily available to the public (e.g., as in New Zealand and Australia);
- national regulations that apply to all jurisdictions, namely at the region, state, port and terminal levels;
- States' commitment to consistently enforce their national regulations (e.g., as in New Zealand);
- a collaborative approach by regulators and local port authorities to engage often with IWC providers and other stakeholders to consistently improve practices to meet environmental regulations (e.g., as in Belgium and the Netherlands);
- a standardized method for approving and assessing IWC equipment and cleaning (such as ISO standards 20679 and 6319[6]); and
- ongoing training programmes are implemented for personnel at the national, regional, state and port levels, including port operators and specialist divers (e.g., as in New Zealand, Australia).

While these elements may be commonly referred to in policy implementation, the examples above show that they can be (and are being) implemented to manage ships' biofouling with respect to IAS.

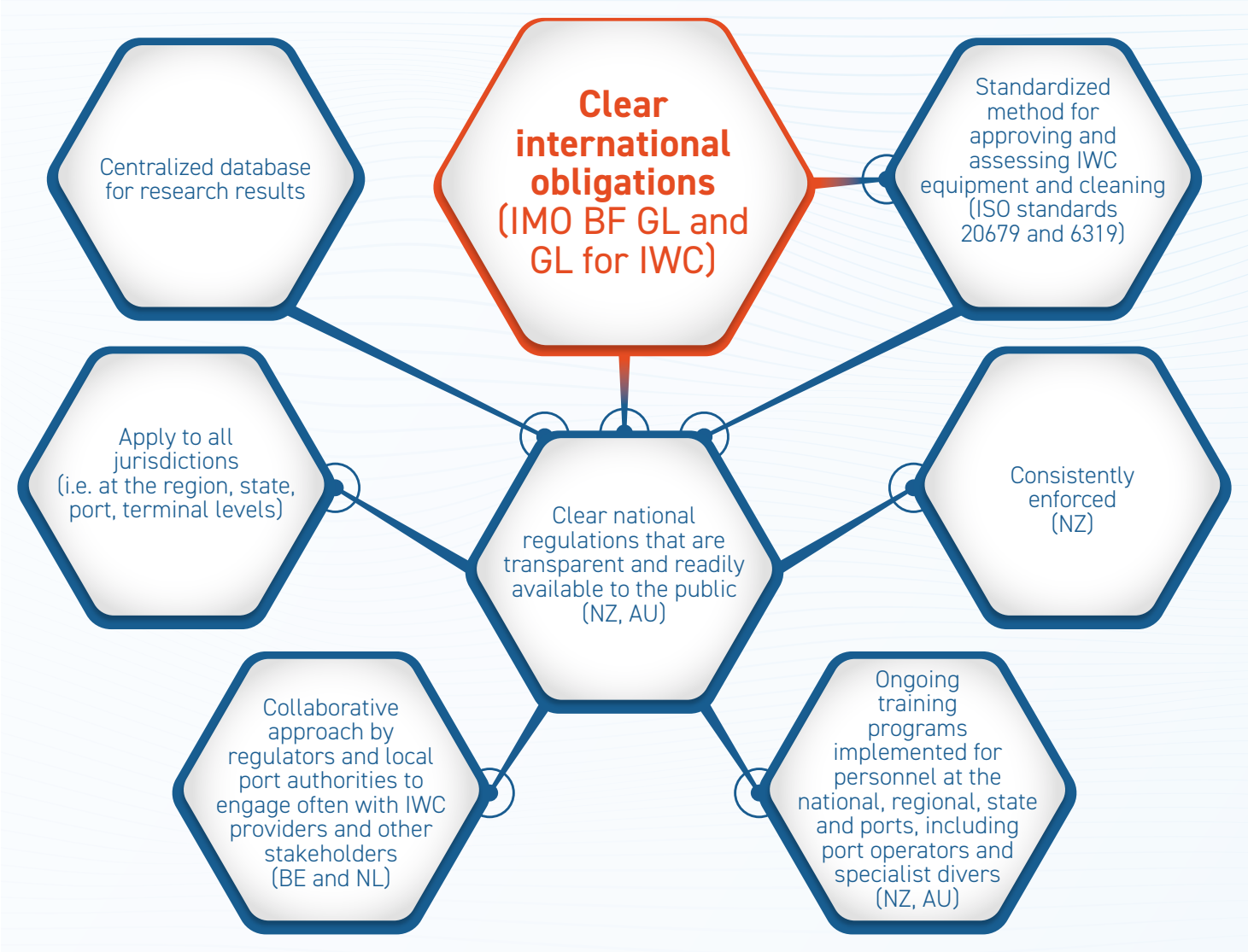
Regarding data availability, there is a need for a cohesive, global-scale programme to share data on IAS and biofouling research results. At present, efforts to collect and compile data are fragmented. The largest scale of data sharing occurs at a regional level and efforts tend to be focused in Europe, North America, New Zealand and Australia, with less information available from other parts of the globe, thus, a central database is needed.

A universal (and persistent) concern in data management is the support required to develop and maintain the database (which typically incurs salary costs) and the support required by users to enter data (which typically involves in-kind costs from the participants). To minimize these costs, for a database to be enduring, the data entry and maintenance need to be streamlined. Thus, for any such database, it is suggested that a simple set of questions is used, and instead of having a complex interface with many columns, key words, and phrases are used to search for information.

In conclusion, the maritime community is well-positioned to implement a robust, global management programme. International guidelines are already in place, and regulations incorporating them are implemented in many countries. Additionally, some countries, regions, ports and terminals have developed legal frameworks or strategies to implement policies in line with the IMO Biofouling

[6] *Under development at the time of writing.*

Figure 3. Potential model for global biofouling management in ports, marinas and harbours



Guidelines, and some are enforcing regulations. The result is two-fold. On one hand, it highlights the importance of managing biofouling, and it provides direction to stakeholders, whether they are shipowners who must effectively manage biofouling on their ships or IWC service providers who will need approval to provide their services in ports. On the other hand, while these early adopters are helpfully moving the field forward, without a clear, unified approach, the regulations can, at times, be confusing. Thus, there is an urgent need for a well-defined, transparent, and globally consistent approach at all scales, that is, to implement national frameworks following the existing IMO Biofouling Guidelines.

Ideally, should a mandatory regime be adopted, for example, following Norway's suggestion (IMO 2023c), then national frameworks should already be in place. In tandem, international standards for IWC are being developed with stakeholder input by ISO, and additional guidance on IWC by IMO (with a target date of completion in 2025). Clear, international standards are necessary to level the playing field for IWC service providers and provide confidence to all stakeholders (e.g., IWC service providers, shipowners and regulators).

Finally, because research on biofouling is siloed and difficult to aggregate, a global database that houses research results is recommended. This tool would facilitate communication across research and groups, thus speeding work on technical issues related to biofouling management. The resulting international approach will serve stakeholders well and protect marine environments.

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ANNEX 1

SURVEY QUESTIONS FOR PORT STAKEHOLDERS

The survey questions to port stakeholders are shown below. Additionally, the survey was posted on the GloFouling LinkedIn site.

STUDY ON PORT PERSPECTIVES FOR BIOFOULING MANAGEMENT

The survey should take approximately 10 minutes, and we would be very grateful if you could kindly answer the following questions (if you can only answer some of the questions, that is fine; partial responses are welcome).

The information shared will be included in the final (and publicly available) report, but no individual's contact information will be disclosed.

Thank you in advance for your time.

Start of Block: Main survey

Q1 What port, state, region or country do these answers refer to? (Please be specific)

_____

Q2 Please kindly provide your work email address, which we need for quality-control purposes (it will be kept confidential and not included in the final report).

_____

Q3 Do you require or request that ships follow the International Maritime Organization (IMO) 2023 or 2011 Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species (i.e., 2023 or 2011 Biofouling Guidelines)?

○ Yes (1)

○ No (2)

Q4a Do you have any biofouling practices, policies or legislation in place or planned (e.g., in-water cleaning policies)?

○ Yes (1)

○ No (2)

Q4b If yes, please provide the name, and if possible, please provide the link or upload the document.

_____

Q4c Document upload: Biofouling practices, policies or legislation in place or planned

Q5a Do you have any training programmes regarding biofouling management in place or planned (e.g., for port State control officers)?

○ Yes (1)

○ No (2)

Q5b If yes, please provide the name, and if possible, please provide the link or upload the document.

_____

Q5c Document upload: Training programmes regarding biofouling management in place or planned

Q6a Do you have any anti-fouling practices, policies or legislation in place under the IMO International Convention on the control of harmful anti-fouling systems on ships (i.e., AFS Convention)?

○ Yes (1)

○ No (2)

Q6b If yes, please provide the name, and if possible, please provide the link or upload the document.

_____

Q6c Document upload: Anti-fouling practices, policies or legislation in place

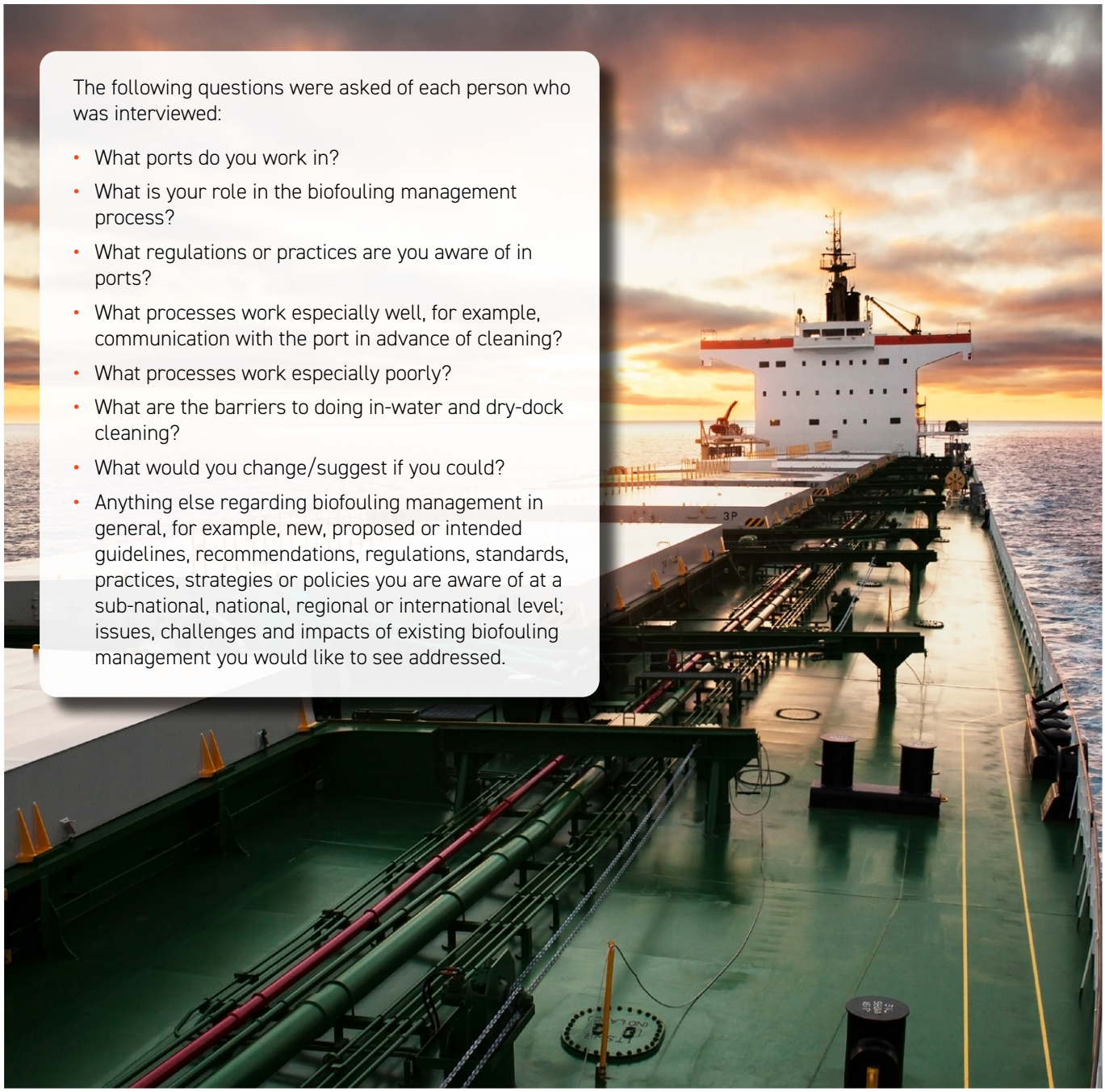
Q7 If you have any further comments, please share them here.

_____

End of survey

ANNEX 2

INTERVIEW QUESTIONS FOR PORT STAKEHOLDERS



The following questions were asked of each person who was interviewed:

- What ports do you work in?
- What is your role in the biofouling management process?
- What regulations or practices are you aware of in ports?
- What processes work especially well, for example, communication with the port in advance of cleaning?
- What processes work especially poorly?
- What are the barriers to doing in-water and dry-dock cleaning?
- What would you change/suggest if you could?
- Anything else regarding biofouling management in general, for example, new, proposed or intended guidelines, recommendations, regulations, standards, practices, strategies or policies you are aware of at a sub-national, national, regional or international level; issues, challenges and impacts of existing biofouling management you would like to see addressed.

ANNEX 3

SURVEY QUESTIONS FOR SCIENTIFIC WORKING GROUPS

The survey was sent to the following scientific working groups, as well as to other members of the research and testing communities who were known to the study authors:

- International Council for the Exploration of the Sea (ICES) working groups (WGs); some people are members of multiple WGs:
  - ICES/Intergovernmental Oceanographic Commission (IOC)/IMO Working Group on Ballast and Other Ship Vectors (WGBOSV) https://www.ices.dk/community/groups/pages/wgbosv.aspx (88 members);
  - ICES WG on Introductions and Transfers of Marine Organisms (WGITMO) https://www.ices.dk/community/groups/Pages/WGITMO.aspx (78 members); and
  - ICES WG on Shipping Impacts in the Marine Environment (WGSHIP) https://www.ices.dk/community/groups/Pages/WGSHIP.aspx (24 members); and
- Global TestNet, which has the aim to "promote comparable and accurate test results on the performance evaluation of technologies and methodologies to control the risk of bio-invasion and harmful species introductions by shipping, through an open exchange of information, transparency in methodologies and advancing the science of testing" (https://globaltestnet.org/) (12 members).

The questions detailed in Annex 2 were sent to researchers and testing organizations to solicit information about research specific to biofouling as well as IAS in general. The last row was added in a second email message to testing organizations members.

Table 1. Table sent to biofouling and IAS researchers to catalogue ongoing work and registries

Topic	Name or topic of research or registry (link, if applicable)	Lead organization	Start and end dates (or years)	Any additional information
Ongoing scientific research related to biofouling				
Registry of invasive aquatic species			N/A	
Database of research on invasive aquatic species			N/A	
Test facilities for IWC equipment of ships' biofouling				

ANNEX 4

RESPONSES FROM PORT STAKEHOLDERS

Table 2. Responses from Port Stakeholders

Country	Aware of IMO Biofouling Guidelines?	Biofouling Management practices in place (or planned)	Please elaborate	Biofouling Management Training in place (or planned)	Type of training(s) delivered	Antifouling Practices in place (or planned)	Please elaborate
Country	Aware of IMO Biofouling Guidelines?	Biofouling Management practices in place (or planned)	Please elaborate	Biofouling Management Training in place (or planned)	Type of training(s) delivered	Antifouling Practices in place (or planned)	Please elaborate
Kenya	Yes	No	n/a	no	n/a	No	n/a
Madagascar	No	Yes	Draft IWC Regulations	Yes	National workshop on Biofouling management plans and record books	No	n/a
Madagascar	Yes	Yes	n/a	Yes	Member of GloFouling Partnerships National Task Force	Yes	National law 2017 – 035 acceding to AFS Convention (2001)
Morocco	Yes	No	n/a	No	No	Yes	AFS must be applied in a dry dock

Country	Aware of IMO Biofouling Guidelines?	Biofouling Management practices in place (or planned)	Please elaborate	Biofouling Management Training in place (or planned)	Type of training(s) delivered	Antifouling Practices in place (or planned)	Please elaborate
Nigeria	Yes	Yes	Following Biofouling Management Guidelines	Yes	Workshop with stakeholders and other african countries on implementation on IMO Biofouling Management Guidelines	Yes	
Senegal	No	No	n/a	n/a	No	n/a	n/a
Belgium	Yes	Yes	Port procedure on permitted hull cleaning and propeller polishing intend to refer to it in next update of hull cleaning and propeller polishing procedures (eg. wrt the distinction between macro and micro fouling)	No	n/a	Yes	AFS is directly applicable and no separate documents
Estonia	Yes	Yes	Port rules explicitly mention biofouling management	No	n/a	No	n/a

Country	Aware of IMO Biofouling Guidelines?	Biofouling Management practices in place (or planned)	Please elaborate	Biofouling Management Training in place (or planned)	Type of training(s) delivered	Antifouling Practices in place (or planned)	Please elaborate
Germany	Yes	Yes	-	No	We do organise an annual roundtable on biofouling bringin together stakeholders from various fields to discuss matter on biofouling management and in-water cleaning.	No	n/a
Germany	Yes	No	n/a	No	n/a	No	n/a
Germany	Yes	Yes	Guidelines for the issue of in-water cleaning permits in the port	No	n/a	Yes	-
Germany	Yes	Yes	-	No	n/a	No	n/a
Germany	No	No	n/a	No	n/a	No	Due to strong tidal currents there have been no requests for in-water cleaning
Germany	Yes	No	n/a	No	n/a	No	n/a
Greece	No	No	n/a	No	n/a	No	n/a

Country	Aware of IMO Biofouling Guidelines?	Biofouling Management practices in place (or planned)	Please elaborate	Biofouling Management Training in place (or planned)	Type of training(s) delivered	Antifouling Practices in place (or planned)	Please elaborate
Ireland	Yes	Yes	SI No. 82/2008 Sea Pollution regulations	No	n/a	Yes	1991-2006 Sea pollution and miscellaneous provisions Acts
Norway	Yes	Yes	We have in progress regulations to implement the 2023 Guidelines and have monitoring programmes in priority ports	No	n/a	Yes	-
Norway	Yes	Yes	Preparing test procedures for in-water cleaning systems with capture of biofouling to be part of hull-cleaning procedures in the port	No	n/a	No	n/a
Portugal	No	Yes	Cleaning work on hulls is not permitted in the area of maritime jurisdiction	No	n/a	No	n/a
Romania	No	No	n/a	No	n/a	No	n/a

Country	Aware of IMO Biofouling Guidelines?	Biofouling Management practices in place (or planned)	Please elaborate	Biofouling Management Training in place (or planned)	Type of training(s) delivered	Antifouling Practices in place (or planned)	Please elaborate
Spain	No	Yes	Port authorities are very much concerned with in-water cleaning (IWC) activities, whether and how they can be authorized. Draft recommendations have been presented to OSPAR-HELCOM Joint Group on Ballast and Biofouling and will be revsed after IMO guidelines on in-eater cleaning	No	n/a	No	n/a
Spain	No	Yes	-	No	n/a	Yes	Hull cleaning is not permitted for TBT or cybutryne
United Kingdom	Yes	No	Not mandated but ports are developing biosecurity plans and being encouraged in this area	No	n/a	Yes	AFS are not mandatory in UK waters but if used, must comply with AFS regs / Convention
Egypt	No	Yes	-	No	n/a	Yes	National legislation related to AFS Convention is currently under development

Country	Aware of IMO Biofouling Guidelines?	Biofouling Management practices in place (or planned)	Please elaborate	Biofouling Management Training in place (or planned)	Type of training(s) delivered	Antifouling Practices in place (or planned)	Please elaborate
Egypt	Yes	No	-	No	n/a	No	n/a
Egypt	No	Yes	Port instructions available	No	n/a	Yes	Port instructions comply with AFS Convention and a national legislation is being developed
Canada	Yes	Yes	Voluntary guidelines are available for authorities and published by transport Canada on In-water Cleaning of vessels	Yes	Transport Canada is developing materials to support the implementation of the voluntary guidelines	Yes	The AFS Convention is implemented through the Vessel Pollution and Dangerous Chemicals Regulations
Panama	No	No	n/a	No	n/a	No	n/a
Panama	No	No	n/a	No	n/a	No	n/a
Brazil	No	No	n/a	No	n/a	Yes	NORMAM-401 (Chapter 3)
USA	Yes	No	Requirements are outline in the 2013 VGP. These will eventually be replaced by the new VIDA regulations	No	n/a	Yes	Clean Hull Act (2009)

Country	Aware of IMO Biofouling Guidelines?	Biofouling Management practices in place (or planned)	Please elaborate	Biofouling Management Training in place (or planned)	Type of training(s) delivered	Antifouling Practices in place (or planned)	Please elaborate
USA	Yes	Yes	Article 4.8 Biofouling Management to minimize the transfer of nonindigenous species from vessels arriving at California Ports	Yes	Internal inspection materials based on our regulations	No	n/a
USA	No	Yes	-	No	n/a	No	n/a
USA	No	Yes	-	No	n/a	No	n/a
USA	No	Yes	State dept. of Fish and Wildlife and dept. of Ecology have policies that allow for microfouling removal in water with or without capture. No in-water removal of macrofouling is permitted regardless of capture capability. As a service provider I am required to get approvals from the 2 regulatory agencies. This requires submission of hull coating type and date of application, video or pictures of the hull condition and level of fouling, ship identification and location of intended cleaning.	No	n/a	No	n/a

Country	Aware of IMO Biofouling Guidelines?	Biofouling Management practices in place (or planned)	Please elaborate	Biofouling Management Training in place (or planned)	Type of training(s) delivered	Antifouling Practices in place (or planned)	Please elaborate
Cambodia	No	No	n/a	No	n/a	No	n/a
China	No	No	At present China has no regulations on biofouling in place, but work in underway and the administration is following the work and outcomes at IMO. There are approximately 20 countries that offer biofouling cleaning services. Most are in dry dock and a few offer in-water cleaning services	No	n/a	China is party to the AFS Convention	n/a
Indonesia	No	No	n/a	No	n/a	Yes	n/a
Timor Leste	No	No	n/a	No	n/a	Yes	n/a
Japan	No	No	n/a	No	n/a	Yes	n/a
Loas	No	No	n/a	No	n/a	Yes	n/a
Malaysia	No	No	n/a	No	n/a	Yes	n/a
Malaysia	Yes	No	n/a	No	n/a	Yes	n/a
Myanmar	Yes	No	n/a	No	n/a	Yes	n/a

Country	Aware of IMO Biofouling Guidelines?	Biofouling Management practices in place (or planned)	Please elaborate	Biofouling Management Training in place (or planned)	Type of training(s) delivered	Antifouling Practices in place (or planned)	Please elaborate
Pakistan	Yes	No	n/a	No	n/a	Yes	n/a
Pakistan	Yes	Yes	n/a	Yes	PQA provides in house training	Yes	n/a
Philippines	No	No	n/a	No	n/a	Yes	n/a
Philippines	No	No	n/a	No	n/a	Yes	n/a
Philippines	No	No	n/a	No	n/a	Yes	n/a
Philippines	No	Yes	Issuance is not specific to biofouling practice but a general issuance under Sec 2 (a) and Sec 3 (b), Article 4 of the Port Authority's General Port Rules and Regulations	No	n/a	No	n/a
Singapore	Yes	No	n/a	No	n/a	No	n/a
Singapore	Yes	Yes	-	No	n/a	Yes	-
Singapore	Yes	No	-	No	n/a	No	n/a
Singapore	Yes	No	-	No	n/a	No	n/a

Country	Aware of IMO Biofouling Guidelines?	Biofouling Management practices in place (or planned)	Please elaborate	Biofouling Management Training in place (or planned)	Type of training(s) delivered	Antifouling Practices in place (or planned)	Please elaborate
Republic of Korea	Yes	Yes	We are developing voluntary national guidance for stakeholders including ship owners and operators, in-water cleaning system manufacturers, service providers etc based on the 2023 Guidelines	No	n/a	Yes	Article 40 of the Marine Environment Management Act
Sri Lanka	No	No	Sri Lanka is a Lead Partner Country of the GlFouling Project and we are in the process of making necessary guidelines and procedures	Yes	IMO Biofouling Management Course	No	n/a
Thailand	Yes	No	n/a	No	n/a	No	n/a
Vietnam	No	No	n/a	No	n/a	Yes	National Technical Regulation on Anti-fouling systems of sea-going ships training program for surveyor to inspection of antifouling systems
Vietnam	Yes	No	n/a	No	n/a	No	n/a

Country	Aware of IMO Biofouling Guidelines?	Biofouling Management practices in place (or planned)	Please elaborate	Biofouling Management Training in place (or planned)	Type of training(s) delivered	Antifouling Practices in place (or planned)	Please elaborate
Vietnam	Yes	No	n/a	No	n/a	No	n/a
Australia	Yes	Yes	Port handbook has procedures and practices	No	n/a	No	n/a
Australia	No	Yes	Managed through VesselCheck and Independent Marine Biologists based on State needs	No	n/a	No	n/a
Australia	Yes	No	No regulations that are port specific, state legislation however has requirements to follow biofouling guidance documents (Marine Order 11/2022)	No	n/a	No	n/a

Country	Aware of IMO Biofouling Guidelines?	Biofouling Management practices in place (or planned)	Please elaborate	Biofouling Management Training in place (or planned)	Type of training(s) delivered	Antifouling Practices in place (or planned)	Please elaborate
Australia	No	No	n/a	Yes	As part of our environmental awareness for our own marine staff we include information on biofouling risks	Yes	Our main dredge vessel is regularly inspected and routinely slipped and cleaned. This vessel does not generally trael internationally however it does undertake works in other Australian ports so doesn't prevent a potential biosecurity risk
Australia	Yes	Yes	An example is the Port Procedures for the Port of Cairns, refer Section 10.1 an Work Permit requirements for in-water/hull works.	Yes	Not presently available but planned as part of broader biosecurity awareness	No	No formal check/ controls/ inspections at a "port operations" level
Australia	No	Yes	-	No	n/a	No	n/a

Country	Aware of IMO Biofouling Guidelines?	Biofouling Management practices in place (or planned)	Please elaborate	Biofouling Management Training in place (or planned)	Type of training(s) delivered	Antifouling Practices in place (or planned)	Please elaborate
Australia	Yes	Yes	Planned: NSW state agencies are progressing development of in-water cleaning process	No	n/a	No	n/a
Australia	Yes	Yes	We are currently guided by the Qld Biosecurity Act and the national Antifouling and in-water cleaning guidelines while we wait for the revised version to be released by Australis DAFF. Queensland will then develop state based in-water cleaning policy/ guidelines	Yes	We are planning general marine biosecurity education and awareness sessions which will incorporate biofouling	No but yes, see Q284	n/a
Australia	Yes	Yes	Draft Policy Being Developed currently by Biosecurity TAS (currently there is a ban on in-water hull cleaning) policy will provide a process for application and approval	No	n/a	No	n/a

Country	Aware of IMO Biofouling Guidelines?	Biofouling Management practices in place (or planned)	Please elaborate	Biofouling Management Training in place (or planned)	Type of training(s) delivered	Antifouling Practices in place (or planned)	Please elaborate
Australia	No	Yes	We refer to the national guidelines on in-water cleaning by DAFF and do risj assessments and due diligence assessment and due diligence assessments for projects/contractors. We also have a port notice permit for in-water cleaning	Yes	We do in house training for port staff on biosecurity only. We use DAFF e-learning module.	No	n/a
Australia	No	No	n/a	No	n/a	No	n/a
Fiji	Yes	No	n/a	No	n/a	Yes	EIA Process under the Environment Management Act 2025
New Zealand	Yes	Yes	New Zealand's new biofouling rules: https://www.customs.govt.nz/globalassets/documents/misc/mpi-new-biofouling-requirements.pdf	Yes	-	No	n/a
New Zealand	Yes	Yes	https://www.mpi.govt.nz/dmsdocument/19757-Craft-Risk-Management-Standard-for-Vessels	Yes	-	No	n/a

Country	Aware of IMO Biofouling Guidelines?	Biofouling Management practices in place (or planned)	Please elaborate	Biofouling Management Training in place (or planned)	Type of training(s) delivered	Antifouling Practices in place (or planned)	Please elaborate
New Zealand	-	-	MPI is the governing body – each port is governed by the permissions granted by MPI. Some ports have MPI permission – these are likely to be those that have vessels at dry dock. Port Taranki is a Port of First Arrival (PoFA) but does not have MPI permission, so our responsibility is not to bring any vessel in that doesn't have MPI approval. Theoretically, if a vessel needed to berth in an emergency situation, where there was a biofouling requirement, the Harbour Master and the Port would seek emergency dispensation from the MPI	-	-	-	-
New Zealand	Yes	Yes	The Craft Risk Management Standard for Vessels	Yes	-	No	n/a

ANNEX 5

RESPONSES FROM SCIENTIFIC WORKING GROUPS

The results from the survey sent to researchers are shown in the tables below. For clarity, they are grouped by topic: ongoing research on biofouling (Table 2), compiled research on IAS (Table 3), registries of IAS (Table 4), and test facilities for IWC equipment (Table 5).

Table 3. Ongoing scientific research related to biofouling, grouped by category, for example, AF coatings, books, management, etc

Category and title or topic of research	Lead organization(s)	Start (and end) date(s)	Additional information
Antifouling Biocide release coatings	Chalmers University of Technology	2022–2027	Investigations of the minimum necessary doses of different AF biocides to inhibit macrofouling in different European waters
Antifouling Microplastics in coatings	University of Maryland Center for Environmental Science (UMCES)	2023–2024	Investigating the fate, behaviour, and bioavailability of microplastics released from ship AF coatings
Antifouling Sustainable coatings	Luleå University of Technology	2023–2025	Assessing the efficacy and sustainability AF coatings derived from vegetable oil oleogels in the Baltic Sea region, with the goal of fully green, sustainable, self-healing, wear-resistant, anti-corrosion and AF coatings
Antifouling Sustainable coatings development	Luleå University of Technology	2023–2025	Development of natural, lignin-based, eco-friendly AF coatings for marine application in the Baltic Sea region
Antifouling Ultrasonic technologies	DHI (previously the Denmark Hydrographic Institute)	2024–2025	Install ultrasonic AF equipment on vessels, evaluate efficacy and model underwater sound's impact on marine mammals https://dendanskemaritimefond.dk/dhi-ultrasonisk-antifouling-en-ny-standard-for-forebyggelse-af-begroning-af-skibe/
Book	Dr. Matej David Consult and GoConsult	2024	David, J. and Gollasch, S. (2024) "Global Maritime Transport and Ballast Water Management: Issues and Solutions, 2nd Edition". Invading Nature – Springer Series in Invasion Ecology 16, Springer Science+Business Media, Dordrecht, The Netherlands

Category and title or topic of research	Lead organization(s)	Start (and end) date(s)	Additional information
Broad research Including ecology, management, pathways, surveillance, etc. (Marine Biosecurity Porthole)	National Institute of Water and Atmospheric Research (NIWA) and Ministry for Primary Industries (MPI, New Zealand)	2010–	A range of research projects with national and international colleagues to understand the risks to New Zealand from non-native marine species and to support the development of policy and management to minimize their impacts https://www.marinebiosecurity.org.nz/research-3/
Climate change Invasive species	Chalmers University of Technology	2023–2026	Project partners from Sweden, Norway and Denmark, aim to create transnational work between stakeholders in the three countries (Kattegat-Skagerrak area); approaches include oceanographic modelling, ship-traffic mapping, habitat mapping using remote sensing, molecular identification methods, with a focus on marine protected areas https://climateinvasives.gmbl.se
Ecology Barnacle biofouling on oyster farms	Woods Hole Oceanographic Institution (WHOI)	2022–2025	Species-specific seasonal timing and population connectivity
Ecology Thermal adaptation of an invasive tunicate	WHOI	2022–2024	Research based on the Pacific coast of North America involving genomic tracking of invasion pathways and physiological experiments on thermal adaptation in Botryllus schlosseri
Infrastructure	Macquarie University /Sydney Institute of Marine Science	2017–	Designs for infrastructure that could prevent/reduce invasion, considering complexity, materials, light, seeding with native species and gardening
In-water cleaning Autonomous proactive system	UMCES	2022–2024	Evaluation of an autonomous proactive IWC system for ship biofouling
In-water cleaning Performance and safety	UMCES	2020–2025	Evaluations of ship IWC system performance and safety
In-water cleaning Standard development	UMCES	In progress	Development of ISO standards for testing ship biofouling IWC and IWC best practices
Management Invasive species action plan	Chalmers University of Technology	2022–2025	Project partners from Sweden focus on the Swedish west coast https://isap.gmbl.se

Category and title or topic of research	Lead organization(s)	Start (and end) date(s)	Additional information
Management Report on IAS and BF management	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) WG 44: Biofouling Management	In progress	http://www.gesamp.org/work/groups/wg-44-biofouling-management
Management Risk assessment	Korea Institute of Ocean Science and Technology (KIOST)	2021–2025	Techniques for the management and evaluation of biofouling on ship hulls, including risk assessments for IWC, identification of hazardous species and surveillance of invasions
Maintenance Sustainable hull strategies	Chalmers University of Technology	2022–2024	HÅLL 2.0 – demonstration of sustainable ship hull maintenance strategies; assessing the efficacy and sustainability of foul-release coatings and biocidal coatings in European Waters
Marine growth prevention systems (MGPS)	Cawthron Institute	To mid-2024	Investigate whether the recommended dosing for MGPS is effective, and how the placement and operation of MGPS affects performance.
Monitoring Marine non-native species (NNS) monitoring	Orkney Harbours	Started Nov 2012 Ongoing	Annual surveys conducted since 2012, with 34 sites visited annually, and an additional 28 sites have been visited on a one-off basis over the years; monitoring is part of the Orkney Islands Council Harbour Authority's Ballast Water Management Policy for Scapa Flow and Loch of Stenness https://www.orkneyharbours.com/info/docs (under 'Policies')
Monitoring Settling plate study	Smithsonian Environmental Research Center (SERC)	1999–	Field surveys to detect non-native marine species, primarily in coastal bays/estuaries with major commercial ports (but also including some without ports) at a continental scale; in total, 5,000 sample sites have been sampled for community composition with more than 100,000 specimens identified and retained https://serc.si.edu/research/projects/large-scale-surveys-fouling-zooplankton-and-soft-sediment-benthic-habitats

Category and title or topic of research	Lead organization(s)	Start (and end) date(s)	Additional information
Monitoring Shetland Islands Annual Monitoring survey	University of the Highlands and Islands (UHI) Shetland	2012–	Routine monitoring carried out using settlement panels in eight high-risk marinas to monitor for new arrivals of NNS in the Shetland Islands, United Kingdom; research addresses tracking the spread of introduced NNS, biofouling communities, and includes a long-term presence/absence dataset
Monitoring Ship biofouling study	Williams College	1984–	Sampling commercial ships and museum residential ships for 40 years (on an approximately monthly basis; always find living fouling organisms in the niche areas regardless of coating, see copper-resistant fouling bryozoans and hydroids)
Pathway	Cawthron Institute	2022–2026	To identify effective, efficient, practical and scalable marine biosecurity treatments that will help to reduce biosecurity risks associated with high-risk marine biosecurity scenarios, focusing on transfers of shellfish stock and ability to eradicate incursions at scale
Patterns Tracing patterns of vessel movement – understanding secondary spread of fouling marine invasive NNS	UHI Shetland	Beginning Oct 2024	This PhD project will aim to better understand the dynamics of vessel movement around Scotland to assess the impact of hull fouling for the secondary spread of NNS, seek to identify the main routes of secondary spread of marine NNS using spatial analysis of vessel movements and identify potential barriers to NNS movement along these routes and the potential impact to sensitive sites such as protected areas
Risk Assessment Risk assessment to identify factors that influence aquatic invasive species (AIS) introductions by ship biofouling	Fisheries and Oceans Canada (DFO)	2023–2027	This project will collect samples of biofouling from ships and background harbour environment at major Canadian ports (Halifax, NS; Vancouver, BC; and Hamilton, ON); new data will be used to update a risk assessment that quantifies the probability of AIS establishments via biofouling and determine factors that may influence the risk of ships transporting AIS on hulls

Category and title or topic of research	Lead organization(s)	Start (and end) date(s)	Additional information
Testing Performance testing for in-water cleaning company approval	Korea Marine Equipment Research Institute (KOMERI) (independent testing organization) LR (Competent organization) TAS GLOBAL (Cleaning company)	2023–2024	Verification testing of IWC systems by assessing separation and/or treatment of captured waste substance and the impact on local water quality (using the Procedure for testing and certification of in-water cleaning companies, Baltic and International Maritime Council (BIMCO), 2023)
Vectors Hot spots	Chalmers University of Technology	2023–2026	Project partners from Sweden using ship traffic mapping (automatic identification system (AIS) data) to identify "hotspot ports" in Sweden for IAS; molecular methods are used for identification and mitigation efforts are evaluated with a focus on niche areas (sea chests), AFS, and copper anodes AIS

Table 4. Compilations of research on invasive aquatic species grouped by category (conference proceedings, networks and working groups). Note that some of the registries listed in Table 4 also serve as networks

Category and title or topic of research	Lead organization(s)	Start (and end) date(s)	Additional information
Conference proceedings XI International Conference on Marine Bioinvasions	Society for the Study of Marine BioInvasions and Local Organizing Committee at SERC; Baltimore, Maryland, USA	May 15–19, 2023	https://marinebioinvasions.info/program/proceedings
Conference proceedings Invasion Science Research Symposium	University of Florida, Florida, USA	May 6–8, 2024	https://conference.ifas.ufl.edu/invasion/index.php
Database Completing management options in the Baltic Sea Region to reduce risk of invasive species introduction by shipping (COMPLETE) database on Biofouling	Bundesamt für Seeschifffahrt und Hydrographie (BSH)	2017–	The COMPLETE database on Biofouling management provides information on the status and opportunities for IWC of commercial ships and leisure boats in the Baltic Sea Region. The database contains information on ports and marinas, their respective requirements and possibilities for IWC and the companies, which provide IWC service
Database Marine Biosecurity Porthole (via Zotero)	Zotero	1998–	A publication library with access to reports from NIWA and MPI is here.
Database Research on IAS	KIOST	2024–2025	Under preparation
Network Coastal Ocean Marine Biosecurity Integrated Network for the Americas (COMBINA)	SERC, Smithsonian Tropical Research Institute, and Charles Darwin Foundation	2024–	Workshop held in March 2024 to assess the current state and future directions of marine biosecurity (marine bioinvasions) across countries in North, Central and South America; an informal international marine biosecurity network Pan-American network has been developed, tentatively called COMBINA

Category and title or topic of research	Lead organization(s)	Start (and end) date(s)	Additional information
Network The British Ecological Society special interest group (BES SIG) for invasive species is working on producing a list of research expertise within the United Kingdom with input from the Great Britain Non-Native Species Secretariat (GB NNSS)	GB NNSS / BES SIG Invasive Species	In progress	The BES SIG work has not yet started but may be a useful point of contact in the future, or to discuss whether the outputs from this IMO project could be used to inform that work. GB NNSS may be the most useful contact point.
Project COMPLETE	EU Interreg Baltic Sea Region	2017–2020	Project to reduce the risk of the transfer of invasive species by shipping (ballast water and biofouling) https://helcom.fi/helcom-at-work/projects/complete/
Project COMPLETE PLUS	EU Interreg Baltic Sea Region	2021	Implementation of the COMPLETE project outputs and tools https://helcom.fi/helcom-at-work/projects/complete-plus/
Research Group SERC	SERC	1999–	Conducts field surveys to detect non-native marine species, primarily in coastal bays/estuaries with major commercial ports (but also including some without ports) at a continental scale (cumulatively, across sites, more than 5,000 sample sites analysed for community composition and more than 100,000 specimens identified and retained as vouchers; list of ongoing research: https://serc.si.edu/labs/marine-invasions-research/marine-invasions-research-projects
Working Group GESAMP WG 44: Biofouling Management	IMO	2020–	Support IMO, GEF-UNDP-IMO GloFouling Partnerships Project, IOC and other agencies addressing marine biofouling; the emphasis is on biofouling as a vector of IAS as well as addressing data gaps http://www.gesamp.org/work/groups/wg-44-biofouling-management
Working Group ICES WGITMO	ICES	1970–	https://www.ices.dk/community/groups/Pages/WGITMO.aspx
Working Group ICES WGSHIP	ICES	2019–	https://www.ices.dk/community/groups/Pages/WGSHIP.aspx

Category and title or topic of research	Lead organization(s)	Start (and end) date(s)	Additional information
Working Group Institute of Marine Engineering, Science and Technology (IMarEST) Ballast Water SIG	IMarEST	2010–	https://www.imarest.org/group/ballast-water-management.html
Working Group IMarEST Biofouling Management SIG	IMarEST	2013–	https://www.imarest.org/group/biofouling-management.html
Working Group IMO/IOC/ICES WGBOSV	IMO/IOC/ICES	1997–	https://www.ices.dk/community/groups/pages/wgbosv.aspx
Working Group PICES (North Pacific Marine Science Organization)	Inter-governmental (present members are Canada, Japan, People's Republic of China, Republic of Korea, the Russian Federation and the United States of America)	1992–	https://meetings.pices.int/about

Table 5. Registries of invasive aquatic species relevant to biofouling

Registry	Lead organization(s)	Start (and end) date(s)	Additional information
APMPL (Australian Priority Marine Pest List)	Australian Government, Department of Agriculture, Fisheries and Forestry (DAFF)	2013–	Identifies ten of Australia's significant marine pests; this list includes three established and seven exotic species https://www.marinepests.gov.au/what-we-do/apmpl
AquaNIS (Information system on aquatic non-indigenous species)	Klaipėda University	2012–	Covers NIS in marine, brackish and coastal freshwater habitats in Europe and neighbouring regions; in the future, it may be extended to other regions https://aquanisresearch.com/
Artportalen (The Species Portal)	SLU Artdatabanken and partly funded by the Swedish Environmental Protection Agency	2001–	Tool for reporting observations of aquatic animals and plants that are especially important for lakes, streams and oceans; the primary aim is to receive information on species new to Sweden https://www.gbif.org/dataset/38b4c89f-584c-41bb-bd8f-cd1def33e92f
BIOINVASAO Brasil	Instituto Brasileiro de Biodiversidade, Rio de Janeiro	2019–	Digital platform developed to provide records of invasive exotic species in Brazil https://bioinvasaobrasil.org.br/
Bishop Museum Checklist of the Marine Invertebrates of the Hawaiian Islands	Bishop Museum	Mid-1960s–	Compilation initiated to keep track of the marine biota of the Hawaiian Islands; includes invasive species: http://hbs.bishopmuseum.org/invasives/
CABI Invasive Species Compendium	Centre for Agriculture and Biosciences International (CABI)	1998–	Developed in partnership with the US Department of Agriculture and a global team of collaborators it supports research and decision-making for academia, practitioners, government and agricultural researchers https://www.cabidigitallibrary.org/product/QI
Canadian Aquatic Invasive Species Mapping System	DFO	2023–2027	A geodatabase of AIS records from DFO studies, other federal, provincial and territorial partners, and potentially external sources and citizen science that will be made publicly accessible to stakeholders and the public
CIESM (Mediterranean Science Commission Atlas of Exotic Species)	CIESM	2002–	The Atlas consists of four volumes of exotic species in the Mediterranean Sea (crustaceans, fishes, molluscs and seaweeds) https://ciesm.org/online/atlas/

Registry	Lead organization(s)	Start (and end) date(s)	Additional information
DAISIE (Delivering Alien Invasive Species Inventories for Europe)	6th Framework Programme of the European Commission (EC)	2005–	A "one-stop shop" for information on biological invasions from up to 101 countries/regions (including islands) in Europe https://www.gbif.org/dataset/39f36f10-559b-427f-8c86-2d28afff68ca
DCBD (Dutch Caribbean Biodiversity Database)	Funded by the Dutch Ministry of Agriculture, Nature and Food Quality (LNV); parties involved: Wageningen University and Research and the Dutch Caribbean Nature Alliance	2012–	Central repository for biodiversity-related research and monitoring data from the Dutch Caribbean https://www.dcbd.nl/
EASIN (European Alien Species Information Network)	Joint Research Centre of European Commission	2012–	Facilitates information on alien species occurring in Europe and supports the EC services and EU Member States' competent authorities in the implementation of the EU Regulation 1143/2014 on Invasive Alien Species https://alien.jrc.ec.europa.eu/easin
EEPL (National Priority List of Exotic Environmental Pests, Weeds and Diseases)	Australian Government, DAFF	2020–	Contains 168 exotic species of significant environmental and social amenity risk to Australia https://www.agriculture.gov.au/biosecurity-trade/policy/environmental/priority-list
GBIF (Global Biodiversity Information Facility)	GBIF	2001–	Dataset with information from a wide array of sources, including specimen-related data from natural history museums, observations from citizen science networks and environment recording schemes (more than 2 billion records) https://www.gbif.org/

Registry	Lead organization(s)	Start (and end) date(s)	Additional information
GiMaRIS	Privately funded in combination with ad-hoc projects, primarily by ministries responsible for water management and/or nature	2006–	Multiple projects: a fouling community monitoring programme, a shellfish-dependent species inventory, port inventories, fouling assessments of commercial and naval vessel hulls and niches, and the Marine Alien Species Detection Network of the Netherlands https://www.gimaris.com/Projecten/SETL-project https://www.gimaris.com/en-us/Projects/SASI https://www.gimaris.com/en-us/Projects/Harbour-Inventories https://www.gimaris.com/Portals/3/GiMaRIS_2017_09_Hullfouling.pdf https://www.mdpi.com/1424-2818/15/6/719
GISD (Global Invasive Species Database)	Invasive Species Specialist Group of the International Union for Conservation of Nature Species Survival Commission	1998–	Global database of alien and invasive species that negatively affect biodiversity https://www.iucngisd.org/gisd/
GLANSIS (Great Lakes Aquatic Non-indigenous Species Information System)	National Oceanographic and Atmospheric Administration	2003–	Information about aquatic nonindigenous species in the Laurentian Great Lakes region of North America; provides information to limit the introduction, spread and impact of aquatic non-indigenous species in the Great Lakes by providing a comprehensive set of tools https://www.glerl.noaa.gov/glansis/
GRIIS (Global Register of Introduced and Invasive Species)	Global Invasive Alien Species Information Partnership	2020–	Validated and verified checklists of introduced (alien) and invasive alien species at the country, territory level https://invasionevs.com/griis/ https://www.gbif.org/dataset/6b64ef7e-82f7-47a3-8ddb-ec6794ea07d6 (Contiguous United States)
INVEMAR (Especies Marinas Costeras Introducidas en Colombia)	INVEMAR	2014–	Information about marine and coastal species introduced in Colombia http://invasoresmarinos.invemar.org.co/

Registry	Lead organization(s)	Start (and end) date(s)	Additional information
iDigBio (Integrated Digitized Biocollections)	U.S. National Science Foundation (NSF)	2011–	Data and images of more than 100 million biological specimens https://www.idigbio.org/
Especies MMA (Inventario Nacional de Especies de Chile)	Ministerio del Medio Ambiente (MMA)	2005- (1st National Species Inventory)	Information on both natural history and management of native wild species in Chile as well as some exotic feral species https://arclim.mma.gob.cl/biodiversity/home/ https://clasificacionespecies.mma.gob.cl/
KIOST	KIOST	2023–2025	Under preparation
Macroalgal Herbarium Consortium Portal	NSF	2019–	The goal is to image, database and georeference the macroalgal specimens in 49 herbaria from New England to Florida, to Hawaii and Guam https://macroalgae.org/portal/index.php
MAMIAS (Marine Mediterranean Invasive Alien Species)	United Nations Environment Programme	2013	Information and distributional data of non-indigenous species in the Mediterranean area from many different sources by using standards. https://spa-rac.org/en/sig/show/id/14/label/marine-mediterranean-invasive-alien-species-mamias
Marine Biosecurity Porthole	MPI and NIWA	2010–	Map of marine non-indigenous and cryptogenic species distribution within New Zealand waters and associated survey data (date, method, taxonomy, etc.). https://www.marinebiosecurity.org.nz/search-for-species/
NAS (Nonindigenous Aquatic Species database)	United States Geological Survey	1990–	Repository for spatially referenced biogeographic accounts of introduced aquatic species in the United States https://nas.er.usgs.gov/default.aspx

Registry	Lead organization(s)	Start (and end) date(s)	Additional information
NEMESIS (National Estuarine and Marine Exotic Species Information System)	SERC	1997–	A synthesis of non-native marine and estuarine species for the continental US and Alaska (excluding Hawaii) https://invasions.si.edu/nemesis/ It includes separate portals for Panama and Ecuador, and the intention is to expand the scope of this to include other countries with local collaborators https://invasions.si.edu/nemesis/Panama/ https://invasions.si.edu/nemesis/Galapagos/
NIMPIS (National Introduced Marine Pest Information System	Australian Department of Agriculture, Water and the Environment	2001–	Provides information on the biology, ecology and the distribution of marine pests either established or that pose a risk of future introduction to Australia https://nimpis.marinepests.gov.au/
NIS (Neobiota Information System)	BSH	2016–	This interactive network allows us to gather and qualitatively check biofouling and aquatic species data of the German North and Baltic Sea's coast as well as freshwater locations; a web-based application is publicly available in BSH's internal MARLIN (Marine Life Investigator) network https://marlin.bsh.de/MARLINDMZ/publicSites/MainAppPublic.jsf
NISIC (National Invasive Species Information Center)	US Department of Agriculture	2005–	Gateway to invasive species information; covering federal, state, local and international sources https://www.invasivespeciesinfo.gov/aquatic
NNSS (Great Britain Non-native Species Information Portal)	Developed by the British Trust for Ornithology and the Marine Biological Association; led by the UK Centre for Ecology and Hydrology	2019–	Distribution data for over 3,000 NNS in Great Britain as well as additional information such as place or origin, date of introduction and methods of introduction https://www.nonnativespecies.org/non-native-species/information-portal/
NOBANIS (European Network on Invasive Alien Species)	Initiated with funding by the Nordic Council of Ministers	2002–	Database with updated information from all the countries in North and Central Europe

Registry	Lead organization(s)	Start (and end) date(s)	Additional information
OBIS (Ocean Biodiversity Information System)	IOC United Nations Educational, Scientific and Cultural Organization	1999–	Knowledge base on the diversity, distribution and abundance of all marine organisms using an integrated and standardized format; more than 20 OBSI nodes around the world connect 500 institutions from 56 countries https://obis.org/
OCEANIC Marine Biofouling Database	OCEANERA-NET/ FCT and the SEASNAKE project	2018–	Aims to provide maritime industry players such as marine renewable energy developers and operators, as well as regulators, a quick overview of geographical biofouling distribution to facilitate informed decisions; based on five of the most problematic biofouling groups: macroalgae (specifically kelp), bryozoans, mussels (and other relevant bivalves), and calcareous tubeworms; access must be requested https://www.wavec.org/en/services/tools/marine-biofouling-database
Shetland long-term dataset of target marine NNS presence	UHI Shetland	2021–	Register of target fouling NNS for Shetland Islands, United Kingdom, from annual settlement panel analysis
WRiMS (World Register of Introduced Marine species)	Funding from the University of Auckland, Census of Marine Life's OBIS funding, European Marine Observation and Data Network Biology (EMODnet) and LifeWatch Belgium	2008–	Global records of which marine species in the World Register of Marine species have been introduced deliberately or accidentally by human activities to geographic areas outside their native range; it excludes species that colonized new locations naturally (so-called 'range extensions'), even if in response to climate change https://www.marinespecies.org/introduced/

Table 6. Test facilities to evaluate IWC equipment or processes

Name of facility	Lead organization(s)	Start (and end) date(s)	Additional information Type of testing and location
Center for Corrosion and Biofouling Control	Florida Institute of Technology	1984–	Research with stakeholders on all aspects of corrosion and biofouling control; current research relevant to IWC includes the development of proactive in-water ship hull cleaning to work synergistically with fouling control coatings Melbourne, Florida, USA https://research.fit.edu/ccbc/
Marine Environment Center	KOMERI	2021–	Testing IWC system (biofouling removal and capture), AF testing of material and paint, and buoyancy testing Tank size: 24 m x 8 m x 8 m; volume: 1,500 tonnes Geoje, Gyeongnam, South Korea https://komeri.re.kr/eng/content.php?id=10508010
Maritime Technology Evaluation Facility	DHI	2019–	Efficacy of cleaning technologies, ecotoxicity tests, risk assessment of effluent water, leaching studies Hørsholm Denmark https://maritime-tech.dhigroup.com/biofoulingnews/
RI.SE	RISE Research Institutes of Sweden – Material Reliability in Marine Environment	2012–	Participants include cleaning companies, coatings manufacturers and classification societies; access to a test bed https://www.ri.se/en/what-we-do/expertises/material-reliability-in-marine-environment https://www.ri.se/en/what-we-do/test-demo/materials-in-marine-environment

ANNEX 6

LIST OF EXISTING RELEVANT INTERNATIONAL GUIDELINES

The following guidelines and standards are available:

- BIMCO and International Chamber of Shipping "Procedure for independent testing and certification of in-water cleaning companies" (2023) https://www.bimco.org/about-us-and-our-members/publications/procedure-for-independent-testing-and-certification-of-in-water-cleaning-companies;
- IMO Guidance for Minimizing the Transfer of Invasive Aquatic Species as Biofouling (Hull Fouling) for Recreational Craft in 2012, applicable to recreational craft less than 24 metres in length https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/MEPC.1-Circ.792.pdf;
- IMO Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species (IMO Biofouling Guidelines 2023) https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/MEPCDocuments/MEPC.378%2880%29.pdf;
- International Petroleum Industry Environmental Conservation Association's "Alien Invasive Species and the oil and gas industry: Guidance for prevention and management" https://www.ipieca.org/resources/alien-invasive-species-and-the-oil-and-gas-industry;
- ISO standard 6319 "Conducting and documenting in-water cleaning of ships' biofouling" (in development) https://www.iso.org/standard/85997.html;
- ISO standard 20679 "Testing ship biofouling in-water cleaning systems" (in development) https://www.iso.org/standard/86393.html; and
- International Association of Independent Tanker Owners' "Guide to Modern Anti-fouling Systems and Biofouling Management" https://www.intertanko.com/info-centre/intertanko-guidance/guidancenotearticle/guide-to-modern-antifouling-systems-and-biofouling-management.

ANNEX 7

OVERVIEW OF THE VARIOUS PRACTICES AND PROCEDURES IN CANADIAN PORTS WITH REGARDS TO IN-WATER CLEANING

Table 7. In-water Cleaning inclusion in Practices and Procedures of Canadian Ports

Port	In-water Cleaning requirements in available practices and procedures
Belledune Port Authority	Practices and Procedures not published online
Halifax Port Authority	Include detailed rules on IWC and process for obtaining permission
Hamilton-Oshawa Port Authority	Requires a permit and specifies that "measures must be taken to ensure that the wastes or hull coatings or abrasive materials do not enter the Port waters
Montreal Port Authority	Prohibited
Nanaimo Port Authority	Not Included
Port Alberni Port Authority	Not Included
Prince Rupert Port Authority	Prohibited
Quebec Port Authority	Not Included
Saguenay Port Authority	"Overside maintenance" which may produce wastes such as hull coatings or abrasive materials that may fall into the water is forbidden
Saint John Port Authority	Specify that "Measures must be taken to ensure that the wastes or hull coatings or abrasive materials do not enter the Port waters
Sept-Isles Port Authority	No scraping of old paint or painting may be conducted on the ship's hull
St. John's Port Authority	Specify that "Measures must be taken to ensure that the wastes or hull coatings or abrasive materials do not enter the Port waters

Port	In-water Cleaning requirements in available practices and procedures
Thunder Bay Port Authority	Practices Procedures not published online
Toronto Port Authority	Prohibit the release of "deleterious substances"
Trois Rivieres Port Authority	Not Included
Vancouver Fraser Port Authority	Requires a permit
Windsor Port Authority	Practices and Procedures requires discharges to follow the Nova Scotia Fisheries Act

Table 8. Overview of the various practices and procedures in Canadian ports with regards to in-water cleaning

Province/Territory	Relevant Legislation and Regulations
Alberta	Fisheries (Alberta) Act: http://www.qp.alberta.ca/documents/Acts/F16.pdf; and Fisheries (Ministerial) Regulation: http://www.qp.alberta.ca/documents/Regs/1997_220.pdf
British Colombia	Wildlife Act http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_96488_01; Controlled Alien Species Regulation http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/94_2009; and Permit Regulation http://www.bclaws.ca/civix/document/id/complete/statreg/253_2000
Manitoba	The Water Protection Act C.C.S.M. c. W65 https://web2.gov.mb.ca/laws/statutes/ccsm/w065.php Aquatic Invasive Species Regulation https://web2.gov.mb.ca/laws/regs/current/_pdf-regs.php?reg=173/2015
New Brunswick	Exotic Animals Act: https://www.canlii.org/en/nb/laws/stat/snb-2017-c-52/latest/snb-2017-c-52.html
New Foundland and Labrador	Wild Life Act: https://www.assembly.nl.ca/legislation/sr/statutes/w08.htm; and Wild Life Regulations: https://www.assembly.nl.ca/Legislation/sr/Regulations/rc961156.htm#83

Province/Territory	Relevant Legislation and Regulations
Nova Scotia	Fisheries and Coastal Resources Act S.N.S. 1996, c. 25 https://nslegislature.ca/sites/default/files/legc/statutes/fisheries%20and%20coastal%20resources.pdf Live Fish Possession Regulations: https://novascotia.ca/just/regulations/regs/fcrlivefish.htm
Nunavut	Wildlife Act, SNu 2003, c. 26: http://canlii.ca/t/51x1n
Ontario	Invasive Species Act, 2015, S.O. 2015, c. 22 - Bill 37 https://www.ontario.ca/laws/statute/s15022 Ontario Regulation 354/16: https://www.ontario.ca/laws/regulation/r16354
Prince Edward Island	Wildlife Conservation Act https://www.canlii.org/en/pe/laws/regu/pei-reg-ec676-98/latest/pei-reg-ec676-98.html Fish and Game Protection Act General Regulations https://www.princeedwardisland.ca/sites/default/files/legislation/F%2612G-Fish%20and%20Game%20Protection%20Act%20General%20Regulations.pdf
Saskatchewan	The Fisheries Act (Saskatchewan), 2020 https://publications.saskatchewan.ca/api/v1/products/107927/formats/121107/download The Fisheries Regulations: https://pubsaskdev.blob.core.windows.net/pubsask-prod/1869/F16-1r1.pdf

ANNEX 8

LIST OF SELECTED SOFTWARE & FRAMEWORKS

To reduce the risk of IAS from biofouling, a number of software program packages and frameworks (flow charts) are available, which are useful to regulators, vessel owners/operators, or IWC services providers, or a combination of these stakeholders.

Table 9. Risk assessment programmes and frameworks

Name	Lead organization	Additional information
BMP+	Biofouling Solutions Pty Ltd	For shipowners to create vessel-specific, IMO-compliant biofouling management plans; the programme is free to regulators https://www.biofoulingsolutions.com.au/summary-of-services
LITEHAUZ RA	LITEHAUZ and Marine Benchmark	Prototype software package to conduct risk assessments; presented at the 2023 GloFouling Partnerships International Workshop on Biofouling Management to Prevent the Spread of Invasive Aquatic Species in Marine Protected Areas and Particularly Sensitive Sea Areas https://www.glofouling.imo.org/post/galapagos-islands-host-international-workshop-on-biofouling-management-in-marine-protected-areas
Multi-criteria decision analysis model	COMPLETE	For Shipowners as well as regional maritime and environmental regulators to develop make decisions regarding optimum biofouling management actions and solutions taking into account both costs related to fuel consumption and biofouling management methods (coating type and IWC) as well as environmental risks (Luoma et al., 2022); stakeholder review of the model available at https://plus.balticcomplete.com/attachments/article/6/COMPLETE%20PLUS%20Memorandum%20multicriteria%20DSS%20for%20biofouling%20management%20FINAL.pdf
Risk assessment of in-water cleaning (IWC) of ships in the Baltic Sea Region	COMPLETE PLUS	For regulators and vessel managers; the proposed harmonized risk assessment is to determine if IWC is allowed for ships operating in the Baltic Region https://plus.balticcomplete.com/attachments/article/7/A3.3_Proposal%20of%20a%20risk%20assessment%20as%20basis%20for%20the%20permission%20of%20IWC%20of%20ships%20in%20the%20BSR_BSH.pdf
Vessel Check	DHI	For regulators, vessel managers and service providers to determine if vessels are using best practices in biofouling management; delivers an indicative "Overall Risk Assessment" that considers seven factors; the programme is free to vessel operators

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