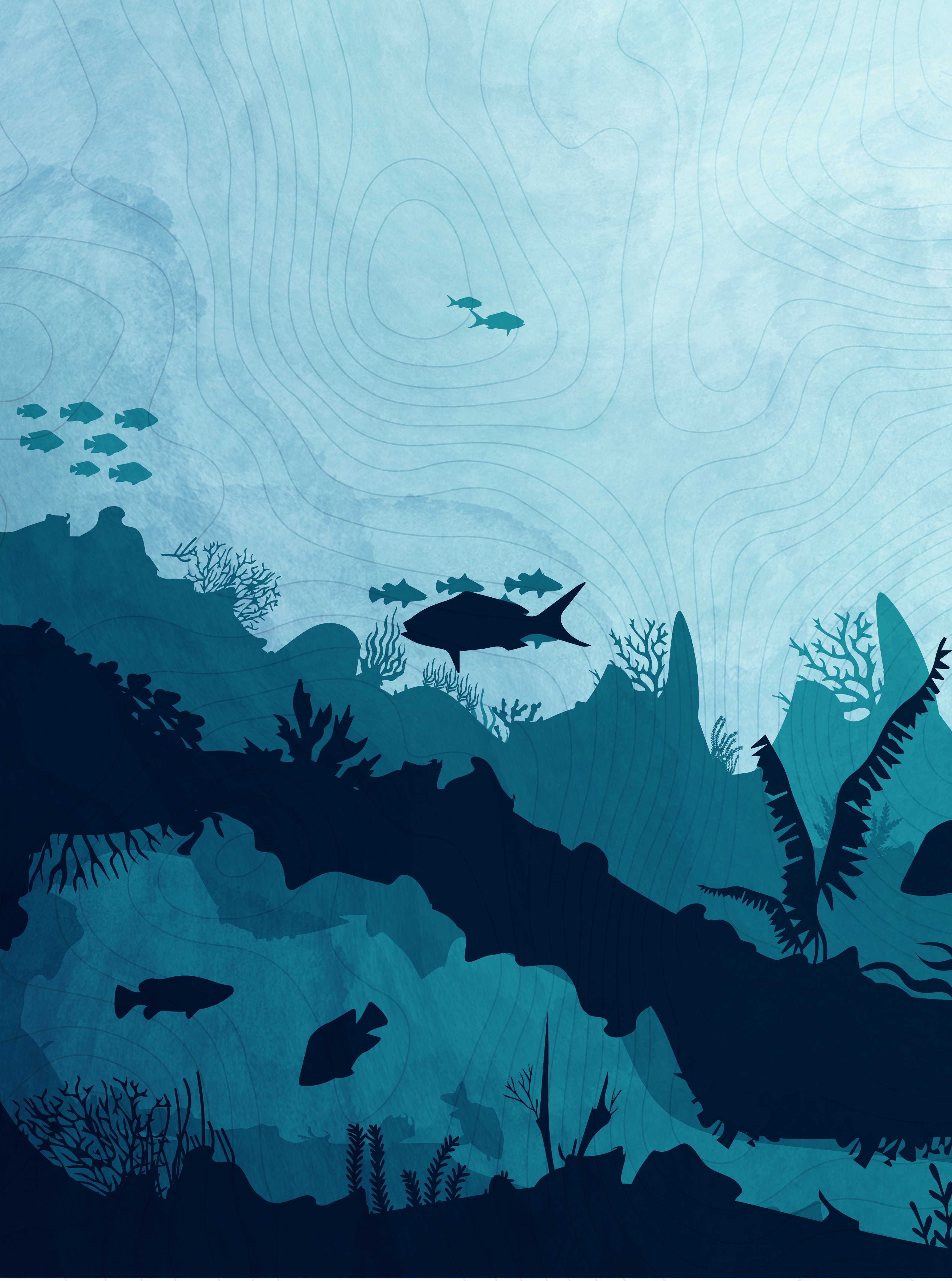
BIOFOULING MANAGEMENT IN MARINE PROTECTED AREAS AND PARTICULARLY SENSITIVE SEA AREAS

Compendium of recommendations for the prevention and early detection of and rapid response to invasive aquatic species

An output of the International workshop on biofouling management to prevent invasive aquatic species in Marine Protected Areas and Particularly Sensitive Sea Areas, Galapagos Islands, Ecuador, June, 2023.



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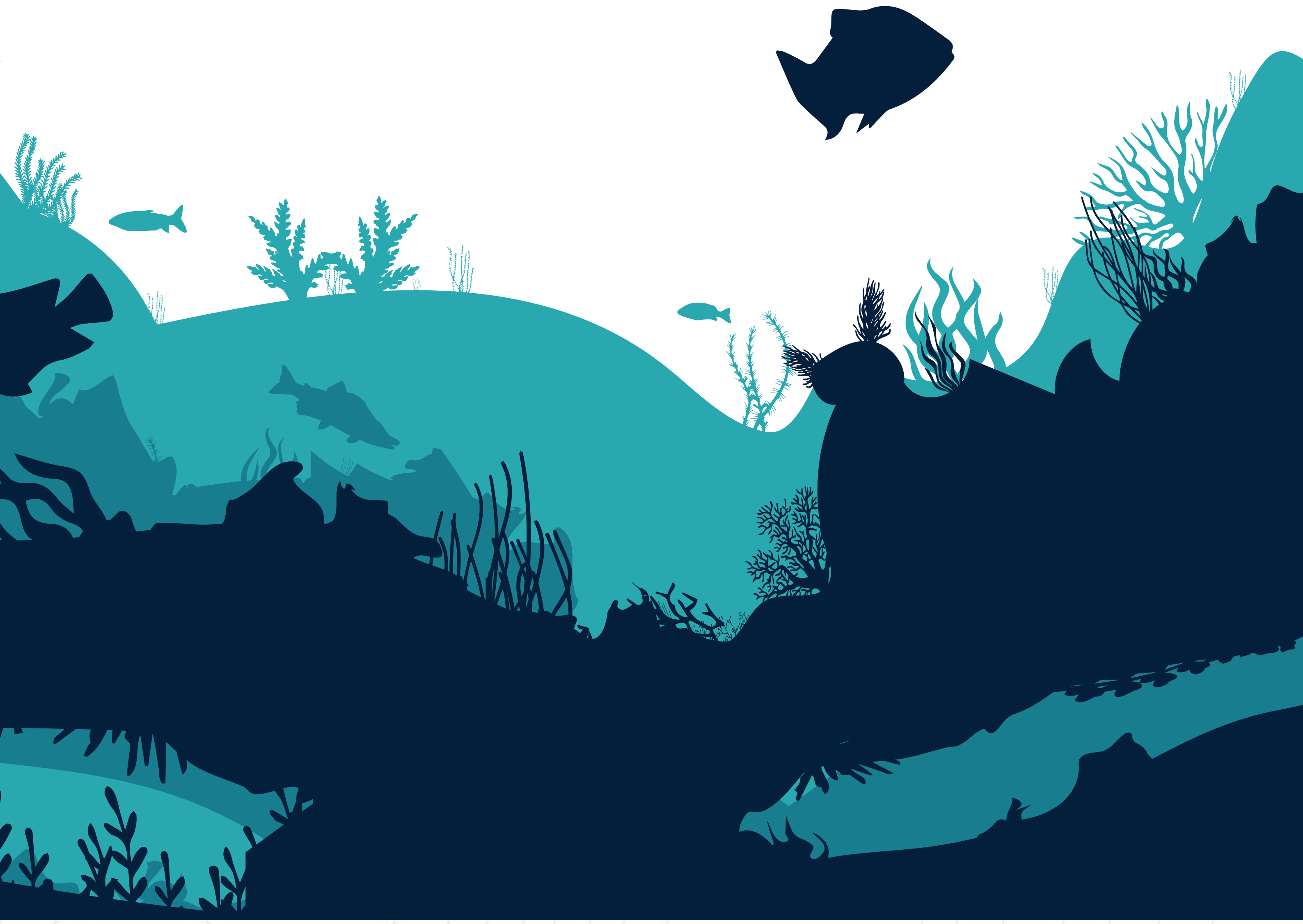

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GloFouling Partnerships
Building Partnerships to Assist Developing Countries to Minimize the Impacts from Aquatic Biofouling (GloFouling Partnerships) is a collaboration between the Global Environment Facility (GEF), the United Nations Development Programme (UNDP) and the International Maritime Organization (IMO). The GloFouling Partnerships is a six-and-a-half-year global project aimed at protecting biodiversity by tackling the transfer of harmful aquatic species through biofouling in some of the developing regions of the world. The project encourages the sharing and adoption of technologies and innovative solutions that can improve biofouling management across all maritime industries and the energy efficiency of ships. www.glofouling.imo.org

Funding Agency:
The Global Environment Facility (GEF) is a multilateral fund dedicated to confronting biodiversity loss, climate change, pollution, and strains on land and ocean health. Its grants, blended financing and policy support help developing countries address their biggest environmental priorities and adhere to international environmental conventions. The GEF connects 185 member governments with sustainability leaders across civil society, Indigenous Peoples and the private sector, and works closely with other environmental financiers for efficiency and impact. Over the past three decades, the GEF has provided more than $22 billion in grants and blended finance and mobilized $120 billion in co-financing for more than 5,000 national and regional projects. www.thegef.org

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Executing Agency:
The International Maritime Organization (IMO) is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships. www.imo.org

[1] Electronic version available for download at https://www.glofouling.imo.org/publications-menu

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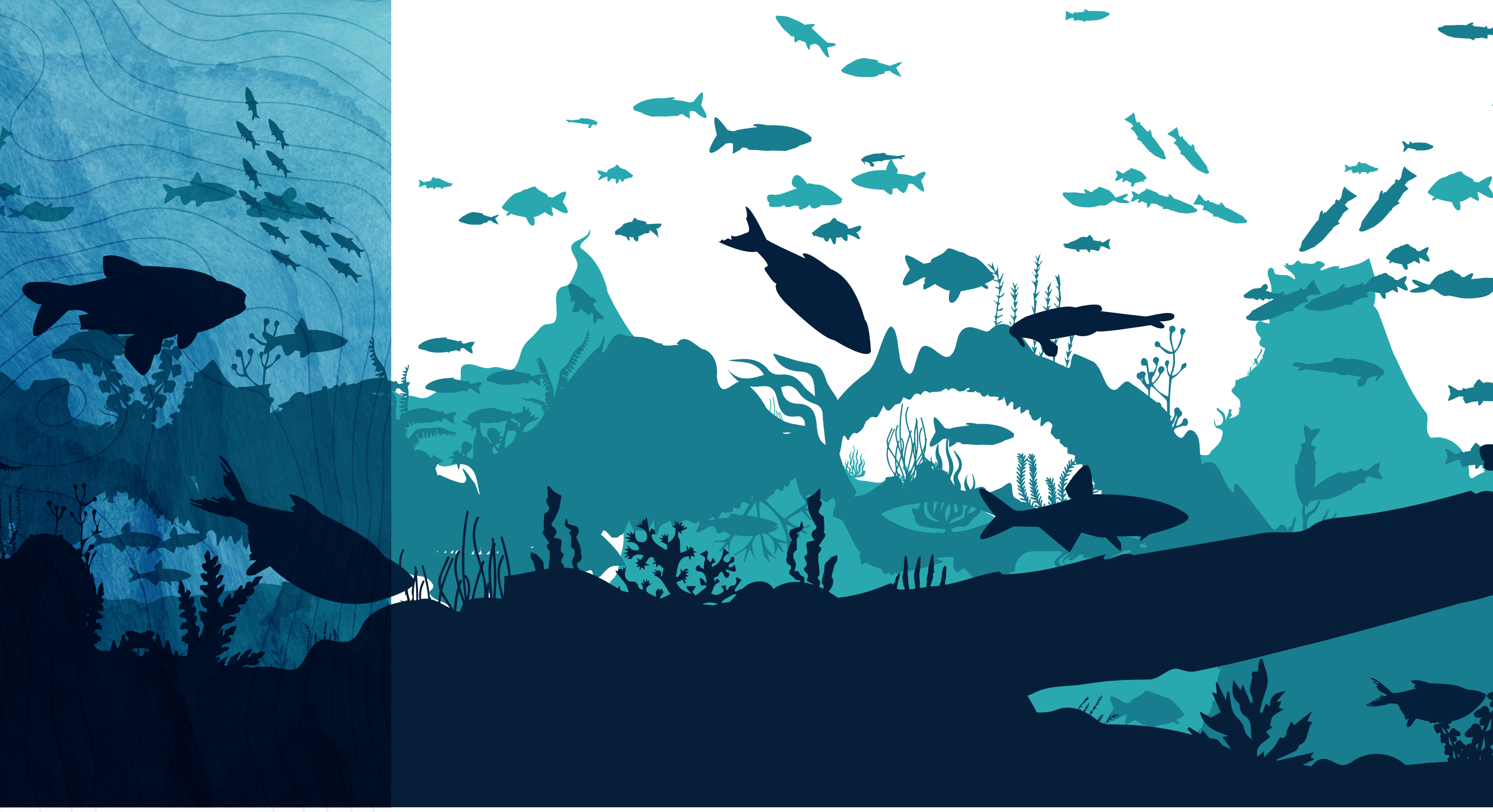

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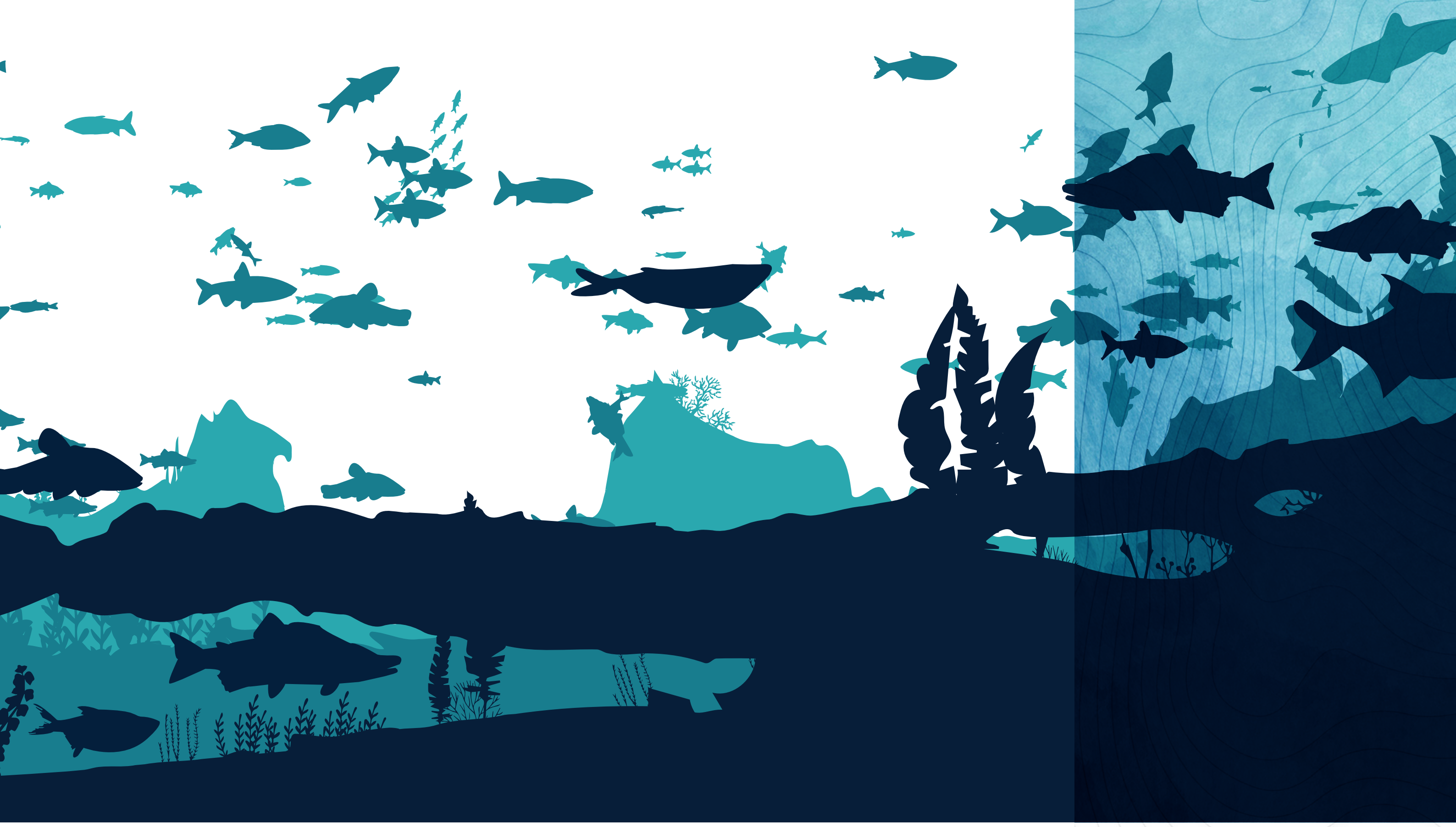

ACRONYMS AND ABBREVIATIONS

ABNJ	Areas beyond national jurisdiction
AFS (Convention)	International Convention on the Control of Harmful Anti-fouling Systems on Ships
BFMP	Biofouling Management Plan
BFRB	Biofouling Record Book
CBD	Convention on Biological Diversity
EEZ	Exclusive Economic Zone
GEF	Global Environment Facility
GFP	Building Partnerships to Assist Developing Countries to Minimize the Impacts from Aquatic Biofouling (GloFouling Partnerships) referred to as “GEF-UNDP-IMO GloFouling Partnerships Project”
GISP	Global Invasive Species Programme
IAS	Invasive Aquatic Species
IMO	International Maritime Organization
km	Kilometres
MoU	Memorandum of Understanding
MEPC	Marine Environmental Protection Committee of IMO
MPA	Marine Protected Area
NIMS	Non-indigenous Marine Species (also commonly referred to as Non-native species)
PCR	Polymerase chain reaction is a widely used technique to make many copies of a specific DNA sample rapidly
PSC	Port State Control
PSSA	Particularly Sensitive Sea Area
TBT	Tributyltin
UNCLOS	1982 United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme

GLOSSARY OF TERMS

Anti-fouling system (AFS)	A coating, paint, surface treatment, surface or device that is used on a ship to control or prevent attachment of organisms.
Anti-fouling coating (AFC)	A surface coating or paint designed to prevent, repel or facilitate the detachment of biofouling from hull and niche areas that are typically or occasionally submerged.
Aquatic	Freshwater, brackish or marine.
Benthic	Anything associated with or occurring on the bottom of a body of water. The community of organisms that live on or in the bottom are known as "benthos".
Biocide	A chemical substance sometimes incorporated into anti-fouling systems to prevent settlement or survival of aquatic organisms.
Biofouling	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. For microfouling and macrofouling, see definitions below.
Biofouling Guidelines	IMO resolution MEPC.378(80): 2023 Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species.
Cryptogenic species	A marine species that is not demonstrably native or introduced (non-native).
Dry-dock cleaning	The cleaning of the submerged areas when the ship is out of water.
Fouling rating	The allocation of a number for a defined inspection area of the ship surface based on a visual assessment, including description of biofouling present and percentage of macrofouling coverage.
Compendium	Refers to this document throughout.
Guidance for Recreational Craft	IMO resolution MEPC.1/Circ.792: Guidance for minimizing the transfer of invasive aquatic species as biofouling (hull fouling) for recreational craft (12 November 2012).
In-water cleaning	The removal of biofouling from a ship's hull or other submerged structure while in the water.
Invasive aquatic species (IAS)	A species not native to a particular ecosystem which may pose threats to human, animal and plant life, economic and cultural activities and the aquatic environment.
Macrofouling	Biofouling caused by the attachment and subsequent growth of visible plants and animals on structures and ships exposed to water. Macrofouling are large, distinct multicellular individual or colonial organisms visible to the human eye such as barnacles, tubeworms, mussels, fronds/filaments of algae, bryozoans, sea squirts and other large attached, encrusting or mobile organisms.
Marine growth prevention system (MGPS)	An AFS used for the prevention of biofouling accumulation in niche areas or other surface areas but may also include methods which apply surface treatments.
Microfouling	Biofouling caused by bacteria, fungi, microalgae, protozoans and other microscopic organisms that creates a biofilm also called a slime layer.

Niche areas A subset of the submerged surface areas on a ship that may be more susceptible to biofouling than the main hull due to structural complexity, different or variable hydrodynamic forces, susceptibility to AFC wear or damage, or inadequate or no protection by AFS.

Non-native species Species introduced outside their natural past or present range which might survive and subsequently reproduce.

Oil and gas Naturally occurring hydrocarbon deposits including crude oil, natural gas and condensates (or a mixture of some/all of these) extracted in either gaseous or liquid form.

Pelagic Relating to the water column of the ocean.

Prevention Refers to preventing the arrival of a fouled vessel at the border.

Ship A vessel of any type whatsoever operating in the aquatic environment, including hydrofoil boats, air-cushion vehicles, submersibles, floating craft, fixed or floating platforms, floating storage units (FSUs) and floating production storage and off-loading units (FPSOs).

Transfer pathway The process or mechanism by which an organism is moved from its native area into a new area.

Vector The specific mode via which a pathway transfers a non-native species. In the case of shipping, both ballast water and biofouling are recognized vectors of non-native species.

Waste substances Dissolved and particulate materials that may be released or produced during cleaning or maintenance, and may include biocides, metals, organic substances, removed biofouling, pigments, microplastics or other contaminants that could have a negative impact on the environment.

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This compendium was written by Julian Peter Roberts, Director and Senior Consultant, Blue Resources Ltd, with contributions, editorial review, comments and input from Lilia Khodjet El Khil, Project Technical Manager, John Alonso and Will Griffiths, Project Technical Analysts, GloFouling Partnerships project, Subdivision for Partnerships and Projects, Technical Cooperation and Implementation Division, IMO.

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Marine Protected Area (MPA) managers should consider integrating IAS into the MPA management plan. Currently 3 MPAs in the world enforce strict standards on ship biofouling before entry to marine parks or protected areas

The application of the IMO particularly sensitive sea area (PSSA) concept, along with spatial management measures, such as ships routeing measures, is relevant to prevent Invasive Aquatic Species (IAS) introductions.

Ships' routeing measures may include recommended routes, areas to be avoided, reporting obligations, mandatory non-anchoring areas.

Although to date, all PSSAs have been designated within Exclusive Economic Zones (EEZs) designation in the high seas by IMO is possible and so the PSSA framework can be applied to areas beyond national jurisdiction (ABNJ).

EXECUTIVE SUMMARY

The transport and introduction of invasive species is widely recognized as a significant threat to marine biodiversity. The development of maritime activities in particular has provided new and enhanced pathways for the global spread of invasive aquatic species (IAS), which are now documented in the majority of the world's marine ecoregions. Much attention has been paid to the fact that many species are translocated via ballast water, however, the attachment of biofouling organisms to the hulls of vessels and other mobile marine structures also represents a key vector for IAS transfer.

IAS, when introduced to a non-native range can give rise to a broad range of environmental, economic and social impacts resulting in loss of species diversity or ecosystem services, or significant alteration of trophic interactions and can result in significant costs to treat or remediate affected areas. Thus, preventing and responding to IAS incursions in a timely manner is seen as a key priority for marine managers.

Marine protected areas (MPAs) are an important tool for marine biodiversity conservation, providing, as they do, the means to protect critical habitats or areas of biodiversity value. They can also be used to build resilience into marine systems under ever-increasing pressure due to global climate change. The list of globally designated MPAs contains a wide variety of biotopes including, coral reefs, salt marshes, mangroves, offshore reefs, seamounts and ice-covered areas.

The introduction of IAS to MPAs may have significant impacts on their ecological structure and function. However, while the impacts of IAS are considered a management concern by many marine biologists and biosecurity experts, the issue is often overlooked in MPA planning and management and very few MPAs - even those with robust and well implemented management plans - have specific measures in place to control the threat of invasive fouling organisms. Some exceptions to this include the Galápagos Marine Reserve (Ecuador), the Kermadec and Subantarctic Islands (New Zealand) and the Papahānaumokuākea Marine National Monument (PMNM; Hawaii, USA), which enforce strict standards on biofouling before entry to marine parks or protected areas.

International experience demonstrates the numerous challenges involved in responding to and eradicating an IAS once it has established, based on the practicalities of intervention, the likely costs involved and limited chances of success. Attempting eradication within an MPA may be even more difficult because many of the response tools normally considered may cause significant harm to native biodiversity. As such, the primary focus for MPA managers should be in preventing the arrival of a fouled vessel in the first place. Unless vessels are entirely excluded from entering an MPA, it is very likely that non-indigenous species associated with biofouling on vessels will eventually be introduced. Robust and cost-effective tools for early detection and monitoring of IAS are therefore a critical element in the efforts to prevent future invasions, as well as the further spread of existing AIS.

The International Maritime Organization (IMO) has been at the forefront of international efforts to tackle IAS by taking the lead in addressing the transfer of non-indigenous organisms through shipping including, among other measures, the adoption of the Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species". These were subsequently complemented by the Guidance for minimizing the transfer of invasive aquatic species as biofouling (hull fouling) for recreational craft.

To support the implementation of the Biofouling Guidelines, the GEF-UNDP-IMO GloFouling Partnerships Project (GFP) was launched in December 2018, to build

capacity in developing countries for implementing the IMO Biofouling Guidelines, as well as other relevant guidelines relating to biofouling management, to catalyse overall reductions in the transboundary introduction of biofouling-mediated IAS. Recognizing the unique needs of MPAs in this regard, the GFP has developed this compendium, which aims to provide MPA managers and policymakers alike with information to assist them in the management of biofouling vectored IAS. This compendium draws from the outcomes of discussions held among a group of MPA managers and biofouling experts during an international biofouling workshop, organized by the GFP and held in the Galápagos Islands, Ecuador in June 2023.

The compendium summarizes existing practices that can be used by MPA managers to protect MPAs from the impacts of IAS through ships' biofouling. These practices, when incorporated into broader MPA Management Plans, should ensure that such plans are able to respond more effectively to the broad range of threats facing MPAs. Throughout the compendium, a broad range of issues and opportunities are identified as well as a corresponding set of high-level recommendations (summarized below), with the aim of creating the enabling environment to support biofouling control and management.

RECOMMENDATIONS

Biofouling and MPAs

Recommendation 1: Develop and implement a capacity-building package (in conjunction with IUCN/WCPA) to raise awareness among MPA planners and managers about biofouling management and the threat posed by IAS.
Recommendation 2: Support/undertake research into the environmental, economic and sociocultural impacts of established IAS.

Governance Arrangements

Recommendation 3: Prepare and trial a set of model instruments to support and harmonize the implementation of biofouling management arrangements within marine protected areas. Such instruments could include, but not necessarily be limited to:

- a model legal instrument for biofouling management; and
- model IAS Response (Contingency) Plan.

Recommendation 4: Undertake an assessment of possible models of sustainable finance to support the development and implementation of MPA-specific biofouling management arrangements.

Prevention of Biofouling and Management of Biofouling Pathways

Recommendation 5: Undertake a study to correlate high risk species with certain pathways or areas within a pathway.
Recommendation 6: Prepare a simplified record book to enable recreational vessel owners to record their vessel's biofouling management history.
Managing Biofouling Risk
Recommendation 7: Build capacity among MPA managers to support vessel risk profiling and border inspection.

Monitoring, Control and Eradication

Recommendation 8: Prepare a more detailed guideline on Monitoring and Rapid Response to IAS Incursions with a specific focus on the specific needs of MPA managers.
Recommendation 9: Provide support through pilot projects to prepare baseline surveys for key MPAs.
Recommendation 10: Provide protocols and support to enable MPA managers to define or refine "target species lists".

PART 1:
OVERVIEW AND CONTEXT

1 INTRODUCTION

1.1 BACKGROUND TO THE COMPENDIUM

According to the most recent assessment undertaken by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the introduction of invasive species is one of the key drivers of change in nature, along with changes in land and sea use, direct exploitation of organisms, climate change and pollution (IPBES, 2019). In the case of the oceans, the development of maritime transport activities in particular has provided new and enhanced pathways for the global spread of invasive aquatic species (IAS). As a result, IAS have now been documented in the majority of the world's marine ecoregions.

For many years, it was believed that ships' ballast water was the primary vector for the transport and introduction of IAS. More recently, however, the attachment of fouling organisms to the hulls of vessels and other mobile marine structures has also been recognized as an important vector for the transfer of IAS (GEF-UNDP-IMO GloFouling Partnerships Project, 2022a). In fact, it has been estimated that up to 55% of recognized non-native marine species detected around the world could have been introduced by biofouling on mobile marine structures (Hewitt and Campbell, 2010).

In response to global concerns about the risks associated with ship-borne biofouling, in 2011 the International Maritime Organization (IMO), through its Marine Environmental Protection Committee (MEPC), adopted the *Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species* (hereafter "Biofouling Guidelines"). These Guidelines were recently revised and adopted in 2023. Additionally, IMO adapted these recommendations specifically for the recreational boating sector, and published the *Guidance for minimizing the transfer of invasive aquatic species as biofouling (hull fouling) for recreational craft.*

Global concerns over the threat posed by invasive species are also reflected in recent developments under the Convention on Biological Diversity (CBD). In December 2022, the CBD Conference of Parties adopted the Kunming-Montreal Global Biodiversity Framework (GBF). Target 6 of the GBF seeks to *"eliminate, minimize, reduce and or mitigate the impacts of invasive alien species on biodiversity and ecosystem services by identifying and managing*

pathways of the introduction of alien species, preventing the introduction and establishment of priority invasive alien species, reducing the rates of introduction and establishment of other known or potential invasive alien species by at least 50 per cent, by 2030, eradicating or controlling invasive alien species especially in priority sites, such as islands."

Marine protected areas (MPAs) and other area-based conservation measures, including specific measures adopted by IMO, have the potential to address many of the pressures threatening marine biodiversity, and have been widely adopted by the vast majority of coastal and island nations as a cornerstone of their national conservation strategies. However, MPAs themselves are also at risk of impacts of human activities (including fishing, tourism, maritime transport, aquaculture, tourism and extractive industries such as oil and gas production), which may compromise the ability of individual MPAs to realize desired marine conservation goals. The introduction of IAS to MPAs in particular may have significant impacts on their ecological structure and function, due to changing species composition and habitat modification. IAS introductions into MPAs are also considered likely to increase under future climate conditions, a finding that is consistent with predicted trends for ocean systems globally (Iacarella et al., 2019a).

While the impacts of IAS are considered a management concern by many MPA experts (Iacarella et al., 2019b), the issue is often overlooked in MPA planning and management, with only a small proportion of MPA management plans addressing the management of non-native species (Iacarella et al., 2020). To date, MPAs, invasive species, and the human activities that connect the two have largely been managed separately. Effective long-term conservation will, however, require integrated policies and coordinated efforts to reduce invasions and their impacts (Iacarella, et al. 2020).

While there is increased emphasis on the control and management of biofouling as a vector for the transfer of IAS, the focus of current efforts remains very much on international vessels and certain key economic sectors such as aquaculture and offshore energy.

Managers and policymakers wishing to implement biofouling management strategies aimed at protecting specific MPAs are largely limited to the application of domestic measures that may not adequately respond to the specific threats present in their respective MPA, such as international shipping.

However, the growing appreciation of the threat of IAS to MPAs has led several MPA management authorities (including the Galápagos Islands in Ecuador, the Kermadec Islands Marine Reserve in New Zealand and the Papahānaumokuākea Marine National Monument in Hawaii, (USA)) to adopt stringent access controls on vessels seeking to operate with their respective MPA boundaries.

1.2 PURPOSE AND SCOPE OF THE COMPENDIUM

To support implementation of the IMO Biofouling Guidelines, the GFP was launched in December 2018, to build capacity in developing countries for implementing the guidelines, as well as other relevant guidelines relating to biofouling management, as a means to catalyse a reduction in the transboundary introduction of biofouling-mediated IAS.

Recognizing the unique needs of MPAs in this regard, the GFP has developed this Compendium, which aims to provide MPA managers and policymakers alike with information to assist them in the management of biofouling vectored IAS. This Compendium draws from the outcomes of discussions held among a group of MPA managers and biofouling experts during an international biofouling

workshop, organized by the GFP and held in the Galápagos Islands in June 2023 (Galápagos biofouling management workshop).

The Compendium presents existing practices that can be used by MPA managers to protect MPAs from the impacts of IAS through ships' biofouling. These strategies, when incorporated into broader MPA Management Plans, should ensure that such plans are able to respond more effectively to the broad range of threats facing MPAs.

This Compendium is presented in three parts which consist of a total of eight chapters.

Following this introduction (**chapter 1**), **chapter 2** presents a brief summary of the problem including:

- an overview of the biofouling process and the biofouling invasion pathway;
- an overview of the international policy framework for biofouling management;
- an introduction to the concept of marine protected areas, including the range of area-based management tools available to IMO for the protection of vulnerable marine ecosystems; and
- an overview of the potential impacts of IAS on marine protected areas.

Part 2 of this Compendium details the range of management approaches that are available for preventing and controlling the spread of IAS. These include the governance arrangements that are necessary to implement effective biofouling management (**chapter 3**); the measures that can be employed to prevent the transmission of IAS across different transfer pathways (**chapter 4**); the management options that can be deployed to ensure that high-risk vessels are not allowed to enter the port/MPA (**chapter 5**); and the options available to MPA managers to monitor, control and possibly eradicate invasive organisms once they have been identified within an MPA (**chapter 6**).

To conclude the Compendium, **part 3** presents a summary of the current gaps and critical issues with respect to IAS management in MPAs that were identified during the Galápagos biofouling management workshop, as well as a set of concomitant recommendations that have been identified to address those gaps (**chapter 7**). To support this Compendium, **chapter 8** provides details of reference material and information sources that might be useful for MPA managers wishing to develop MPA-specific biofouling management strategies.

2 CONTEXT AND PROBLEM DEFINITION

2.1 INVASIVE AQUATIC SPECIES AND BIOFOULING PROBLEM DEFINITION

2.1.1 Invasive aquatic species (IAS)

The ocean is home to a variety of species that have evolved in disconnected habitats, separated by large distances and natural barriers. Some of these species, however, have been moved beyond their native geographic range, intentionally or otherwise, as a result of human activities. When some competitive advantage (such as the absence of natural predators) exists, such non-native species may become established, reproduce and spread in a new location, with the potential to cause harm to the local environment, economic activities and human health. These species are generally referred to as invasive aquatic species (IAS)[2]. It is important to note, however, that not all non-native species will become invasive. Similarly, indigenous species may also become invasive in their native environment, usually as a result of altered environmental conditions.

The majority of IAS are shallow water benthic species from inshore waters that generally (but not always) flourish in conditions similar to their native range. Successful IAS frequently share a set of life history and ecological traits that facilitate their establishment, such as broad environmental tolerance, rapid growth rates, the production of large numbers of offspring, the ability to reproduce both sexually and asexually, opportunism, early maturity and the ability of an organism to change in response to stimuli or inputs from the environment. When combined with a large number of organisms released from a specific source and the frequency by which organisms can be released, the chances of survival in a new environment can be considerably enhanced.

2.1.2 Biofouling as a vector for the introduction of IAS

IMO defines biofouling as:

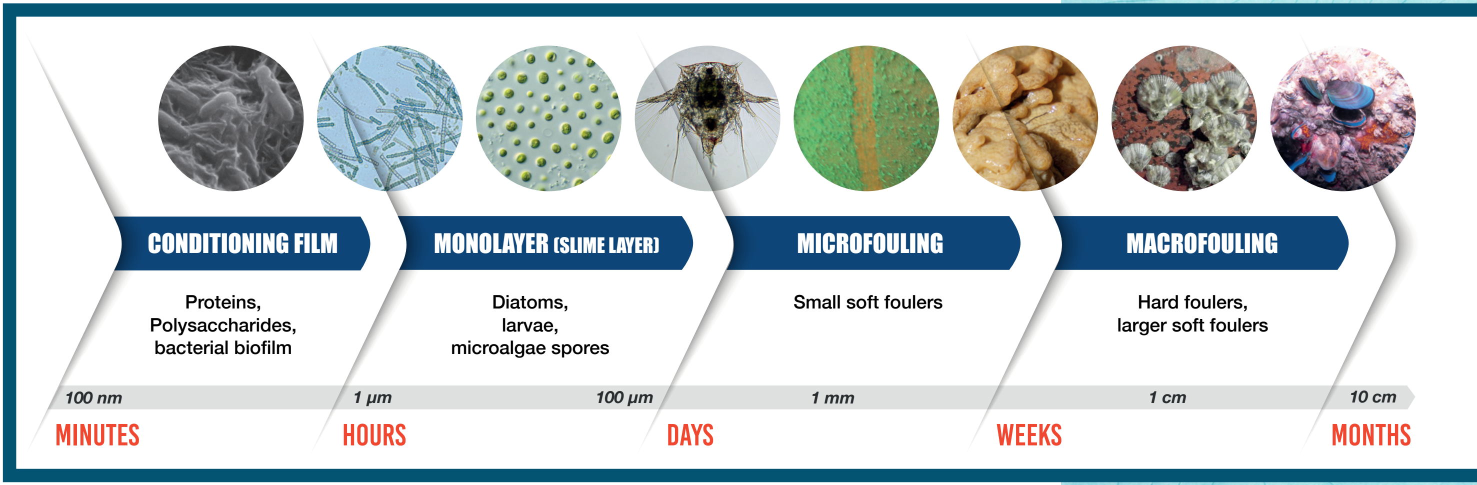
> *The accumulation of aquatic organisms such as microorganisms, plants and animals on surfaces and structures immersed in or exposed to the aquatic environment. Biofouling can include pathogens.*

When a surface – be it a ship's hull, a jetty or even a rope – is placed in the sea, it may be colonized by a variety of marine species. In the first instance (as soon as an unprotected surface is immersed in water), organic materials adhere to the surface creating what is known as a Conditioning Layer. Colonization then begins by organisms such as diatoms, bacteria and microalgae, creating a biofilm (commonly called a slime layer). This is followed by a gradual succession and growth of larger macrofouling species, such as other algae, sessile animals (sponges, anemones), mobile benthic animals (worms, shrimps, crabs) and associated parasites. The process is illustrated in Figure 1 below.

Most marine organisms, whether they are "pelagic" (living in the water column), "benthic" (associated with the seabed), mobile or sessile, have larvae that actively disperse into the water column. Any given volume of untreated water is likely to contain potential fouling organisms seeking a suitable substrate on which to settle. The nature of the surface has a strong influence on whether larvae settle – for example algae prefer surfaces exposed to light, whereas many invertebrate species prefer dark areas that are protected from hydrodynamic forces.

[2] The term 'invasive marine species' (IMS) is also correctly used to define non-native marine species that become invasive. However, the term IAS is used in the 2023 Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species (IMO Resolution MEPC.378(80)) and will, therefore, be used throughout this document.

Figure 1: Biofouling growth process

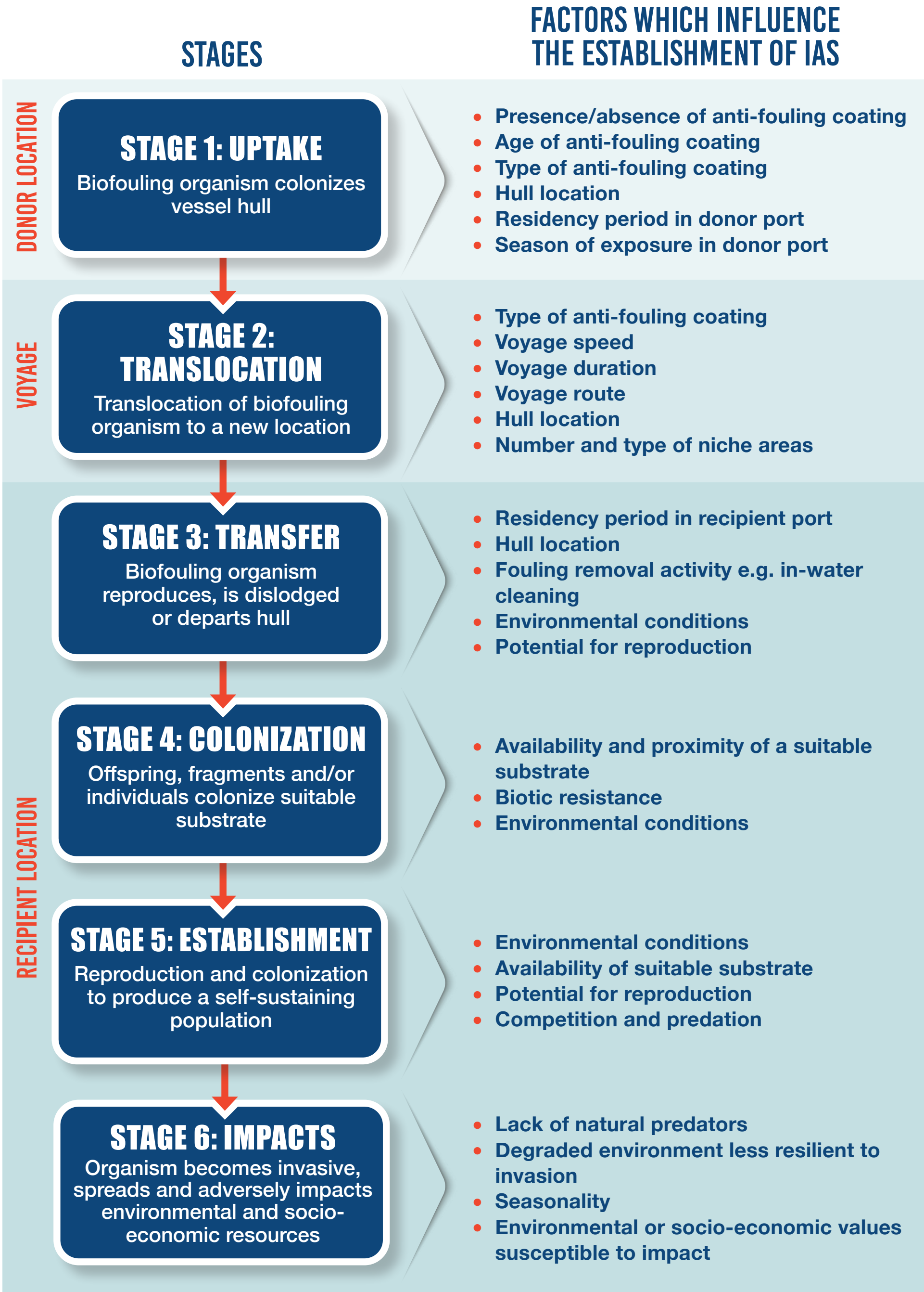


Well-established biofouling communities may also include loosely attached and mobile organisms, such as snails, crabs, seastars and sea urchins, and even various species of fish, that live in the matrix of other species, and in crevices or niche areas that are protected from hydrodynamic forces.

Figure 2: Lobster found in a niche area of a ship in Galapagos Island, Ecuador

Ships and other mobile structures, if moved, can transport these organisms over significant distances beyond the limits of their natural geographic range. However, biofouling, in and of itself, does not necessarily translate to the introduction of IAS into new environments, since, as noted above, this requires the presence of appropriate environmental conditions for survival and reproduction. Only those organisms that survive the local conditions may become invasive in a recipient region. Many factors affect each stage of the biofouling invasion pathway (see Figure 3 below), and it is thus very challenging to predict which non-native marine species will become invasive in a specific location.

Figure 3: General biofouling invasion pathway stages and associated selective pressures for IAS establishment (Adapted from Coutts et al. 2009)



2.1.3 Biofouling transfer pathways

IAS may be introduced to new marine areas via a number of mechanisms, including intentional introduction (e.g. for fisheries or aquaculture purposes) and unintentional means, such as discharge of ships' ballast water, biofouling, aquarium escapees, marine debris, and natural dispersal through navigation canals or waterways (e.g. the Suez and Panama canals). The transport of species from one location to another occurs through a number of recognized transfer "pathways" as follows:

Natural pathways (i.e. those not aided by humans) include wind, currents (including the transportation of marine debris), and other forms of natural dispersal that can bring species to a new habitat.

Anthropogenic (human-mediated) pathways are those which are created or enhanced by human activity and may either be intentional (such as the introduction of a new species for aquaculture purposes) or unintentional (such as the transfer of an organism on a ship's hull).

The main anthropogenic transfer biofouling pathways are illustrated in Figure 4 below.

Figure 4: Potential pathways for the introduction of IAS through biofouling

Those anthropogenic pathways that are responsible for the initial introduction of a non-native fouling organism into a new recipient location, for example an international trading ship, are termed **"primary pathways"**. Where a non-native species has already been introduced, on the other hand, it may be distributed more widely by **"secondary pathways"**, such as coastal vessels, recreational craft, or local fishing vessels.

The risk associated with biofouling may be unevenly distributed between different maritime sectors and between regions. For example, non-trading vessels such as offshore oil and gas infrastructure, fishing vessels, recreational craft or renewable energy structures may in some circumstances present a higher risk of IAS transfer through biofouling, due to slower transit speeds, complex niche areas and greater periods of time spent in coastal waters, often stationary, where they are subject to biofouling recruitment.

2.2 INTERNATIONAL FRAMEWORK FOR BIOFOULING MANAGEMENT

Currently there are no mandatory international requirements relating to management of biofouling. There are however a number of international guidelines relevant to biofouling management that may be relevant for MPAs. These are outlined below.

2.2.1 IMO Biofouling Guidelines

In July 2011, IMO adopted the 2011 Biofouling Guidelines, in response to concerns raised by its Member States about the risk of transfer of IAS posed through biofouling on ships. These Guidelines were reviewed and revised by

IMO Member States and Consultative Organisations and, as a result, the 2023 Biofouling Guidelines were adopted by the IMO Marine Environment Protection Committee (MEPC) in July 2023 (IMO, 2023)[3]. As with all guidance documents the Biofouling Guidelines remain non-binding on States, but it should be noted that the definition of "ship" includes:

> *A vessel of any type whatsoever operating in the aquatic environment and includes hydrofoil boats, air-cushion vehicles, submersibles, floating craft, fixed or floating platforms, floating storage and production units (FSUs) and floating production storage and off-loading units (FPSOs).*

The Biofouling Guidelines focus on preventative measures to minimize biofouling, and are intended to provide useful recommendations for measures to minimize biofouling for all types of ships (IMO, 2023). They are intended for use by a multitude of stakeholders, including not only shipowners and ship operators, but also ship designers, shipbuilders, anti-fouling paint manufacturers and suppliers, shipmasters, port authorities, ship cleaning and maintenance operators, inspection organizations, ship repair, dry-docking and recycling facilities.

The Guidelines recognize that effective anti-fouling application and maintenance are the primary means of biofouling prevention and control for existing ships' submerged surfaces, including hull and niche areas. They include guidance on:

- Ship design and construction in order to minimize biofouling;
- choosing, installing, maintaining, reinstalling and repairing of anti-fouling systems (AFS);
- contingency action plans (in case of the occurrence of biofouling);
- inspection and inspection regimes; and
- cleaning and maintenance.

In addition, a key component of the Guidelines is the preparation of ship-specific biofouling management plans (BFMP) and biofouling record books (BFRB). The Guidelines include specific recommendations for inclusions in BFMP and BFRB, and templates for each. This documentation is the cornerstone of many current and proposed national and sub-national biofouling management policies and practices (IMO, 2023).

At the time of publication of this Compendium, guidance on in-water cleaning is under development as a future stand-alone guidance document from IMO.

2.2.2 Biofouling on recreational craft

In 2012, IMO also produced the *Guidance for minimizing the transfer of invasive aquatic species as biofouling (hull fouling) for recreational craft.* In-water cleaning is recommended only for removing light fouling (microfouling) with gentle techniques to minimize potential environmental risks, noting the need to seek local authority approval for proper disposal beforehand. Capture technology is recommended with appropriate onshore disposal of waste.

Although the Guidance does not include recommendations on BMFP and BFRB, it recommends retaining biofouling information in one place such as the logbook, including information such as details of the AFS used, inspections and notes on the effectiveness of the AFS. The records should include a diagram of the hull and niche areas with plans on how to minimize biofouling.[4]

[3] This Compendium takes the 2023 Biofouling Guidelines as its main reference.

[4] More detailed information and resources on biofouling prevention and management specifically aimed at the recreational boating sector can be found in "Biofouling Management for Recreational Boating: Recommendations to Prevent the Introduction and Spread of Invasive Aquatic Species", GloFouling Partnerships, 2022. Available here: https://www.glofouling.imo.org/publications-menu.

2.2.3 International Convention on the Control of Harmful Anti-fouling Systems on Ships

In response to concerns over the toxicity of tributyltin (TBT)-based anti-fouling coatings, in 2001 IMO adopted the International Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS Convention). The AFS Convention prohibits the use of organotin-based anti-fouling systems on ships and establishes a mechanism to prevent the potential future use of other harmful substances in anti-fouling.

There is an obvious relationship between the AFS Convention and biofouling management. However, the AFS Convention is not intended to address biofouling management. Instead, the AFS Convention provides a framework to limit the impact of harmful AFS.

Parties to the convention are required to prohibit and/or restrict the use of harmful anti-fouling systems on ships flying their flag, as well as ships not entitled to fly their flag but which operate under their authority and all ships that enter a port, shipyard or offshore terminal of a Party. Although there are some exceptions (including fixed and floating offshore oil installations and military and other government ships) this applies to the vast majority of ships on the ocean.

2.3 MARINE PROTECTED AREAS

2.3.1 The concept of Marine Protected Areas

In its broadest sense, a Marine Protected Area (MPA) can be defined as any area of the coastal zone or open ocean, conferred some level of protection for the purpose of managing the use of resources and ocean space, or protecting vulnerable or threatened habitats and species (Agardy, 1997). However, probably the most common definition for an MPA is that of the International Union for the Conservation of Nature (IUCN) (Kelleher 1999):

> *Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment.*

The list of designated MPAs globally contains a wide variety of biotopes such as coral reefs, salt marshes, mangroves, offshore reefs, seamounts and ice-covered areas (OECD, 2017). The benefits of MPAs have been shown for both ecosystem structure and functioning; as well as providing specific protection against known threats, MPAs enable application of the “precautionary principle”. They provide a means to protect critical habitats or areas of biodiversity value and, recognizing that scientific knowledge is far from complete, can provide a physical area within which to apply a buffer against unforeseen yet potentially irreversible damage. They can also be used to build resilience into marine systems under ever-increasing pressure due to global climate change.

MPAs may range from small, highly protected “no-take” reserves that sustain species and maintain natural resources to very large multiple-use areas, in which the use and removal of resources is permitted but controlled to ensure that conservation goals are achieved (for example the Great Barrier Reef Marine Park). The management of individual MPAs varies depending on the nature of the resources, their utilization and the human activities occurring within them. A range of management tools must therefore be applied: in some areas protection may be given from all the activities which could give rise to environmental damage, whereas in other areas protection may be provided by limiting the types of activities allowed. While larger MPAs are generally desired, even small MPAs are beneficial for biodiversity, especially if they form a network over relatively short distances (Ardura et al. 2016).

The Convention on Biological Diversity places great emphasis on in situ conservation, calling upon Parties to adopt measures ranging from the establishment of a system of protected areas to the rehabilitation of degraded ecosystems and the protection of natural habitats and species in natural surroundings.

Target 3 of the 2022 Global Biodiversity Framework seeks that *"by 2030 at least 30 percent of terrestrial, inland water, and of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem functions and services, are effectively conserved and managed through ecologically representative, well-connected and equitably governed systems of protected areas and other effective area-based conservation measures"*.

The IUCN has developed a standardized system of protected area management categories that classify protected areas according to their management objectives. The categories are recognized as the global standard for defining and recording protected areas by international bodies such as the CBD, many of the UN Regional Seas organizations, and by many national governments. Table 1 below summarizes the seven IUCN protected area categories, although

Table 1: IUCN Protected Area Management Categories

Ia	**Strict Nature Reserve** Strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphological features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring.
Ib	**Wilderness Area** Generally larger and less strictly protected from human visitation than category Ia: although not usually subject to mass tourism they may be open to limited numbers of people prepared for self-reliant travel such as on foot or by boat, which is not always the case in Ia.
II	**National Park** Usually combine ecosystem protection with recreation, subject to zoning, on a scale not suitable for category I.
III	**Natural monument or feature** Generally centred on a particular natural feature, so that the primary focus of management is on maintaining this feature, whereas objectives of Ia are generally aimed at a whole ecosystem and ecosystem processes.
IV	**Habitat/Species Management Area** Generally protect fragments of ecosystems or habitats which often require continual management intervention to maintain. Category Ia areas on the other hand should be largely self-sustaining and their objectives preclude such management activity or the rate of visitation common in category IV. Category IV protected areas are also often established to protect particular species or habitats rather than the specific ecological aims of category Ia.
V	**Protected Landscape** Generally cultural landscapes or seascapes that have been altered by humans over hundreds or even thousands of years and that rely on continuing intervention to maintain their qualities including biodiversity. Many category V protected areas contain permanent human settlements. All the above are incompatible with category Ia.
VI	**Protected Areas with Sustainable Use of Natural Resources** resources, which is incompatible with category Ia. However, large category VI protected areas may contain category 1a areas within their boundaries as part of management zoning.

it should be noted that the names of the categories do not necessarily reflect the names used at national or sub-national levels.

The different IUCN management categories may be subject to different levels of protection and management control, ranging from multiple uses, including recreational fishing, to strictly no-take areas utilized purely for scientific research (Kriegl et al. 2021). Thus, within the context of a large, multiple-use MPA, such as the Great Barrier Reef or Galápagos Islands, there may be different levels of protection for different areas (usually depicted as some form of zoning framework) and this may have implications for the ability of MPA managers to control the introduction and spread of IAS.

While it is acknowledged that some IAS may adversely impact MPAs, it should also be acknowledged that, by reducing human use of marine and coastal areas, the designation of MPAs may confer some resilience against the introduction of IAS, for the following reasons:

- fewer transfer pathways are likely to be present within MPAs (e.g. less or no aquaculture, no oil and gas structures and greater restrictions on maritime traffic). As a result, the opportunities for IAS to be transported to and within MPAs are more limited than for unprotected areas;
- environmental stressors are likely to be far less within MPAs than in unprotected areas, resulting in less empty habitat for recruiting than in unprotected spaces; and
- species diversity and abundance are also expected to be higher within MPAs (Ardura et al. 2016). It is well understood that ecosystems with high species richness are more resistant to invaders than those with low biodiversity. Thus, the high native species richness within MPAs could prevent the penetration and settlement of alien species (Giakoumi and Pey, 2017).

Conversely, according to Giakoumi and Pey (2017), several mechanisms could support the opposite argument, i.e. that MPAs favour the spreading of IAS species, since ecosystems with high native species richness could accommodate the establishment of invasives and their coexistence with native species, and therefore support high numbers of IAS.

MPAs remain the fundamental building blocks of virtually all national and international marine conservation strategies. They provide the core of efforts to protect the ocean and are increasingly recognized as essential providers of ecosystem services and biological resources, key components in climate change mitigation strategies, and, in some cases, tools for protecting threatened human livelihoods (Dudley, 2008). To date, very few MPAs – even those with robust and well implemented management plans – have specific measures in place to control the threat of invasive fouling organisms.

2.4 IMO MEASURES FOR THE PROTECTION OF VULNERABLE MARINE ECOSYSTEMS

In complement with MPAs, a number of measures adopted by IMO can also be applied for the protection of vulnerable marine ecosystems. In particular, the application of the particularly sensitive sea area (PSSA) concept, along with spatial management measures, such as ships routeing measures, are particularly relevant in this regard.

2.4.1 Particularly sensitive sea areas

Among the numerous measures that IMO has adopted to manage the impacts of shipping on the marine environment, the Particularly Sensitive Sea Area (PSSA) concept is clearly recognized as an important tool to assist States in addressing their obligations under the CBD, insofar as the regulation of shipping is concerned. The ability of IMO to designate a PSSA is provided through IMO Assembly Resolution A.982(24), as amended through resolution MEPC.27(68) in 2015, *(2005 PSSA Guidelines)*. According to the PSSA Guidelines, a PSSA is defined as:

> *An area that needs special protection through action by IMO because of its significance for recognized ecological, socio-economic, or scientific attributes where such attributes may be vulnerable to damage by international shipping activities.*

An application for PSSA designation should contain a proposal for an associated protective measure or measures aimed at preventing, reducing or eliminating the threat or identified vulnerability. In the context of the PSSA Guidelines, associated protective measures are limited to actions that are to be, or have been, approved and adopted by IMO (see Section 2.4.2).

In recent years, the PSSA concept has assumed an important status as a protective measure, for providing protection to MPAs and other vulnerable marine ecosystems from the impacts of shipping. As a result, coastal states are increasingly seeking to apply the PSSA concept in conjunction with MPAs, to enable the adoption of measures aimed at protecting ecologically sensitive areas against specific threats posed by international shipping and not necessarily from other ocean uses.

To date, sixteen PSSAs have been identified and designated. They include some of the world's best known and iconic maritime locations, such as the Great Barrier Reef, which was the first to be designated in 1990 and has since had to extensions, the seas surrounding the North-western Hawaiian Islands (Papahānaumokuākea Marine National Monument) and the Galápagos Islands. These, together with the associated protective measures adopted in each case, are summarized in Table 2 below.

Figure 5: Worldwide map of Particularly Sensitive Sea Areas (PSSAs) (as of 2024).

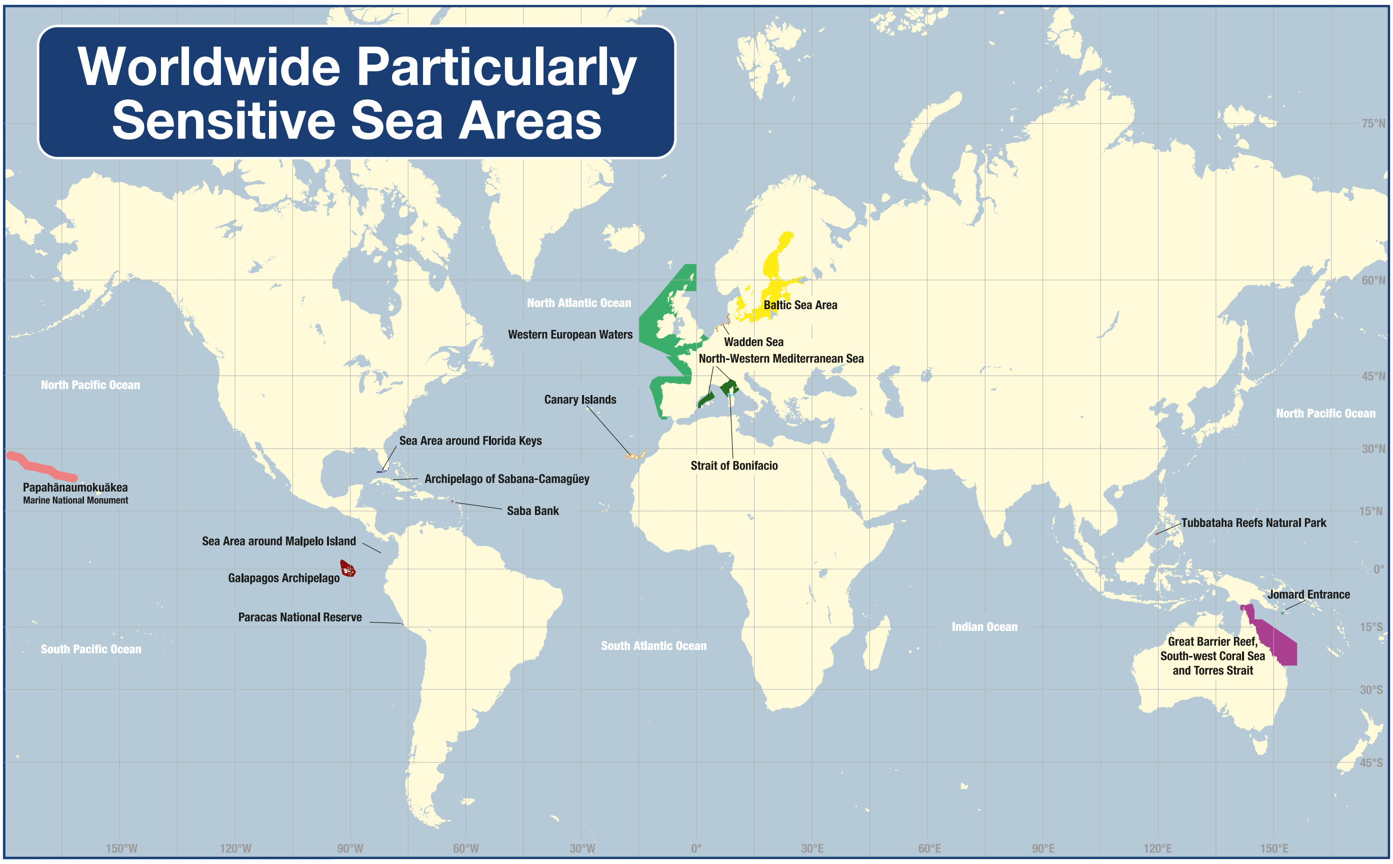


Table 2: PSSA designations to date

PSSA	Designation	Associated protective measures
Great Barrier Reef, Australia	1991	Compulsory pilotage IMO-recommended pilotage Mandatory reporting
Sabana-Camagüey Archipelago, Cuba	1998	Traffic separation schemes Area to be avoided Discharge prohibitions
Malpelo Islands, Colombia	2002	Area to be avoided
Florida Keys, USA	2002	Four areas to be avoided Three mandatory no-anchoring areas
Wadden Sea, North Sea	2002	Mandatory reporting[5] Routeing systems[5] MARPOL special areas[5]
Paracas National Reserve, Peru	2003	Area to be avoided
Western European Waters	2004	Fourteen traffic separation schemes[5] Two deepwater routes[5] Seven areas to be avoided[5] Mandatory 48-hour reporting for single-hull tankers carrying heavy grades of fuel oil
Torres Strait as an extension to the Great Barrier Reef PSSA, Australia/Papua New Guinea	2005	Compulsory pilotage Recommended two-way route
Canary Islands, Spain	2005	Five areas to be avoided Recommended tracks Mandatory ship reporting
Galápagos Islands, Ecuador	2005	Area to be avoided
Baltic Sea	2005	MARPOL Special Area[5] Mandatory reporting* Transit route[5] Deepwater route[5] Fifteen traffic separation schemes[5] Localized compulsory pilotage[5] Deepwater route Two areas to be avoided

[5] Existing measure prior to designation as a PSSA

Table 2: PSSA designations to date – continued

PSSA	Designation	Associated protective measures
Papahānaumokuākea Marine National Monument, USA	2008	Mandatory reporting Six areas to be avoided
Strait of Bonifacio, France/Italy	2011	Two precautionary areas[5] Two-way route[5] Mandatory reporting[5] Recommended pilotage
Saba Bank, Netherlands Antilles	2012	Area to be avoided Mandatory no-anchoring area
Extension of Great Barrier Reef and Torres Strait to encompass the south-west part of the Coral Sea	2015	Area to be avoided (ATBA) Two two-way routes
Jomard Entrance, Papua New Guinea	2016	Four two-way route Precautionary area
Tubbataha Reefs Natural Park, the Sulu Sea, Philippines	2017	Area to be avoided
North-Western Mediterranean Sea to protect cetaceans from international shipping	2023	Speed restrictions

[5] Existing measure prior to designation as a PSSA

2.4.2 Other IMO measures

In addition to the PSSA concept, IMO has developed a number of other spatial management tools that can be applied to reduce the risk to vulnerable marine ecosystems or biodiversity from shipping activities. These include:

- measures to improve safety of navigation through specific routeing measures (such as areas to be avoided and precautionary areas), pilotage or vessel traffic management (such as traffic separation schemes);
- measures to reduce the physical impacts of shipping on wildlife and habitats, such as special anchoring measures (no-anchoring areas) or speed restrictions and reporting services; and
- measures to prevent pollution, such as the application of special areas under the *International Convention for the Prevention of Pollution from Ships* (MARPOL 73/79) and its associated annexes.

2.5 IMPACTS OF IAS ON VULNERABLE MARINE ECOSYSTEMS

To date, research quantifying marine invasion risk to MPAs is limited, despite their potential negative consequences (Iacarella et al. 2020). That said, more broadly, species introduced via biofouling are known to give rise to a range of adverse impacts:

- impacts to biodiversity, habitats or ecological processes (ecological impacts);
- impacts to economic activities and infrastructure (economic impacts); and
- sociocultural impacts (including to human health).

2.5.1 Ecological impacts

Ocean ecosystems and the biodiversity they support are highly interconnected. The introduction of IAS can disrupt the balance of nature by affecting many different species, both directly and indirectly. The ecological impacts of IAS can occur through changes to the local biodiversity and/or alteration of ecological processes caused by that species. IAS may be able to colonize a vacant niche in a native habitat with low biodiversity, or a new habitat unsuitable to local native species, such as human-made habitat in ports and harbours. While the initial impacts may not be apparent, as a population increases over time impacts may increase in severity and include:

- competition with native species for space and food;
- predation upon native species;
- changes to, or replacement of, habitat that lead to loss of native species diversity, alteration of food webs or even local extinctions; and
- alteration of environmental conditions (e.g. decreased water clarity).

Ecological impacts of invasive species introduced by biofouling are not widely documented because, for most, their opportunistic traits result in poor competitiveness against native species within healthy ecosystems. Furthermore, the impact of IAS on the marine environment and its biodiversity can take several years to detect, by which time an IAS may already be established. However, there are exceptions, including the invasion of rocky shores in Europe by the Australasian barnacle *Austrominius modestus* following its introduction in the 1940s, and the European blue mussel *Mytilus galloprovincialis* spreading along more than 2,800 km of the coast of southern Africa since introduction in the 1970s.

INTRODUCTION OF *SARGASSUM HORNERI* TO THE MONTEREY BAY NATIONAL MARINE SANCTUARY (USA)

Sargassum horneri (known as Devil Weed) is a large, brown macroalgae, native to Japan and the Philippines. It was first detected in California in 2003 and rapidly spread to the Channel Islands, California and down to Todos Santos, Mexico. It grows on rocky reefs in the same habitat as giant kelp and other brown algae and is most common between 5 and 20 m. This is the only known introduction of *S. horneri* since; to date it has not been found anywhere else beyond its native range.

S. horneri is most likely to have been spread regionally by recreational boats and through the natural dispersal of mature plants that become detached from the reef and drift on ocean currents.

The species was first discovered in Monterey Bay National Marine Sanctuary in 2019. Its continued expansion and sheer abundance and formation of dense mats has raised concerns about its impact on native ecosystems, since it can outcompete native kelp species and impact commercially and recreationally important species, such as sea urchins and kelp bass, which are dependent on the kelp habitat.

AN INVASIVE CORAL IMPACTING HAWAII'S BIODIVERSITY

Carijoa riisei (known as the snowflake coral) is a soft (non-reef forming) coral that grows attached to hard surfaces, forming carpets. Native to the Caribbean, it was first discovered in Pearl Harbor in 1972 and spread around the islands by hull fouling. The planktonic larval stage facilitates natural dispersal via currents and continues to spread when boats carry colonies to new locations via hull fouling. Colonies eat large amounts of zooplankton and overgrow corals and hard reef surfaces, preventing other species from growing. It can grow up to 2.5 cm every two weeks.

In 2001, a survey of the Black Coral bed in Maui discovered *C. riisei* overgrowing and killing over 60% of the black coral trees between 80 and 105 metres depth and large swathes of the bottom-dwelling community. It now threatens Hawaii's $30 million precious coral industry. The unknown long term ecological impact of *C.riisei* may condition the sustainable harvesting of black coral in the region.

Source: Kahng et al. (2005)

2.5.2 Economic impacts

Economic impacts can occur both as a consequence of fouling on the structure itself (e.g. fouling of ships' hulls) and fouling in the new location (e.g. of other vessels, fouling of water intake pipes and other infrastructure). Economic impacts of IAS may also arise as a result of their interference with biological resources that support fishing and coastal aquaculture (e.g. the subsequent collapse or reduced productivity of fish stocks), interference with fisheries (e.g. fouling of gears), disruption to tourism, damage to infrastructure (e.g. through fouling) and costs of treatment, clean-up or control. All these types of impacts are interconnected, tending to influence and exacerbate one another.

As such, biofouling can have serious implications for a broad range of coastal economic sectors.

These impacts can include:

- costs associated with control and eradication efforts;
- direct and indirect impacts to infrastructure (e.g. biologically induced corrosion);
- costs associated with replacing and repairing structures due to premature aging and degradation;
- decreased operational efficiencies (e.g. frictional drag on vessels creating increased fuel costs; increased cleaning frequencies; increased drag and weight on structures);
- loss of tourism amenity (e.g. coral reef) leading to loss of tourism revenue; and
- loss of aquaculture products due to biofouling of pens and nets, smothering of stock, and predation.

2.5.3 Sociocultural impacts

Sociocultural (including human health) impacts can include reduction in recreational amenity values associated with habitat and beach alteration, and reduction and loss of iconic and culturally significant species through predation and competition.

Additionally, several species can affect human health through physical harm such as cuts and lacerations (e.g. creation of biogenic reefs by the Pacific oyster) as well as the spread of viral and bacterial mediated diseases. Toxins found in seafood can bioaccumulate and lead to gastrointestinal disorders and poisoning in humans and some algal species are also known to create algal blooms that can cause skin irritations in humans on direct contact (Arndt, Robinson and Hester, 2021).

THE IMPORTANCE OF MARINE BIODIVERSITY FOR CULTURAL VALUES

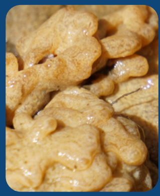
In New Zealand, the Māori culture has a strong relationship with te moana (our oceans and coasts), which is deeply embedded in their culture, identity and history. Maori regard the marine environment as a treasured possession (taonga). Māori have a role as kaitiaki of te moana and mātaitai (fish or food obtained from the sea). Kaitiaki are guardians who carry out the act of tiaki and look after, protect and conserve the resource or taonga; kaitiaki can be a human, animal or a spiritual being. Any detrimental effect of IAS on marine biodiversity can also impact the Māori ability to provide hospitality and generosity to others, including providing food for people and guests.

Source: NZ Ministry for the Environment, (2019)

2.5.4 Examples of Invasive Aquatic Species

CARPET SEA SQUIRT *(Didemnum vexillum)*

Is native to Japan but has been transported around the globe causing a range of issues in ports and marinas. It forms pale orange, cream or off-white colonies of extensive thin (2-5 mm) sheets and can form long pendulous outgrowths.



IMPACT:

As the colony grows, the sea squirts smother local marine life and become a serious threat to biodiversity. On offshore banks in the United States of America, it has shown very extensive coverage of the seabed, potentially outcompeting species living in gravel and affecting shellfish aquaculture for species such as mussels and oysters (Smithsonian Environmental Research Center (SERC), 2024a). In the Kingdom of the Netherlands, it seems to have caused decreases in the numbers of brittle stars and sea urchins. In the United Kingdom, the Carpet sea squirt has been included on the government's "alert" list of non-native (alien) species (Gibson-Hall and Bilewitch, 2018).

SPREAD:

Originally from Japan, *D. vexillum* is now found in the north-east Pacific (British Columbia to Southern California, northeast of the United States, New Zealand, the Kingdom of the Netherlands, north-western France, Ireland and the United Kingdom (England and North Wales). Hitchhiking on the biofouling of boats is the sea squirt's preferred mode of transportation.

LEATHERY SEA SQUIRT *(Styela clava)*

Is native to the Pacific Coast of Asia but is now known to be in Australasia, the Pacific, Europe and North America. As a fouling species, it is common on rocks and pylons and can reach densities of 500 to 1500 individuals per square metre. It can attach itself to concrete, wood, vessel hulls, pontoons and reefs.

IMPACT:

It competes for space and food with local species and predates on the larvae of native species causing population decline. It creates dense fouling on aquaculture and fishing equipment, moorings, ropes and hulls. It has been noted to have an affect on human health contributing to an asthmatic condition in oyster shuckers in Japan. Despite this however, in the Republic of Korea, Styela clava is eaten as seafood.

In Canada, the economic damage to shellfish aquaculture is estimated as high as Can$ 88 million per year (Colautti et al. 2006). In New Zealand, this affects 22% of production areas, with a cost to green mussel producers estimated at $23.9 million (Soliman and Inglis, 2017).

SPREAD:

S.clava has low natural dispersal ability, therefore its global spread is thought to be due to human-aided dispersal on vessels, and a high tolerance to changing environmental conditions (SERC, 2024b).

AUSTRALIAN TUBEWORM
(Ficopomatus enigmaticus)

Thrives in estuarine and coastal environments within sub-tropical and temperate areas throughout the world. This worm builds and inhabits white calcareous tubes (Schwindt, 2009). It grows very fast and abundantly on all surfaces. It forms dense reefs, scattered over hundreds of hectares, which has a major impact on power station cooling systems, marinas and operation of channel locks. It increases ship drag through biofouling.

IMPACT:

The United Kingdom power industry spends more than US$10 million annually to prevent clogging of cooling system water intakes (Williams et al,. 2010). A marina in the United Kingdom had to reduce berthing fees to prevent loss of clients.

SPREAD:

The Australian tubeworm is spread via biofouling of boats and ballast water. It is the small recreational vessels that are important vectors on a regional scale. The worms can attach to the bottoms of vessels or ropes attached to small fishing boats or canoes, and can survive a long period of desiccation.

GREEN ALGAE *(Caulerpa)*

Are fast-growing and attractive species for adding to aquaria. However, in the open waters, this very fast-growing species can quickly attain plague proportions. It rapidly overgrows corals, slower growing macroalgae, seagrass and other benthos in coastal locations, quickly smothering them.

IMPACT:

Economic and social impacts are due to the reduction in catches of fish by commercial fishermen due to the reduction of fish habitats by Caulerpa, and the weed becoming entangled in boat propellers and fishing nets. Economic impacts resulting from the cost of eradication of *C. taxifolia* included approx. US$6 million spent in southern California in 2000-04 and an estimated $A6-8 million in southern Australia (Anderson, 2004).

SPREAD:

Although the initial spread is by release from aquariums, vessels' anchors remove fragments of Caulerpa from estuaries, and conditions inside anchor lockers may enhance fragment survival. This means that boats may be an important vector for dispersal of Caulerpa within and between estuaries (West et al. 2007) across and around the Mediterranean. Sport fishing can also aid local movement of Caulerpa in Italy, with algae attached to fishing equipment. For these reasons, new infestations tend to occur in ports, harbours and marinas (Relini et al. 2000).

Within the Caulerpas, *Caulerpa taxifolia* or Killer Algae is a notoriously invasive species. In California it was eradicated at considerable cost using toxic chemicals. This has led to some states in the United States banning the use of some Caulerpa species in aquaria, to prevent their spread to open waters and damage to local ecosystems. However, later studies seem to indicate a reduction in the growth and spread of *C.taxifolia* and a reduction in its potential impacts. Whereas other members of the genus, such as *Caulerpa racemosa* and *Caulerpa cylindracea*, together or in combination with other species, have proven to negatively impact meadows of *Posidonia oceanica,* the main seagrass in the Mediterranean (Scaffelke, 2008).

THE EUROPEAN GREEN CRAB *(Carcinus maenas)*

Has spread far beyond its native Atlantic Europe. It is now found in waters off North and South America, Asia, South Africa and Australia. It is a voracious omnivore which can consume species from at least 104 families, 158 genera, so food is not a limiting factor.

IMPACT:

C. maenas can cause economic impacts to crab and shellfish industries, with estimates of US$22.6 million of damage per year in predation on shellfish alone on the east coast of the United States. It can degrade habitats, and it has been suggested it has decreased abundance of eelgrass in the Gulf of St. Lawrence.

SPREAD:

Although primarily introduced through ballast water, it can be transported on hull fouling, within niche areas. (Klassen and Locke, 2007).

ZEBRA MUSSEL *(Dreissena polymorpha)*

Native to the Caspian and Black Seas south of Russia and Ukraine, and has since become widespread in both Europe and North America. It has spread through canals and river estuaries, was in London docks in the 1820s, in Sweden in the 1920s, in Alpine lakes in the 1960s and, by 2010, zebra mussels were found in more than 600 lakes and rivers across 26 states of the United States. These are one of the world's most economically and ecologically damaging aquatic invasive species. Once introduced their populations can grow rapidly, and the total biomass of a population can exceed 10 times that of all other native benthic invertebrates (Karatayev et al. 2002).

IMPACT:

The mollusc has blocked water intakes for power plants, water treatment plants and ships. Large populations have devoured plankton affecting local biodiversity and disrupting aquatic food webs. Along shorelines, windrows of mussels destroy beaches, and the decaying mussels produce an extremely foul smell (Bukontaite and Zaiko, 2008). The sharp shell of the *D. polymorpha* is razor-like and is a hazard to barefoot swimmers and beachcombers. This combination spoils the most pristine of locations and prohibits recreational activities.

SPREAD:

Whilst the initial spread has been in ballast water in commercial vessels, the microscopic larvae can continue to be spread between smaller bodies of water by recreational vessels in bilge water, bait buckets, equipment, biofouling or anything else that moves from one body of water to another. Also, adult and juvenile mussels can move on boat hulls and buoys as they move between areas.

QUAGGA MUSSEL
(Dreissena rostriformis bugensis)

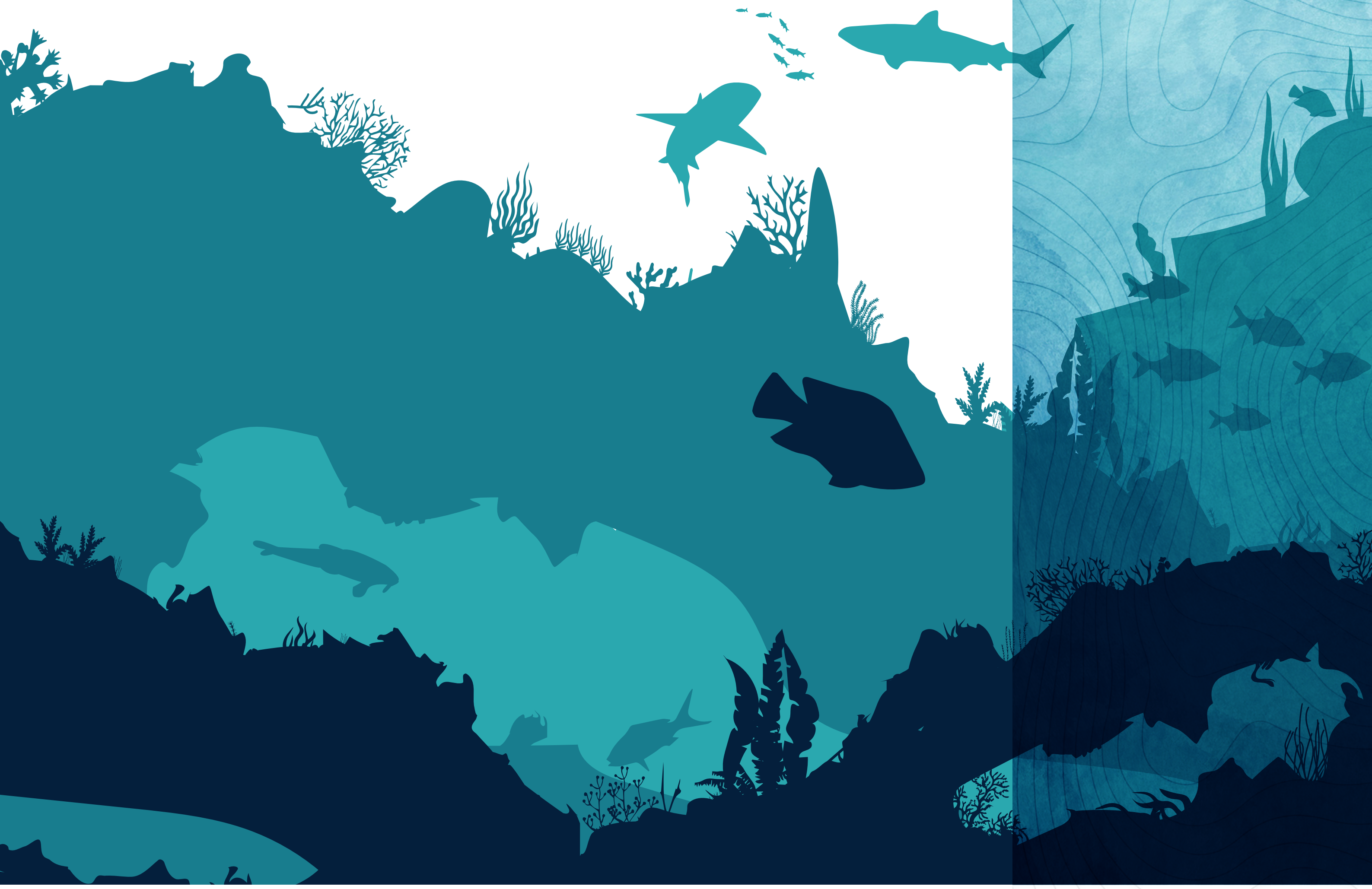
Is similar to the zebra mussel, originating in Ukraine, and is now in North America. This species was identified as the top-ranking invasive species threat to the United Kingdom in a study of almost 600 non-native species (CABI, 2014).

IMPACT:

The dreissenids, including *D. rostriformis bugensis*, are sessile filter-feeders capable of reaching extremely high densities, negatively affecting the environment, food webs and biodiversity of the ecosystems they invade (Karatayev et al. 2002), and causing tremendous economic damage in raw water-using industries, potable water treatment plants, and electric power stations (Wong and Mastitsky, 2014).

SPREAD:

Shipping is considered to be the primary pathway of quagga mussel introductions into new areas located far outside its native range (Orlova et al. 2005). The mussels can travel with a vessel either as adults attached to the biofouling on the hull or as planktonic larvae within ballast water. Accidental introductions of quagga mussels at local and national levels often happen due to overland transportation of recreational boats and fishing gear, which is especially popular in North America.



PART 2:
MANAGEMENT APPROACHES FOR PREVENTING AND CONTROLLING INVASIVE AQUATIC SPECIES INVASIONS

INTRODUCTION

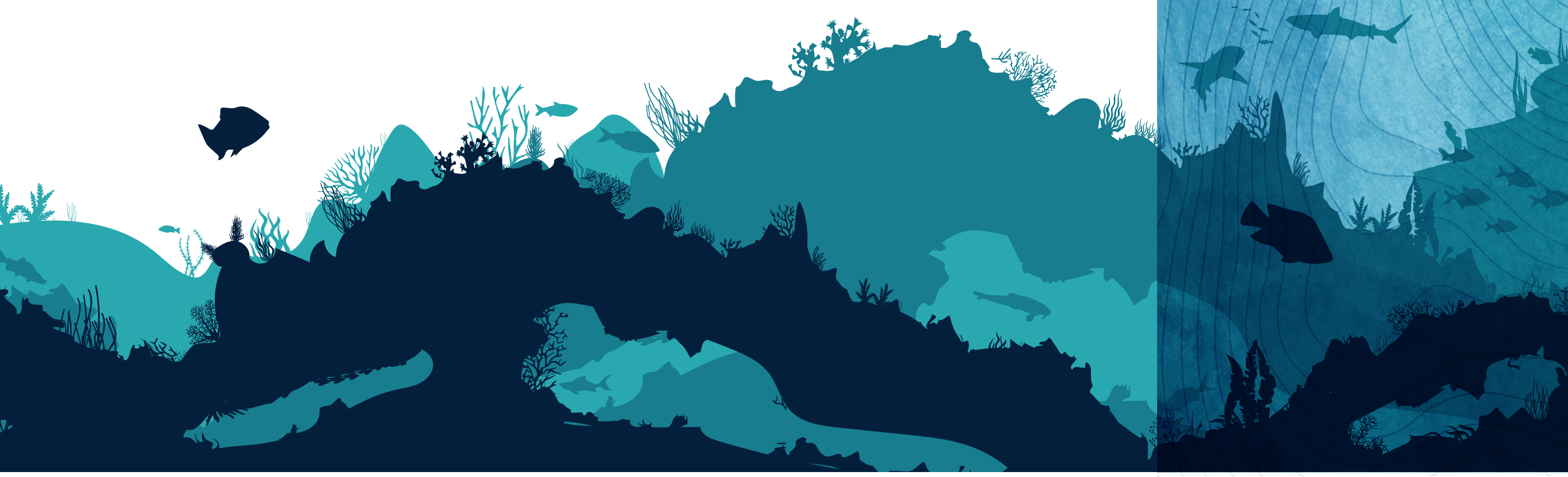
At every stage in the biofouling invasion pathway (Figure 4, see section 2.1.3), management measures may be deployed to reduce the likelihood of a harmful IAS establishing in an MPA. By far the most effective management measure is to prevent the arrival of a fouled organism in the first place. Thereafter, management measures must rely on:

- effectively preventing biofouling growth on a vessel, maintaining the hull of the vessel as clean as possible; or
- excluding a fouled vessel; or
- monitoring, controlling and eradicating the species if an IAS has been introduced.

The further along the invasion pathway the intervention is made, the more difficult it becomes to prevent the establishment of an invasive fouling organism. Those fouling organisms that eventually become invasive have been able to pass through each stage in the pathway and are typically the most sturdy and resistant of species. International experience demonstrates the numerous challenges involved in responding to and eradicating an IAS once it has established, based on the practicalities of intervention, the likely costs involved and limited chances of success. Attempting eradication within an MPA may be even more difficult because many of the response tools normally considered may cause significant harm to native biodiversity. Thus, the primary focus for MPA managers should be in preventing the arrival of a fouled vessel in the first place.

Part 2 of this Compendium provides an overview of the various management options available to MPA managers to minimize the risk of invasions at every stage.

"THE PRIMARY FOCUS FOR MPA MANAGERS SHOULD BE IN PREVENTING THE ARRIVAL OF A FOULED VESSEL IN THE FIRST PLACE."



3 GOVERNANCE ARRANGEMENTS

3.1 OVERVIEW

An overarching theme for minimizing the risk of biofouling for invasive aquatic species is the establishment of an effective governance framework that will provide the tools and resources necessary to effectively manage biofouling at every stage of the invasion. This may include policies and legal frameworks that govern the behaviour of key users and stakeholders; institutional arrangements, including defining institutional roles and responsibilities and how decisions are made and executed; the scientific information needed to support decision-making; and how the public and major stakeholders can participate in decision-making and management.

The overall objective for any governance framework should be to ensure that effective controls exist at every stage in the biofouling invasion pathway to minimize the arrival, release and establishment of an invasive aquatic organism. In particular, governance arrangements need to focus on the two most critical points, namely:

- when a vessel arrives in the MPA; and
- when an IAS is discovered in the wider environment of the MPA.

For both of these critical points, governance arrangements need to be clear to support decision-making, especially with regard to who is responsible for taking action and what those actions could be.

There is no generally applicable biofouling governance framework for MPAs. To be effective, governance arrangements must reflect the specific circumstances of the individual MPA. This is particularly true of the difference between those MPAs where people live and rely on the MPA for their livelihoods (e.g. Galápagos) and those that are remote and uninhabited (e.g. sub-Antarctic Islands). That said, there are a number of broad principles that can be applied to the design and implementation of such frameworks.

3.2 REGULATORY APPROACHES TO MANAGING BIOFOULING IN MPAS

Although the IMO Biofouling Guidelines represent an important step in the development of a comprehensive management framework for biofouling, as guidelines, they are therefore not mandatory.

The Biofouling Guidelines request countries to take urgent action in applying the recommendations included in them. However, in order to drive compliant actions, there is generally a need for regulatory instruments that (i) establish binding rules and standards against which to measure compliance; and (ii) define the penalties that will be imposed for any non-compliant actions. In this way, vessel owners will be incentivized to ensure they meet the relevant biofouling management requirements.

To this end, several jurisdictions have used the IMO Biofouling Guidelines as a basis for mandatory biofouling management regulations, the most comprehensive being those of New Zealand, Australia and the state of California (United States). Each contain mandatory regimes that have documentation, reporting and verification requirements. Despite all being consistent with the IMO Biofouling Guidelines, there are, however, differences in approach, particularly with respect to regulating in-water cleaning (IWC), which may vary according to such factors as the type and level of fouling; the type of anti-fouling system applied to the submerged surface; the submerged area to be cleared; and handling of clean-down waste.

Comprehensive biofouling management policies are still not widespread, and many of those that do exist are not consistent; for example, many existing regulations do not apply to all types of vessels, or provide limited guidance on what are acceptable biofouling management practices. Moreover, few provide for controls that address the unique and vulnerable characteristics of MPAs.

Table 3: Examples of international and national biofouling requirements[6]

Jurisdiction	Requirements
International	
IMO	• (Voluntary) Guidelines based on minimizing fouling through ongoing maintenance using best practice. • Centred around defining biofouling management plans specific to each vessel and documenting implementation in biofouling record books. • Additional focus on contingency action plans and inspection reporting.
National	
New Zealand	• Biofouling is currently addressed through a mandatory Craft Risk Management Standard (CRMS) promulgated under the Biosecurity Act, 1993 • Applies to all ship types. • Vessels to arrive in New Zealand with a "clean" hull - defined under the CRMS depending on the vessel itinerary (i.e. long-stay or short-stay). • All vessels must provide evidence of biofouling management before they arrive in New Zealand. • Requires a biofouling management plan, including a biofouling record book, aligning with IMO guidance. • May be inspected on arrival.
Australia	• Biofouling is currently addressed by the Biosecurity Amendment (Biofouling Management) regulations 2021 (under the Biosecurity Act, 2015). • Mandatory reporting of biofouling management practices prior to arrival within the Australian territorial seas (12 NM). • A proactive biofouling management approach is applied, consistent with the IMO guidelines.
USA - Environmental Protection Agency	• Shipowners must minimize the transport of attached living organisms when travelling into US waters from outside the US EEZ. • The requirements are consistent with management principles established in the IMO guidelines, but not currently an enforcement priority. • The Vessel Incidental Discharge Act (VIDA) was signed into law in late 2018 (anticipated to come into force in 2022). VIDA requires EPA to develop new national performance standards for incidental discharges from commercial vessel. The US Coast Guard is required to develop corresponding implementing regulations. • The above regulations are primarily directed at commercial vessels. • Development of standards for recreational vessels is under the Clean Boating Act.
USA - US Coast Guard	• Remove fouling organisms from the vessel's hull, piping and tanks on a regular basis and dispose of any removed substances in accordance with local, state and federal regulations. • Rinse anchors and anchor chains when the anchor is retrieved to remove organisms and sediments at their places of origin. • Carrying a biofouling management plan in accordance with the IMO guidelines is one way of fulfilling the requirements.

[6] For more information, refer to the report published by the GEF-UNDP-IMO GloFouling Partnerships and the Global Industry Alliance for Marine Biosafety: Compilation and Comparative Analysis of Existing and Emerging Regulations, Standards and Practices Related to Ships' Biofouling Management. Available at: https://www.glofouling.imo.org/publications-menu

Despite the increasing number of national and sub-national policies, few policies exist that recognize the unique environmental values of protected areas and vulnerable marine ecosystems. Some exceptions to this include the Galápagos Marine Reserve (Ecuador), the Kermadec and Subantarctic Islands (New Zealand) and the Papahānaumokuākea Marine National Monument (PMNM) (Hawaii, United States), which enforce strict standards on biofouling before entry to marine parks or protected areas.

Table 4: Examples of MPA-specific biofouling requirements

	Galápagos Marine Reserve (Ecuador)	Papahānaumokuākea Marine National Monument (USA)	Kermadec and Sub-Antarctic Islands (NZ)
General regulatory approach	Biosecurity arrangements for the Galápagos Islands are provided for under the Organic Law of the Special Regime of the Province of Galápagos (2015; LOREG). Under the Law, The Galápagos Biosecurity Agency (ABG) is in charge of controlling, regulating, preventing and reducing the risk of the introduction, movement and dispersal of non-native organisms.	Entry to the Monument is prohibited unless a permit has been issued pursuant to federal regulations for the Monument (50 CFR Part 404). Issuing of a permit is subject to the vessel undergoing and passing a hull inspection.	Coastal management plan promulgated under the New Zealand Resource Management Act. The plan includes policies and rules and the conditions necessary to comply with the rules. Access is permitted subject to being able to meet the standards set out in the plan. All vessels must also comply with the requirements under the NZ Craft Risk Management Standard.
Vessel types subject to requirements	All vessels entering the marine reserve.	All vessels entering the Monument.	All vessels entering within 1 km of MHWS of any of the islands
Documentation requirements	All vessels that set sail from national or international ports must comply with biosecurity and quarantine regulations and present a hull cleaning certificate upon arrival.	Almost all vessel types are subject to visual inspection, prior to departure from mainland Hawaii, and a written report undertaken by an “approved person”. Vessel owners submit a biofouling questionnaire prior to the inspection, which is used to determine the risk profile of the vessel which then dictates the level of inspection.	Almost all vessel types are subject to visual inspection, prior to departure from mainland NZ, and a written inspection report undertaken by an “approved person”.
Compliant actions	All vessels are inspected by the Galápagos Biosecurity Agency (ABG) on their arrival.	All vessels are subject to inspection as part of the entry permit process.	All vessel movements are monitored using AIS.
Options for vessel that cannot comply	Vessels will be asked to leave the marine reserve and to reclean their hull prior to re-entry.	Permits are refused if the vessel does not pass the hull inspection.	Vessels refused entry if the plan requirements cannot be met.

In some cases, these requirements reflect the broader biosecurity frameworks that exist in some countries, while in others these standards have been developed in the absence of a comprehensive national framework. In New Zealand, for example, the requirements for the offshore islands were established in 2012, prior to the coming into force of the CRMS in 2018. In Galápagos, there are currently no national requirements for Ecuador as a whole so the standards apply explicitly to the Galápagos archipelago.

For most MPAs, the highest risk transfer pathways are not necessarily those that present the highest risk at the national level. For example, most MPAs will not receive large numbers of international trading vessels, nor will they support large port facilities, which are often an important hub for the translocation of IAS. Instead, MPAs are more likely to be vulnerable to small, recreational and tourism vessels, which present a different risk profile and may, therefore, need to be subject to different controls.

To this end, MPA managers should consider integrating an IAS strategy into the MPA management plan. The plan should cover all stages, from developing and implementing specific management plans for high-priority invasive species in vulnerable sites, to identifying opportunities to help prevent new invasions and the spread of established invaders. Moreover, it should also focus on increasing awareness among the general public and specific groups, building collaboration programmes to address solutions with research and stakeholder groups, and monitoring invasive species' impacts in order to prioritize management actions (Otero et al. 2013).

3.3 INSTITUTIONAL ARRANGEMENTS FOR MANAGING BIOFOULING IN MPAS

3.3.1 Institutional coordination

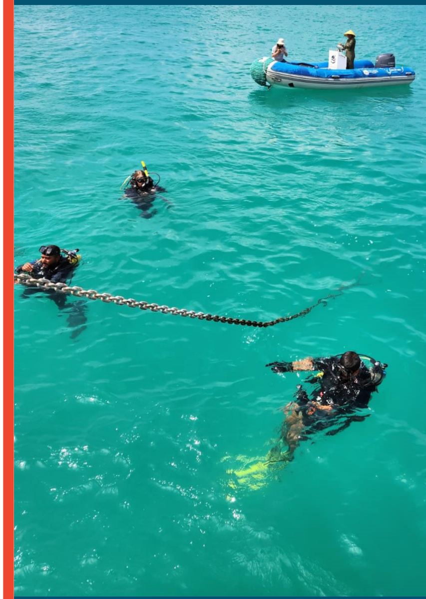
There are particular aspects and decision-making points along the biofouling invasion pathway where any lack of institutional control will be problematic. As such, there is a need to ensure that appropriate authority to regulate the MPA is defined and understood by all parties involved.

In the case of large MPAs, this might involve a specific agency responsible for MPA management (e.g. a national parks authority), which may be distinct from the national authority with overall responsibility for marine biosecurity. In many countries, however, the agency responsible for MPA management will have no mandate for biosecurity management and response and vice versa. Therefore, the ability to have a seamless management framework for biofouling management in MPAs is very difficult. MPA managers also do not usually have a mandate for regulating the various biofouling pathways.

It is generally considered more effective to designate a single agency with overall responsibility for national biosecurity management. This will ensure that decisions can be made in a timely manner and without the need to go through multiple levels of decision-making, which may impact on the ability to respond to suspected IAS incursions in a timely manner.

Whatever institutional arrangements are chosen or in place, it is important that the relevant agency has a legal mandate to act and that no duplication of responsibilities exists elsewhere, as this could lead to confusion and delays in critical decision-making.

BIOSECURITY MANAGEMENT IN GALÁPAGOS



In October 2012, the Agency for Regulation and Control of Biosecurity and Quarantine for Galápagos (ABG) was established by presidential decree and attached to the Ministry of Environment.

ABG has overall responsibility for controlling, regulating and minimizing the risk of introduction, movement and dispersion of exotic organisms that may put at risk human health or the ecological conservation of the land and marine ecosystems or the biodiversity of the province of Galápagos.

ABG works closely with other agencies, such as the Galápagos National Park Directorate, the Ecuadorian Navy and the Charles Darwin Foundation to establish a robust invasive species monitoring, control and enforcement framework for the whole of the Galápagos archipelago.

https://www.facebook.com/people/Agencia-de-Bioseguridad-para-Gal%C3%A1pagos/100087339073986/

AGENCIA DE REGULACIÓN Y CONTROL DE LA **BIOSEGURIDAD Y CUARENTENA PARA GALÁPAGOS**

3.3.2 Inter-agency cooperation

Although many countries have opted for a single lead agency, it is not uncommon for multiple agencies to have an interest in specific IAS incursions. For example, while a national biosecurity agency may well be the lead agency, in the event of a ship with hull fouling, both the port authority and maritime administration may be involved in the management of the vessel, whereas conservation and fisheries agencies may be concerned about the impact to environmental and economic resources. As a result, MPA managers may need to work cooperatively with other key agencies.

For issues that are multi-agency in nature, it is not uncommon for the government to establish some form of multi-agency cooperation platform, usually under the coordination of the lead agency. This allows the views and concerns of multiple stakeholders to be considered in the decision-making process and ensures that stakeholders are kept informed of developments in the response. Such a body must be explicitly mandated to take on this role and to provide a coordination role among all national agencies with a mandate for the management of ocean space generally and IAS specifically.

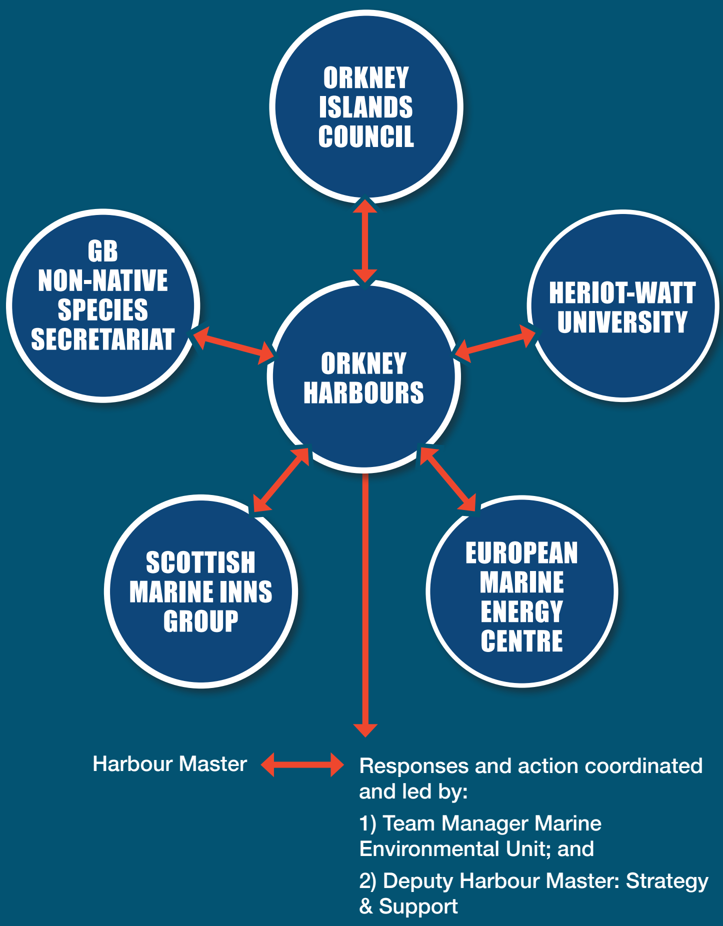
INTERAGENCY COOPERATION IN THE ORKNEY ISLANDS

Orkney Islands Council Harbour Authority (OICHA) is the Statutory Harbour Authority and as such has power and duty to manage the harbour authority areas in Orkney. The Scapa Flow harbour authority area is covered by the Orkney Islands Council Ballast Water Management Policy for Scapa Flow (2013), which consists of two biosecurity measures: (1) a ballast water management and monitoring; and (2) a non-native species monitoring programme. These give OICHA the duty to manage biosecurity and response to invasive species incursions in Scapa Flow.

In 2020, when an IAS was recorded in Scapa Flow, OICHA led the response. OICHA was in direct communication with national organizations: GB Non-Native Species Secretariat, Scottish Marine Invasive Non-Native Species Group, and with relevant local organizations: Orkney Islands Council, Heriot-Watt University and the European Marine Energy Centre. Contact details for these agencies and stakeholders were predetermined as part of the OICHA Biosecurity Contingency Plan.

As there was a single lead agency with power for decisions and funds to conduct surveys to determine if the species had established, it was possible to collate information and advice and action decisions efficiently. In this case there was no requirement to facilitate a forum or multi-agency meeting as surveys at the incursion site confirmed that *S. clava* was not established and there was no requirement for species management plan. Ongoing targeted monitoring is now in place for this species. If a management plan to contain, control or eradicate the species had been required, OICHA would have initiated a multi-agency collaboration with the national and local agencies.

COORDINATING RESPONSE AND LINES OF COMMUNICATION DURING A BIOSECURITY RESPONSE TO *STYELA CLAVA* IN 2020



3.3.3 Contingency planning

Contingency plans are proactive strategies to define an appropriate response to a disruptive event. Contingency plans may be most commonly associated with marine oil spill planning and response, but could also be considered as part of the overall biofouling management framework.

In this regard, a contingency plan can provide structure for the management and implementation of IAS incursion response operations and allow the MPA managers to respond more readily to an incursion by following pre-defined standard operating procedures. In particular, a contingency plan will define institutional roles and responsibilities, including statutory and not-statutory decision-making powers, ensuring preparedness for when an incident occurs.

An important element for all contingency plans is that they are regularly exercised, to test the effectiveness of the defined response procedures and to ensure that all agencies are familiar with (and understand their role in) the decision-making arrangements.

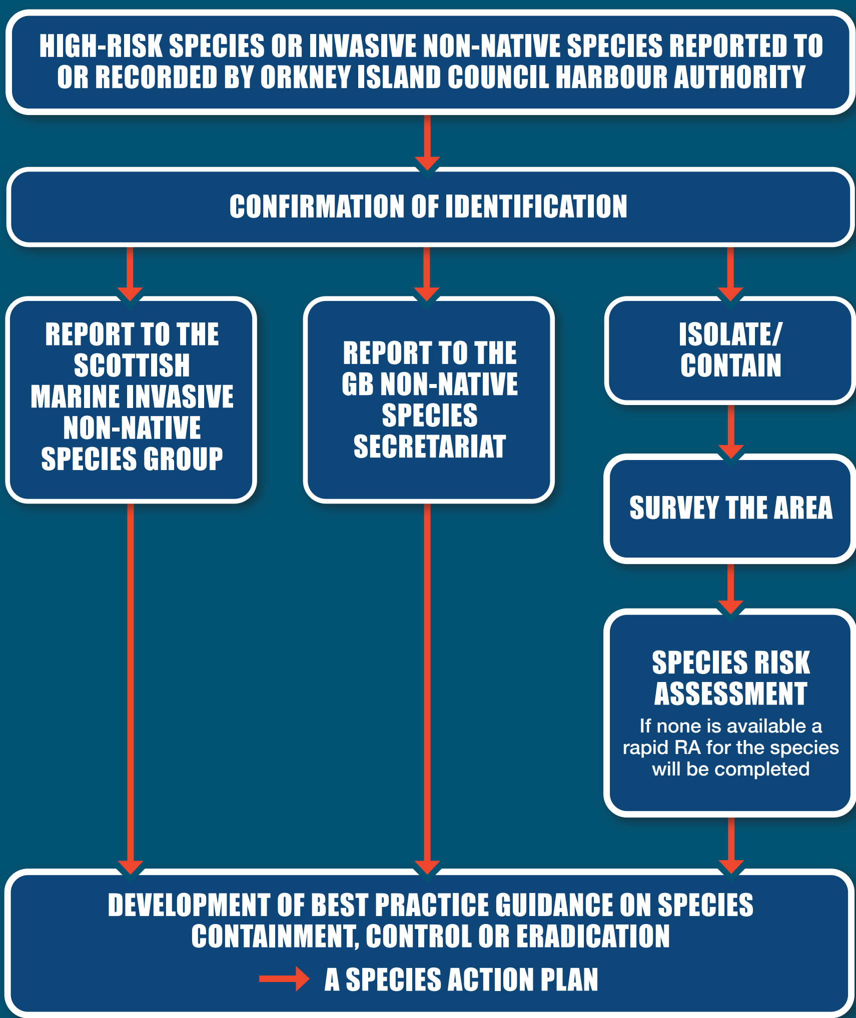
ORKNEY ISLAND BIOSECURITY CONTINGENCY PLAN

Orkney Islands Council is the Statutory Harbour Authority for Scapa Flow – a 324.5km^2 area of deep water and sheltered anchorage in the Orkney Islands, north of mainland Scotland.

In line with its responsibility to enable safe, economic and environmentally sustainable operation of the 29 piers and harbours located in the Orkney Islands, the Orkney Islands Council Harbour Authority has developed a Policy for Ballast Water Management in Scapa Flow.

The approved Policy includes a requirement for the Harbour Authority to carry out a non-native species monitoring and recording process for Scapa Flow.

The Policy includes a list of high-risk marine invasive non-native species of concern to Orkney. If one these species were to be found, the Harbour Authority has a commitment and mandate to lead and coordinate response. The Biosecurity Contingency Plan defines the process, the lead agency and the relevant national and local stakeholders. Response to identified incursions are led by the Team Manager Marine Environmental Unit, Deputy Harbour Master: Strategy and Support and Harbour Master in conjunction with a number of identified stakeholders.



3.3.4 Scientific, research and monitoring institutions

As well as the ability to make decisions and manage the response to an IAS incursion, many countries have general scientific and technical capacity that may be deployed to support activities such as environmental sampling and monitoring, species identification, habitat/resource surveying and mapping, environmental risk assessment and environmental modelling. In some cases, this capacity will reside within a dedicated government research institution or the research arm of a sectoral agency (e.g. Department of Fisheries). In other cases, this capacity may be provided by a national or regional university (or similar higher education institution) although it is not uncommon for both capacities to exist simultaneously.

3.3.5 Engaging with stakeholders and users

Given the range of different biofouling pathways, it is important to engage with a broad range of stakeholders and MPA users, to ensure that any MPA-specific biofouling management arrangements will be both practical and effective. This is particularly critical for those MPAs where people live and derive a living, since stakeholders should be involved in the consultation process that leads to defining and establishing rules as well as having a role to play in their implementation, monitoring and enforcement.

There is a need to commence stakeholder engagement on the issues surrounding biofouling management at the earliest possible opportunity. In particular, such engagement should focus all stakeholders on determining what the objectives of biofouling management governance should be. It is likely that key stakeholders are already identified in the relevant MPA management plan, some of which may already be actively involved in the management of the MPA. However, a specific focus will need to be applied to those stakeholders and users that are involved in "high-risk" activities such as recreational boating, tourism/ferry services and SCUBA diving, which may have different sector-specific interests.

For each of the identified stakeholder groups, it is important to plan key messages and communication opportunities. When consulting stakeholders on the policy, it may be useful to have supporting materials including:

- fact sheets that highlight key messages – these might be pathway-specific and/or for the whole policy;
- frequently asked questions (FAQs) – anticipated frequently asked questions and prepared written answers, in a single document. Some FAQs to anticipate, depending on the policy choices made, might include "How will the mandatory requirement be enforced?", "Will there be penalties for non-compliance", or "How will you ensure biofouling measures are implemented if the guidance is voluntary";
- stakeholder specific questions – it may be useful to develop set questions for different stakeholders to target their feedback on areas that may require their input; and
- website updates with links to the high-level biofouling policy and supporting materials.

A specific requirement for engagement with stakeholders will occur in the event that an IAS is located within the MPA and a decision is made to implement some form of response. In these cases, both the presence of an IAS and the proposed intervention may have implications for the livelihoods and wider interests of local stakeholders and it is critical that they be involved in the decision-making process that leads to any intervention.

3.4 THE APPLICATION OF PSSAs AND OTHER IMO MEASURES TO CONTROL SHIPPING

3.4.1 Particularly Sensitive Sea Areas (PSSAs)

The designation of an area as a PSSA provides a mechanism for reviewing an area that is vulnerable to damage by international shipping and determining the most appropriate way to address that vulnerability. As such, the PSSA concept has considerable utility as one of the measures available to IMO and its members to protect vulnerable marine habitats.

In general, to be identified as a PSSA, three elements must be present:

- the area must meet at least one of the three given criteria (ecological; social, cultural and economic; or scientific and educational);
- it must be vulnerable to damage by international shipping activities; and
- there must be measures that can be adopted by IMO to provide protection to the area from these specifically identified international shipping activities.

Designation of an area as a PSSA offers a number of benefits, including:

- it provides a comprehensive management tool whereby the vulnerability of an area to damage from international shipping activities can be examined and a measure adopted by IMO can be tailored to address the identified vulnerability;
- it provides global recognition of the special significance of a designated area through identification of PSSA status on international charts;
- it informs mariners of the importance of taking extra care when navigating through a region;
- it gives coastal States the opportunity to adopt additional protective measures to address the particular risks associated with international shipping in the area; and
- it provides significant value in communicating the importance of an area and raising awareness around the marine environment in that area.

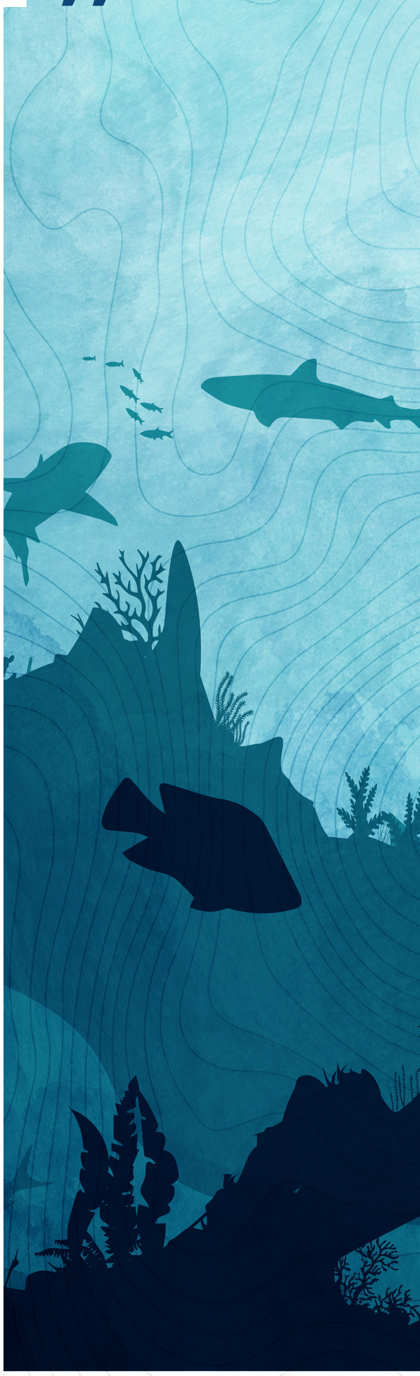
The requirements for the submission of a PSSA proposal are clearly set forth in the PSSA Guidelines. In and of itself, designation of a PSSA confers no direct regulatory benefit, because the concept is created by a non-binding IMO Assembly resolution. Designation of a PSSA therefore does not alter the existing rights and powers of States to control or regulate the passage of ships through the designated area. It is only through the application of associated protective measures that the legal basis for the regulation of shipping can be provided.

The PSSA Guidelines identify three potential legal bases for such measures:

- any measure that is already available under an existing IMO instrument; or
- any measure that does not yet exist but could become available through amendment of an existing or adoption of a new IMO instrument. The legal basis for any such measure would only be available after the IMO instrument is amended or adopted, as appropriate; or
- any measure proposed for adoption in the territorial sea, or pursuant to Article 211(6) of the United Nations Convention on the Law of the Sea where existing measures or a generally applicable measure (as set forth in the second bullet point above) would not adequately address the particularized need of the proposed area.

The PSSA Guidelines make it clear that the identification of an area as a PSSA and the protection of that area through legal measures are two separate but

> “FOR MOST MPAs, THE HIGHEST RISK TRANSFER PATHWAYS ARE NOT NECESSARILY THOSE THAT PRESENT THE HIGHEST RISK AT THE NATIONAL LEVEL”



related issues. The PSSA Guidelines identify several possible measures including Special Areas, ships' routeing measures and vessel traffic services. While this is not an exhaustive list, these represent those measures currently available to IMO through various instruments.

Identification of an area as a PSSA is not, however, a precondition for the adoption of any of these measures. Each measure has a legal basis in an existing IMO instrument, or is recognized as a measure for which IMO has competence to adopt, and may therefore be applied in its own right, irrespective of whether designation of the area as a PSSA is being sought.

Since the IMO Convention as well as PSSA Guidelines and the MARPOL Convention with its relevant annexes apply to all maritime zones, there is nothing preventing IMO from designating PSSAs in the high seas. To date, all PSSAs have been designated within EEZs. However, as with MARPOL special areas, the PSSA framework could also be applied to areas beyond national jurisdiction (ABNJ).

3.4.2 Application of PSSAs for the management of biofouling

There are currently no specific associated protective measures that relate to biofouling management and neither have any PSSAs been established for the purpose of controlling biofouling. However, several MPAs within existing PSSAs have sought to manage the risks associated with biofouling on vessels through the application of the IMO Biofouling Guidelines and domestic legislation enacted in respect to the MPA.

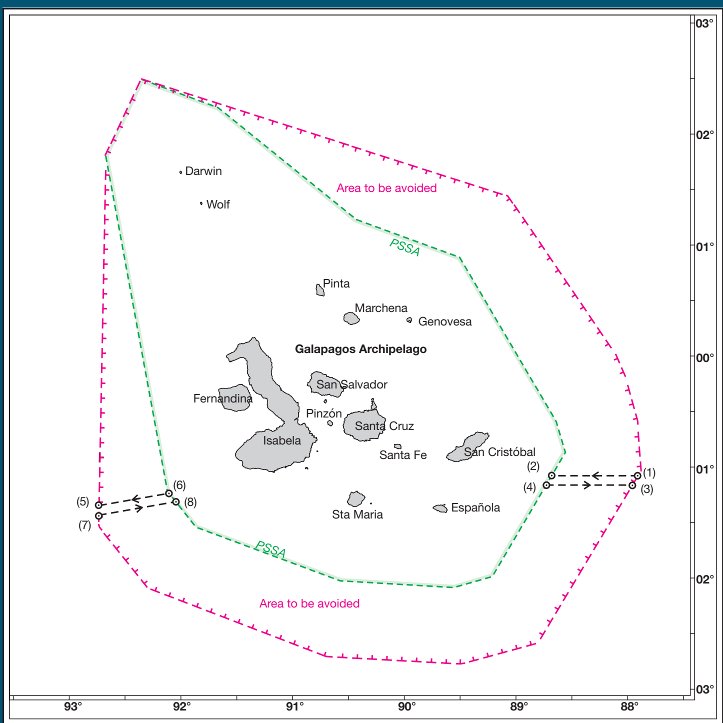
The domestication of the IMO Biofouling Guidelines perhaps represents the most logical associated protective measure for use in a PSSA, since it is both a globally accepted "standard" that may be enforced for all vessels visiting the MPA. For vessels that are simply transiting a PSSA, and not entering a specific MPA, other measures (such as ships routeing measures) may be used to restrict or direct the movements of these vessels away from the most ecologically vulnerable sites.

GALÁPAGOS PSSA

The Galápagos archipelago was designated by IMO as a PSSA in 2005, in recognition of the islands' unique environmental values and its existing status as a marine reserve and a marine World Heritage Site.

The islands are protected by the establishment of an area to be avoided that applies to all vessels carrying cargoes of oil or hazardous materials as well as all other vessels greater than 500 GT[7].

Entry into the PSSA is controlled by the use of two recommended tracks, which are a mandatory condition of port entry. All vessels entering the PSSA are also required to participate in a mandatory ship reporting system.

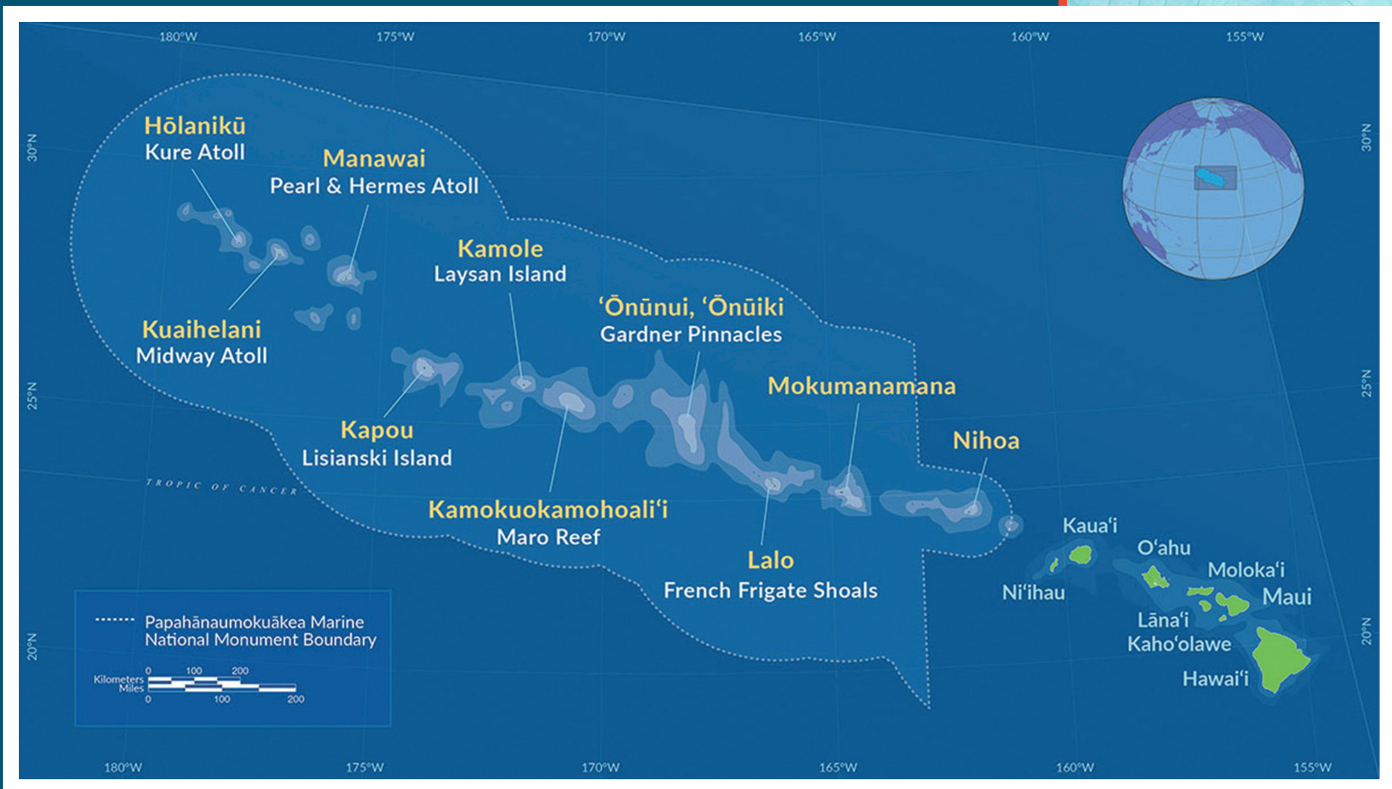


[7] https://www.imo.org/en/About/Conventions/Pages/International-Convention-on-Tonnage-Measurement-of-Ships.aspx

PAPAHĀNAUMOKUĀKEA MARINE NATIONAL MONUMENT

Encompassing 1,508,870 km^2 of the Pacific Ocean, the Papahānaumokuākea Marine National Monument (PMNM) is the largest contiguous fully protected conservation area in the United States, and one of the largest marine conservation areas in the world. The PMNM was established by Presidential Proclamation 8031 on 15 June 2006, to protect an exceptional array of natural and cultural resources. It was transcribed onto the World Heritage List in 2010 as a mixed site representing both cultural and natural heritage.

The PMNM was designated by IMO as a PSSA in 2008 in recognition of its unique environmental values. The islands are protected by the establishment of a series of interconnected areas to be avoided which are to be avoided by all vessels solely in transit. A mandatory ship reporting system is also in force for the PSSA which applies to all vessels of 300 GRT or above and all vessels in the event of a developing emergency, and that are in transit through the reporting area.



> “THE FURTHER ALONG THE INVASION PATHWAY THE INTERVENTION IS MADE, THE MORE DIFFICULT IT BECOMES TO PREVENT THE ESTABLISHMENT OF AN INVASIVE FOULING ORGANISM”

3.4.3 Ships’ routeing measures

A number of IMO-adopted ships’ routeing measures can be applied to control the movement of vessels, either as associated protective measures adopted under a PSSA or as regulatory controls in their own right. Perhaps the most useful of these is the area to be avoided (ATBA) which can be applied to restrict the entry of all, or certain classes of, vessels within a designated spatial area.

ATBAs have been used to protect numerous MPAs around the world, although not necessarily from the risks posed by biofouling. There is, however, nothing to prevent an MPA Management Authority from proposing the designation of an ATBA for the purpose of controlling ships and the associated biofouling risks.

3.4.4 Conditions of port entry

Coastal States have extensive authority to regulate ships that enter their ports and internal waters. This provides the ability for States to establish particular requirements for the protection of the marine environment, as a condition for the entry of foreign vessels into their ports (otherwise known as conditions of port entry). Where a vessel knowingly enters a port that is the subject of such conditions, the vessel has explicitly agreed to be bound by those conditions, which may be enforceable under domestic legislation.

Where a port lies within an MPA, there is nothing preventing an MPA Management Authority from establishing biofouling-related conditions for ships entering that port. Moreover, the definition of port is left for the State to define. Hence, any arrival point in an MPA could, in theory, be defined as a port.

4 PREVENTION OF BIOFOULING AND MANAGEMENT OF BIOFOULING PATHWAYS

4.1 PREVENTING BIOFOULING ON VESSEL HULLS

4.1.1 Overview

Due to the difficulty in predicting the impacts of IAS in a particular habitat, and the costs associated with responding to an IAS incursion, prevention is by far the most effective approach to managing vessel biofouling (Scianni and Georgiades, 2019). Proactive, preventative measures will reduce the likelihood that vessels will transport IAS into MPAs.

A comprehensive biofouling management strategy should include both the use of adequate anti-fouling systems (be it an anti-fouling coating, ultrasonics or by any other means) to protect the hull and niche areas, supplemented with appropriate biofouling management techniques (such as monitoring and cleaning). The precise choice of a biofouling management system will depend on the type of vessel, and how often or where it is used.

In some cases, it may also be desirable to restrict the entry and movement of all or certain classes of vessel to parts of the MPA, through the application of IMO-adopted or domestic legal measures.

4.1.2 Use of anti-fouling systems

Effective anti-fouling systems (AFS) are essential to control the growth of fouling organisms on the immersed surfaces of mobile structures. AFS must provide stable and effective prevention of fouling in all locations where the boat travels throughout the complete boating season. They must be cost-effective and not result in harmful effects on the environment. They must also be safe to install or apply and be robust and durable.

When selecting an AFS, there are several aspects to be considered that are applicable to all kinds of ships:

- location and operation of the vessel (tropical vs temperate, salt vs fresh water);
- type of vessel, number and location of niche areas, construction materials; and
- the anticipated operating or voyage profile of the ship (frequency and pattern of use, speed and activity).

The use of anti-fouling coatings (AFC) is the most widely taken approach to prevent biofouling growth on underwater surfaces. In addition to protecting the hull, it is important to protect all immersed niche areas, such as propellers, propeller shafts and sail drives, bow thrusters, or water inlets from biofouling using specific AFS that can provide adequate protection to the particular characteristics of niche areas.

In the case of local fishermen and/or recreational boaters, it is useful to share and advise on which products are effective in the area where vessels are moored and where they operate. AFC providers also give advice through their websites and product literature. If the AFC is biocidal, it is important to check that it can be legally applied and used in a specific area. In the case of MPAs, a further consideration is whether specific biocides are consistent with the management objectives for the MPA. This is particularly relevant since TBT-based anti-fouling is still widely used on non-trading and recreational vessels in some parts of the world.

WHAT IS AN ANTI-FOULING SYSTEM (AFS)?

The Antifouling Convention defines an AFS as: "Any coating, paint, surface treatment, surface or device that is used on a ship or vessel to control or prevent the attachment of unwanted organisms as biofouling."

However, while anti-fouling coatings are the most common system in use, there are other options, either alternative or that can be used together with the coating. Examples of these include anodes, ultrasonics, UV protection, hull wraps, marine growth prevention systems.

In general, the effectiveness of AFS can vary due to the random nature of biofouling; the presence or absence of species tolerant to the anti-fouling systems (e.g. copper tolerant bivalves and algae); the type, age and condition of the anti-fouling coating; and voyage and vessel characteristics that deter from the suitable performance properties of the selected anti-fouling system. As a result, it is recommended to monitor the performance of the AFS, and, when an issue is identified, to take adequate measures to prevent further accumulation of biofouling.

In addition, there are concerns about the potential biocidal impacts that some anti-fouling coatings may have on non-target marine species and that such coatings may be hazardous to humans during application and removal if the correct precautions are not taken. In some cases, regulators, boat owners and the manufacturers of anti-fouling coatings alike may face a dilemma when considering biocidal anti-fouling paint to maintain performance of the boat and prevent the spread of IAS to protect the local marine environment, especially in high-use or environmentally sensitive marine areas. It should be noted that some biocides previously used in biocidal anti-fouling paints are now banned internationally under the AFS Convention, specifically organotin tributyltin (TBT) and cybutryne.

Table 5 below summarizes the broad range of options that exist for the proactive management of biofouling, describing how they work, and the pros and cons related to their use or performance.

Table 5: Biofouling prevention and management solutions

Anti-fouling system	How it works	Pros	Cons
Biocidal anti-fouling systems			
Biocidal anti-fouling paints (General)[8]	• The paints work by slowly releasing biocide from the dry paint film on the surface of the hull to prevent the settlement of fouling organisms. • Products contain a copper biocide with or without an organic co-biocide or organic biocide(s) which are active against fouling organisms. • Typically there is less biofouling growth in fresh water than in salt water, therefore biocidal anti-fouling paint used in fresh water usually has a lower biocide content and release rate to prevent growth.	• Products available that provide full or multi-season protection against fouling. • In the case of small-scale fishermen or recreational boaters, it is easy to apply by themselves when professional applicators are not available. • Cost effective vs alternative technologies. • Known products with established supply chains. • Products on the market must be reviewed and registered as biocidal products/pesticides under federal and national laws in countries including United States, Canada, EU member states, United Kingdom, Australia, New Zealand, Republic of Korea and Türkiye.	• Products leach biocide and metals to the marine environment when immersed, which has caused ongoing concern over effects on non-target marine life. • Hazardous products may be harmful to humans during application and removal if personal protective equipment is not used. • Surface preparation and application can result in paint residue / flake residue in wash water which must be collected and disposed of in accordance with waste management rules. • Many products emit volatile organic compounds (VOCs) to air during application.

[8] CEPE. Sustainable use of biocidal anti-fouling products.
https://www.vci-nord.de/fileadmin/vci-nord/Bilder/publikationen/1911CEPE_Sustainable_use_Final.pdf

Table 5: Biofouling prevention and management solutions – continued

Anti-fouling system	How it works	Pros	Cons
Biocidal anti-fouling systems - continued			
Soft biocidal anti-fouling paints (self-polishing, ablative)	• Surfaces of soft/ ablative or self-polishing paint films erode or "polish" slowly as biocide is released as water moves over the vessel.	• Coated surface of the hull smooths in service, optimizing hull performance by reducing drag. • Self-polishing effect can maintain a constant biocide release rate throughout the specified lifetime (based on intended vessel activity). • Soft paints are suitable for all vessels except high performance boats where the hull is regularly polished/burnished for optimum performance.	• Soft anti-fouling paints release biocide and metals when cleaned underwater, so abrasive in water cleaning of this type of coatings is a concern in many locations. • Concern that ablative paints may release microplastic when in service. • Specialist coatings needing for high speed elements of the ship (propellers)
Hard biocidal anti-fouling paints	• Hard paints release biocide from the insoluble paint film that does not wear away in-service.	• Hard paints can be suitable for ships operating at faster speed than others (over 30 knots). • Some specific products can be used on propellers and outdrives. • Hard finish anti-fouling paints release less toxicant than soft paints when subject to abrasive underwater cleaning, or jet washing prior to dry storage.	• Not self-polishing / ablative, so may need regular cleaning to maintain efficacy. • Biocide release rate less controlled compared to self-polishing / ablative anti-fouling paints. • Build-up of insoluble layer (leached layer) depleted in biocide at the paint surface when in service, which may reduce efficacy over time.
Hard epoxy resin with copper[9]	• Copper embedded in epoxy resin prevents fouling.	• Can be specified for multi-season performance.	• Precise application required for system to be effective. Initial application relatively expensive. • Uses copper up to the maximum allowed by law. • Not effective against copper-tolerant fouling species. May require pressure washing /brushing in service.
Non biocidal anti-fouling systems			
Biocide-free anti-fouling paints	• Hard and eroding film versions available.	• Hard film products - can also be used on propellers.	• Less well-known products with corresponding lack of experience of efficacy – especially in higher fouling waters.

[9] https://coppercoat.com/

Table 5: Biofouling prevention and management solutions – continued

Anti-fouling system	How it works	Pros	Cons
Non biocidal anti-fouling systems - continued			
Silicone elastomer based fouling release coatings[10]	• Foul release coatings are non-biocidal and function by generating a 'non-stick surface' effect at the coated surface preventing fouling organisms from attaching and maintaining adhesion once the boat is under way. • Also generate a smooth surface optimizing hull performance. • (Note: Fouling release coatings are also now available that contain biocide).	• Smooth surface that is copper and biocide free. Suitable primarily for higher activity, faster boats or where the hull can be regularly cleaned. • Products are available that are suitable for propellers, propeller shafts, sail drives and other immersed niche areas. • Can be specified for multi-season performance. • More complex to apply than traditional anti-fouling paints. • Versions available that can be applied by boaters themselves and by professional applicators.	• Requires regular use of vessel at higher speeds (typically > 8 knots) to encourage the fouling to release, therefore generally not suitable for little used boats, or slower vessels (e.g. non-racing yachts and motor cruisers). • Can be damaged by abrasion and physical contact (such as fender damage and abrasive hull cleaning). • Use in boatyards must be carefully managed to avoid contamination of other coatings with overspray containing silicone. • Typically, silicon elastomer coatings contain oils which may leach from the coating into water when in service. • Majority of products result in emission of VOCs into the air during application.
Ultrasound[11]	• Ultrasonic transducers emit multiple bursts of ultrasonic sound waves in multiple frequencies, creating a pattern of alternating positive and negative pressure. • Microscopic bubbles are created from the negative pressure, while the positive pressure implodes them due to cavitation. This deters settlement of microscopic settling stages of fouling organisms and destroys single cell organisms such as algae, stopping further growth of biofouling organisms.	• Physical mechanism - no chemicals are used. Does not harm non-target marine life. • Can be used with other anti-fouling systems to prevent fouling of all immersed areas to keep the hull clean for extended periods, including when the boat is in static conditions, without the need for regular mid-season cleaning. • Effective in niche areas.	• Initial outlay for installation. • Longer vessels require more transducers. Requires reliable power source. • May require occasional lift outs and cleaning.

[10] https://doi.org/10.1021/acs.langmuir.9b03926

[11] https://www.yachting-pages.com/articles/a-complete-guide-on-yacht-ultrasonic-antifouling.html

Table 5: Biofouling prevention and management solutions – continued

Anti-fouling system	How it works	Pros	Cons
Non biocidal anti-fouling systems - continued			
Boat wrap – adhesive film applied to hull of small recreational vessels (like wallpaper)	• The surface of the film/ wrapping mimics the "sea-urchin" principle with an artificial spiney surface with very fine flexible plastic fibres that stand out vertically from the surface. Microfouling organisms find it difficult to attach to these spines.	• Biocide free. • Robust and can be cleaned with pressure washer or mechanical in-water systems. • Provides additional protection to the hull.	• Needs to be professionally applied. • Needs occasional cleaning. • Concern that microplastic maybe released when in service and during cleaning.
In-water dock / slip liner	• Option applicable for smaller (recreational) vessels, where they are stored at berth in an external liner which covers the hull. Water inside the liner is completely enclosed and isolated from external water, excluding settling stages of biofouling organisms from entering. Any biofouling organisms enclosed in the wrap as the vessel enters the liner are starved of oxygen, light and nutrients, thus do not settle.	• Available for power boats and yachts with keels. • Avoids need for anti-fouling paint. • No hazardous chemicals needed. • Can be used in a marina or swing mooring. • Does not require boat to be lifted out of the water.	• Cannot use through hull inlets/outlets whilst in the wrap. • Only available at "home" berth. • Liner requires regular cleaning.

While using anti-fouling coatings is considered to be the first and most important line of defence against biofouling, further issues can arise when organisms become resistant to anti-fouling coatings. Some species, such as the bryozoan *Watersipora subtorquata*, are able to settle readily on some types of coating. The attachment of these resistant organisms then allows for the recruitment of other marine fouling organisms that are able to attach to the new layer of fouling.[12]

4.2 BIOFOULING MANAGEMENT ON VESSELS

Even effective anti-fouling coatings do not always keep vessels free from biofouling, especially when ships are operating at reduced activity. Effective "hull husbandry" is essential to ensure both that the hull remains free of biofouling and that the integrity of the anti-fouling coating is not compromised.

The removal of biofouling can be achieved in two ways. The first is by removing the vessel from the water and manually removing organisms on its hull and niche areas. Such "dry dock" cleanings are usually reserved for when anti-fouling coatings need to be reapplied. The second is in-water cleaning (IWC), which usually occurs between dry-dockings. In-water cleaning typically involves divers or remotely operated vehicles (ROV) that enter the water and clean the hulls of ships. In-water cleaning is faster and far less expensive compared to dry dock cleaning.

[12] https://dlnr.hawaii.gov/ais/ballastwaterbiofouling/biofouling

4.2.1 In-water hull cleaning

In-water cleaning has developed to address vessel performance / fuel consumption as an alternative to dry-docking or lifting the vessel out of the water along with associated costs and time. Proper cleaning removes all traces of biofouling and should not remove or damage the coating or cause any increased surface roughness. Underwater cleaning is performed either by a diver with brushes, or by a remotely operated vehicle (ROV).

Although the technique is referred to as "hull cleaning", any part of a vessel that is submerged for any period of time may present an opportunity for IAS uptake and discharge. As such, cleaning should focus on the following critical areas of a vessel:

- submerged hull;
- topside immersible equipment (topside anchors, chain lockers, mooring ropes, etc.); and
- internal seawater systems.

The IMO Biofouling Guidelines define two types of in-water cleaning (see Table 6 below):

Proactive cleaning (commonly called in-water or hull grooming) means the periodic removal of microfouling on ships' hulls to prevent or minimize the build-up of macrofouling.

Proactive cleaning can prevent the biofilm from developing into hard fouling with associated marine growth. It is important to use cleaning techniques that do not damage the anti-fouling coating and impair its function. A light sponge or brush of a biofilm should remove the biofilm, while minimizing both the release of toxic substances from the anti-fouling and the degradation of the anti-fouling coating system.

Hull grooming tends to be common for recreational vessels but less common for commercial vessels which tend to complete periodic in-service maintenance procedures such as propeller polishing and, where biofouling is thought to be problematic, reactive in-water cleaning.

Reactive cleaning means corrective action during which biofouling is removed from a ship's hull and niche areas either in-water with capture or in dry dock. Reactive cleaning is likely to include the use of brushes or water jets that can remove (some) macrofouling.

Depending on the level and type of biofouling, both can be conducted through divers or ROVs.

While mechanical proactive cleaning is effective in removing most biofilm, small areas of tenacious low-profile biofilm may persist. How effectively in-water cleaning can control biofouling on hulls depends on the fouling pressure, the frequency of treatment, the season, the type of tool used (e.g. rotating brush or other type) and the forces imparted by the tool (Arndt, Robinson and Hester, 2021). Vessels with biocide-free AFCs are likely to require more regular in-water cleaning.

Table 6: Hull cleaning options for biofouling management

In-water solutions			
Proactive in-water cleaning (hull grooming)	• Gentle brushing of hull when boat is at anchor or at mooring by diver or autonomous robot. • Hull grooming removes surface biofilms as a proactive measure to prevent further biofouling.	• Relatively quick to carry out, without lifting the boat from the water. Can be completed mid-season or before use of vessel to increase hull efficiency. • Can be carried out on immersed anti-fouling paint films without significant biocide or microplastics release.	• Works primarily on soft fouling. Therefore, must be carried out regularly to remove biofilms before hard fouling settles. • Commercial systems more available for larger vessels than for smaller boats / craft. • Non-capture cleaning systems release biofilm material into water.
Reactive in-water hull cleaning	Approaches: • Mechanical cleaning of hull when boat is at anchor or at mooring by diver or autonomous robot. • Drive-in boat washing station (similar to car wash) removes fouling by brushing, jetting or robotic cleaning system.	• Quick operation, without lifting vessel, can be completed mid-season or before use of vessel to increase hull efficiency.	• Coatings must be hard enough to withstand physical cleaning (brushes, jetting, etc). • Generates biological waste that must be collected/ managed to prevent release of potentially invasive species. • If not captured, paint particles (microplastics) may be released into surrounding water during hull cleaning. • Commercially available systems primarily suitable for boats without keels (powerboats).
Out-of-water solutions			
Floating docks[13] (form of dry sailing)	Different types: • Modular dock made of floating polypropylene blocks which the boat drives up onto using own outboard/outdrive, lifting hull clear of the water. • Lift systems, using air or hydraulics to lift vessel clear of the water.	• Available for vessels typically up to 3 tonnes, such as ribs, personal watercraft and power boats with inboard outdrives. • Prolonged periods with hull completely out of water avoids biofouling. • Other systems available for heavier boats. • Also protects vessel from waves and currents.	• Requires fixed berth for attachment. Only available for use at home berth. • High initial cost. Requires power to operate. • Not suitable for vessels with keels.

[13] https://www.dockmarine-europe.com/en/news/428_everything-you-need-to-know-about-boat-and-jet-ski-drive-on-docks

Table 6: Hull cleaning options for biofouling management – continued

Out-of-water solutions – continued			
Storage ashore / dry sailing / stacking / trailer boats [14]	• Boats are taken out of the water and stored /stacked in secure areas when not used. • Suitable for many boat types including motorboats, racing yachts, sailing dinghies, ribs, portable canoes, paddle boards and personal watercraft.	• Avoids need for anti-fouling paints completely for some vessels. • Avoids build-up of slime layer / biofouling. Clean hull optimizes fuel efficiency / performance. • Trailer boats / portable craft can be transported to multiple locations during the season and stored on shore when not in use.	• Dry stack / dry sailing can be expensive. • Trailer boats and portable craft need to be cleaned and dried between water bodies to prevent transport of invasive aquatic species.

[14] https://www.metstrade.com/news/marina-and-yard/drystacking-sustainability-marines/

4.2.2 Verification of hull cleanliness

One of the important elements in the chain of prevention is to ensure that vessels seeking to enter the MPA have effectively managed their biofouling such that the hull and niche areas are considered to be free of biofouling. While the BFMP and BFRB are important in this regard, many jurisdictions now require advance written verification that a hull has been cleaned and does not support harmful levels of biofouling.

The issue of "hull hygiene" or cleanliness is therefore a key consideration for MPA managers. This raises the important question *"What constitutes a clean hull?"*

It is generally accepted that to be considered "clean" a hull should have no more than a thin coat of microfouling present. Table 7 (see next page) illustrates the different levels of fouling that are defined in the IMO Biofouling Guidelines[15].

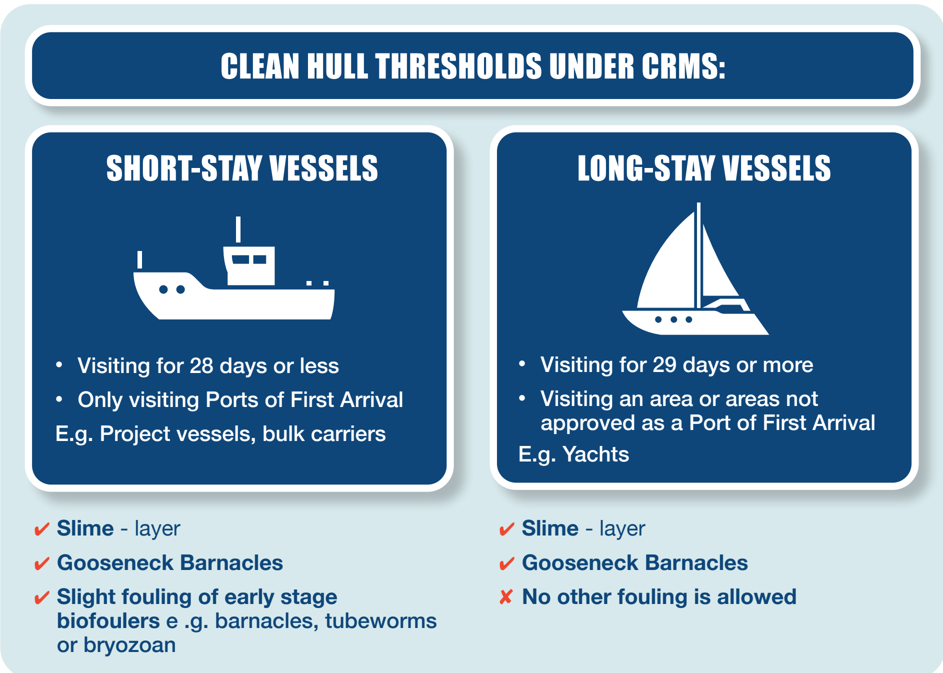
In New Zealand, for example, this is achieved through the adoption of regulatory requirement, known as the *Craft Risk Management Standard* (CRMS), which applies to all international vessels entering New Zealand. The CRMS takes various risk factors into account, and thus permits varying amounts of biofouling on vessels, depending on the intended duration of a vessel's stay in New Zealand. The CRMS includes specific thresholds for the presence of broad taxonomic groups, and, for vessels intending to stay short-term in New Zealand, sizes of organisms on different hull locations (Figure 6 see next page).

[15] 2023 Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species (IMO Resolution MEPC.378(80)).

Table 7: Rating scale to assess the extent of fouling on inspection area

Rating	Description	Macrofouling cover of area inspected	Recommended cleaning
0	**No fouling** Surface entirely clean. No visible biofouling on surfaces. Typical as applied AF coating.	-	
1	**Microfouling** Submerged areas partially or entirely covered in microfouling or light slime. Metal and painted surface may be visible beneath the fouling.	-	Proactive cleaning may be recommended
2	**Light macrofouling** Presence of microfouling and multiple macrofouling patches (small calcareous or weed). Fouling species cannot be easily wiped off by hand. Heavy slime. Visual estimate of macrofouling cover of area inspected: 1-15% of surface.	10-15% of surface	Cleaning with capture is recommended. It is recommended to shorten the interval until next inspection. If the AFS is significantly deteriorated, dry-docking with maintenance and re-application of AFS is recommended
3	**Medium macrofouling** Presence of microfouling and multiple macrofouling patches. Visual estimate of macrofouling cover of area inspected: 16-40% of surface.	16-40% of surface	
4	**Heavy macrofouling** Large patches or submerged areas entirely covered in macrofouling. Visual estimate of macrofouling cover of area inspected: 41-100% of surface.	41-100% of surface	

Figure 6: Hull cleanliness standards under the New Zealand Biofouling Craft Risk Management Standard. *Source: New Zealand Ministry of Primary Industries (MPI), (2018)* [16]



[16] https://www.mpi.govt.nz/dmsdocument/27444-Craft-Risk-Management-Standard-FAQs

Several MPA management authorities have also set very strict limits, disallowing vessels with any macrofouling. For example, macrofouling is prohibited on vessels in both the Papahānoumakuākea Marine National Monument and the Galápagos Marine Reserve.

Verification that these standards have been complied with is, in the first instance, the responsibility of the vessel owner/operator. To achieve this, vessels generally undergo an inspection and, if necessary, hull cleaning, prior to departing for the MPA. Several authorities require written evidence that this has been completed to be provided by a third party, which may or may not have been approved by the relevant authorities.

Table 8: Examples of acceptable fouling levels for MPAs

	Galápagos Marine Reserve	Papahānoumakuākea Marine National Monument	Kermadec and Subantarctic Islands
Fouling threshold	No macrofouling visible	All submerged and waterline surfaces must be free of macro-scale biofouling consisting of marine plants and animals. Surfaces must be free of any green, brown or red macro-algal species. Additionally, surfaces must be free of macro-invertebrate biofouling communities.	There are two thresholds of biofouling depending on whether the vessel is subject to inspection or not (see Text Box on Fouling Thresholds for the New Zealand Kermadec and Subantarctic Islands below).
Method of verification	Visual inspection undertaken by Government inspectors on arrival in the main port in the Galápagos.	Review of vessel's operation history and records, combined with a visual inspection undertaken before vessels depart from the main Hawaiian Islands by an approved person. If vessel is originating outside of the area, a risk assessment can be performed and entry authorized based on operational history, maintenance and husbandry e.g. recent dry dock and/or in-water-cleaning with documentation and/or photographic evidence provided.	Visual inspection undertaken by an approved person before the vessel departs mainland New Zealand; or Record of hull maintenance records (such as a biofouling record book) to be submitted on request by Department of Conservation.
Pre-arrival notification	Hull cleaning certificate to be presented on arrival	Inspection report	Inspection report

FOULING THRESHOLDS FOR THE NEW ZEALAND KERMADEC AND SUBANTARCTIC ISLANDS

FOULING THRESHOLD FOR INSPECTIONS

For any inspection conducted [in accordance with Performance Standard 2] the degree of vessel biofouling must not exceed microfouling (slime layer) and/or goose barnacles.

NOTE: In practice, most classes of vessel are required to meet this threshold.

FOULING THRESHOLD AT OTHER TIMES

Prior to each departure from port to the Kermadec or Subantarctic Islands, the vessel operator must be satisfied, on the basis of all the available information (required by Performance Standards 1.3 and 2.3), that for the areas included in the table in this performance standard, the biofouling will not exceed the following threshold while that vessel is within 0.54 nm (1000 m) of MHWS of any of the Islands:

Area of vessel	Biofouling threshold
Hull area	• Microfouling (slime layer) and/or goose barnacles; • Incidental (maximum of 1%) coverage of one organism type of either tubeworms, bryozoans or barnacles, occurring as: - isolated individuals or small clusters that have no algal overgrowth; and - a single species, or what appears to be the same species.
Niche areas	• Microfouling (slime layer) and/or goose barnacles; • Scattered (maximum of 5%) coverage of one organism type of either tubeworms, bryozoans or barnacles, occurring as: - widely spaced individuals and/or infrequent, patchy clusters that have no algal overgrowth; and - a single species, or what appears to be the same species • Incidental (maximum of 1%) coverage of a second organism type of either tubeworms, bryozoans or barnacles, occurring as: - isolated individuals or small clusters that have no algal overgrowth; and - a single species, or what appears to be the same species.

4.2.3 Biofouling management plans and biofouling record books

A major component of the IMO Biofouling Guidelines is the preparation and maintenance of biofouling management plans (BFMP) and biofouling record books (BFRB), as tools for continuous improvement of biofouling management.

The BFMP is a very specific tool developed for individual vessels which defines the management measures aimed at reducing the unwanted accumulation of biofouling and potential IAS on the submerged hull and inside internal seawater systems throughout the service life of the ship. Given the wide variation in ships, their operating profiles, and the factors which influence the accumulation of biofouling and potential transfer of IAS, BFMPs are necessarily vessel-specific and should consider the following factors:

- details of the coating systems and operational practices or treatments used, including those for niche areas;
- hull locations susceptible to biofouling, schedule of planned inspections, repairs, maintenance and renewal of anti-fouling systems;
- details of the recommended operating conditions suitable for the chosen anti-fouling systems and operational practices; and
- details relevant for the safety of the crew, including details on the anti-fouling system(s) used.

The development of the BFMP requires input from shipowners, operators, managers and/or crew to ensure that the resulting plan is achievable. It is vital that some members have an understanding as to how, why and where biofouling can accumulate on the general hull, amongst niche areas and within internal seawater systems so that proactive and realistic measures can be considered and implemented.

For more information on how to develop biofouling management plans and record books, refer to the guide published to this effect by the GEF-UNDP-IMO GloFouling Partnerships.[17]

4.2.4 Documentation for recreational vessels

For recreational vessels, development of a BFMP and keeping a BFRB is not common practice. Evidence from research undertaken in Europe suggests that the highest rates of biofouling occur on those vessels whose owners had no information about the applied AFC.[18] This suggests that by planning biofouling management and keeping some form of biofouling record book, recreational vessels could significantly reduce their risk of IAS transfer as well as the input of biocides (HELCOM, 2020).

A first step to improving biofouling management on recreational vessels is to keep information about the actual AFC on board. IMO recommends that, for recreational vessels of less than 24 m in length, vessel owners retain the vessel's biofouling management information in one place, such as the vessel's logbook. This information could include details of the anti-fouling system used on the vessel, receipts or documentation of cleaning actions, any inspections made and notes on the effectiveness of the anti-fouling coating applied. For more information and practical recommendations specifically for all types of recreational vessels, refer to the guide published to this effect by the GEF-UNDP-IMO GloFouling Partnerships.[19]

[17] https://www.glofouling.imo.org/publications-menu

[18] https://www.bsh.de/DE/THEMEN/Forschung_und_Entwicklung/Aktuelle-Projekte/BMVI-Expertennetzwerk-TF2/_Anlagen/Downloads/Hull_Fouling.pdf;jsessionid=B7CA233F6262E4573B2F4874C0C37C15.live11291?__blob=publicationFile&v=2

[19] https://www.glofouling.imo.org/publications-menu

4.2.5 Routine inspection

Adopting the structure and content of a BFMP does not necessarily reduce the likelihood of biofouling or IAS accumulating on the submerged hull, unless there are also ongoing monitoring and biofouling management measures undertaken. The 2023 Biofouling Guidelines request operators to undertake periodic inspections carried out by organizations, crew or personnel competent to undertake inspections to determine level of biofouling and the condition of the AFS.

The inspection frequency or dates for in-water inspections during the in-service period of the ship should be based on the ship-specific biofouling risk profile, including inspection as a contingency action, and specified in the BFMP. The BFMP should also specify management actions to be taken when biofouling is identified during inspections (e.g. cleaning), including changes to inspection frequency.

The Biofouling Guidelines recommend that subsequent inspections occur at least every 12 to 18 months and may need to increase to confirm the continued effectiveness of aging or damaged anti-fouling systems. In-water inspections should seek to coincide with existing subsea operations (e.g. underwater inspections in lieu of dry-dock or any other in-water inspections), including any unscheduled subsea operations. If no anti-fouling systems are installed in areas of a ship and no other measures are undertaken such as in-water cleaning or propeller polishing, then inspections should occur more frequently (<12 months) to manage the risk of biofouling accumulation.

In-water inspections should assess biofouling across the entirety of a ship's hull and niche areas. If high levels of biofouling are identified, and there are reasons to suspect issues with the AFS effectiveness, actions should be taken to manage the biofouling and subsequent inspections should occur more frequently, for example biannually until dry-docking and re-coating of AFC.

In-water inspections should determine the level of biofouling of the hull and niche areas and the condition of the AFS. The inspection areas should be sub-divided into appropriate sections and the fouling rating for each area on the ship should be the highest rating identified in the inspected areas. The following should be investigated during the inspection:

- rating of the type and approximate extent of biofouling in line with the definitions in Table 7 above;
- condition of the AFC on the hull and in niche areas; and
- functionality of the MGPS in niche areas.

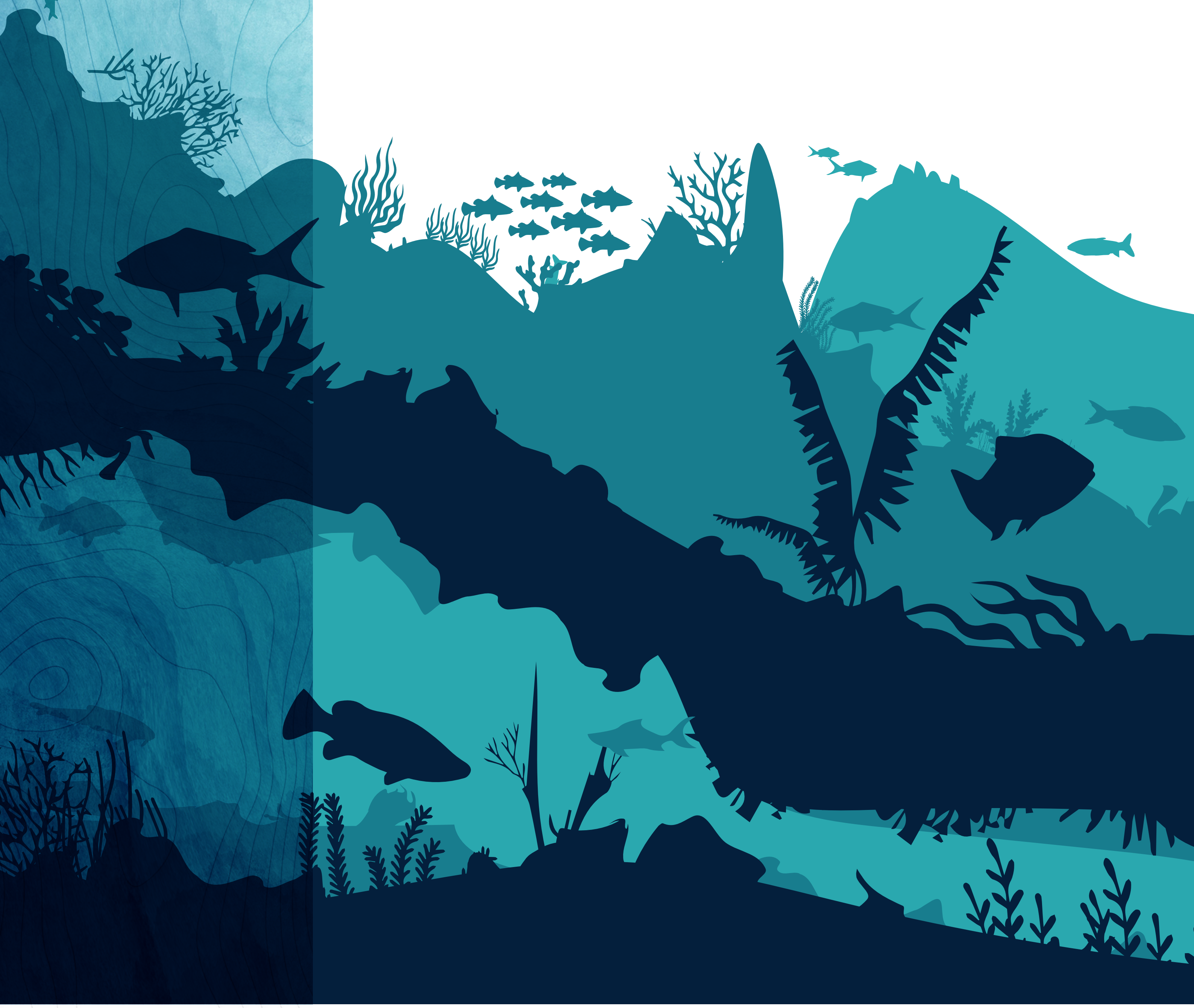
The IMO Biofouling Guidelines recommend that a report should be prepared after an inspection. The report should record the details of the biofouling management actions undertaken on the ship. The inspection report should be prepared by the inspection provider. It may also be relevant to prepare a report after an inspection carried out by ship's crew as part of contingency actions.

Digital tools may be applied for the reporting and/or assessment of results. The conclusion from the reports should be recorded in the BFRB including reference to the detailed report/assessment.

4.3 RESTRICTIONS ON ENTRY AND MOVEMENT OF VESSELS

Given that even the best biofouling management activities may not entirely remove the risk of IAS introduction, some MPAs have placed strict controls on the entry and movement of all, or certain classes of, vessels. While such controls can be enacted unilaterally by a coastal State within their territorial, internal or archipelagic waters, the adoption internationally accepted measures (such as vessel routeing measures) through IMO provides a more robust regulatory framework that is more widely accepted by the international maritime sector.

In particular, the application of PSSAs and a range of associated protective measures (as outlined in section 3.3 above) have been successfully utilized as tools to protect MPAs from the impacts of shipping.



5 MANAGING BIOFOULING RISK

5.1 OVERVIEW

While the combination of effective anti-fouling systems and good hull husbandry will significantly reduce biofouling risk, it is not always possible to prevent the arrival of vessels or marine structures with biofouling. Furthermore, for some vessel types, there is likely to be a latent risk associated with biofouling within niche areas (New Zealand Government, 2011). If a vessel arrives at the border with fouling, there is a risk that fouling organisms can either spawn into the local environment or that individuals transfer from the vessel to a local substrate (such as a wharf or pontoon).

Preventing the entry of a fouled vessel at the border, therefore, represents the next best opportunity to intervene in the invasion pathway, to control the risk of IAS introduction. To this end, it is necessary to consider a range of options to mitigate biofouling when the vessel arrives and is inspected at the border. "high-risk" vessels are either effectively cleaned or excluded from the MPA after the detection of biofouling growth.

For those authorities managing the arrival of vessels within a MPA, two issues are therefore relevant:

- How are such vessels identified? and
- How are such vessels dealt with in a manner that does not pose a risk of IAS release to the wider environment?

5.2 IDENTIFYING HIGH RISK VESSELS

To assess the risk associated with visiting vessels, many authorities have implemented a system of pre-arrival notification and physical border inspection. This allows an assessment of the extent to which a vessel's biofouling management system complies with domestic biosecurity requirements. In most cases, existing domestic regulations are aligned with the IMO Biofouling Guidelines. This information forms the basis of vessel "risk profiling" by which authorities can determine what, if any, actions may be required on the vessel's arrival.

The degree of complexity of the pre-arrival requirements may vary between different jurisdictions, depending on the resources available to manage the border. There is also no accepted timeframe for the pre-arrival notification but current practice requires a minimum of 72 hours prior to scheduled arrival.

In a study undertaken in British Columbia (Canada), researchers evaluated the use of a questionnaire model to determine the likelihood of macrofouling presence on recreational vessels (Clarke Murray et al. 2013). Using four easily obtained variables (boat type, age of anti-fouling paint, storage type, and occurrence of long-distance trips) the questionnaire was able to reliably identify boats carrying macrofouling species. The study showed that such questionnaires, validated by underwater surveys, provide the highly detailed data required to develop effective predictive models.

Where resources and capacity are limited, such fouling model tool could be applied in border inspection or quarantine situations where decisions must be made quickly (Clarke Murray et al. 2013). Similarly, these questions could be used to form the basis of a pre-arrival notification procedure.

In the specific case of MPAs, not every MPA will have the capability or the facilities to allow inspection of a vessel at its border/point of entry. In such cases, the inspection and risk profiling process will be undertaken as part of the pre-arrival inspection and arrival process either in that country's main port of entry or in the port of last departure.

NEW ZEALAND PRE-ARRIVAL REQUIREMENTS

In order to demonstrate compliance with New Zealand's Craft Risk Management Standard (CRMS) all vessels entering New Zealand's territorial waters must submit the following information in advance of their arrival:

- Advance notice of arrival;
- Biofouling and ballast water declaration;
- Master's declaration;
- Verifiable evidence that one of the three management options to meet the biofouling standard have been completed:
  - carry out hull cleaning within 30 days of arrival;
  - provide evidence of continual hull maintenance in accordance with best practice (e.g. anti-fouling certificate, biofouling management plan, biofouling record book, report from last hull cleaning); and
  - book an appointment to haul out a vessel at an approved facility with 24 hours of arrival;
- Details about the vessel's anti-fouling coating (AFC) such as date of last renewal, certificate of treatment and service life;
- Intended length of stay within New Zealand and the places the vessel intends to visit;
- Whether a biofouling management plan (BFMP) and biofouling record book (BFRB) (or any other forms of records) are kept; and
- Whether the vessel has spent extensive time idle or extended periods mainly stationary in a single location.

These requirements apply to all vessels.

This information is used by the Ministry for Primary Industries (MPI) to carry out a biofouling risk assessment, the rating of which determines the level of verification that MPI Quarantine Officers will carry out on a vessel once it has arrived in NZ waters.

PRE-ARRIVAL INSPECTION AND NOTIFICATION REQUIREMENTS FOR THE PAPAHĀNAUMOKUĀKEA MARINE NATIONAL MONUMENT

The pre-arrival procedures for vessels entering the PMNM differ from the New Zealand situation since entrance into the PMNM is strictly regulated, and all vessels (except for Emergency Response, Law Enforcement, Armed Forces, or innocent passage without interruption) must apply for a permit to enter. There are 6 kinds of permits offered: Scientific research; Education; Conservation and management; Native Hawaiian Practices; Special Ocean Use (film making, etc.); and Recreation. It should be noted, however, that recreational vessels are only permitted to access Midway Atoll and very few permits are issued for recreational vessels.

Management of the Monument is conducted through four Co-Trustees and seven Co-managing agencies, including the Hawaii Hawaii State Department of Land and Natural Resources (DLNR), the US Fish and Wildlife Service (FWS), the National Oceanic and Atmospheric Association (NOAA), and the Office of Hawaiian Affairs (OHA).

As part of the entry permit application process, all vessels shall be inspected for the presence of marine alien species prior to approval for an entry permit. The vessels that fall under these six permits all must meet the same standards for biofouling during inspections (PMNM, 2009).

Prior to inspection, the vessel that has applied for a permit will send a completed hull husbandry questionnaire (appendix A, see pages 61-64). This is used to assess the risk profile of the vessel.

Papahānaumokuākea Marine National Monument Biofouling Questionnaire for Vessels Requesting Entry

Vessel Information & Particulars	
Vessel Name	
Official / IMO Number	
Vessel type (containership, barge etc)	
Responsible Officer's Name and Title (Person filling this form)	
Vessel/Company/Agent **Email** address	
Date of Submission (**Day/Month/Year**)	
Vessel Age (years)	
Vessel typical speed (laden speed in knots over the last four months)	
Vessel typical port residence time (hours or days)	_____hours **OR** _____days

Previous Dry Docking	
Since delivery, has the vessel been removed from water for maintenance?	Yes ☐ No ☐
If **YES**, enter the date and location of the most recent out-of-water maintenance:	Date (Day/Month/Year): City/Port: Country:
If **NO**, enter the delivery date and location where the vessel was built:	Delivery Date (Day/Month/Year): City/Port: Country:

Anti-Fouling Paint (A/F Paint)	
Were the vessel's **submerged portions** coated with an anti-fouling paint (includes foul-release paint) during the out-of-water period listed above?	Yes ☐ No ☐
If not, when was the last anti-fouling coating applied to the vessel?	Date of A/F paint application (**Day/Month/Year**):
For the most recent anti-fouling coating, what product (top coat A/F paint) was used for **hull surfaces**? Please list more than one if necessary and indicate what parts of the hull each product was used on?	For the **hull bottom** Manufacturer/Company: Product Name: For the **hull sides** Manufacturer/Company: Product Name:
Were additional anti-fouling coatings used for other submerged surfaces (e.g. rudder, thrusters, sea-chests)?	No ☐ Don't know ☐ Yes ☐ If yes, what products were used Manufacturer/Company: Product Name: Manufacturer/Company: Product Name:

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PRE-ARRIVAL INSPECTION AND NOTIFICATION REQUIREMENTS FOR THE PAPAHĀNAUMOKUĀKEA MARINE NATIONAL MONUMENT - CONTINUED

Do you know when the next out-of-water maintenance is scheduled?	Yes ☐ Month & Year ______________ Don't know ☐
Sea chests	
Were the sea-chests inspected and/or cleaned during the most recent out-of-water maintenance listed above? If there has been no out-of-water maintenance since delivery, select Not Applicable. **Check all that apply.**	Yes, sea chests were inspected ☐ Yes, sea chests were cleaned ☐ No, sea chests were **not** inspected or cleaned ☐ Not applicable ☐
Are **Marine Growth Protection Systems (MGPS)** installed in the sea-chests and/or sea strainers? (Note, these are not just cathodic protection against corrosion, but anti-fouling systems to prevent marine growth)	Yes ☐ If yes, MGPS installed in (please check one option) Sea chest ☐ Sea strainer ☐ Both ☐ If yes, provide the name of the Manufacturer__________________________ Model __________________________________ No ☐
Are the MGPS operational?	Yes ☐ No ☐
In-water cleaning	
Has the vessel undergone in-water cleaning of the submerged portions of the vessel since the last out-of-water period?	Yes ☐ No ☐
If <u>yes</u>, when and where did the most recent in-water cleaning occur? Do not include out-of-water cleaning.	Date (Day/Month/Year): City/Port: Country: Vendor providing cleaning service:
If <u>yes</u>, what underwater portions of the vessel were cleaned in-water? **Check all that apply.**	Propeller ☐ Hull surfaces ☐ Intake Gratings ☐ Bilge keels ☐ Rudder ☐ Thrusters ☐ Unknown ☐
If <u>yes</u>, what method was used for in-water cleaning?	Divers ☐ Robotic ☐ Both ☐
If yes, were any steps taken to capture the removed material (debris) during cleaning?	Yes ☐ Which method?: Net ☐ Suction ☐ No ☐ Don't know ☐
Are other areas treated (rinsed, cleaned etc) to prevent or limit biofouling accumulation? Check all that apply.	Anchors ☐ Anchor chains ☐ Chain locker ☐ Tow lines ☐ Other ☐ Specify: ___________________
Recent Voyage History	
Since the hull was last cleaned, has the vessel visited the **Panama Canal**?	Yes ☐ How many times? ____ No ☐
Since the hull was last cleaned, has the vessel visited tropical ports (between 23.5°S and 23.5°N latitude) **outside** of Hawaii?	Yes, ☐ How many times? ____ No ☐
Since the hull was last cleaned, has the vessel visited	Yes ☐ How many times? ____

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PRE-ARRIVAL INSPECTION AND NOTIFICATION REQUIREMENTS FOR THE PAPAHĀNAUMOKUĀKEA MARINE NATIONAL MONUMENT - CONTINUED

freshwater ports?	No ☐
List the **previous 10 ports** visited by this vessel prior to arrival in Hawaii. Start with the most recent port (your last port prior to Hawaii) and list them in the reverse order they were visited. Check this box if the vessel visits the same ports on a regular route - ■ - and only list the route once even if it is fewer than 10 ports.	Port & Country: Date (Day/Month/Year):
	Port & Country: Date (Day/Month/Year):
	Port & Country: Date (Day/Month/Year):
	Port & Country: Date (Day/Month/Year):
	Port & Country: Date (Day/Month/Year):
	Port & Country: Date (Day/Month/Year):
	Port & Country: Date (Day/Month/Year):
	Port & Country: Date (Day/Month/Year):
	Port & Country: Date (Day/Month/Year):
	Port: Date (Day/Month/Year):
Periods of Inactivity (Lay-Ups)	
Since the most recent hull cleaning (in- or out-of--water) or delivery, has the vessel spent **10 or more consecutive days** in any single location? Do not include time spent out-of-water or during in-water cleaning.	Yes ☐ No ☐
If **NO**, provide the date, location and duration of the longest amount of time spent in a single location:	Date of arrival(D/M/Y): City/Port: Country: Duration of Stay: ____hours **OR** 4.6 days
If **YES**, list all of the occurrences whereby the vessel spent 10 or more consecutive days in any single location since the last hull cleaning. Begin with the most recent and list in reverse order. Include the instance of maximum duration at one location since the last hull cleaning.	Date of arrival(D/M/Y): City/Port: Country: Duration of Stay: ____days
	Date of arrival(D/M/Y): City/Port: Country: Duration of Stay: ____days
	Date of arrival(D/M/Y): City/Port: Country: Duration of Stay: ____days
	Date of arrival(D/M/Y): City/Port: Country: Duration of Stay: ____days
	Date of arrival(D/M/Y): City/Port: Country: Duration of Stay: ____days
	Date of arrival(D/M/Y):

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PRE-ARRIVAL INSPECTION AND NOTIFICATION REQUIREMENTS FOR THE PAPAHĀNAUMOKUĀKEA MARINE NATIONAL MONUMENT - CONTINUED

	City/Port: Country: Duration of Stay: ____days
	Date of arrival(D/M/Y): City/Port: Country: Duration of Stay: ____days
	Date of arrival(D/M/Y): City/Port: Country: Duration of Stay: ____days
	Date of arrival(D/M/Y): City/Port: Country: Duration of Stay: ____days
	Date of arrival(D/M/Y): City/Port: Country: Duration of Stay: ____days
Biofouling Management Plan and Record Book	
Are you familiar with the International Maritime Organizations' *"2011 Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species"*?	Yes ☐ No ☐ If yes, do you keep a copy of the IMO biofouling guidelines on board? Yes ☐ No ☐
Do you have a biofouling management plan and record book for your vessel?	Yes ☐ No ☐ If yes, when was this implemented? Month & Year ________________

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5.2.1 Raising awareness of pre-arrival requirements

To ensure compliance with the pre-arrival notification requirements, there is a need to ensure that vessel owners and operators are aware of the requirements. This can be achieved through the use of a signed pre-arrival statutory declaration, confirming that the vessel owner or operator is aware of, and has complied with, the entry requirements. MPA managers can utilize a number of possible stakeholders to achieve this, including:

- marinas and yacht clubs (for recreational vessels) identified as the main departure hubs;
- recreational vessel associations or industry groups (particularly for regattas, etc.);
- port authorities (for commercial vessels);
- ship and yacht agents (for example, all foreign yachts entering the Galápagos are required to employ a local agent to clear in and out of the islands);
- through the lead national agency responsible for biosecurity management (website); and
- through the agency responsible for MPA management (website).

Figure 7: An example of a settlement plate used in the MPA.

PRE-ARRIVAL NOTIFICATION IN GALÁPAGOS

All vessels scheduled to arrive in Galápagos are required to submit the following Vessel Inspection Request at least 48 hours before their arrival to Galápagos waters. This form includes basic details about the vessel (name, ID number, flag State, departure point, arrival port, name of captain/officer and date/time of arrival).

The form is typically sent via the vessels nominated shipping agent and must be signed by the agent.

By submitting the form, the vessel owner/operator agrees to produce certificates upon arrival – including written evidence that the hull has been cleaned.

REPÚBLICA DEL ECUADOR

Agencia de Regulación y Control de la Bioseguridad y Cuarentena para Galápagos

SOLICITUD DE INSPECCIÓN DE EMBARCACIONES

Lugar y fecha: _______________________________/_____/_____/_______

Mgs.
Jean Pierre Cadena Murillo
DIRECTOR EJECUTIVO
AGENCIA DE REGULACION Y CONTROL DE LA BIOSEGURIDAD Y CUARENTENA PARA GALAPAGOS
En su Despacho

El motivo de la presente es para solicitar la inspección de cubierta y de casco como establecen la Resolución del Directorio de la Agencia, **No. D-ABG-057-06-2023**; y cumpliendo con lo establecido en el **INSTRUCTIVO DE REGULACIÓN Y CONTROL PARA LAS EMBARCACIONES QUE INGRESAN Y OPERAN EN LA RESERVA MARINA EN GALÁPAGOS.** Para lo cual adjunto la respectiva papeleta de depósito por la prestación de este servicio.

A continuación detallo información de la embarcación para la inspección/verificación.

SHIP PARTICULARS AND ARRIVAL TO PORT DATE

Embarcación: _______________________________,
Matrícula: _______________________________,
Bandera: _______________________________,
Procedente de: _______________________________,
Puerto a arribar: _______________________________,
Nombre Capitán: _______________________________,
Fecha de arribo: _________________; Hora: ______,

SHIP AGENT DETAILS

Atentamente,
Agencia Naviera: _______________________________,
Contacto: _______________________________,
Nombre de Representante: _______________________,

f.) ___________________________,
C.I ___________________________,

INSPECTION PAYMENT INSTRUCTIONS

NOTA: El pago por la prestación del servicio que solicita; se la realizará en la Cta. Cte.: No. 7435290 banco del pacifico a nombre de la Agencia de Regulación y Control de la Bioseguridad y Cuarentena para Galápagos, de acuerdo a la siguiente tabla:

4,0	Inspección de medios de transportes marítimos y aéreos		
4.1	Inspección de veleros procedentes de otros países	Inspección	100
4.2	Inspección de yates procedentes de otros países	Inspección	200
4.3	Inspección a barcos de turismo que vienen de realizar mantenimiento desde otros países a la provincia de Galápagos	Inspección	300
4.4	Inspección embarcaciones de turismo que vienen de realizar mantenimiento desde el Ecuador continental a la provincia Galápagos	Inspección	100

Dirección: Av. Baltra, diagonal a la gruta del Divino Niño
Código postal: EC200350/ Puerto Ayora-Ecuador
Teléfono: +593-5 252 7414
www.bioseguridadgalapagos.gob.ec

EL NUEVO ECUADOR

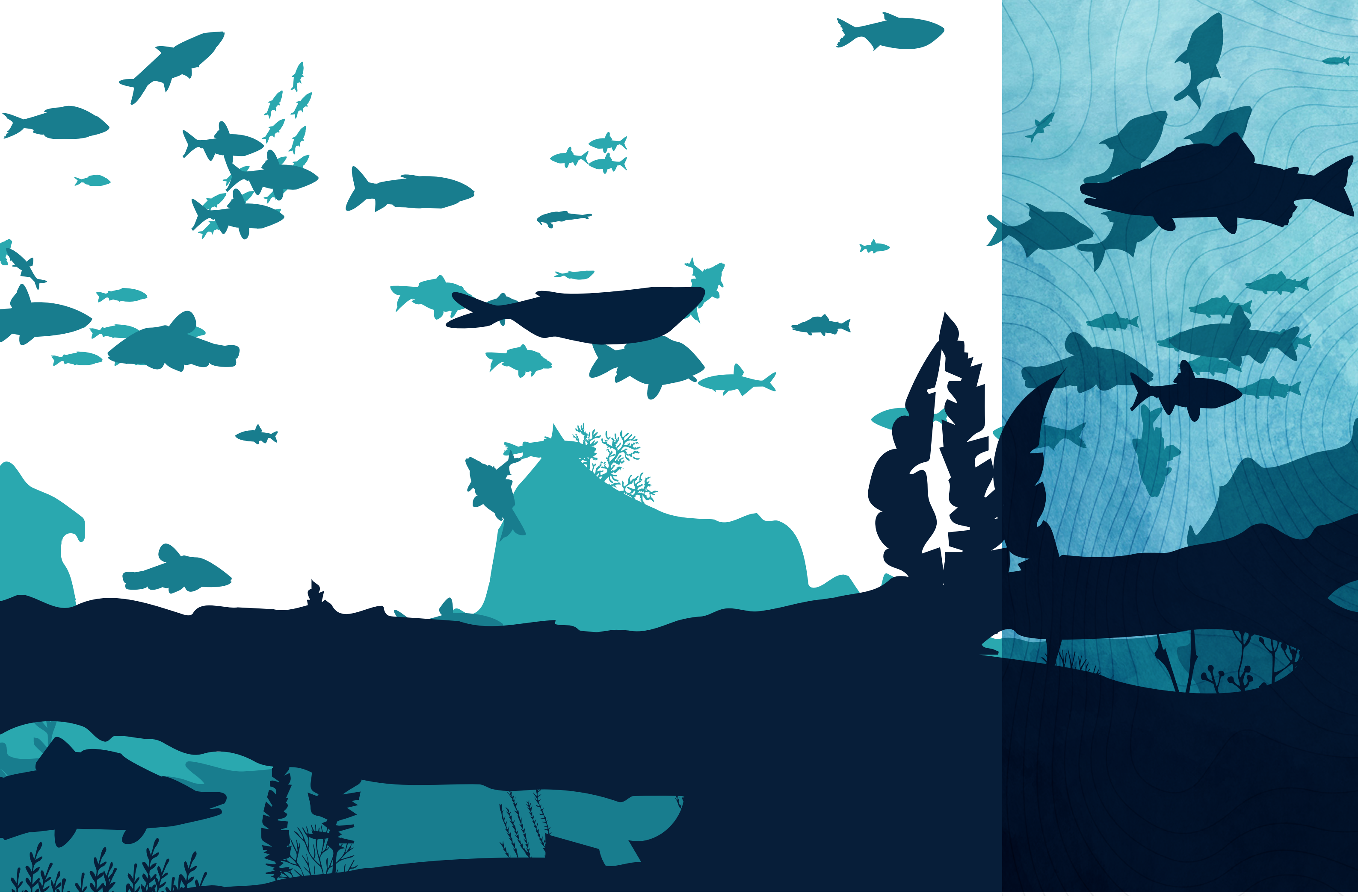
5.2.2 Pre-arrival risk profiling

Based on the pre-arrival information submitted, authorities can assess the level of intervention each vessel may be subject to on arrival. Even in cases where simple documentation of regular maintenance is used as a standard, periodic assessment of ship biofouling should occur for compliance and verification purposes (i.e. to determine the efficacy of maintenance activities).

A range of factors should be considered when assessing the risk profile of an individual vessel, including, but not necessarily limited to:

- type of vessel and operational profile;
- planned duration of stay;
- port of last departure (environmental compatibility and known IAS presence);
- unsatisfactory pre-arrival inspection report;
- date of last AFC application;
- deviation from AFS specifications (e.g. salinity, speed, temperature);
- deviation from AFS/hull maintenance schedule;
- deviation from regular pro-active cleaning or necessary reactive cleaning;
- extended idle time (with no subsequent cleaning); and
- evidence of damage to the AFS.

For example, prior to their inspection, vessels applying for a permit to enter the PMNM send a completed biofouling questionnaire regarding hull husbandry practices. This is used to conduct a risk assessment using the standard template presented in Figure 7 below. If a vessel is determined to be low-risk, sometimes a pole-camera or ROV is used instead of a diver.



Inspector: ____________________ Vessel: ________________ Date: ________

Alien Species Probability Assessment Form
GAR Evaluation Scale

Rate the following where:
1 = low risk and 5 = the highest risk

		Comments
In-Port Periods: Maximum time spent in-port during last 6 months		
Dry Dock Interval: Time sense last dry dock period		
Hull Husbandry: Frequency and thoroughness of in-water cleanings		
Vessel Speed: typical cruising speed		
Ports of Call:Geographical location of ports visited in last 6 months		
Marine Growth Protection Systems (MGPS) installed in the sea‐chests and/or sea strainers?		

0
Total Risk

Green = 6 - 10 (Low Probability)
Amber = 11- 20(Medium Probability)
Red = 21 - 30 (High Probability)

Inspector's Signature

Refer to Scoring Legend for a more detailed description of Probability Considerations

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Figure 8: Standard risk assessment form for assessing inspection requirements for vessels entering the Papahānaumokuākea Marine National Monument

Alien Species Probability Scoring Legend

1. In-Port Periods: Maximum time spent in-port during last 6 months.
- 5 > 4 weeks
- 4 3-4 weeks
- 3 2-3 weeks
- 2 1-week
- 1 Typical in-port < 3 days

2. Dry Dock Interval: Time sense last dry dock period
- 5 5 + years
- 4 <4 years
- 3 < 3 years
- 2 < 2 years
- 1 < 1 year

3. Hull Husbandry: Frequency and thoroughness of in-water cleanings
- 5 Never cleaned
- 4 Annually
- 3 Semi-annually
- 2 Quarterly
- 1 Monthly/after each port visited

4. Vessel Speed: typical cruising speed
- 5 < 5 knts
- 4 5-10 knts
- 3 10-15knts
- 2 15-20 knts
- 1 >20knts

5. Ports of Call:Geographical location of ports visited in last 6 months
- 5 Tropical/Sub-tropical for > 3 weeks
- 4 Tropical/Sub-tropical < 3 weeks
- 3 temperate > 3 weeks
- 2 temperate < 3 weeks
- 1 polar/temperate < 3 weeks

6. Marine Growth Protection Systems (MGPS) installed in the sea-chests and/or sea strainers?
- 5 NO
- 1 YES

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VESSEL-CHECK ONLINE RISK PROFILING TOOL

One example of a risk assessment tool is "Vessel-Check", a cloud-based solution to aid in the mitigation of IAS. Vessel-Check focuses on two key areas:

- the ability to consistently assess the risk associated with a vessel's biofouling based on the vessel's biofouling management practices; and
- effective pre-border communication and awareness with industry stakeholders outlining indicative risk profiles, and how the biosecurity risk can be managed appropriately to as low as reasonably practicable.

The Vessel-Check portal is designed for vessel owners/operators providing information to regulators, seeks what vessel biofouling management is being undertaken for a vessel and assesses whether the outlined management is sufficient to mitigate the transfer of non-indigenous species to as low as reasonably practicable.

The indicative risk provided by the Vessel-Check portal indicates the likely efficacy to mitigate the transfer based on the management practices being employed on a vessel.

Based on the information provided, the tool calculates an indicative risk associated with the vessel based on the following seven metrics covering the vessels biofouling management practices: biofouling management plan; hull husband approaches and history; niche management; AFC information and history; layup history and profile; external niche implementation; and internal niche implementation.

The indicative risk for each metric is determined from the vessel's biofouling management profile and the information provided by the vessel managers/operator for their vessel(s). The "Overall Risk Assessment" for a vessel represents the average of the seven individual biofouling management risk metrics.

Thresholds used within the risk metric calculations are determined by the jurisdiction relative to their legislative requirements providing a clear avenue for vessel operators to quickly understand the expectations of the jurisdiction they intend to visit.

Source: *https://vessel-check.com*

Even in the absence of such a risk profiling tool, or where resources are severely limited, MPA managers can use the port of origin as a proxy, especially when vessels arrive from ports with a known presence of high-risk IAS. Similarly, particular attention should be paid to slow-moving vessels – since these achieve little operation benefit in reducing hydrodynamic drag – and poorly maintained, old or decommissioned vessels, since these are often unemployed and remain stationary for long periods of time. When they do move they tend to do it to a new location for a long period of time.

5.3 VESSEL HULL INSPECTIONS

Where the risk profiling process raises questions about individual vessels, the authorities may decide to inspect the vessel on its arrival to determine (a) whether the pre-arrival documentation provided is correct; (b) whether the vessel poses a risk; and (c) what, if any, remedial measures should be required to mitigate that risk. In addition to the operational benefits of inspection, there is evidence that the threat of inspection results in vessel owners being more conscious of biofouling management, if there is a risk that an inspection may have operational impacts (Ellard, 2021).

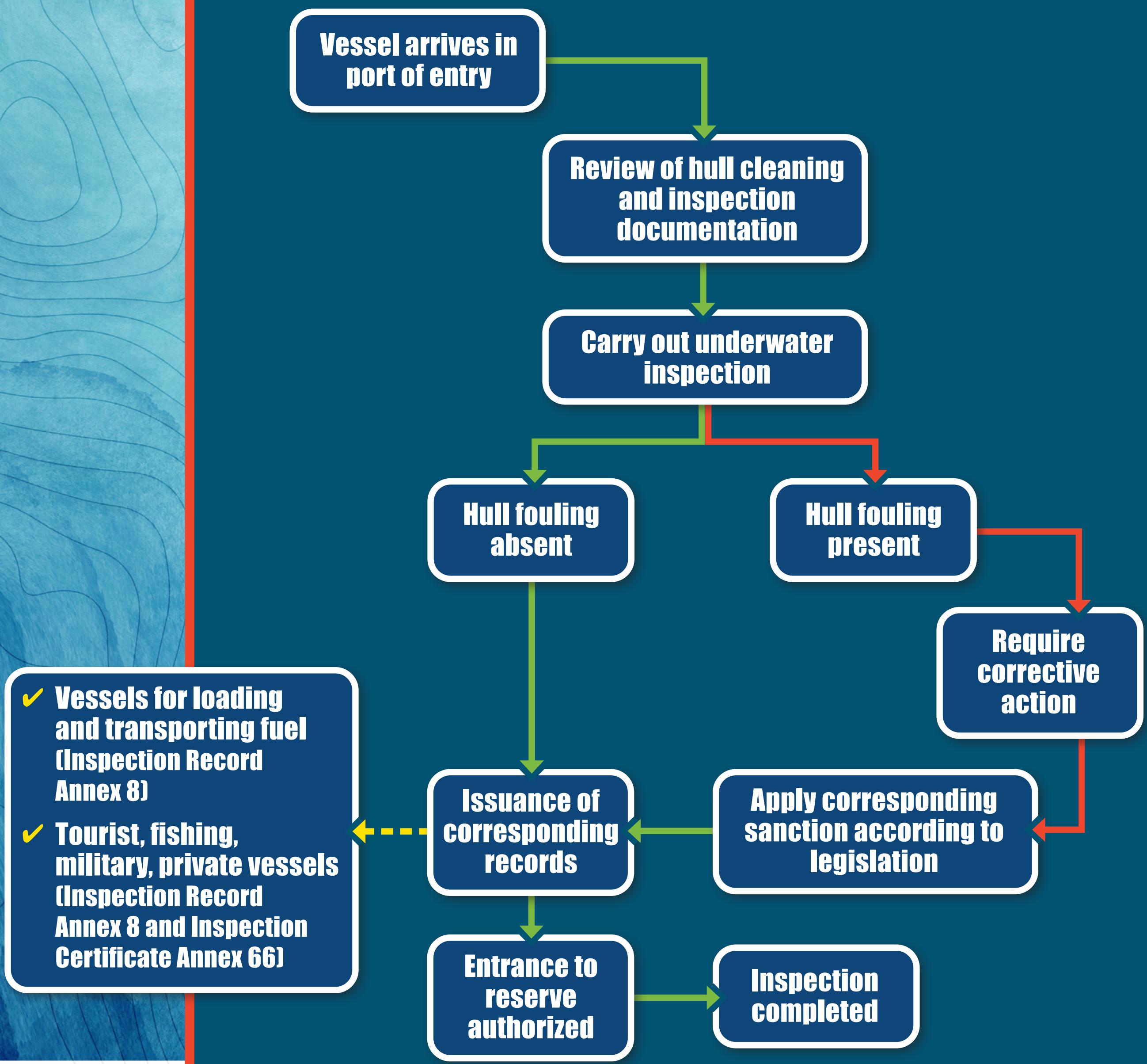
INSPECTION REQUIREMENTS IN GALÁPAGOS

International vessels entering the Galápagos Marine Reserve may only anchor in one of the official main ports of the archipelago. Regulations require vessels to clean before arrival and disallow any encrusting organisms. Upon arrival all vessels (including yachts, cruise ships, commercial cargo and fishing vessels) are inspected by local authorities including the ABG (the Ecuadorian Biosecurity Agency, the Agencia de Regulación y Control de la Bioseguridad y Cuarentena para Galápagos), the GNPD (Galápagos National Park Directorate), the CCREG (Consejo de Gobierno del Regimen Especial de Galápagos), and the Ecuadorian Navy.

Inspections are mandatory and detailed written protocols include a dockside inspection of the hull above the waterline and in-water visual inspection of the entire hull and niche areas. Divers from the ABG marine unit inspect vessels that come into the Islands from international destinations and record the last port of entry (Agencia de Bioseguridad Galápagos (ABG), 2017).

When divers find encrusting organisms, protocols require that they collect samples representative of all taxa encountered. The ABG reports this information to the GNPD, which can then turn them away if they fail to comply, and request them to leave the Islands and return for a second inspection once the hull has been cleaned, if they wish to enter the reserve (Carlton, Keith and Ruiz, 2019).

HULL INSPECTION FLOW CHART



5.3.1 Surface inspection methods

For MPAs, since the introduction of IAS has been mostly associated with the presence of macrofouling organisms, any macrofouling found on the hull of an arriving vessel should be treated as high risk. As a starting point, therefore, a dockside visual observation of the hull may be sufficient to identify heavily fouled vessels and, therefore, to quickly (but accurately) identify higher risk vessels that may require more detailed examination while screening out lower risk vessels that do not require additional intervention. Higher risk vessels could then be subject to detailed inspection and/or quarantine that would allow characterization of species actually present and allow removal of potential invasive species before they have an opportunity to become established.

However, while the presence of macrofouling organisms may indicate the existence of a biosecurity risk, it may be difficult to detect the presence of fouling organisms from the surface due to factors such as water clarity and wharf access. While the presence of waterline fouling may indicate more substantial fouling below the waterline, the absence of waterline fouling does not necessarily indicate the absence of substantial fouling elsewhere on the hull. Furthermore, this method has obvious difficulties for assessing the extent of fouling within niche areas.

Where suitable equipment is available, inspection for macrofouling entails a rapid visual inspection of the hull from the waterline followed by an underwater inspection focusing on any niche areas such as grates, thruster housings, intake and discharge points and appendages such as the rudder, propeller and driveshaft.

5.3.2 Underwater inspection methods

Compared to surface-based inspection methods, underwater assessments, such as scuba, snorkel or ROV surveys, are far more resource-intensive and require specialized and skilled operators/inspectors.

Scuba diving

Commercial divers are commonly employed to inspect vessels and underwater structures, so the operational and logistical considerations for diver surveys are well understood. Divers offer a number of advantages over other inspection techniques. They can record written and photographic data, which can be used to describe the pattern and extent of biofouling, estimate percent cover of both general hull surfaces and niche areas, and provide a basic description of taxonomic and community detail. They also have the ability to collect physical samples from the vessel, which can be used for taxonomic analysis thereby allowing exact identification of specimens, and subsequent analysis of their biogeographic status.

An additional advantage of diving surveys is the ability of divers to observe biofouling organisms in places that cannot be easily accessed by ROVs and static cameras.

However, diver-based inspections require careful planning, communication, and adherence to safety protocols to ensure the safety of the divers and the success of the inspection. This includes preparation, planning and risk assessment of the dive, and pre-dive briefings that review the inspection plan, communication procedures, emergency protocols, and roles and responsibilities of each team member. Where possible, diver teams should include a dive supervisor, divers and a designated standby diver who remains on the surface and is ready to respond to emergencies. Diving operations should be followed by a post-dive debrief with the dive team to discuss the findings, observations, challenges and lessons learned, and identify areas for improvement.

LEVEL OF FOULING SCALE

A simple approach to inspecting and assessing fouling risk is the use of a Level of Fouling Index such as the one applied by the Auckland Regional Council (New Zealand) in conjunction with the Cawthron Research Institute. However, it should be noted that, while the LoF scale has been widely used to assess levels of fouling on (particularly) recreational vessels, the results have been mixed depending on such factors as vessel type and surfaces, whether the accuracy of the index has been calibrated for the local environment. Overall, the application of the LoF index had a 66.4% success rate in predicting fouling status (fouled vs.clean boats). The dockside rankings correctly predicted the presence of underwater fouling for 78.9% and absence of fouling in 50.2% of boats surveyed. *Source: Clarke Murray et al. (2013)*

Another important aspect when considering scales to assess the level of biofouling is to have a unified reference that can ensure a common understanding among authorities and vessel operators at the international level and avoid confusions derived from the use of different scales. In this regard, the IMO Biofouling Guidelines include a biofouling scale, available in Table 7 (under chapter 4) that classifies the level of fouling from 0 to 4, with a description of biofouling surface coverage (percentage intervals).

"DIVERS AND ROVs SHOULD BE SEEN AS COMPLEMENTARY INSPECTION METHODS"

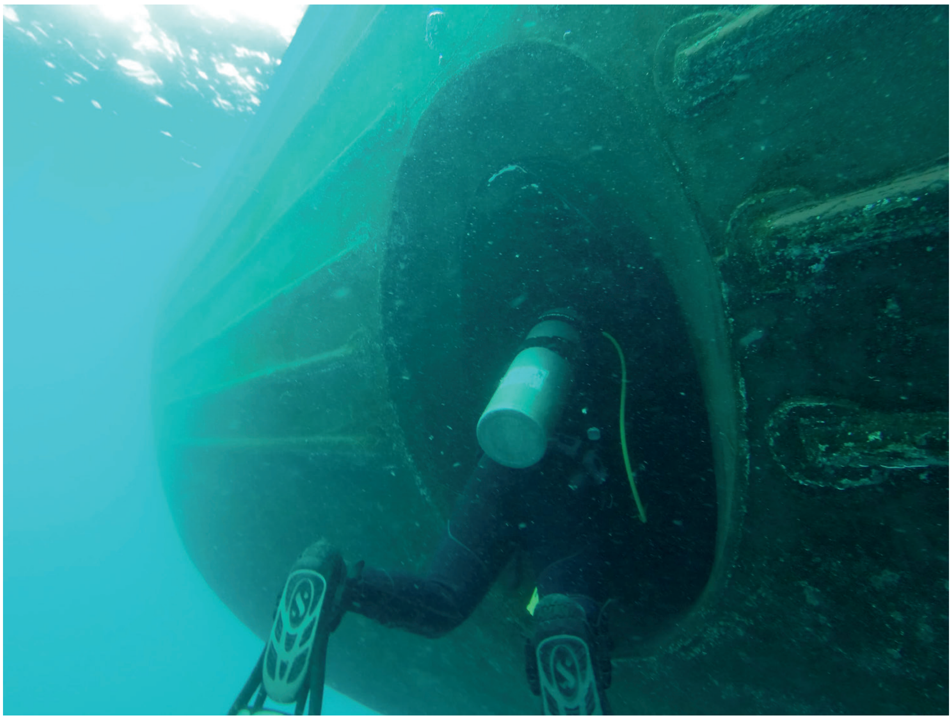


Figure 9: Diver inspecting a niche area of a vessel

Snorkelling

Snorkel surveys have many of the same benefits as scuba surveys with the added advantage that no specialized training or equipment is required. However, snorkel surveys are only suitable for small shallow draughted vessels. Moreover, it is probably not a feasible option in environments with restricted underwater visibility.

Remotely operated vehicles

Remotely operated vehicles (ROVs) can be deployed at short notice and be used in environments that are considered unsafe for divers. In recent years, the capabilities of small underwater ROVs have resulted in improved capability and versatility. These developments have occurred concurrently with a reduction in purchase price, particularly amongst smaller units. As such, there are now significant economic and logistical benefits of using ROVs.

The new generation of ROVs are more portable and less reliant on surface power systems. Advances in ROV technology make them more efficient, easier to maintain and have better overall manoeuvrability (Ellard, 2021). Overall it is estimated that ROV surveys may be approximately ¼ of the cost of a similar diving survey. However, ROVs are still less versatile than divers in terms of recording information from hard-to-reach places and taking physical samples.

Overall, both divers and ROVs should be seen as complementarity inspection methods, both of which can be deployed at the same time under the right circumstances. ROVs can on occasion add to the security level of divers.

Static (pole) cameras

In the absence of any other tools, static pole video cameras can be deployed by inspectors from the wharf. Like ROVs, these can provide real-time footage of the state of the hull, but their ability to access the whole hull and, particularly, niche areas is very limited. As such, static pole cameras may be a useful tool for confirming the presence of macrofouling but are unlikely to be effective as a tool for surveying an entire vessel.

Table 9: Considerations for the use of ROV versus diver surveys for biofouling assessment. *Source: Zabin et al. (2018)*

Considerations	Inspection-class ROV	Divers
Environmental conditions	• Water turbidity • Current and wind speeds	• Water turbidity • Current and wind speeds • Dangerous marine life • Toxic pollutants
Personnel	• Minimum of two trained staff	• Minimum of three trained staff • Annual recertification process
Safety	• Lockout-tagout of ship	• Lockout-tagout of ship • Emergency plan, including port police and coastguard notification
Logistics	• Power supply access† • Battery run time† • Tether length limits†	• Bottom time limits • Support boat • Surface interval requirements
Data sampled	• Still photos • Video transects • Live reporting to surface • Specimen collection difficulty*	• Still photos • Video transects • Live reporting to surface • Specimen collection ease • In-person qualitative evaluation

† Depends on ROV power system.

* Specialized "manipulator arms" or syringes may be used, usually one sample per dive, but to date there are biosecurity concerns for sampling with ROVs.

PAPAHĀNOUMAKUĀKEA MARINE NATIONAL MONUMENT (PMNM) IN HAWAII, PRE-ARRIVAL INSPECTIONS

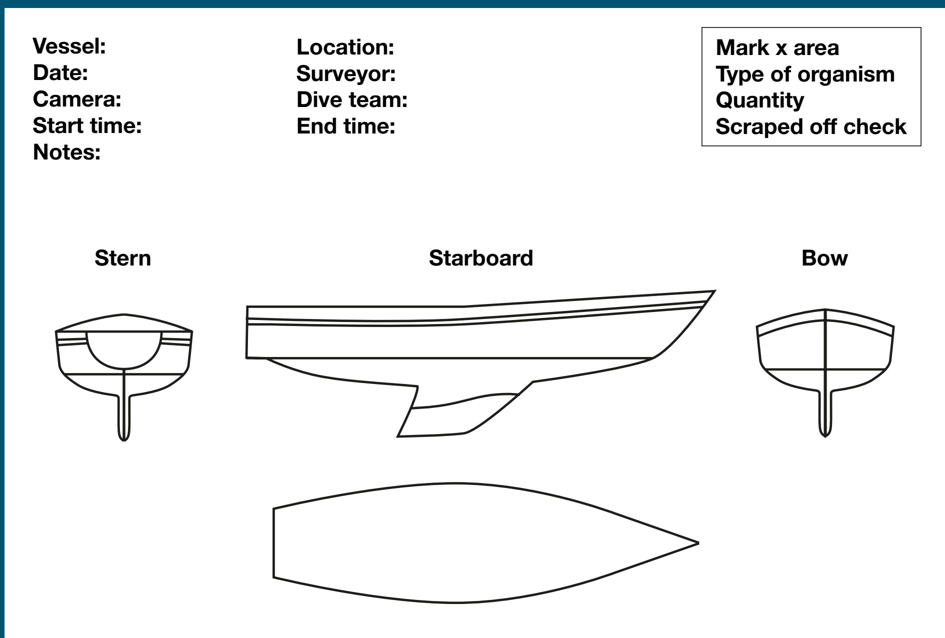
Pre-arrival inspections are undertaken as part of the approval process for entry into the PMNM. The inspection follows a prescribed format with divers recording visual estimates of percent cover of biofouling in each of the following areas:

- Bow:
  - – Bow thruster; and
  - – Bulbous bow (if present);
- Mid-ship:
  - – Sea chest intakes;
  - – Keel coolers (if present); and
  - – Stabilizer fins (if present);
- Stern:
  - – Propeller, shaft and rudder;
- Keel block locations and zinc anodes; and
- Above the water line.

Any morphologically distinct species found may be collected for taxonomic identification.

Where a vessel is determined to be low-risk, or where a vessel had previously entered the Monument under an earlier permit (and had been thoroughly inspected by divers) sometimes a pole-camera or small ROV is used. In instances where the ROV found niche areas to be free from fouling, regulators assumed the remainder of the hull was also clean and allowed re-entry (Zabin *et al.* 2018).

Entry permits are refused if the vessel does not pass the hull inspection.



Example data sheet for hull fouling surveys (One sheet is used for the port and one for the starboard sides).

PAPAHĀNOUMAKUĀKEA MARINE NATIONAL MONUMENT (PMNM) IN HAWAII, PRE-ARRIVAL INSPECTIONS – CONTINUED

Alien Species Survey

Date: July 30, 2021

Vessel: [redacted]

Operational History: Home Port-Vessel is moored in the southern portion of Kaneohe Bay on Oahu. Vessel is run and operated by [redacted] and is used for education programs, private charters, scientific and cultural expeditions, company events and safety escorts. Vessel recently completed drydock and was returned to the water on May 24, 2021.Vessel then spent three days in Kewalo before returning to its mooring in Kaneohe Bay where it sat idle from May 28- June 5th. June 5-9th the vessel was mobile on an interisland trip and returned to Kaneohe Bay mooring from June 9th until its departure to PMNM on June 17th. Vessel was then utilized for short trips and sat idle in Kaneohe Bay until departure for PMNM on July 31, 2021.

Purpose for Survey: PMNM Access for OHA Co-Managers Permit

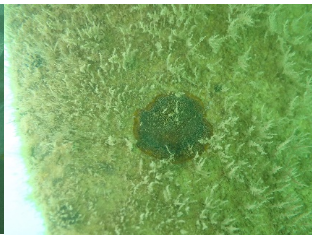
Surveyor(s): [redacted]

Surveys Conducted: Alien Species Survey with Snorkelers

Findings and Recommendations

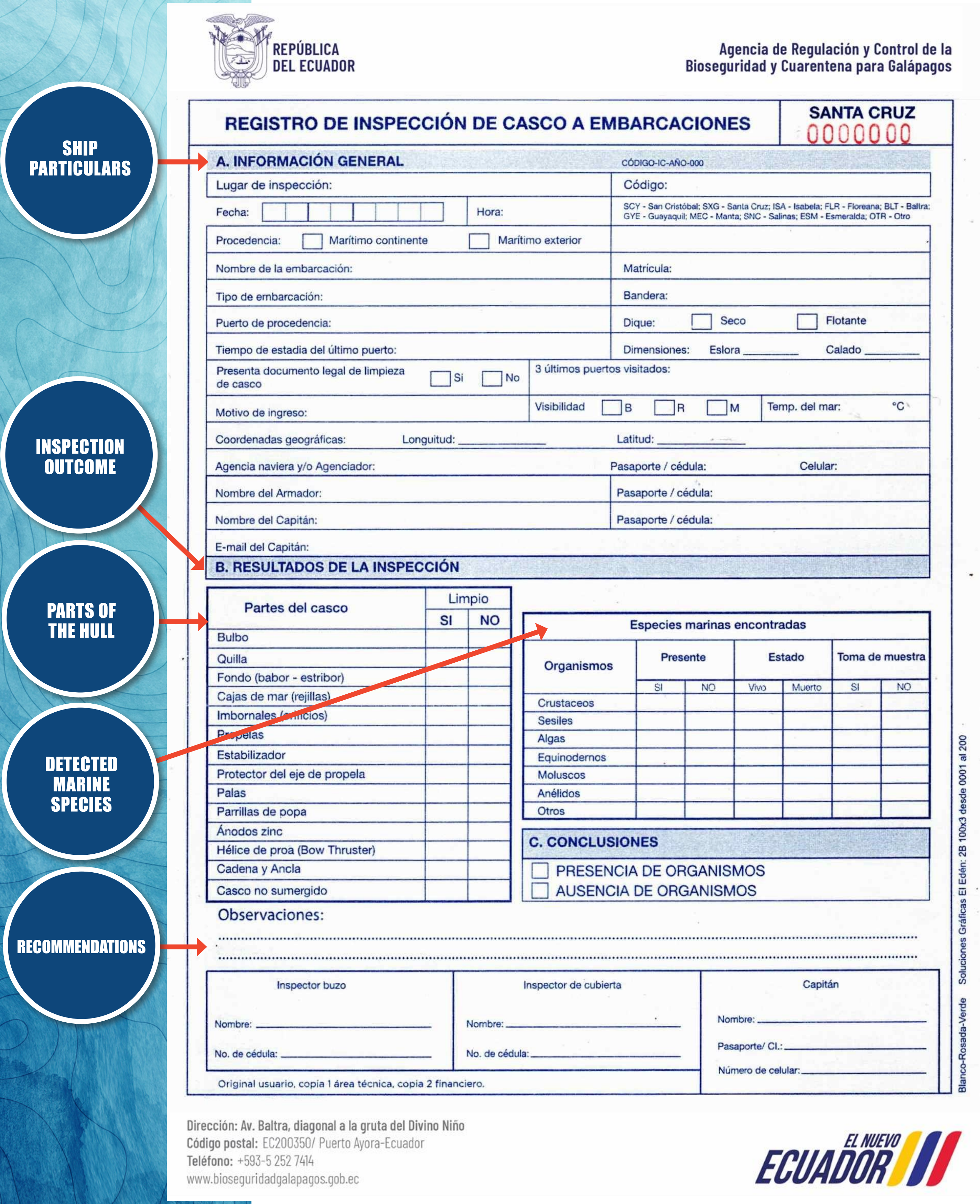
Biofouling summary: The [redacted] team found approximately 100 organisms on the hull of the Makani Olu. Particularly abundant were gooseneck barnacles, bryozoans, and hydroids including the invasive Christmas tree hydroid, *Pennaria disticha*. See figures below for examples and schematic of vessel hull which highlighting the problem areas.

Update: Vessel operators and science party were notified of these organisms and ship's force addressed the issues utilizing scuba while docked at [redacted] on July 31, 2021 before departing for PMNM. On board [redacted] representatives vouched for removal efforts provided by crew. Vessel is now a low risk due to the recent dry dock period and husbandry actions prior to departure.



Illustrated example of the completed vessel pre-arrival biofouling survey undertaken by PMNM biosecurity surveyors

Figure 10: Sample underwater hull inspection record sheet used for vessels arriving in the Galápagos *Source: Agencia de Bioseguridad Galápagos*



REPÚBLICA DEL ECUADOR

Agencia de Regulación y Control de la Bioseguridad y Cuarentena para Galápagos

REGISTRO DE INSPECCIÓN DE CASCO A EMBARCACIONES — SANTA CRUZ 0000000

A. INFORMACIÓN GENERAL — CÓDIGO-IC-AÑO-000

Lugar de inspección: | Código:

Fecha: | Hora: | SCY - San Cristóbal; SXG - Santa Cruz; ISA - Isabela; FLR - Floreana; BLT - Baltra; GYE - Guayaquil; MEC - Manta; SNC - Salinas; ESM - Esmeralda; OTR - Otro

Procedencia: ☐ Marítimo continente ☐ Marítimo exterior

Nombre de la embarcación: | Matrícula:

Tipo de embarcación: | Bandera:

Puerto de procedencia: | Dique: ☐ Seco ☐ Flotante

Tiempo de estadía del último puerto: | Dimensiones: Eslora ________ Calado ________

Presenta documento legal de limpieza de casco ☐ Si ☐ No | 3 últimos puertos visitados:

Motivo de ingreso: | Visibilidad ☐ B ☐ R ☐ M | Temp. del mar: °C

Coordenadas geográficas: Longitud: ____________ Latitud: ____________

Agencia naviera y/o Agenciador: | Pasaporte / cédula: | Celular:

Nombre del Armador: | Pasaporte / cédula:

Nombre del Capitán: | Pasaporte / cédula:

E-mail del Capitán:

B. RESULTADOS DE LA INSPECCIÓN

Partes del casco	Limpio	
	SI	NO
Bulbo		
Quilla		
Fondo (babor - estribor)		
Cajas de mar (rejillas)		
Imbornales (orificios)		
Propelas		
Estabilizador		
Protector del eje de propela		
Palas		
Parrillas de popa		
Ánodos zinc		
Hélice de proa (Bow Thruster)		
Cadena y Ancla		
Casco no sumergido		

Especies marinas encontradas

Organismos	Presente		Estado		Toma de muestra	
	SI	NO	Vivo	Muerto	SI	NO
Crustaceos						
Sesiles						
Algas						
Equinodernos						
Moluscos						
Anélidos						
Otros						

C. CONCLUSIONES

☐ PRESENCIA DE ORGANISMOS
☐ AUSENCIA DE ORGANISMOS

Observaciones:
....
....

Inspector buzo	Inspector de cubierta	Capitán
Nombre: ____________	Nombre: ____________	Nombre: ____________
No. de cédula: ____________	No. de cédula: ____________	Pasaporte/ CI.: ____________
		Número de celular: ____________

Original usuario, copia 1 área técnica, copia 2 financiero.

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www.bioseguridadgalapagos.gob.ec

EL NUEVO ECUADOR

5.4 MITIGATION OF BIOFOULING RISK

Once a high-risk vessel has been identified a decision must be made as to how to respond to it. If the vessel is unable to meet the hull hygiene standards then it may be refused entry. Otherwise the vessel will require cleaning to meet whatever hull hygiene standards are in force.

Hull cleaning may be used to remove biofouling (i.e. macrofouling) from those vessels for which preventive management has been ineffective, those that have been inadequately maintained, or from areas where anti-fouling coatings have been poorly applied or have become damaged. This may occur at the quarantine wharf or require moving the vessel to a specific location designated for such activity. There are various cleaning methods available and more under development.

5.4.1 In-water cleaning – risks and benefits

Macrofouling is more difficult to remove from a hull than a slime layer and may support a diverse range of organisms that are reproductively mature. As the level of fouling increases, the level of abrasion required to remove it will also increase. As a result, if not performed correctly, in-water cleaning can result in several unintended consequences (Scianni and Georgiades, 2019), including:

- in-water mechanical cleaning of large and distinct biofouling (e.g. barnacles, tubeworms or fronds of algae) generates waste or debris that may create a pulse of biocide that could harm the local environment;
- in-water cleaning systems can facilitate the release (e.g. stress-induced spawning, larval release, or non-capture of fragments) and establishment of IAS. Some uncaptured or dispersed macrofouling species are capable of remaining viable and establishing in the marine environment; and
- a further concern with in-water cleaning, beside the release of biocides and potential IAS, is that many existing anticorrosive and anti-fouling marine coatings use synthetic polymers as binding agents and are a potential source of microplastic pollution.

The level of biofouling will affect these consequences. For example, a light sponge or brush of a biofilm should remove the biofilm which will have limited IAS and should not remove any anti-fouling paint or release biocides. However, as the level of abrasion required increases, so too will the amount of biocides, paint chips and/or fouling organisms that are released into the receiving environment. A further concern with in-water cleaning, beside the release of biocides and potential IAS, is that many existing anticorrosive and anti-fouling marine coatings use synthetic polymers as binding agents and are a potential source of microplastic pollution.

For these reasons, some areas have banned in-water cleaning for recreational boats (for example, Washington State, United States) whereas others have strict guidelines for divers carrying out in-water cleaning.

To address these concerns, in-water clean and capture systems are increasingly appearing on the market, including some that physically filter waste to remove potential IAS, paint chips and other potential contaminants.

In the context of MPAs, if there is a biosecurity risk or danger of releasing paint chips or other contaminants, in-water cleaning should only be conducted if the waste can be collected, removed and treated. If this cannot be achieved the vessel should be removed from the water for cleaning and maintenance.

Operators undertaking in-water reactive cleaning should be aware of any regulations or requirements. Regulations regarding the discharge of biofouling and waste substances into the marine environment and the location of sensitive areas (such as MPAs) may be relevant. Figure 10 below highlights the aspects that should be considered when conducting in-water cleaning to avoid biosecurity and contamination risks.

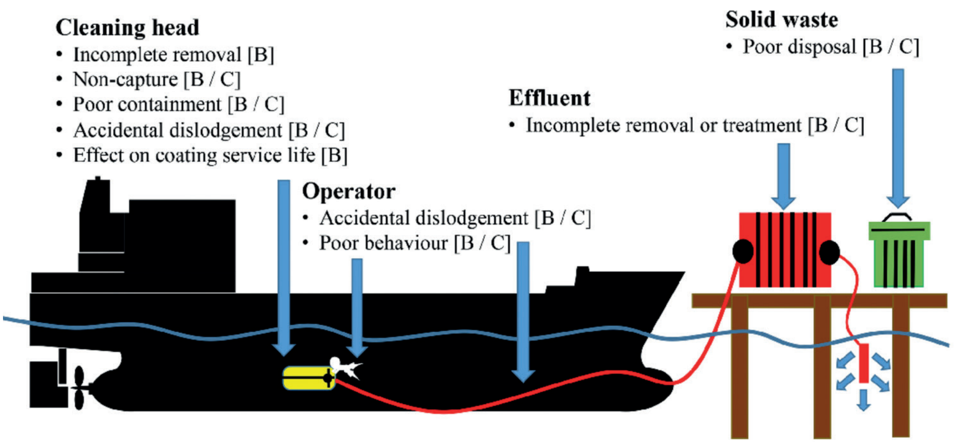


Figure 11: Identification of biosecurity (B) and chemical contamination (C) risks associated with operation of reactive in-water cleaning and capture systems
(Scianni and Georgiades, (2019))

5.4.2 Land-based treatments
Out of water treatment of vessels can be achieved where travel lifts, dry docks or similar services are available. It should be noted that the process of removing a vessel from the water can have an associated likelihood of releasing organisms into the receiving environment during vessel removal. This is especially the case when travel- lifts, synchro-lifts or slipways are used. However, unlike in-water cleaning, haul outs occur at discrete locations allowing targeted monitoring and mitigation.

An important consideration for the use of land-based cleaning is the manner in which any cleaning effluent is treated. Many such cleaning facilities are fitted with coarse gratings or filters to capture large debris and paint chips. However, these will not stop the release of smaller viable propagules and as such may result in the release and subsequent establishment of non-indigenous organisms.

5.4.3 Hull encapsulation and enclosure systems
In-water hull encapsulation and enclosure treatments for the destruction of biofouling are emerging as a viable technology for the treatment of biofouling on vessel hulls. The treatment involves fully enclosing the hull with a sheath and then either adding chemical biocides or using anoxia of the stagnating encapsulated water around the hull, with the aim of destroying all living biofouling associated with the vessel hull. The effectiveness of these treatment systems relies heavily on the efficacy of the applied treatment (Ammon et al. 2019).

These systems provide an alternative approach to treating the biofouling on vessel hulls, where hull anti-fouling and cleaning have failed to prevent biofouling, or where lifting the vessel out of the water for cleaning may not be practical or appropriate. In-water hull encapsulation and enclosure systems have attracted the most interest and use in Australasia, especially New Zealand.

A comprehensive overview of current hull encapsulation and enclosure treatments is provided by Ammon et al. (2019).

5.4.4 Refusing entry of a vessel

If following further cleaning and inspection the vessel is still considered a risk, the authorities may make the decision to refuse entry for the vessel. It should be noted that the ability for inspectors to either refuse entry or require that a vessel is cleaned will entail a clear understanding of the legal functions, powers and duties for inspectors to require this. Furthermore, authorities in one jurisdiction should proceed cautiously where the exclusion of a vessel would result in the biosecurity risk being transferred to another jurisdiction, particularly one that may be less well equipped to deal with the biosecurity risk.

5.5 RESPONDING TO UNPLANNED EVENTS

While the preceding measures can be routinely applied for “normal” predictable vessel traffic patterns, a specific risk arises in the event of unpredictable or random events, such as the presence of a fouled vessel in distress requiring a place of refuge, a vessel grounding or sinking, or the presence of illegal and unauthorized fishing vessels.

International experience demonstrates that a critical risk is presented by vessels that are forced to arrive under emergency conditions (such as through mechanical failure of severe weather). These vessels are often non-compliant with the normal entry requirements for vessels and therefore present one of the highest risk groupings of all vessels. Given the fact that on many occasions entry cannot be denied to these vessels (due to other parameters such as safety and potential pollution), authorities should have contingency action plans to minimize their biosecurity risk.

It is also important to be aware of one-off activities that may increase the risk of IAS transfer, such as the construction or maintenance of coastal infrastructure that require the presence of floating platforms or barges. Often the authorization process for such activities may fall outside of the scope of the MPA management authority and biosecurity concerns may not be fully addressed.

6 MONITORING, CONTROL AND ERADICATION

6.1 OVERVIEW

Unless vessels are entirely excluded from entering an MPA, it is very likely that non-indigenous species associated with biofouling on vessels will eventually be introduced. Robust and cost-effective tools for early detection and monitoring of IAS are therefore a critical element in the efforts to prevent future invasions, as well as the further spread of existing AIS.

There are very few confirmed cases of successful eradication of known IAS, and any chance of success normally goes hand-in-hand with early detection. For example, in the case of the highly invasive algae Caulerpa taxifolia, an incursion in California in 2000 was quickly detected and successfully eradicated within six months of its discovery. In contrast, delays in decision-making in the Mediterranean allowed the same species to invade thousands of hectares off the coasts of Spain, France, Monaco, Italy, Croatia and Tunisia, making it impossible to eradicate. Prompt action is not only much more effective but is also more economically viable (Monaco and Genovesi, 2014).

Unfortunately, early detection of IAS can pose formidable technical challenges and, by comparison to preventing such incursions, monitoring and response measures are labour-intensive, time-consuming, expensive, and often achieve limited success. On most occasions, discovery happens too late to act, or eradication attempts fail. Due to the wide range of pathways that can introduce and spread IAS, containment options are difficult to implement successfully.

For the design and implementation of a successful monitoring programme, it is important that the following aspects are taken into consideration within the specific context and characteristics of the MPA (Government of Australia, 2020):

- How do you monitor for the presence of a non-native species?
- How do you determine which non-native species present the greatest risk of becoming invasive? and
- How do you determine the most appropriate management intervention for an established IAS?

6.2 MONITORING FOR THE PRESENCE OF NON-NATIVE SPECIES

Given the costs and resources required to undertake large-scale environmental monitoring, monitoring should focus on those areas considered to be at greatest risk of IAS introduction (such as ports and marina facilities). To achieve this, a number of steps may be necessary:

Step 1: Biofouling pathway analysis
Developing an understanding of the various pathways by which a biofouling organism may be introduced is an important initial step in identifying in which locations any monitoring effort should be focused. An analysis of the potential biofouling transfer pathways should consider a number of factors, including, but not necessarily limited to:

- What types of vessels/structures are arriving?
- From where are they coming?
- Where are they going within the MPA?
- What is the volume and frequency of different types of vessel visiting? and
- How long will individual vessels remain in the location?

These factors will help MPA managers to build up a picture of the "inoculant pressure" – a measure of the degree of possible exposure of the recipient location to biofouling organisms.

In an ideal world, all vessels visiting a MPA will arrive at a single point of entry (either within or outside of the MPA), through which the vessel is inspected and cleared. In these cases, the decision where to focus monitoring is relatively easy. However, this is often not the case, and a decision as to the most important areas for monitoring will need to be taken. In this regard, MPA managers may wish to consider whether it is possible to specify a single port/point of entry so that any future monitoring and subsequent control efforts can be contained within that area. This may be achieved using ship routeing measures.

There is also a need to determine what types of habitat should be monitored. Most fouling species are intertidal and will settle on substrates that most closely resemble intertidal habitats, such as wharf piles, seawalls and jetty structures.

Step 2: Establish the baseline
In order to provide early warning of any newly arriving non-native species, it is vital to know the baseline of species (native, non-native and cryptogenic) in the recipient location. This will provide an overall picture of what species are present, against which the identification of any new species can be measured.

Without this, it will not be possible to determine whether an organism is introduced, or has been resident for some time. Initially at least, the selection of monitoring sites is explicitly driven by the biofouling pathway analysis outlined in Step 1 above.

Step 3: Routine monitoring
Once the baseline has been established, routine monitoring may be undertaken of the priority sites, to identify the presence of any introduced species of interest.

6.2.1 Monitoring programme design

Sampling and monitoring programmes related to marine biosecurity involve the collection and analysis of data to identify the presence of non-native species and to assess the impacts of those species once established. Sampling methods must be selected to ensure comprehensive coverage of habitats and should provide presence/absence information and/or semi-quantitative indices of abundance.

Monitoring can be conducted in many ways, and the selection and combination of monitoring and sampling methods may vary depending on the specific objectives, available resources, and the characteristics of the target marine ecosystem. Sampling methods appropriate for fouling organisms are summarized in Table 10 and Table 11 below.

CRIMP PORT BASELINE SURVEY PROTOCOL

The Australian Centre for Research on Introduced Marine Pests (CRIMP) has developed a technical protocol for carrying out port baseline surveys. This has been used successfully in a number of locations worldwide, including most ports in Australia, all ports in New Zealand and, in a modified format, in the six countries that participated in the IMO GloBallast project (Brazil, China, India, Iran (Islamic Republic of), South Africa and Ukraine), with the result that there is now good knowledge on port biota from a variety of international ports, as well as increased experience with the implementation and adaptation of this protocol.

The protocol provides design criteria and methodologies for the collection of baseline data from port areas. It also allows for the inclusion of a targeted approach that gives extra priority to habitats associated with a known group of species.

Apart from targeted species, it also helps in determining the distribution and abundance of other introduced species in ports (Hewitt and Martin, 2001). For a comprehensive overview of how to design and execute a monitoring programme, refer to the IMO Guidance on Port Biological Baseline Surveys[20] (Awad et al. 2014).

While this guidance was developed to support the undertaking of port surveys to identify the presence of invasive species from ballast water, it is equally applicable for biofouling monitoring.

[20] https://wwwcdn.imo.org/localresources/en/OurWork/PartnershipsProjects/Documents/Mono22_English.pdf

Table 10: Common monitoring and sampling methods

Name	Description
Rapid visual assessment survey	There are a number of rapid assessment methods that can be used, but they typically focus on all epibiota growing on submerged features such as pontoons, boat hulls, pilings, walls or submerged artificial substrates. This would include pulling up and examining ropes, cages and fenders where possible. Samples are photographed in situ and preserved for laboratory identification if required.
Underwater visual surveys	Underwater visual surveys, conducted by divers or remotely operated vehicles (ROVs), allow for direct observations of marine organisms and their habitats. These surveys can help detect and monitor the presence of invasive species and assess the health of marine ecosystems.
Placement of settlement plates in the water column	Normally conducted in association with visual surveys, settlement plates are deployed to measure the recruitment of fouling species on the site. They can be made of plastic or metal squares suspended below the water and left for a period of months, during which, they are periodically removed, and the biota analysed in the laboratory.
Water sampling	Water sampling involves collecting water samples from marine environments, to analyse for the presence of invasive species or pathogens. These samples can be analysed for the genetic material (DNA) shed by organisms into the environment. By detecting specific DNA sequences associated with invasive species or pathogens, eDNA can provide an early detection method for monitoring their presence in marine ecosystems.
Sediment sampling	Sediment sampling involves collecting sediment samples from the sea floor to assess the presence of invasive species or pathogens. Sediments can harbour dormant stages or resting cysts of organisms that may become invasive if introduced to new areas.
Remote sensing	Remote sensing techniques use satellite imagery, aerial photography, or drones to monitor large areas of marine habitats for the detection of changes in water quality, coastal erosion, or the presence of algal blooms. Remote sensing can aid in identifying areas prone to invasive species or pathogen introductions.

Table 11: Appropriate sampling techniques for detecting introduced species in different habitats

	Taxa sampled	Soft substrate	Hard substrate
Visual surveys	Macro-biota	✘	✘
Video / photo transect	Sedentary/encrusting	✘	✘
Quadrat scraping	Sedentary/encrusting		✘
Settlement plates	Sedentary/encrusting		✘
Traps	Fish/crustacea	✘	✘
Water samples (eDNA)	All	Adjacent water column	Adjacent water column
Sediment samples	Benthic infauna	✘	

Two of the most robust and commonly used approaches are the use of settlement plates and, increasingly, the use of eDNA to analyse water samples.

6.2.2 Settlement plates

In order to develop a comprehensive picture of the inoculant pressure in a specific location, there is a need to sample both fixed and floating structures, since species, when they spawn exhibit either a geotropic (response to the stimulus of gravity) or a phytotrophic response (response to the stimulus of light). To sample this, one approach is to fix sample plates to represent both fixed and floating structures (such as piles and pontoons respectively).

A number of countries are using the Smithsonian "MarineGEO Fouling Community Monitoring Protocol", which provides a standardized set of measurements for characterizing the biodiversity of fouling communities within a locality. Data are gathered from standardized settling plates during monthly intervals (30, 60 and 90 days) which allow fouling species to recruit naturally.

It is recommended that within the partner site, settlement plates deployments be prioritized for artificial substrate (e.g. local docks or marinas), and additional deployments are suggested for other habitats currently being monitored through other protocols (e.g. seagrass beds, mangroves, reefs).

The protocol comprises four components:

- photographs taken of settlement plates to assess community composition via percent cover;
- a detailed list of sessile fauna and their origin (i.e. native or non-native) on settlement plates after 90 days;
- biomass of the entire community; and
- identification and enumeration of small mobile associated fauna (optional).

This protocol[21] is available for use by any party and includes a PDF document with step-by-step methods, a data entry sheet to print, and an Excel workbook to use for data submission (Janiak, 2021).

EXAMPLE OF IAS MONITORING IN GALÁPAGOS ISLANDS

Monitoring for IAS in the Galápagos Marine Reserve commenced in 2012, led by the Charles Darwin Foundation (CDF) in collaboration with a number of government and academic institutions.

The research focuses primarily on fouling communities on artificial habitats using settlement plates that act as a standardized, passive sampling device and through the use of subtidal ecological monitoring survey data to evaluate the status of invasive species in the Galapagos Marine Reserve, testing for spillover of introduced species from anthropogenic habitats (e.g. docks and moorings) to natural habitats across the archipelago.

While a range of methods are utilized, one of the main approaches used by the Charles Darwin Foundation is the Smithsonian Environmental Research Centre (SERC) Smithsonian "MarineGEO Fouling Community Monitoring Protocol", a standardized protocol developed and used by Smithsonian Institutions for the study of marine invasive species around the world.

This protocol utilizes the deployment of PVC settlement plates in port and harbour areas in order to passively collect benthic invertebrates (which settle on these) to create a baseline of the species present in the Galapagos Marine Reserve. Plates are deployed for period of 30, 60 and 90 days respectively, after which they are retrieved and analysed to identify all the organisms colonizing each plate.

Plates are suspended at a 1-metre depth with the plate oriented horizontally (facing downward and parallel to the bottom). To exclude predators, which may bias the results, a proportion of the plates are enclosed in mesh cages.

In addition, the Charles Darwin Foundation collects oceanographic data at study sites, in order to better understand diversity patterns and why certain species are present in certain areas, as well as performing DNA metabarcoding, to identify organisms that cannot be identified taxonomically as well as to verify those that are identified.

As a result of this ongoing monitoring, a total of 53 introduced marine invertebrates and 33 cryptogenic invertebrates, algae, and halophytes have been identified. 48 of the identified introduced species are newly reported or newly recognized as non-indigenous. 17 species were already known but previously regarded as native in the Galápagos, but are now treated as introductions (Carlton, Keith and Ruiz, 2019).

[21] https://smithsonian.figshare.com/articles/online_resource/MarineGEO_Fouling_Community_Monitoring_Protocol/14510649/1

6.2.3 Genetic monitoring of water samples

A new and emerging early detection and monitoring tool for IAS is environmental DNA (eDNA). This technology allows resource managers to take a simple environmental sample and analyse it for genetic (DNA) material to gain an overview of the species presence. This new tool provides an alternative to traditional sampling methods, allowing researchers to detect hundreds of species by extracting and sequencing the DNA from a mixed biological sample, or by analysing the DNA the organisms have released into the seawater. As a result, eDNA analysis has greatly improved the ability to detect species in the environment. With simple sampling methods, and no need for extensive taxonomic expertise, eDNA can provide a snapshot of marine biodiversity at a specific site. It allows for the detection of species that can otherwise be difficult to identify visually, either due to their cryptic nature, early life stage or due to the lack of taxonomic expertise for invasive species.

The methodology is simple and accessible to most countries and local institutions engaged in biodiversity conservation. At its simplest form, a sample can be one litre of water that is collected from the environment, the DNA is extracted from this sample, and the species that are in the location can be analysed through polymerase chain reaction (PCR) and sequencing of the DNA sample. Specialized molecular laboratories and equipment are required for sample processing, but in many cases this work can also be outsourced from commercial laboratories. eDNA analysis is highly data-intensive, and requires good data management and analysis practices. It is also dependent on reference databases, named sequences that the collected sequences are compared to for annotation of taxonomic names. Currently, reference databases are still incomplete, many species are not represented (have not been sequenced) especially in the tropical regions of the globe. Therefore, more work is still required to collect and sequence taxonomic specimens. However, despite these points of development, eDNA analysis holds great promise in simplifying biodiversity (and IAS) monitoring and therefore enabling more frequent and higher resolution monitoring data.

The value of eDNA in IAS monitoring is starting to be recognized with the inclusion of these analysis techniques into the monitoring and surveillance activities of several IAS monitoring programmes.

USE OF AUTOMATED REEF MONITORING STRUCTURES

Triginally developed to study the diversity of coral reef organisms, Automated Reef Monitoring Structures (ARMS) are passive monitoring systems made of stacked settlement plates that are placed on the sea floor. The three-dimensional structure of the settlement units mimics the complexity of marine substrates and attracts sessile and motile benthic organisms. After a certain period of time these structures are brought up, and visual, photographic and genetic (DNA metabarcoding) assessments are made of the lifeforms that have colonized them. These data are used to systematically assess the status of, and changes in, the hard-bottom communities of near-coast ecosystems.

More than 2000 ARMS have been deployed around the world, many of these through international cooperation networks, and others through local projects.

Data from ARMS observatories provide a promising early-warning system for marine biological invasions by i) identifying newly arrived non-native species at each ARMS site; ii) tracking the migration of already known non-native species; and iii) monitoring the composition of hard-bottom communities over longer periods.

APPLICATION OF eDNA TO IAS MONITORING IN THE PACIFIC

The Pacific islands Marine Bioinvasions Alert Network (PacMAN) project is a 3-year UNESCO project that aims to develop a marine invasive species monitoring system as well as an early-warning decision-support tool for Pacific island States. PacMAN will increase the technical and scientific capacity in marine invasive species early warning and early detection using international standards and best practices, and will provide information to implement national and international policies with the aim of reducing and preventing the introduction of new invasive species into the marine environment

This project will use the latest technologies in genomics and DNA metabarcoding to detect marine invasive species using water samples in conjunction with visual and other laboratory sampling techniques. The scientific knowledge, tools and services will directly support the development and implementation of national strategic action plans for the control and management of ship's biofouling.

PacMAN will be gathering marine biodiversity data by analysing DNA from samples collected at the port of Suva (Fiji). The project will therefore provide vital baseline information on marine biodiversity as well as provide support to Fiji's national management agencies to prepare and react to incursions of unwanted species coming in via international ships. In this regard, the PacMAN project will take a two-pronged approach to the monitoring of the marine environment.

On the one hand metabarcoding of genetic markers with broad target communities will be used to describe the local marine biodiversity, enable identification of unexpected/novel IAS and increase knowledge on the ecosystem state for environmental management. On the other hand, to ensure rapid detection and the possibility of early response, specific target species will be monitored using quantitative polymerase chain reaction (qPCR), allowing for specific and sensitive detections of the potentially most harmful invasive species for Fiji.

As part of the project, UNESCO-IOC has prepared a detailed Monitoring Plan[22] detailing the field sampling and analysis protocols to be used during the project.

22 https://unesdoc.unesco.org/ark:/48223/pf0000379204.locale=en

PRIORITY MARINE ALIEN INVASIVE SPECIES WATCH LIST FOR THE PACMAN PROJECT

As part of the UNESCO-IOC PacMAN project, the project team undertook a comprehensive literature review to prepare a Target List of the species known to be the most invasive and harmful organisms in the world, with an emphasis on those that have been found in the tropical South Pacific.

The assessment drew heavily on the Australian list of priority species (the result of an extensive risk assessment procedure). In addition, local aquaculture experts from the University of the South Pacific and SPC, key local agencies (e.g. Ministry of Waterways and Environment, Biosecurity of Fiji, Fiji Ports Corporation Limited (FPCL), Maritime Safety Authority and Ministry of Fisheries), regional partners at SPREP and global partners at the Global Invasive Species Database (GISD) were surveyed to decide on target species for monitoring.

Source: UNESCO/IOC, (2021)

6.3 DETERMINING WHICH NON-NATIVE SPECIES PRESENT THE GREATEST RISK OF BECOMING INVASIVE

In the event that an IAS establishes, the success of any control and eradication measures will depend on early detection and immediate action. While routine monitoring may lead to the identification of a large number of non-native species, it is generally not feasible to assess the risks of a large number of species. Instead, many jurisdictions focus their routine monitoring on a "Target List" of a small number of the most high-risk species, based on prior knowledge of a specific organism's behaviour in other environments similar to the recipient location. A measure of the success of the biofouling management measures in place can then be assessed by monitoring whether any species on the target list are identified in the MPA.

The advantage of having a target list that identifies High, Medium and Low priority species is that, when a High priority species is found, it is possible to respond immediately. In the absence of such a list, and the process of validation and risk assessment needed to develop the list, it will be very difficult to determine whether a particular organism is a problem or not, and, therefore whether to respond (Government of Australia, 2020). Another advantage of this approach is that it allows species-specific rapid response protocols to be prepared in advance of any incursion, thereby facilitating a more rapid response. Nevertheless, concentrating only on a small set of species by using target lists also presents its difficulties, such as keeping a target list updated or ignoring the potential establishment of species that have not been included in the list.

The ability to predict impacts of IAS and their magnitude is notoriously difficult, due to the ecological complexities involved. Not only is there a need to know what organisms are transported via a specific pathway, but there is also a need to know how each organism may respond once released.

The following factors may be helpful in defining the species to be included on a Target List:

- evidence that the organism has invaded other region/s and caused demonstrable harm;
- evidence to suggest that the organism of interest is potentially invasive and capable of causing harm;
- the degree of similarity between the environmental conditions of the receiving region and those colonized by the organisms of interest in their natural and other introduced ranges;
- the degree of "invader friendliness" of the recipient location; for example:
    - evidence of other recently established IAS;
    - the presence of artificial, heavily modified or disturbed habitats that offer vacant niches due to the novelty of new surfaces or unsuitability of the modified environment to native assemblages; and
    - the presence of environmentally compromised native communities through, for example, pollution, overfishing, physical habit damage;
- the range of secondary pathways available to aid onward spread; and
- the presence of biological communities offering naturally vacant niche space owing to relatively low biodiversity.

Even with this approach, it may still not be possible to accurately predict the impacts of all IAS, which may only become apparent after they have occurred and been observed through monitoring of the wider environment, particularly where a species is identified that was not included on the Target List. In this case work it will be required to determine the biological characteristics of the organism and likely response and impacts of the species using the criteria outlined above.

Table 12: Priority marine alien invasive species watch list for the PacMAN project.
Source: UNESCO/IOC, (2021)

Species	Description
Chinese mitten crab ***Eriocheir sinensis***	*E. sinensis* has had significant impacts in freshwater and brackish environments. Also impacts infrastructure and industry including blocking of cooling systems of power plants as well as damage to local fisheries. Has the potential to harm human health, as it is an intermediate host for lung fluke and can bioaccumulate toxins and heavy metals. Has wide temperature tolerances (reproductive temperature range is 9 to 30 °C).
Harris' mud crab ***Rhithropanopeus harrisii***	Is known to affect prey species richness and diversity negatively, altering prey population size and structure. *R. harrisii* is native to the Atlantic coast of the Americas from New Brunswick to north-east Brazil. It is a highly successful invader, having established in 20 countries across 45 degrees of latitude. Has wide temperature tolerances (optimum temperature range 15 to 25 °C).
Asian shore crab ***Hemigrapsus sanguineus***	Is on priority list for tropical Queensland but not Darwin, some debate over if it is impacting native crabs by competition or disease transfer.
Asian paddle crab ***Charybdis japonica***	*Charybdis japonica* is a portunid (swimming) crab native to marine environments of Central and South-East Asia. It may impact native estuarine communities by competing for space and resources with native crabs. As it transmits disease and preys on native shellfish it is a potential threat to fisheries and traditional shellfishing. Native to Central and South-East Asia. Is on priority list for tropical Queensland.
Black-striped false mussel ***Mytilopsis sallei***	*M. sallei* has serious impacts on biodiversity, by outcompeting and excluding native species and by modifying habitat through its dense settlement. Native to the tropical central Atlantic Ocean—the Caribbean Sea. It remains the only well-established IAS to have been eradicated.
Brown mussel ***Perna perna***	*P. perna* forms dense aggregations, where densities of 27,200 individuals per square metre have been recorded. Native to tropical and subtropical waters of Africa.
Asian green mussel ***Perna viridis***	*P. viridis* is a bivalve mussel native to the Asia-Pacific region where it is widely distributed. It has been introduced elsewhere around the world through ship ballast, hull fouling and the experimental introduction for farming. P. viridis can quickly form dense colonies in a range of environmental conditions. Detected in Singapore.
Asian bag mussel ***Arcuatula senhousia***	Prefers intertidal to subtidal soft substrates (e.g. sediments). Tolerates wide variety of temperatures and salinities. Native to the waters of tropical and temperate Asia. (MSPC 2018) The impacts of this species decline over time.
Charru mussel ***Mytella strigata***	Brackish water mussel known to be problematic in India and Singapore. Easily mistaken by a non-specialist for the Fiji native species *Xenostrobus securis.*
White colonial sea squirt ***Didemnum perlucidum***	Potential to be highly invasive due to its rapid reproductive output. Fast-growing and can occupy disturbed habitats. Can overgrow native species. Subtropical to tropical. Can be very difficult to identify from local species of *Didemnum.*
Spaghetti bryozoan ***Amathia verticillata***	First described from the Mediterranean Sea and now widespread in tropical, subtropical, and warm temperate waters. Established in Hawaii. Colonies of *A. verticillata* have had negative impacts by clogging shrimp fishing gear, fouling cultured pearl oysters, and overgrowing and killing eelgrass.
Pickleweed ***Batis maritima***	Native to the Americas, invasive in Hawaii with mangroves, where they can destroy habitats of local species.

6.4 RESPONDING TO AN ESTABLISHED IAS

Once an IAS has established or spread, control approaches are the only actions available to limit the further spread of the species and their negative impacts on the MPA.

In this case, a decision must be made as to whether any form of intervention to control the spread of or eradicate the organism is feasible or warranted. Response and management control methods for marine species, however, are not well developed, and approaches that are effective on one species or in one location might not be effective elsewhere.

6.4.1 Monitoring, control and containment

Once the presence of a High-Risk IAS has been established, the next step would be to understand:

- How far that organism has spread from the initial point of release/settlement. This would involve a delimitation survey to determine, with confidence, the extent of the spread (vessels, structures, seabed habitats etc.) as well as to assess the impacts of the species on the local environment; and
- What possible pathways exist that could aid secondary transmission to other areas. These will mainly consist of activities associated with movement of fouling organisms, such as vessel movements.

In controlling an invasive species, efforts are aimed at keeping the population low enough that it can be expected to have minimal environmental or socio-economic impacts. Containing invasive species involves confining them within a defined area and stabilizing or reducing their populations. Methods to reduce or limit the spread might include quarantine and vessel movement restrictions, as well as treatment for decontamination. Ideally these control methods can take a range of forms, from reducing the level of the activity in the area, to reducing the risk of activities spreading the IAS further. The main objective should be to limit, as far as practicable, the risk of spread of IAS and reduce the chances of IAS being translocated off-site.

EXAMPLES OF MONITORING IN THE GALÁPAGOS

Two particular examples from the Galápagos highlight the difficulties associated with IAS response decision-making:

The Charles Darwin Foundation has been monitoring *Caulerpa racemosa* in Tortuga Bay, Galápagos, since 2012. *C. racemosa* is considered to be one of the most invasive species in the Galápagos. However, ongoing monitoring of the Tortuga Bay marine community has found that the species exhibits a natural seasonal variation in abundance. Monitoring has also found that, despite initial concerns over the possible spread of the species, it is so far contained. More recent research has suggested that there may in fact be two variants of the species present in Galápagos – one native and one non-native, but that both coexist.

A second species of Caulerpa *(C. chemnitzia)*, which has been present in Galápagos for a long time and exists in other parts of the Pacific, is considered to be a native species that has now become invasive specifically in Darwin and Wolf Island, to the north of the archipelago. These islands support the last remaining structural coral reefs in the Galápagos, which are considered to be highly vulnerable to the impacts of climate change. Recent changes in the behaviour of *C. chemnitzia* have resulted in it exhibiting "smothering" behaviour across the reef, preventing the settlement of new coral, and is competing with other species on sandy areas.

To address concerns for the reef, the Galápagos National Parks Directorate have prepared a conservation management strategy for coral. As part of this strategy, both GNPD and CDF are undertaking trials to pilot different eradication methodologies including suction pump to surface, and physical (hand) removal.

EXAMPLES OF CONTROLLING THE EXPANSION OF A SPECIES WITHIN THE HAWAIIAN ARCHIPELAGO

Two examples of biosecurity issues surrounding nuisance marine algae in the Papahānaumokuākea Marine National Monument (North-west Hawaiian Islands):

Chondria tumulosa is new to science and was recently described in 2020 after scientists found it smothering coral reefs at Manawai (Pearl and Hermes Atoll). The origin of this alga is a mystery and very little is known about its ecology, physiology, or potential biological drivers. The cryptogenic species has invasive characteristics and is overgrowing some of the most pristine coral reefs in Hawaii. NOAA divers first detected the alga in 2016, but it was misidentified and not reinvestigated until 2019 after the algae was found growing into thick mats and outcompeting nearly all the species typically living in these ecosystems. In 2021 *C. tumulosa* was documented on the adjacent atoll Kuaihelani (Midway Atoll) and more recently, in July 2023 it was discovered growing cryptically at Hōlanikū (Kure Atoll). This recent range extension expands the known distribution to the upper third of the archipelago and furthest extent of the Monument, about 1,350 miles from Honolulu.

A second alien alga species, *Acanthophora spicifera*, was discovered in 2022 at Kuaihelani while researchers were further expanding surveys and biosecurity experiments on *C. tumulosa. A. spicifera* is one of the most widespread alien alga species throughout the main Hawaiian Islands and at this point is only known to be at one location within Papahānaumokuākea.

To combat the further spread of these species, managers from Papahānaumokuākea developed best management practices (BMPs) aimed at limiting the further spread of these species throughout other areas of the archipelago. Several series of lethality experiments were conducted in the field with *C. tumulosa* to provide data and guidance for BMP development on the effectiveness of various disinfection methods (chemical, desiccation, freezing etc.) Current BMPs consist of rigorous inspections, disinfection protocols, access limitations, and equipment restrictions for any activities conducted in or around the atolls with these species present. Permittees applying to conduct activities that fall outside of the BMP are required to develop a biosecurity plan with agency staff to mitigate risks associated with these activities. At this point, species control at the atoll level is not an option due to the vastness and remote nature of Papahānaumokuākea and efforts are focused on mitigating risks associated with permitted activities within areas of known distribution. Tools like environment DNA (eDNA) have been very useful for maintaining an early detection monitoring programme throughout the rest of the island chain.

6.4.2 Eradication of IAS in MPAs

The final response option available is the application of population level controls or "eradication". Eradication of IAS in marine waters has only been documented in a few rare cases and, consequently, eradication is often deemed neither effective nor cost-efficient.

The basis of eradication for any IAS is rapid, effective quarantine of the infested area and any potentially contaminated vectors, and elimination of the pest where it is found. Most, if not all, of the successful eradications have been in shallow, enclosed environments. In open coastal waters with moderate-to-high water exchange, individuals may be dispersed over a wide area. Where surveys indicate that an infestation is widespread, eradication action may involve attempting a site-wide eradication attempt and is unlikely to be successful. Where, however, an organism is newly established or present in isolated patches, eradication may be successful as a rapid response option and may, for example, be as simple as removing an affected structure from the water.

A range of options may be applicable; however, the choice of control or eradication method will largely be driven by cost and logistical feasibility. Control/eradication methods fall into four main categories (Table 13 below), which may be used individually or in combination depending on the nature of the site in question. A combination of the methods outlined above may be an effective way to control the further spread of IAS or slow the establishment on site.

Table 13: Methods for the removal and eradication of IAS

Control Method	Description
Removal/Air drying	The cheapest and easiest way to treat small to medium-sized structures is to simply remove them from the marine environment, allowing to air dry for between 48-72 hours. This will have the effect of desiccating any attached aquatic organisms. This approach is appropriate for anything from a rope to small/medium-sized structures, but is not practical for larger structures.
Physical removal	Mechanical removal can be conducted using scrapers, suction devices or jet washers. Every care should however be taken to contain the material removed using screens or booms and capture for sending to landfill or composted where appropriate. Although not typically conducted underwater, mechanical removal can be undertaken in the same way as on land, but extra care must be taken not to fragment and disperse INNS whilst doing this. As such, mechanical removal in the water column has limited practical applications.
Physical smothering	Various methods of smothering have been implemented to remove IAS, including covering the seabed with non-breathable material (plastic or soil); wrapping structures (such as wharf piles) with polyurethane to make them watertight and making custom made bags to fit around pontoons or other structures (including vessels). The aim is to stop the water flow and create anoxic conditions, thus containing and removing the organism.
Chemical/thermal treatment	Chemical and thermal treatments can be used in a number of ways and have been applied in a range of scenarios. Bleach can be used in high concentration to speed air drying and is frequently used in aquaculture sites to treat mussels, where the accelerants kill epiphytes but not the mussels. Bleach has also been used to speed up smothering, where high doses were added to bags to increase effectiveness.

6.4.3 Considerations for successful eradication

The decision to undertake control or eradication activities within a marine protected area may require greater consideration than in other marine or port areas because of the high value and uniqueness of the biodiversity present in MPAs. Most, if not all, of the techniques commonly utilized are, by definition, harmful to marine life.

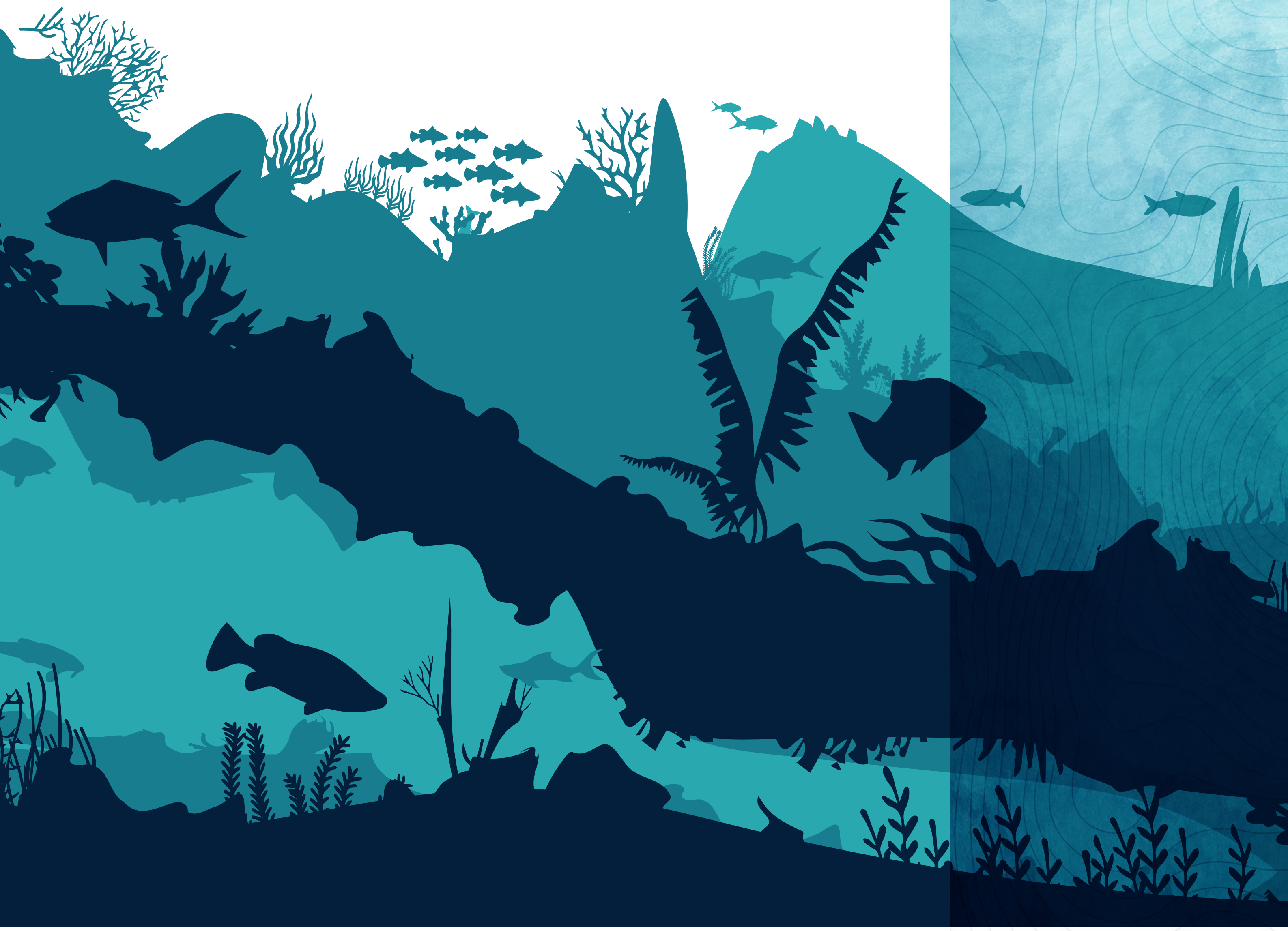
As such, a careful assessment must be made as to whether the control and removal of IAS will actually be more harmful than leaving it in situ and monitoring the spread. Such decision can only be made on a case-by-case basis and with the best available information. In such cases, it may be prudent to undertake small-scale trials of different techniques to assess (a) the efficacy of the technique; and (b) the likely impact on native flora and fauna.

While it may not be possible to entirely eradicate a species from an area, it may be possible to eradicate the species from a particularly high-value area. In this regard, eradication activities should be considered as scalable, depending on the impacts and conservation goals. Furthermore, global experience to date demonstrates that eradication is unlikely to be a one-off activity, but rather is likely to require ongoing monitoring and response over a period of years.

The following factors should be considered when considering the likely success of any eradication programme:

- Is the species detectable at an early stage and capable of being detected during ongoing surveillance?
- Can the species be accurately identified in the field? Otherwise, how do you know what you are responding to?

- Can the species be detected at very low densities (if ongoing treatments are effective)?
- Is the distribution of the species restricted and confidently confined to an area or could it be present in the wider environment?
- Is there a single lead agency responsible for managing the response with clear lines of authority to all other agencies involved?
- Are sufficient resources (eradication tools, funding, people, etc.) available to support the response? This is particularly relevant where the response may last for an extended period of time;
- Is there a strong legal basis for undertaking the response or are there any legislative impediments to undertaking the response?
- Clear lines of authority – must have a central agency coordinating response (chain of command) and all relevant stakeholders involved;
- Have all relevant stakeholders been identified and engaged? This is particularly important where any response activities may impact local livelihoods;
- Are there proven and cost-effective treatments for killing all life stages of the organisms?
- Are the impacts of identified treatments less harmful than allowing the organism to proliferate? This is particularly relevant in the case of an MPA with important biodiversity values that may be harmed by the response to an IAS; and
- Have the possible pathways for reintroduction of the organism been identified and can they be controlled?



PART 3:
RESEARCH AND DEVELOPMENT NEEDS

7 RECOMMENDATIONS FOR FUTURE RESEARCH AND DEVELOPMENT

This Compendium presents an overview of the options available to marine protected area planners and managers, for managing the risks associated with the transfer of invasive biofouling organisms via ships. The Compendium draws heavily on deliberations that took place during the Galápagos biofouling management workshop organized by the GEF-UNDP-IMO GloFouling Partnerships.

The overall picture that emerges from the workshop is that, while invasive aquatic species are recognized as a significant threat to the ecological integrity of marine protected areas, very few management plans and operational strategies applicable to these areas have included risks related to IAS introductions. While the IMO Biofouling Guidelines do offer a useful basis for the management of biofouling related risks, their implementation in the context of MPAs is constrained by several factors.

Evidence from a number of large offshore MPAs indicates that effective management of biosecurity risks related to biofouling requires a specific framework to exist, which, if properly implemented, would provide MPA managers with a robust regime through which to manage biofouling risks and thereby to minimize the likelihood of IAS incursions within specific MPAs.

The final section of this Compendium presents a set of **ten** (10) recommendations designed to address the most critical gaps and barriers to the implementation of effective biofouling management arrangements that were identified during the Galápagos biofouling management workshop.

7.1 BIOFOULING AND MPAS

Recommendation 1: *Develop and implement a capacity-building package (in conjunction with IUCN/WCPA) to raise awareness among MPA planners and managers about biofouling management and the threat posed by IAS.*

Rationale

One of the gaps identified during the workshop was the apparent lack of knowledge among MPA managers of both the threat posed by biofouling organisms, and the management responses available to MPA planners and managers to respond to that threat.

Using existing and well-established networks of MPA experts (for example, through collaboration with the IUCN World Commission on Protected Areas - WCPA) to raise awareness among MPA planners and managers could aid in the uptake of effective biofouling management strategies. This would also provide an opportunity to highlight the potential application of other IMO measures as tools to strengthen the protection of MPAs from the impacts of shipping (including but not limited to biofouling).

Such a capacity-building package should include information relating to the following key areas:

- IAS and their impacts;
- biofouling pathways;
- biofouling management practices (including AFCs/AFS, hull management, hull cleaning);
- governance arrangements for biofouling management; and
- other possible measures to prevent the introduction of IAS to MPAs (e.g. PSSAs, ships routeing measures).

Recommendation 2: *Support/undertake research into the environmental, economic and sociocultural impacts of already established IAS.*

Rationale

Numerous IAS have already been recorded globally, many of which have been prioritized in terms of their invasion potential. However, limited data exist for many of these species with which to evaluate their impacts on environmental and socio-economic values. This is partly due to the lack of funding available for ongoing monitoring once an IAS has established and been identified.

To facilitate better understanding of the risks associated with specific organism, an analysis of the impacts of previously established pests could be undertaken to provide a more comprehensive database with which to assess IAS risks. Such a study could be undertaken as a desktop study through engagement with global biofouling/IAS experts.

7.2 GOVERNANCE ARRANGEMENTS

Recommendation 3: *Prepare and trial a set of model instruments to support and harmonize the implementation of biofouling management arrangements within marine protected areas. Such instruments could include, but not necessarily be limited to:*

- *a model legal instrument for biofouling management; and*
- *a model IAS Response (Contingency) Plan.*

Rationale

Governance has been identified as a common theme that underpins all aspects of biofouling management. A number of critical needs are identified, including a regulatory framework; a robust institutional framework, preferably with a lead agency with overall responsibility for biosecurity; and the engagement of stakeholders.

Although individual countries will need to prepare legal instruments that reflect their unique circumstances, IMO does have a history of preparing "model" legal instruments that can be modified to reflect the needs of individual countries. Such model instruments ensure that critical issues are given appropriate attention in a country's legal framework, while at the same time avoiding the need to develop new instruments from first principles.

In addition to a legal framework, it is important that institutional roles and responsibilities are clearly defined and demarcated, particularly in the event of a response to an IAS incursion. One tool that can assist in this regard is a contingency or emergency response plan. As such, consideration should be given to preparing a draft model contingency plan and testing this across two or three participating countries.

Recommendation 4: *Undertake an assessment of possible models of sustainable finance to support the development and implementation of MPA-specific biofouling management arrangements.*

Rationale

Funding has been identified as both a critical need and a constraint for the successful implementation of biofouling management arrangements. As the tolerance for risk (vis-à-vis the introduction of IAS to an MPA) decreases, the costs associated with reducing that risk increase commensurately.

To this end, MPA managers need access to a sustainable source of funding to support the development and long-term implementation of an effective biofouling management regime that also extends to monitoring and control arrangements in the event that an IAS is identified within the MPA.

There is, however, no specific model for how such arrangements can be funded. It is reasonable to argue that funding should come from the "risk creator" i.e. those vessels visiting the MPA and potentially transferring IAS from other locations. It is recommended to undertake an assessment of the possible funding sources and mechanism(s) that could be deployed by MPA managers. This should include the full range of options such as user charges, MPA entry fees, levies on shipping, insurance instruments, and fines and other penalty payments for non-compliance.

7.3 PREVENTION OF BIOFOULING AND MANAGEMENT OF BIOFOULING PATHWAYS

Recommendation 5: *Undertake a study to correlate high-risk species with certain pathways or areas within a pathway.*

Rationale

It is widely accepted that cleaning the hull alone will not remove the risk of biofouling completely, since many vessels harbour biofouling organisms in hard-to-reach "niche" areas and internal systems. Given the logistical complexities associated with comprehensively inspecting a vessel, any steps that can be taken to improve the effectiveness of inspections would most likely both reduce the risks of IAS incursion while at the same time reducing the resource burden on the regulatory authorities. Understanding the relationship between different species and different pathways would help authorities to streamline their inspections regimes to focus on the most high-risk pathways.

One way to achieve this could be to identify whether individual species are more or less likely be found in certain areas of a vessel. Since many of the most high-risk species have already been identified, such an assessment should be possible, in collaboration with those authorities that already carry out comprehensive inspection regimes. In the first instance, such a study could be undertaken as a desktop study, but further data validation would need to be undertaken during vessel inspections.

Recommendation 6: *Prepare a simplified record book to enable recreational vessel owners to record their vessel's biofouling management history.*

Rationale

The IMO Biofouling Guidelines provide for the use of a biofouling management plan and associated biofouling record book. While in theory these documents can be used for any type of vessel, in practice they are generally only used for commercial vessels; the documentary requirements for completing these make it largely unrealistic to expect the owners of small recreational vessels to achieve the same level of record-keeping.

This notwithstanding, records of a vessel's biofouling management history provide an important tool for inspection and compliance monitoring. The lack of a standardized way of recording such information for recreational vessels represents a real gap in the current biofouling inspection tool kit for biosecurity authorities.

To address this need, a simplified record-keeping system that reflects the risks associated with recreational vessels could be prepared and made available with the recreational boating guidance. This would provide a user-friendly method to demonstrate to MPA managers that vessels are well maintained and are up to date with respect to their biofouling management.

7.4 MANAGING BIOFOULING RISK

Recommendation 7: *Build capacity among MPA managers to support vessel risk profiling and border inspection.*

Rationale

A critical need for MPA management authorities is the capacity, resources and necessary governance framework to allow risk profiling and inspection of all vessels entering the MPA. This capacity may already exist at the national level in many countries and may not need to be duplicated for individual MPAs. However, where MPAs are remote from coastal ports of entry, MPA managers should consider whether such a capacity is necessary for the effective management of the MPA.

To this end, a capacity-building programme should be developed that addresses the specific needs of MPA managers vis-à-vis biofouling management. Such a programme should draw on existing practice with the implementation of the IMO Biofouling Guidelines, particularly as they have been applied for MPAs. In particular such a capacity-building programme should focus on the following key areas:

- data requirements for vessel risk profiling and inspection, including pre-arrival questionnaires, inspection or reporting);
- automated information gathering and processing tools and how to use them for assessing biofouling risk;
- inspection modalities and approaches including for hard-to-reach areas such as niche areas and internal pipework;
- inspection protocols and verification of hull hygiene standards;
- evaluating and interpreting vessels biofouling management records; and
- risk management options for MPAs.

7.5 MONITORING, CONTROL AND ERADICATION

Recommendation 8: *Prepare a more detailed guideline on Monitoring and Rapid Response to IAS Incursions with a specific focus on the specific needs of MPA managers.*

Rationale

A considerable amount of work has been undertaken to support the implementation of the IMO Biofouling Guidelines. In particular, the GEF-UNDP-IMO GloFouling Partnerships Project has delivered a number of capacity-building activities to support implementation of the Guidelines and biofouling management more broadly.

In contrast, however, very little information is available to support the monitoring and response requirements discussed in this Compendium. As such, it would be useful if a further guidance document could be prepared that provides more detail on monitoring and response to IAS incursions. Such a resource could provide information on the following areas of interest:

- information on the various monitoring protocols that are available and in use (including pros and cons of each);
- information about different sampling and analytical techniques;
- resources (equipment) needed to undertake monitoring;
- data management and handling;
- mechanisms to engage and raise awareness among stakeholders/ community in monitoring;
- guidance on the considerations for determining the most appropriate response option to an IAS incursion;
- information relating to the various response techniques for controlling or eradicating IAS from MPAs including the application of new and novel techniques; and
- governance arrangements for monitoring and response.

Recommendation 9: *Provide support through pilot projects to prepare baseline surveys for key MPAs.*

Rationale

As noted in this Compendium, baseline surveys are an essential prerequisite for undertaking any monitoring of, or response to, an IAS incursion. Very few countries have adequate baseline surveys of their most high-risk environments, particularly MPAs. That said, many MPAs do undertake regular environmental monitoring and support a variety of scientific research activities. As such, capacity to undertake such baseline surveys may exist in many regions.

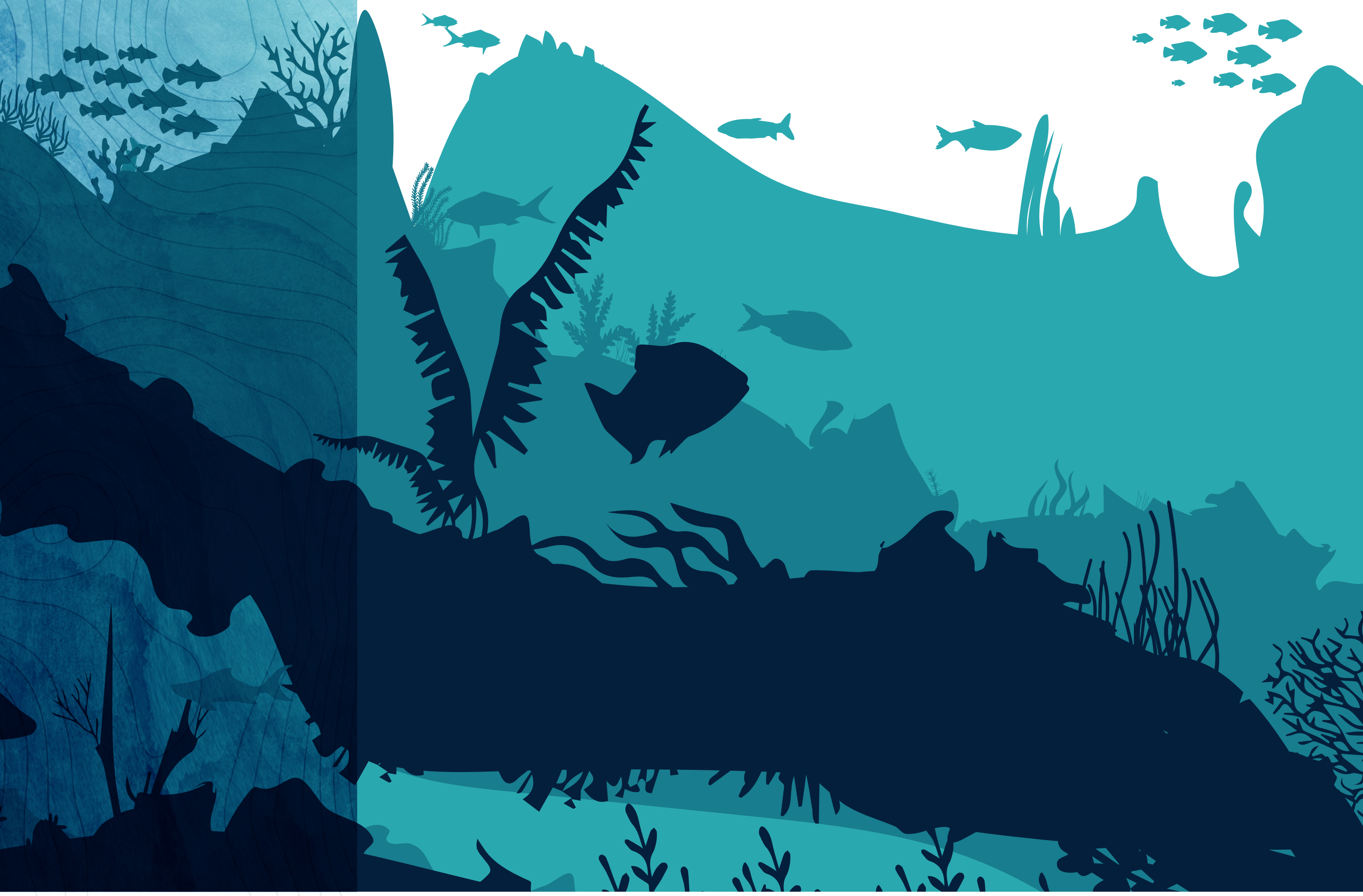
Consideration should be therefore given to providing support to a number of countries, benefiting from the GEF-UNDP-IMO GloFouling Partnerships Project through the delivery of pilot projects, to support the preparation of baseline surveys for key MPAs, including with the use of innovative analytical tools (such as eDNA).

Recommendation 10: *Provide protocols and support to enable MPA managers to define or refine "target species lists".*

Rationale

As noted in this Compendium, in order to target monitoring for IAS, there is a need to define a "Target List" of high-risk species of interest. While global databases of IAS are available, there is limited experience among MPA managers of actually assessing the risk of IAS and of preparing MPA-specific Target Lists.

Building capacity and raising awareness of the approaches needed to complete and utilize such lists will therefore be an essential step in helping to develop biofouling monitoring and response capacity among the MPA community. This could be facilitated through the development of specific protocols which define how to define or refine "target species list" for specific MPAs. These could be trialled as part of wider country-specific pilot studies.



8 REFERENCES AND SOURCES OF INFORMATION

Agardy, T. (1997). *Marine Protected Areas and Ocean Conservation.* (R.G. Landes Company: Georgetown, Texas). 244 pp.

Agencia de Bioseguridad Galápagos (ABG) (2017). *Inspección cuarentenaria en el transporte.* Procedimiento 02 Marítimo Continental. Versión 3.0. Febrero/ 2017.

Ammon, U., Swift, L., Brand, S., Jeffs, A. and Swift, S. (2019). *Review of in-water hull encapsulation and enclosure treatments for eliminating marine biofouling.* Report prepared for the New Zealand Ministry of Primary Industries (MPI). MPI Technical Paper No: 2019/06. 61 pp.

Ardura, S.E., Juanes, F., Planes, S.E. and Garcia-Vazquez, E. (2016). "Rate of Biological Invasions is Lower in Coastal Marine Protected Areas". *Scientific Reports,* 2016(6). https://doi.10.1038/srep33013.

Anderson, L. (2004). "Eradication of Caulerpa taxifolia in the US 5 years after discovery; are we there yet?" *Proceedings of the 13th International Conference on Aquatic Invasive Species.* Ennis, Co. Clare, Ireland, September 2004.

Arndt, E., Robinson, A. and Hester, S. (2021). *Factors that Influence Vessel Biofouling and its Prevention and Management.* (Centre of Excellence for Biosecurity Risk Analysis [CEBRA]: Melbourne, June 2021. 98 pp.

Awad, A., Haag, F., Anil, A.C. and Abdulla, A. (2014). GEF-UNDP-IMO GloBallast Partnerships Programme, IOI, CSIR-NIO and IUCN. *Guidance on Port Biological Baseline Surveys.* GEF-UNDP-IMO GloBallast Partnerships, London, UK. GloBallast Monograph No. 22. 48 pp.

Bukontaite, R. and Zaiko, A. (2008). "Dreissena polymorpha (zebra mussel)". In *CABI Compendium,* (CABI: Wallingford, UK, 2024). https://www.cabidigitallibrary.org/doi/full/10.1079/cabicompendium.85295.

Carlton, J.T., Keith, I., Ruiz, G.M. (2019). "Assessing marine bioinvasions in the Galápagos Islands: implications for conservation biology and marine protected areas". *Aquatic Invasions,* 14(1). 1–20. https://doi.org/10.3391/ai.2019.14.1.01.

Colautti, R.I., Bailey, S.A., van Overdijk, C.D.A., Amundsen, K. and MacIsaac, H.J. (2006) "Characterized and projected costs of non-indigenous species in Canada." *Biological Invasions* 8. 45–59. https://doi:10.1007/s10530-005-0236-y.

Cottalorda, J. M., Barceló, A., Bergere, H., Houard, T., Lefebvre, C. and Robert, P. (2010). *Le Parc national de Port-Cros : une structure référence dans la mise en oeuvre de stratégies de contrôle de la Chlorobionte envahissante Caulerpa taxifolia (Valh) C. Agardh.* Sci. Rep. Port-Cros Natl. Park, Fr., 24 : 105-126.

Clarke Murray, C., Therriault, T.W. and Pakhomov, E. (2013). "What Lies Beneath? An Evaluation of Rapid Assessment Tools for Management of Hull Fouling." *Environmental Management* 52:374–384. DOI 10.1007/s00267-013-0085-x.

Coutts, A.D.M., Piola, R.F., Hewitt, C.L., Connell, S.D. and Gardner, J.P.A. (2009). "Effect of vessel voyage speed on survival of biofouling organisms: implications for translocation of non-indigenous marine species". *Biofouling,* 26(1). 1-13.

Davidson, I., Scianni, C., Hewitt, C.L., Everett, R., Holm, E., Tamburri, M. and Ruiz, G. (2016). "Assessing drivers of ship biofouling management: aligning industry and biosecurity goals." *Biofouling* 32. 411-428.

Dudley, N. (Editor) (2008). *Guidelines for Applying Protected Area Management Categories.* Gland, Switzerland: IUCN. x + 86 pp.

Ellard, K. (2021). *Review and Enhancement of Remotely Operated Vehicles for Marine Pest Surveillance.* Project Report prepared by: Invasive Species Branch of Biosecurity Tasmania, Tasmanian Department of Primary Industries Parks Water and Environment. 60 pp.

Giakoumi, S. and Pey, A. (2017). "Assessing the Effects of Marine Protected Areas on Biological Invasions: A Global Review". *Frontiers in Marine Science* 4(49). 1-6. https://doi.org/10.3389/fmars.2017.00049.

Gibson-Hall, E and Bilewitch, J. (2018). "Didemnum vexillum The carpet sea squirt." In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews.* (Marine Biological Association of the United Kingdom: Plymouth. Available online at: https://www.marlin.ac.uk/species/detail/2231.

Government of Australia (2020). *Rapid Response Manual Generic.* Version 2.0 January 2020. (Department of Agriculture: Canberra, December 2020). 75 pp.

Government of New Zealand (2017). *Kermadec and Subantarctic Islands Regional Coastal Plan.* (Department of Conservation: Wellington, September 2015).

HELCOM (2020). *Proposal for a Regional Baltic Biofouling Management Roadmap.* Report of the Baltic Marine Environment Protection Commission. Report Number MARITIME 20-2020. 11 September 2020.

Hewitt, C.L. and Campbell, M.L. (2010). *The relative contribution of vectors to the introduction and translocation of marine invasive species.* Commissioned by the Department of Agriculture, Fisheries and Forestry (DAFF), Canberra, Australia.

Hewitt, C.L. and Martin, R.B. (2001). *Revised Protocols for Baseline Port Surveys for Introduced Marine Species: Survey Design, Sampling Protocols and Specimen Handling.* CRIMP Technical Report No. 2. (Centre for Research on Introduced Marine Pests [CRIMP]: Hobart, Tasmania, April 2001). 46 pp.

Iacarella, J.C. Burke, L., Davidson, I.C., DiBacco, C., Therriault, T.W. and Dunham, A. (2020). "Unwanted networks: Vessel traffic heightens the risk of invasions in marine protected areas". *Biological Conservation* 245 (2020) 108553. https://doi.org/10.1016/j.biocon.2020.108553.

Iacarella, J.C., Lyons, D.A., Burke, L., Davidson, I.C., Therriault, T.W., Dunham, A. and DiBacco, C. (2019a). "Climate change and vessel traffic create networks of invasion in marine protected areas". *Journal of Applied Ecology* 2020(57). 1793–1805. https://doi.10.1111/1365-2664.13652.

Iacarella, J.C., Saheed, D., Dunham, A. and Ban, N.C. (2019b). "Non-native species are a global issue for marine protected areas". *Frontiers in Ecology and the Environment* 17(9). 495–501, https://doi.org/10.1002/fee.2100.

IMO (2023). *2023 Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species.* IMO document PPR 10/WP.5, 27 April 2023. https://www.glofouling.imo.org/regulations-imo.

IPBES (2019). *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* Brondizio, E.S., Settele, J., Díaz, S. and Ngo, H.T. (editors). IPBES secretariat, Bonn, Germany. 1148 pp. https://doi.org/10.5281/zenodo.3831673.

Janiak, D. (2021). *MarineGEO Fouling Community Monitoring Protocol.* (Tennenbaum Marine Observatories Network, MarineGEO, Smithsonian Institution.). 21 pp. https://doi.org/10.25573/serc.14510649.v1.

Kahng, S.E. and Grigg, R.W. (2005). “Impact of an alien octocoral, Carijoa riisei, on black corals in Hawaii.” *Coral Reefs* 24, 556–562. https://doi.org/10.1007/s00338-005-0026-0.

Karatayev, A., Burlakova, L., & Paddila, D. (2002). *Impacts of Zebra Mussel on Aquatic Communities and Their Role as Ecosystem Engineers.* Invasive aquatic species of Europe, Kluwer Academic Publishers, 433-446.

Klassen, G., and Locke, A. (2007). “A biological synopsis of the European green crab, *Carcinus maenas." Canadian Manuscript Report of Fisheries and Aquatic Sciences,* 2818.

Kelleher, G. (ed). *Guidelines for Marine Protected Areas. World Commission on Protected Areas.* Best Practice Protected Area Guidelines Series No. 3 (Gland, Switzerland / Cambridge, UK: IUCN, 1999), xxiv+ 107 pp.

Kriegl, M., Elias Ilosvay, X.E., von Dorrien, C. and Oesterwind, D. (2021). “Marine protected areas: At the crossroads of nature conservation and fisheries management”. *Frontiers in Marine Science* 8 (676264). 13 pp. https://doi.org/10.3389/fmars.2021.676264.

Monaco, A. and Genovesi, P. (2014). *European Guidelines on Protected Areas and Invasive Alien Species.* (Council of Europe: Strasbourg/Rome, November 20154). 58 pp.

New Zealand Government (2011). *Risk Analysis: Vessel Biofouling*. (Wellington: Ministry of Agriculture and Fisheries, February 2011). 145 pp.

OECD (2017). *Marine Protected Areas: Economics, Management and Effective Policy Mixes.* (OECD: Paris, 2017). 179 pp. http://dx.doi.org/10.1787/9789264276208-en.

Orlova, M., Therriault, T., Antonov, P. and Scherbina, G. (2005). “Invasion ecology of quagga mussels *(Dreissena rostriformis bugensis)*; a review of evolutionary and phylogentic impacts.” *Aquatic Ecology* 39(4), 401-418.

Otero, M., Cebrian, E., Francour, P., Galil, B., and Savini, D. (2013). *Monitoring Marine Invasive Species in Mediterranean Marine Protected Areas (MPAs): A Strategy and Practical Guide for Managers.* (IUCN Centre for Mediterranean Cooperation: Malaga, Spain, 2012). 136 pp.

(PMNM (2009). *Papahānaumokuākea Marine National Monument: Marine Alien Species Inspection Standards for Maritime Vessels.* PMNM BMP #001. https://nmspapahanaumokuakea.blob.core.windows.net/papahanaumokuakea-prod/media/archive/permit/pdf/001_marinealien.pdf.

Relini, G., Relini, M., and Torchia, G. (2000). “The role of fishing gear in the spreading of allochthonous species; the case of Caulerpa taxifolia in the Ligurian sea.” *ICES Journal of Marine Science* 57(5), 1421-1427.

Schaffelke, B. (2008). “*Caulerpa taxifolia* (killer algae)”. In *CABI Compendium.* (CABI: Wallingford, UK, 2024). https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.29292.

Schwindt, E. (2009). "*Ficopomatus enigmaticus* (tubeworm)." In *CABI Compendium*. (CABI: Wallingford, UK, 2024). https://doi.org/10.1079/cabicompendium.108338.

Scianni, C. and Georgiades, E. (2019). "Vessel In-Water Cleaning or Treatment: Identification of Environmental Risks and Science Needs for Evidence-Based Decision Making". *Frontiers in Marine Science* 6(467). https://doi.org/10.3389/fmars.2019.00467.

Smithsonian Environmental Research Center [SERC] (2024a). *SERC's National Estuarine and Marine Exotic Species Information System [NEMESIS]. Didemnum vexillum.* Available at: https://invasions.si.edu/nemesis/species_summary/-334.

SERC (2024b). *NEMESIS. Styela clava.* Available at: https://invasions.si.edu/nemesis/species_summary/159337#:~:text=Fisheries%3A%20The%20largest%20economic%20impacts,mussel%20culture%20(Locke%20et%20al.

Soliman, T. and Inglis, G.J. (2017). "Forecasting the economic impacts of two biofouling invaders on aquaculture production of green-lipped mussels *Perna canaliculus* in New Zealand." *Aquaculture Environment Interactions* 10. 1-12. https://doi.org/10.3354/aei00249.

Summerson, R., Skirtun, M., Mazur, K., Arthur, T., Curtotti, R., & Smart, R. (2013). *Economic evaluation of the costs of biosecurity response options to address an incursion of Mytilopsis sallei (black-striped mussel) into Australia.* Canberra: ABARES Report to client prepared for Plant Health Australia.

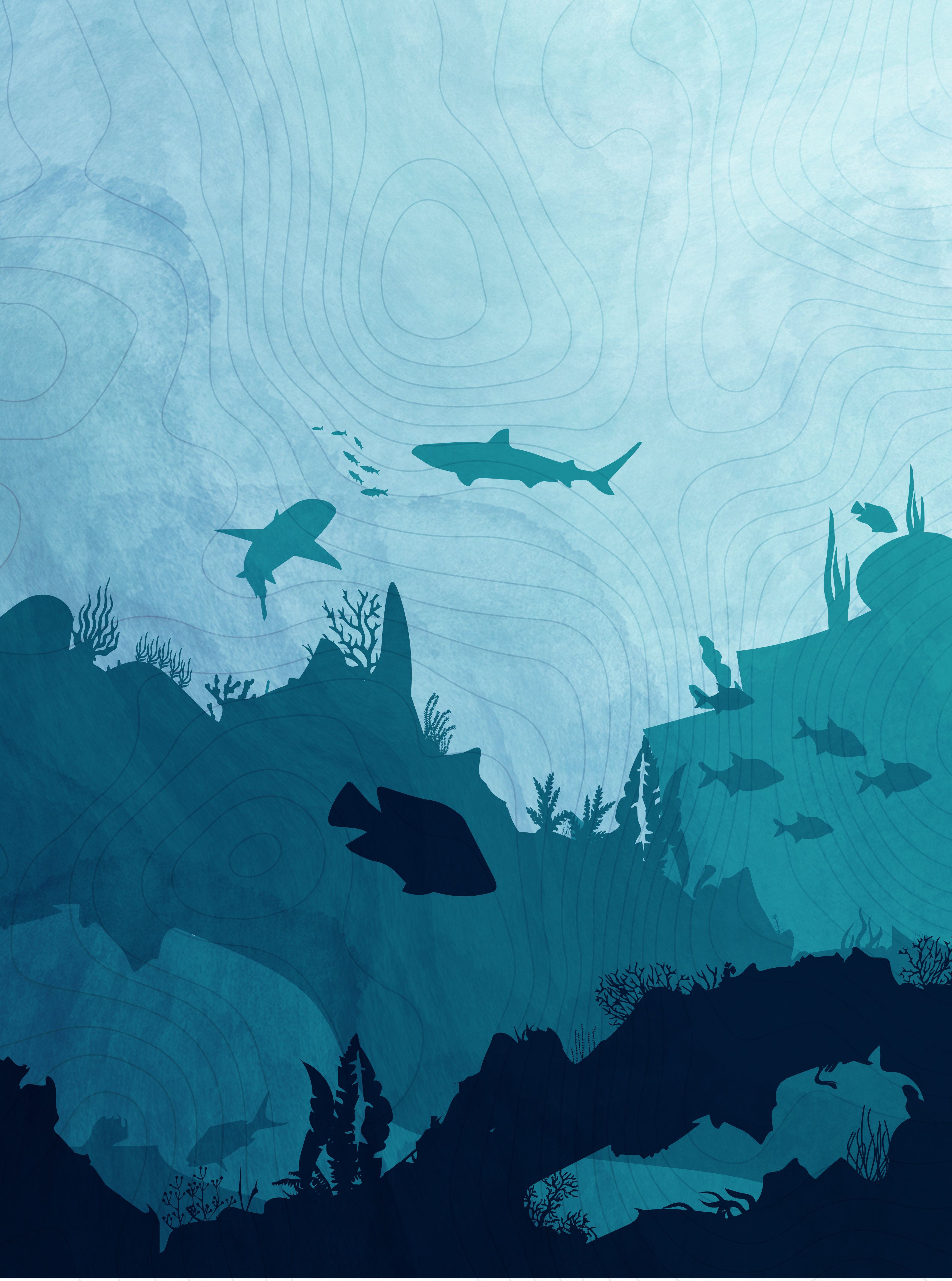
UNESCO/IOC (2021). *Pacific Islands Marine Bioinvasions Alert Network (PacMAN) Monitoring Plan.* Suominen, S. et al. (eds), Paris, UNESCO. (IOC Technical Series, 168).

West, E., Barnes, P.B., Wright, J.T. and Davis, A.R. (2007). "Anchors aweigh; fragment generation of invasive Caulerpa taxifolia by boat anchors and its resistance to desiccation." *Aquatic Botany* (87(3)), 196-202.

Williams, F.E., Eschen, R., Harris, A., Djeddour, D.H., Pratt, C.F., Shaw, R.S., Varia, S., Lamontagne-Godwin, J.D., Thomas, S.E. and Murphy, S.T. (2010). *The economic cost of Invasive Non-Native Species on Great Britain.* Available online at: https://www.mari-odu.org/academics/2018s_adaptation/commons/library/Williams_etal_2010.pdf.

Wong, D and Mastitsky, S. (2014). "*Dreissena rostriformis bugensis* (quagga mussel)." In *CABI Compendium* (CABI: Wallingford, UK, 2024). https://doi.org/10.1079/cabicompendium.107770.

Zabin, C.J., Davidson, I.C., Holzer, K.K., Smith, G., Ashton, G.V., Tamburri, M.N. and Ruiz, G.M. (2018). "How will vessels be inspected to meet emerging biofouling regulations for the prevention of marine invasions?" *Management of Biological Invasions* 9(3). 195–208. DOI: https://doi.org/10.3391/mbi.2018.9.3.03.



SUSTAINABLE DEVELOPMENT GOALS

5 GENDER EQUALITY

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

13 CLIMATE ACTION

14 LIFE BELOW WATER

3 GOOD HEALTH AND WELL-BEING

17 PARTNERSHIPS FOR THE GOALS

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