Intergovernmental Oceanographic Commission

GloFouling PARTNERSHIPS

IOC TECNICAL SERIES Nº 174

Biofouling Prevention and Management in the Offshore Oil and Gas Industry

Best Practices in Biofouling Management - Volume 2

INTERNATIONAL MARITIME ORGANIZATION

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Biofouling Prevention and Management in the Offshore Oil and Gas Industry

Volume 2

Best Practices in Biofouling Management

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This report is designed to assist environmental managers and other responsible parties within the offshore oil and gas industry to develop and implement effective processes to manage the spread of invasive aquatic species (IAS) in association with biofouling. The document provides practical overarching mechanisms to achieve this goal and showcases successful approaches for the management of biofouling across all stages of offshore projects including exploration (i.e. searching for potential hydrocarbon reserves through geophysical exploration and the drilling of exploratory wells), field development (i.e. mobilization and installation of semi-permanent infrastructure), production (i.e. ongoing operation of offshore wells including recovery, processing, storing and offtake of reserves) and decommissioning (i.e. removal of infrastructure and equipment following the completion of production stages).

Considering the complexity of offshore developments and the diversity of equipment and infrastructure mobilized throughout the life span of a project, this report does not provide detailed advice regarding the management of specific assets or vessel types. Instead, the focus is on providing a summary of effective approaches to biofouling management and developing overarching management plans that address the full scope of biofouling-related risks at the scale of the entire project. Such plans need to clearly identify the acceptable standard of biofouling management for vessels and infrastructure operating within the project area and provide clear advice on the application of biofouling management tools to ensure this standard is maintained. Furthermore, overarching plans should provide decision-support tools that clearly identify biofouling management pathways to assist contractors in understanding what options are available to them, and to ensure that proactive management approaches are considered well in advice of mobilization.

Offshore oil and gas projects frequently operate across multiple jurisdictions, and considering the global nature of the industry, this document does not provide guidance of specific biofouling management standards that should be applied to offshore operations or review relevant regulations. It is the responsibility of the offshore oil and gas operator (or titleholder) to ensure that overarching plans and all operations supporting a project address applicable regulatory requirements and that plans are approved by relevant authorities.

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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 project aims to develop tools and solutions to help developing countries to reduce the transfer of aquatic invasive species through the implementation of the IMO Guidelines for the control and management of ships' biofouling. www.glofouling.imo.org

Funding Agency

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IOC UNESCO - the Intergovernmental Oceanographic Commission of UNESCO - is the United Nations body responsible for supporting global ocean science and services. IOC is partnering with IMO in implementing the non-shipping elements of the GloFouling Partnerships project. https://ioc.unesco.org

This report was developed under the GEF-UNDP-IMO GloFouling Partnerships project, a joint global initiative between the Global Environment Facility (GEF), the United Nations Development Programme (UNDP) and the International Maritime Organization (IMO), in collaboration with the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (IOC-UNESCO).

The GEF-UNDP-IMO GloFouling Partnerships project aims at driving actions to implement the IMO Biofouling Guidelines and best practices for biofouling prevention and management in other maritime industries through policy development, capacity building, awareness raising and knowledge sharing.

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1 Biofouling and invasive aquatic species

1.1. Biofouling formation and invasive aquatic species colonization

Biofouling refers to the accumulation of marine organisms attached to, or associated with, artificial structures immersed in aquatic environments. While the nature and composition of biofouling can vary depending on how long an object has been in the water and the geographical location, typically this process follows a standard sequence of succession. This starts with the microbial conditioning of the surface and the settlement of diatomaceous slimes and algae, followed by secondary settlement of larger macro-invertebrates such as serpulid tubeworms, acorn barnacles and bryozoans. If biofouling is allowed to develop over longer periods, a tertiary layer of organisms can establish involving more complex communities and a broader range of species including bivalves, tunicates, sabellid worms, sponges and a range of other groups. Heavy assemblages of biofouling form a complex habitat matrix that also supports free-living organisms such as swimming crabs and fish, as well as other species that live nestled within the biofouling habitat (e.g. polychaete worms and small crustaceans).

While the recruitment of biofouling communities to artificial substrates reflects natural processes, a certain subset of biofouling species are well adapted to taking advantage of such surfaces and thrive. Furthermore, while some artificial structures remain stationary once introduced to the marine environment (e.g. wharfs, pylons, moorings, etc.), many marine structures such as ships are designed to move between regions and across oceans. This has resulted in an anthropogenic transportation pathway that is capable of transferring biofouling species all around the globe. Because port environments are defined by large accumulations of artificial substrates and are often considered disturbed environments with higher levels of pollutants, some biofouling species and communities well adapted to such conditions have now achieved almost circum-global distributions (Ashton et al., 2016; Darling and Carlton, 2018; Beermann et al., 2020). Some invasive aquatic species (IAS), a subset non-native species transferred in association with human transportation pathways, are capable of spreading to undisturbed regions, where they can result in impacts to the environment, public amenity and coastal industries (Thresher, 1999; Sakai et al., 2001; Katsanevakis et al., 2014).

The historical focus of biofouling management has addressed the operational and cost impacts of biofouling. Mariners have long been concerned with the contribution of biofouling to drag, which slows vessel transits and causes additional fuel use. However, emerging concerns over the environmental and economic impacts associated with IAS (Cuthbert et al., 2021), and the estimation that biofouling is one of the major global transportation pathways for IAS (Hewitt et al., 1999, 2004; Hewitt and

Campbell, 2010; de Castro et al., 2017), has resulted in a renewed focus on biofouling management to address environmental impacts. Furthermore, growing concerns over the impacts of global warming have created a renewed focus on the role of best practice biofouling management in meeting greenhouse gas reduction targets (Davidson et al., 2016; GEF-UNDP-IMO GloFouling, 2022a).

Research estimates that up to 47% of IAS introductions have been facilitated by biofouling (de Castro et al., 2017) and once established, biofouling on domestic vessels serves to distribute IAS from port regions into adjacent coastal ecosystems (Floerl et al., 2009). Although it is difficult to quantify global impacts specifically for biofouling species, recent estimates regarding economic impacts suggest that aquatic (and semi-aquatic) invasive species (such as Aedes spp., Dreissena spp., etc.) have cost the global economy over US$345 billion, and that IAS in 2020 alone cost the global economy at least US$23 billion (Cutherbert et al., 2021). It should be noted that only 1% of aquatic invasion costs have been made by marine invasive species (Cutherbert et al., 2021).

IAS can have a range of impacts on natural marine ecosystems and, unlike many other stressors such as coastal pollution and oil spills, once established in a marine environment, are very difficult and often impossible or prohibitively expensive to eradicate (Cutherbert et al., 2021). Moreover, the impacts and cost of eradication often increase over time as an IAS increases its population and expands its geographic range (Bax et al., 2003). IAS can dominate benthic habitats, disturb native communities and displace local species due to their generalist ecology, phenotypic plasticity and life history characteristics (Bax et al., 2003; Smith, 2009; Goodenough, 2010), such as high reproductive output, mass settlement and rapid

Figure 1. Biofouling eventually accumulates on all marine structures.
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Figure 2. Once established, IAS can form dense aggregations and be almost impossible to eradicate. These images show the invasive Charru mussel (left) in Singapore and the invasive Mediterranean fanworm in Port Phillip Bay, Australia monopolizing habitats in their invasive range.

growth rates (Coma et al., 2011; Alonso and Castro-Díez, 2012; Katsanevakis et al., 2014). Environmental impacts associated with IAS can fall into a number of broad categories, including predation on and competition with native species for space and resources and the alteration of broader habitat dynamics (Tait et al., 2020). Some IAS have been shown to drive fundamental changes in ecosystems, such as a shift from native mussels to alien oysters (Kochmann et al., 2008), the modification of physical structure by the European fanworm Sabella spallanzanii (O'Brien et al., 2006), or damage due to the erosion of river and lake embankments by Chinese mitten crabs (Veldhuizen and Stanish, 1999). In addition to monopolization of space and resources, IAS can impact native species by shading, sweeping, smothering or reducing settlement by consuming larvae and juveniles (Wyatt et al., 2005).

While some examples exist of localized IAS eradication following early detection (e.g. Willan et al., 2000; Anderson, 2005), successful eradication efforts are very rare and typically dependant on environmental conditions, biological constraints or physical barriers which significantly limit the ability of the IAS to spread beyond the point of introduction. Because of the difficulty in eradicating or controlling established IAS, investment in preventing impacts from IAS are far better allocated to pre-border protection and managing IAS pathways than attempting to react to established IAS. In particular, this requires the implementation of ongoing best practice management to ensure biofouling risks are maintained within an acceptable threshold prior to arrival.

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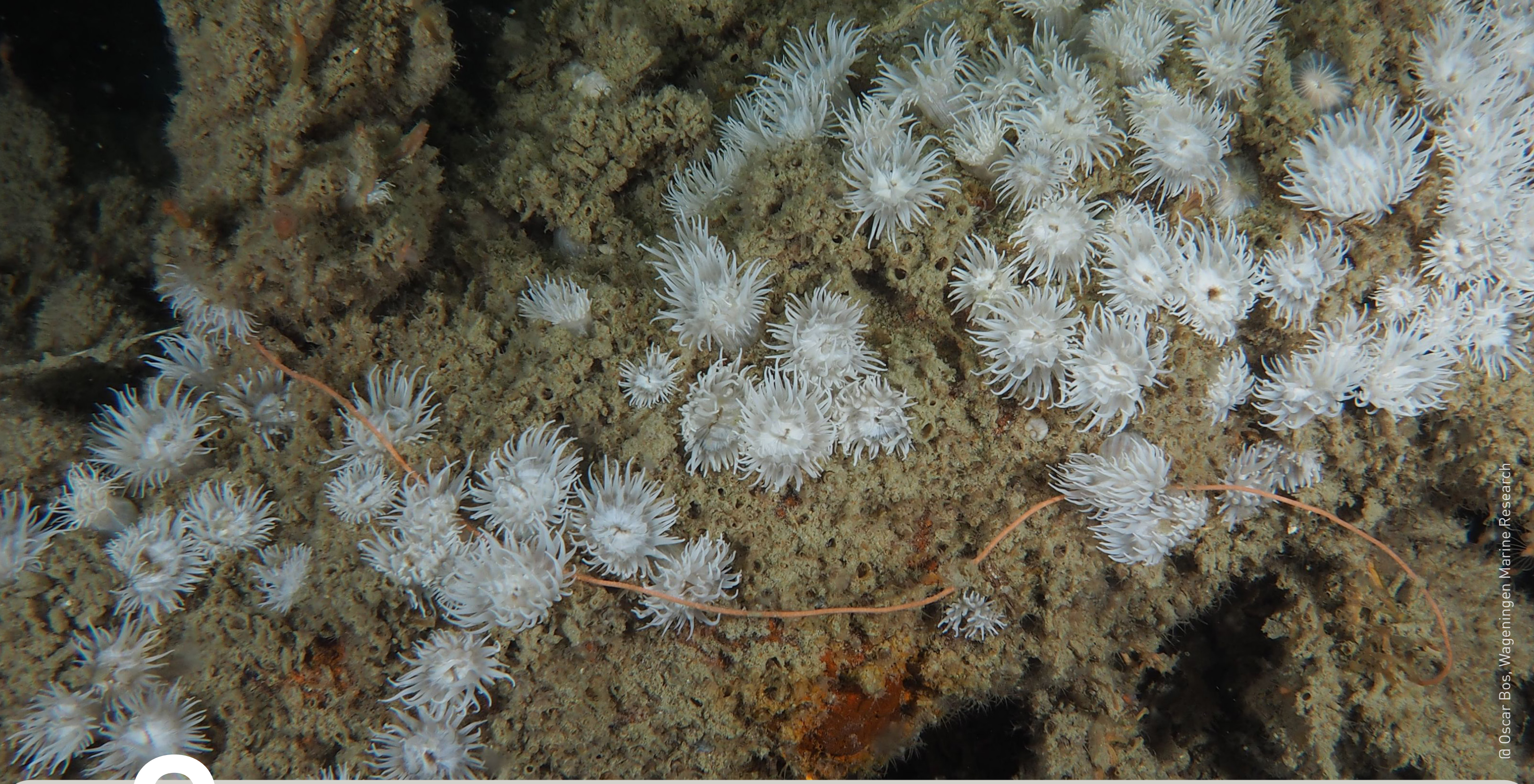

2 Biofouling in the offshore environment

The offshore oil and gas industry is entirely dependent on maritime structures and vessels to support all stages of operation. All maritime platforms eventually accumulate biofouling organisms which cause a range of operational and environmental impacts. While some impacts operate on a scale comparable to other maritime sectors (e.g. biofouling on support vessels), the nature of offshore operations creates unique challenges for managing biofouling. In many cases, offshore projects and associated vessels create novel transportation hubs and introduce industrial scales of endeavour to regions that have previously seen little traffic (IPIECA, 2010). Biofouling can, thus, create novel pathways for IAS to arrive in new locations, and may operate on a scale and over a timeframe that introduces a significant risk of IAS transfer and establishment. Upstream and midstream activities (onshore and offshore activities from exploration to decommissioning) can create direct and indirect pathways for AIS (IPIECA, 2010).

The global response to the threat of IAS transfer in association with biofouling has included a number of specific local, national and regional requirements focusing on species-specific management, with some jurisdictions implementing specific requirements for the offshore oil and gas industry due to an increased risk being identified in association with the industry. For example, the Western Australian Department of Primary Industries and Regional Development has broad powers to manage the transfer and introduction of listed IAS (referred to as noxious fish) into state waters and has primarily focused compliance oversight on offshore vessels in the past decade. With increasing scrutiny, many offshore oil and gas operators have taken the initiative to implement strong precautionary approaches to limit the spread of IAS in association with biofouling, and in many cases such approaches are applied independently of any specific regulatory requirements. While many offshore operators have developed independent approaches to managing biofouling to reduce the transfer of IAS and other environmental impacts, the introduction of globally consistent approaches to biofouling management assists both industry operators and contractors engaged to support projects, as well as regulators with a mandate to ensure such operations do not impact the environment.

2.1. General biofouling on offshore vessels

Through the life of an offshore project, numerous vessel categories are used to support a vast range of operational requirements. In general, biofouling affects these vessels in a similar manner to vessels in other maritime sectors, with the rate of biofouling accumulation dependant on the area of operation, the proportion of time active compared to static, periods of prolonged inactivity, the age and condition of antifouling coatings and other systems, and the efficacy of any in-water biofouling management conducted since the previous dry-dock.

Figure 3. A diverse range of vessel types support offshore oil and gas operation offering a range of niches suitable for transferring IAS as biofouling.
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However, offshore support vessels regularly transit between projects in remote offshore locations and create linkages between offshore project installations, remote coastal environments that typically might not be exposed to significant maritime traffic, and commercial port environments servicing local, regional and international shipping. As a result, biofouling on offshore support vessels may create a heightened risk of IAS transfer to new marine regions compared with typical commercial maritime traffic (which is largely restricted to transiting between commercial ports).

In addition to this unique pattern of operation, a number of features of offshore vessel operations affect the nature of biofouling and the associated risk of IAS transfer. Because offshore contracts are driven by demand and project development status, offshore support vessels in some cases experience extended unplanned lay-ups when contracts are not available. It is not uncommon for some categories of offshore vessels to have unpredictable patterns of operation with extended lay-ups interspersed with more-or-less constant activity. When unexpected lay-ups occur, these mainly take place in shallow waters adjacent to coastal habitats, where strong biofouling pressure and a heightened risk of IAS recruitment and transfer arise (Davidson et al., 2020). This could provide opportunities for a compromised performance of antifouling coatings. Conversely, ideal operating conditions result in offshore vessels spending a large portion of time in offshore waters where they are exposed to a lower-than-average biofouling pressure. Biofouling assemblages recruited naturally in offshore environments are unlikely to include IAS due to the lack of IAS source populations and are generally composed of cosmopolitan species adapted to offshore environments and often with broad natural distributions. However, IAS can become an important part of these communities due to recruitment prior to mobilization to the project site, or through interactions with other assets and vessels (e.g. Gust et al., 2019). Because offshore projects involve numerous support vessels over long timeframes, IAS and biofouling risk needs to be examined independently for each vessel and in the context of those vessels' operations. For a project perspective, the cumulative risk of multiple vessels servicing the field over the entire lifetime of the project should also be considered.

2.2. Biofouling on non-standard offshore infrastructure

Some offshore platforms have unique operational and functional parameters that create specific biofouling management challenges. Equipment such as mobile offshore drilling units (MODUs), jack-up rigs and some drill-ships have a functional purpose significantly different from normal vessels (e.g. passenger vessels). Because access to appropriate docking facilities may

Figure 4. Mobile offshore drilling units (left) and other non-standard maritime platforms used in the offshore industry often have complex subsea niches (right) and can support diverse biofouling communities.
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be impractical for offshore infrastructure types, or due to operational requirements of some structures, docking frequencies for some offshore equipment can be considerably longer than typical vessels. For example, a typical passenger vessel should undergo docking twice in every 5 years, while for offshore equipment this period could be extended to a dry-dock interval of 7.5 years. Coating selection on offshore infrastructure, which spends significant time moored, is also less focused on fuel economies. As a result, submerged surfaces are frequently coated with abrasion-resistant epoxies as opposed to antifouling coating technologies designed to deter biofouling accumulation. MODUs and other equipment also have a range of complex subsea niche features including keel-cooling arrays, jack-up legs, and pontoon configurations that support biological communities adapted to a range of aspects from flat surfaces to walls and overhangs. Finally, many types of offshore equipment are not self-propelled, or if they are, are designed to move at very low speeds or under tow. As a result, mobilizations of such equipment are typically implemented at relatively slow speeds which might facilitate a higher rate of survival for entrained organisms.

The unique features of offshore infrastructure predispose them to high levels of biofouling and in some cases, mature offshore reef communities can establish over long periods supporting diverse marine ecosystems. For example, in one incident where a MODU was thoroughly cleaned to manage biofouling-related risks due to the identified presence of an IAS, a total of over 160 tonnes of biofouling was removed following a cleaning operation facilitated by raising the MODU on a heavy lift vessel (Biofouling Solutions, 2015). In this example, the biofouling community included an extremely diverse ecosystem supporting corals, hydroids, bryozoans, brittle stars, echinoids, serpulid and spirorbid polychaetes, acorn barnacles, solitary and colonial ascidians, sponges, oysters, mussels, clams, limpets, portunid crabs, grapsid crabs, whelks and many others. Additional organisms that are more typically associated with mature reef ecosystems were also present, including octopus, painted crayfish, and various reef associated fishes such as serranids, acanthurids and pomacentrids.

The potential diversity of entrained organisms on such structures means that unmanaged mobilizations of such equipment are capable of transporting intact and mature marine communities between regions, and may represent one of the most significant marine biosecurity risks currently operating in the world (e.g. Coutts and Taylor, 2004). This risk is of particular concern when equipment is mobilized from shallow water coastal ecosystems to fields that are in comparable climate zones and are adjacent to shallow water or coastal habitats due the potential high rate of survival for entrained organisms. Even when not in direct proximity to shallow water ecosystems, the operation of support vessels may facilitate IAS introductions to nearby coasts and ports. Considering the heightened risk of IAS transfer associated with offshore equipment, best practice biofouling management should carefully consider each mobilization to determine if available biofouling management measures reduce the risk of IAS transfer to an acceptable level for the project (see 5.1). Where this is not the case, major in-water cleaning operations or dry-docking might be required to manage biofouling effectively.

2.3. Biofouling on long-term infrastructure

One of the most significant biofouling challenges for the offshore oil and gas industry is the management of assets that are designed to be installed for extended periods in the offshore environment. This category of infrastructure includes fuel production, storage and

Figure 5. Offshore fields in the North West Shelf of Australia with multiple assets in proximity. Such equipment is often designed to remain in the field for long periods and is serviced by a fleet of support and offloading vessels, creating a potential IAS transportation hub.
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offtake facilities, central processing facilities, floating liquified natural gas facilities and other equipment designed to store, process, divert or offload hydrocarbon extractions. In some cases, such equipment is designed to remain in a field for up to 25 years with little scope for in-water biofouling management, and only infrequent (or in some cases non-existent) opportunities to demobilize for periodic maintenance in dry-dock. In addition to the risk of transferring IAS during the first mobilization to the offshore field, such infrastructure experiences a constant risk of being colonized with new IAS when interacting with support vessels that are not effectively managed. Once colonized with an IAS, such offshore infrastructure represents a significant risk of transferring AIS to adjacent shallow water environments and regional service ports. In some cases, this has resulted in stringent biofouling control measures being applied to domestic conveyances and support vessels by local regulators leading to significant and unplanned biofouling management overheads for ongoing operations. A good case-study of effective biofouling approaches and the logistic considerations of managing the mobilization of major infrastructure is provided in Gust et al. (2019).

Assets colonized by IAS are almost impossible to clean thoroughly when positioned in the field due to offshore sea conditions and risks to divers and as a result, IAS dissemination adds costly logistic complications to decommissioning stages of the project. This is because the presence of IAS on platforms may impose consequences for policy decisions concerning the future of these structures (Page et al., 2006). For example, offshore structures colonized with the invasive sun coral (Tubastrea coccinea) in the Gulf of Mexico and in Brazil pose a considerable biosecurity risk to adjacent coastal regions (Creed et al., 2017). Similarly, the presence of IAS on platforms in the Gulf of Mexico might pose significant environmental effects at other locations if these structures are planned to be transferred and re-deployed as part of the 'rigs to reefs' programme (Reggio, 1989). Partial or complete removal of a platform colonized with IAS could also lead to the dispersal of IAS if the removal is haphazardly conducted (Page et al., 2006). Increasingly stringent biosecurity regulations mean that many decommissioning options are not available without significant investments in biofouling removal or without a thorough study of the risks induced by the presence of IAS, which might lead to different choices as to whether the platforms should be left in place or relocated to be used as artificial reefs (Vidal et al., 2022).

2.4. Biofouling on subsea equipment

While typically of concern primarily due to operational impacts, biofouling on subsea infrastructures, such as risers, could provide substrate to support IAS and, thus, could in theory lead to introductions. Operational impacts of biofouling on subsea infrastructure, such as the potential impact of calcium carbonate deposits on freedom of movement for oscillating riser support structures, needs to be considered carefully in the design phase prior to installation. However, because most subsea equipment is transported to the offshore field as dry cargo, the IAS risk profile is of primary concern post-installation, and IAS risks are typically only considered in the context of decommissioning operations. Where concerns over IAS contamination on subsea equipment are identified, careful consideration needs to be applied to the management of biofouling, especially where equipment is towed or transported to coastal environments for disposal.

Figure 6. An example of biofouling and marine communities associated with deep water assets (>190 m depth) in the North West Shelf of Australia.
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3 Biofouling management plans and record books

In 2011, the International Maritime Organization (IMO) introduced the Guidelines for the Control and Management of Ships' Biofouling to minimize the transfer of IAS (IMO Biofouling Guidelines). IMO is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. IMO also introduces standards to maintain appropriate records to ensure that coastal states and other regulators can effectively monitor the implementation of biofouling management measures. While IMO does not presently administer any international conventions governing biofouling management, the IMO Biofouling Guidelines are intended to provide a globally consistent approach to the management of biofouling. They were adopted by the Marine Environment Protection Committee at its sixty-second session in July 2011 and were the result of three years of consultation between IMO member states. The IMO Biofouling Guidelines represent a decisive step towards reducing the transfer of IAS by ships. These Guidelines are currently being revised by IMO member states[1].

While the IMO Biofouling Guidelines remain a voluntary measure, jurisdictions that have adopted mandatory biofouling requirements have used the approach detailed within these guidelines, in particular the use of ship-specific biofouling management plans and biofouling record books. The IMO Biofouling Guidelines apply to all vessel types, including offshore, vessels, fixed or floating platforms, etc. (see 'ship' definition in the IMO Guidelines) and should be used as the basis of best practice management within the offshore oil and gas industry.

Using Biofouling management plans (BFMPs) and biofouling record books (BFRBs) to document how biofouling management is carried out form the core requirement of best practice biofouling management approaches outlined in the IMO Biofouling Guidelines. These documents should be developed independently for each vessel and specifically address management approaches in the context of the vessel's configuration (i.e. the nature and location of niche areas vulnerable to biofouling) and its intended operation (i.e. average speeds, ratio of time static to active and itinerary (places visited and duration of stay). The development of an effective BFMP should consider the entire in-service period of a vessel and include both explicit proactive and reactive biofouling management measures. Proactive refers to management measures which are adopted primarily while the vessel is in a vessel maintenance facility to

1 This report was drafted before the adoption of the *2023 Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species* (Biofouling Guidelines) (resolution MEPC.378(80)) at the Marine Environment Protection Committee (MEPC) eightieth session in July 2023. For more information about the Biofouling Guidelines see: https://www.imo.org/en/OurWork/Environment/Pages/Biofouling.aspx

either maximize the immunity of the vessel to biofouling settlement and to establish ongoing management measures, such as in-water biofouling inspection and cleaning schedules throughout the vessel's in-service period. Reactive measures are applied when vessels deviate from their proposed operating profiles or encounter unacceptable levels of biofouling or if the ship is suspected to be the source pathway of IAS.

In developing a BFMP, operators should commence with determining the vessel's proposed operational profile, as this will influence which anti-fouling systems are most suitable. Given that there are a wide range of anti-fouling systems on the market which are designed to perform according to a vessel's proposed operational profile, it is vital that vessel operator works very closely with their anti-fouling coating and marine growth prevention system (MGPS) suppliers to ensure the most suitable systems for the vessel's proposed operational profile are installed. It is also vital that the vessel operator and the anti-fouling system supplier consider the most appropriate anti-fouling systems for use to protect niche areas.

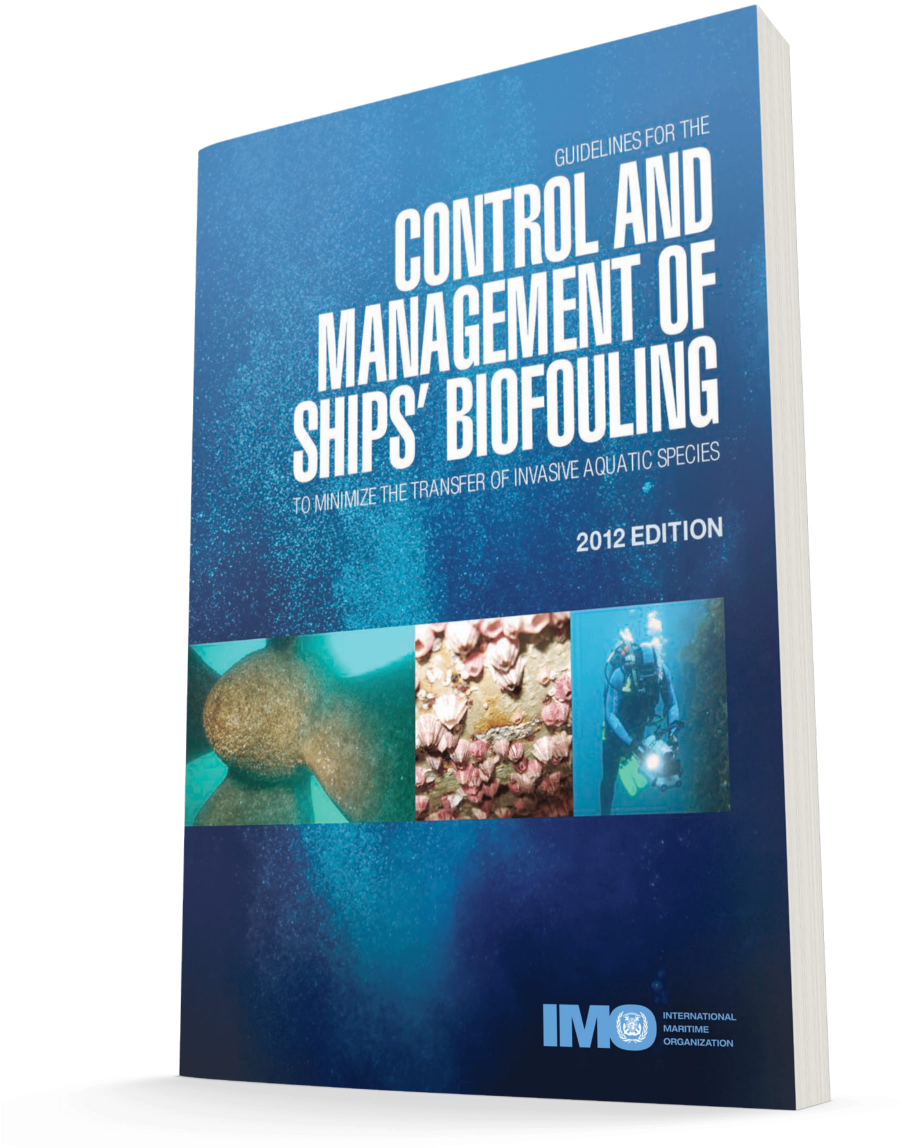
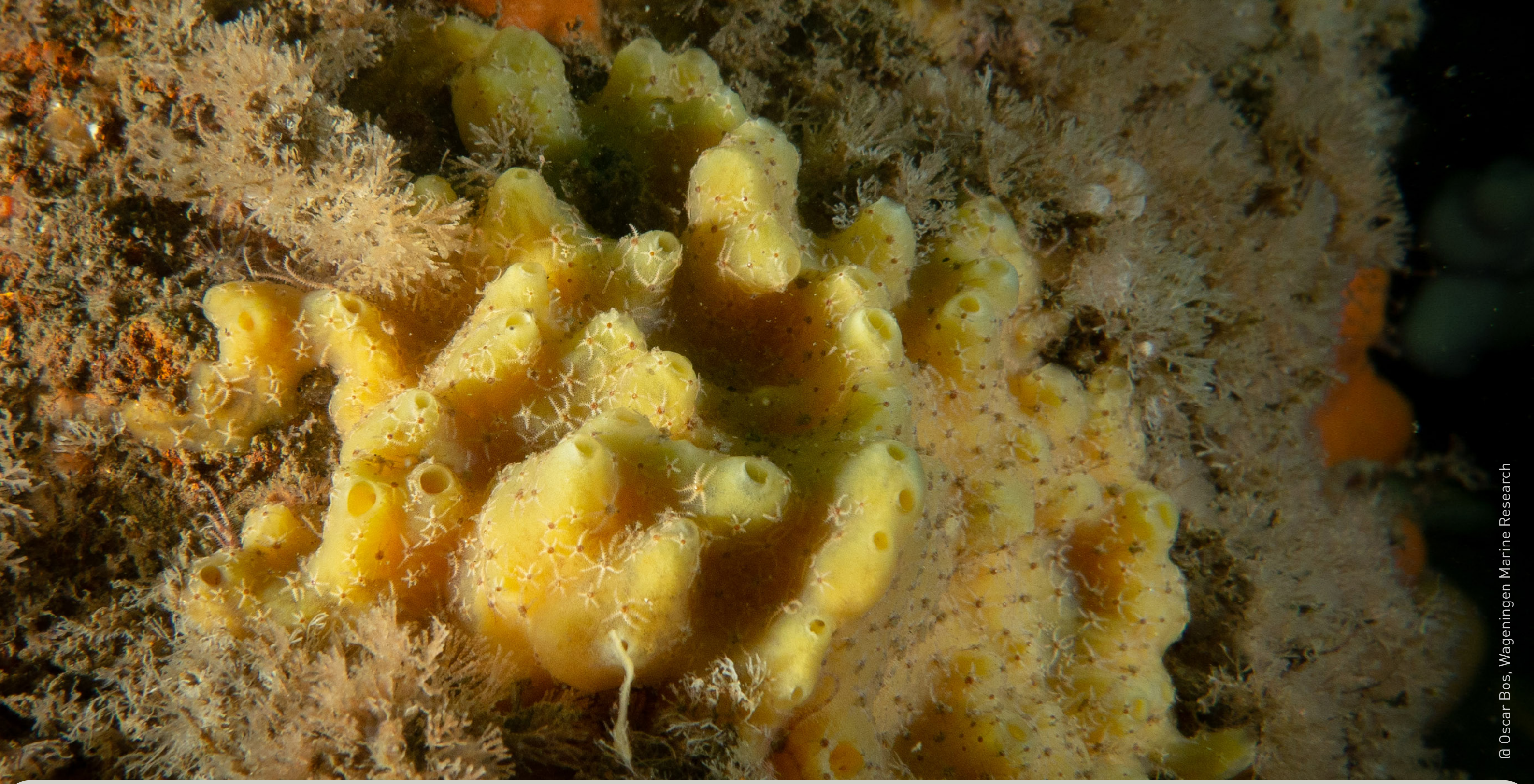


Figure 7. Vessel operators should refer to the IMO Guidelines for the Control and Management of Ships' Biofouling to minimize the transfer of IAS when creating vessel-specific biofouling management plans and record books, as well as any guidelines produced by other relevant authorities[2].

2 This report was drafted before the adoption of the *2023 Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species* (Biofouling Guidelines) (resolution MEPC.378(80)) at the Marine Environment Protection Committee (MEPC) eightieth session in July 2023. For more information about the Biofouling Guidelines see: https://www.imo.org/en/OurWork/Environment/Pages/Biofouling.aspx



4 Delineation of responsibilities for biofouling management

Offshore oil and gas operations involve a broad range of professional and onsite personnel, external stakeholders and numerous independent contractors. It is important to recognize the direct responsibility of various positions and their role in the management of biofouling to prevent the spread of IAS. Figure 8 provides an overview of the role various entities play in this process and the reporting obligations and documentary controls that govern these activities.

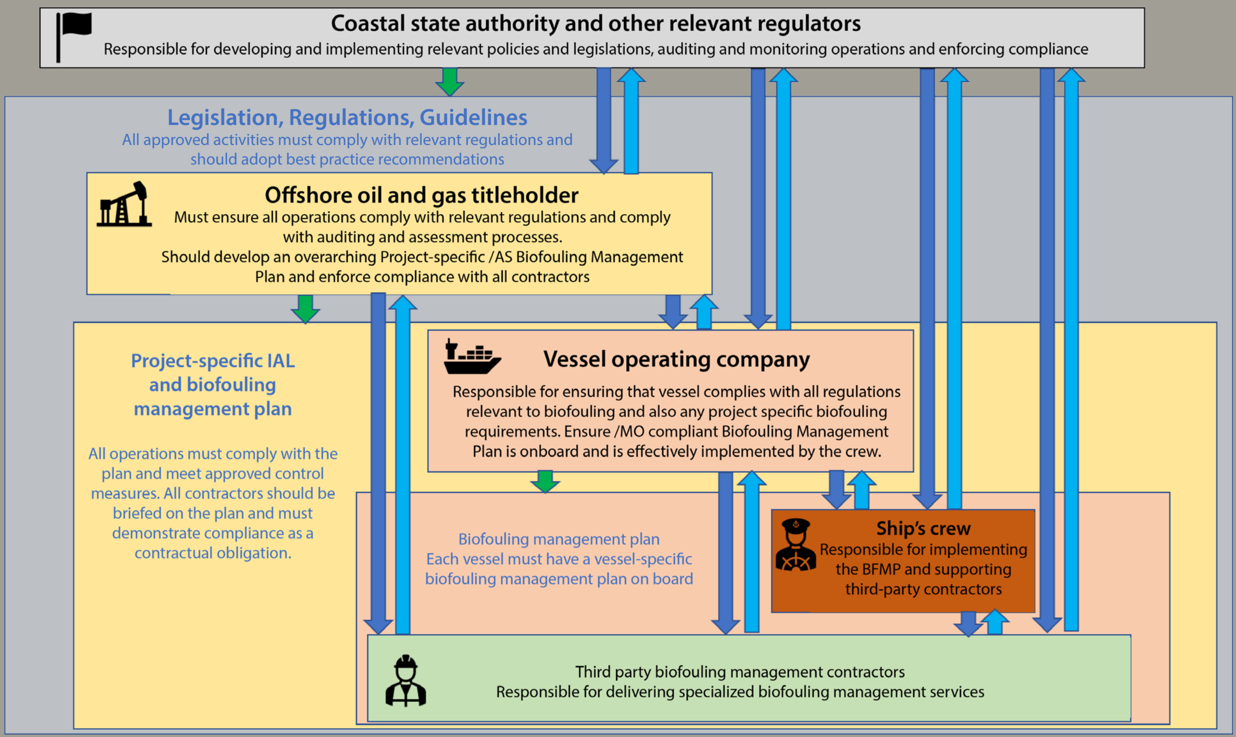


Figure 8. The roles and responsibilities of various entities responsible for managing biofouling in the offshore industry. Green arrows denote a responsibility to draft and maintain indicated instruments. Dark blue arrows indicate lines of authority in the management process and light blue arrows show reporting and compliance obligations. Notably, third-party contractors often have reporting obligations across multiple tiers.

4.1. Coastal state regulators

Offshore operations must comply with a range of regulatory instruments relevant to biosecurity and biofouling specifically, and environmental protection in general. Any single project will typically need to demonstrate compliance with numerous legislative instruments relevant to IAS transfer, often with different pieces of legislation administered by different departments. Furthermore, permitting authorities (often a different department to the one administering specific environmental legislation) are normally responsible for approving environmental plans (or analogous documents) for particular projects, and subsequently auditing offshore operations to ensure that environmental controls (including biofouling management) are adequately implemented as per the approved plan.

Offshore operations frequently straddle regulatory jurisdictions and require the consideration of multiple regulatory bodies both within a coastal state (e.g. federal and state or regional jurisdictions), and across coastal state borders (see Figure 9). For example, offshore support vessels are frequently required to mobilize for short-term contracts that create the need for regular movement between projects located in different jurisdictions. When maritime services are not available in close proximity to a field, some projects also require support vessels to be based in supply ports in different countries, necessitating frequent transit between jurisdictions which complicates approval processes.

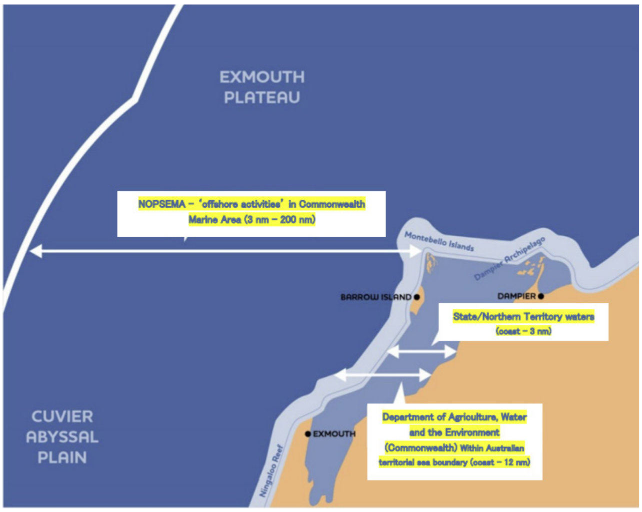


Figure 9. Example of multiple jurisdictions responsible for managing environmental impacts of offshore oil and gas operations in Australian waters.

Source: Adapted from NOPSEMA (2020).

While some regulatory bodies have developed specific pieces of legislation for managing ships' biofouling, more commonly the transfer of IAS is administered through broader biosafety legislation preventing the introduction of invasive or non-native species, or more generally protecting marine ecosystems from environmental impacts and pollution. Currently, a number of regulators are in the process of developing and implementing new policies and/or mandatory regulations focused specifically on biofouling management (in some cases in the oil and gas industry context) applicable to all vessels, including those in the offshore sector (GEF-UNDP-IMO GloFouling, 2022b, 29–30).

Coastal state administrations' legislation relevant to the transfer of IAS have a responsibility to ensure that all offshore oil and gas operations comply with relevant regulations within their area of jurisdiction. However, to ensure that compliance oversight is effective, administrators also have a responsibility to ensure that legislative processes and compliance oversight are coordinated between departments within a particular coastal state.

Compliance officers should also have a clear understanding of how related legislation affects the ability for a particular vessel or operator to meet a required standard. For example, if a particular vessel is required to be free of biofouling, yet in-water cleaning is prohibited within coastal state waters and dry-docking facilities are unavailable, meeting this requirement might be logistically impractical, or might encourage unsafe operations. In some instances, stringent biofouling standards coupled with prohibitions on in-water cleaning have driven vessel operators to engage in offshore cleaning activities that have increased health and safety risks for commercial divers due to sea state and distance from emergency services.

While this document does not attempt to address the full range of responsibilities for coastal states, it is important to note that the education and training of compliance personnel is critical to ensuring the effective implementation of biosecurity policy in general, and biofouling management goals in particular. A practical knowledge of how biofouling operates to transfer IAS, combined with a basic understanding of marine biology and an appreciation for the biofouling management options available to vessel operators, is essential. This knowledge enables compliance assessment personnel to screen biosecurity risks and consider appropriate response options to unacceptable risks more effectively.

4.2. Offshore operators or titleholders

Offshore oil and gas operations are often joint ventures involving multiple corporate bodies; however, in all instances one entity should be designated at the 'operator'

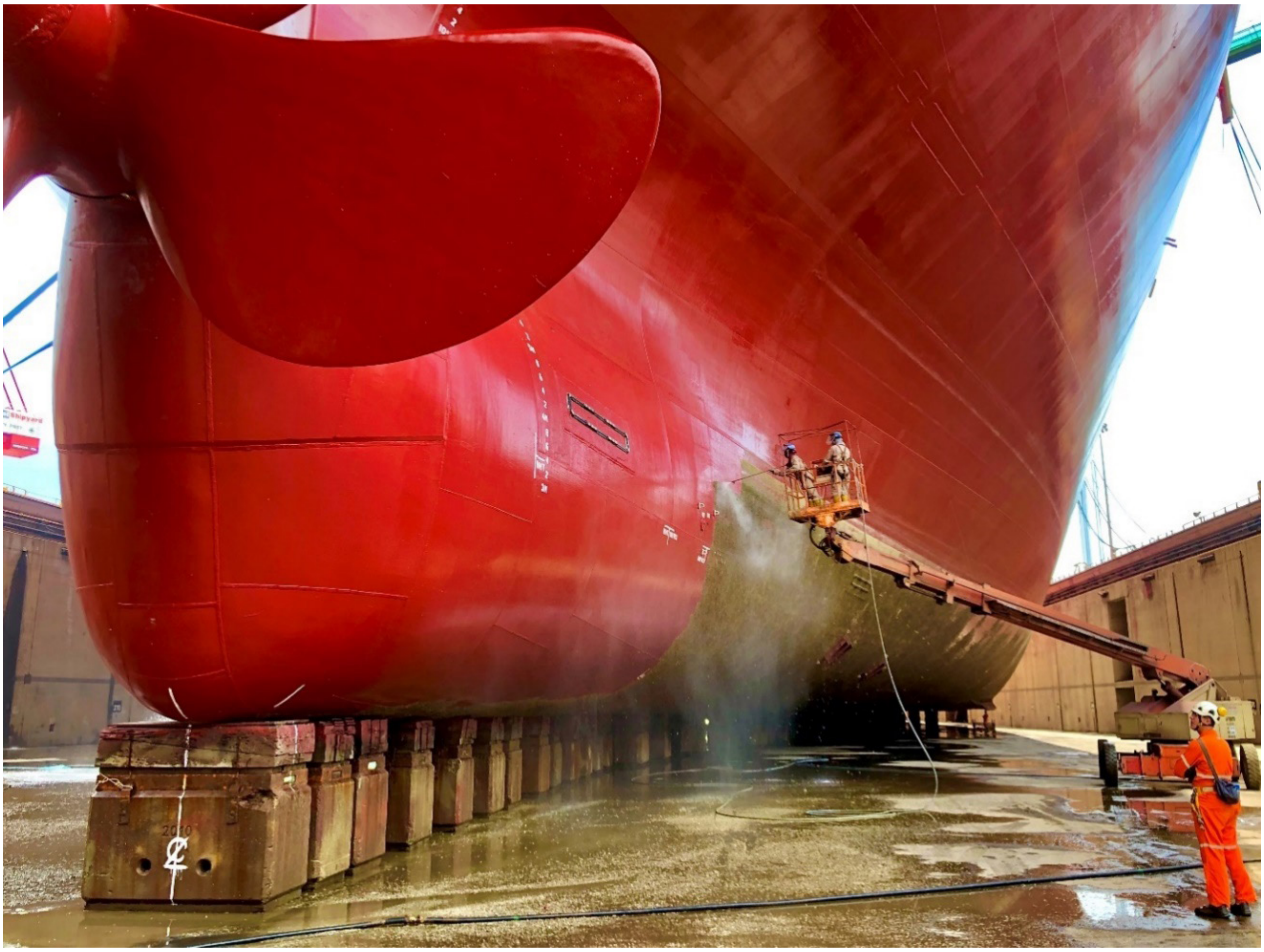


Figure 10. Offshore oil and gas operators, or titleholders, have a responsibility to ensure all contractors involved in servicing a field comply with relevant regulatory requirements.
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or 'titleholder' for a particular project. This entity takes on the full responsibility for ensuring that the entire operation complies with relevant legislation, and that all project-specific requirements relevant to biofouling management are adhered to by vessels and infrastructure servicing the project. Where biofouling management requirements are not mandated, the offshore operator should still take responsibility for developing and implementing effective management plans to reduce the risk of transferring IAS through biofouling to an acceptable level for a particular project (see 5.1).

This document sets out a range of best practice approaches designed to assist the titleholder to develop an overarching strategy to minimize IAS risk and provide clear guidance for all personnel and contractors engaged by the project. It should be the responsibility of the titleholder to ensure that the overarching strategy to manage biofouling incorporates an up-to-date analysis of relevant regulations and provides clear advice regarding management expectations and acceptable (see 5.1) or cost-effective approaches to managing biofouling. The titleholder also takes responsibility for screening operations, both within the organization and those managed by third-party contractors, to ensure that management strategies are effectively implemented. This includes the requirement to ensure that effective management is integrated into the entire supply chain including procurement, and that auditing processes are in place to monitor biofouling and IAS management practices on all vessels.

4.3. Contractors supplying vessels/ equipment

Vessel operators contracted to supply vessels and infrastructure to offshore projects should always seek to manage biofouling to prevent the transfer of IAS. Irrespective of their engagement through the offshore industry, commercial vessel operators should follow the recommendations of the IMO Biofouling Guidelines as well as any local, regional or national requirements that apply to biofouling and IAS. However, offshore operations are typically under significantly greater regulatory scrutiny than other maritime sectors, and vessels servicing the offshore industry are often required to comply with a suite of project-

Figure 11. Companies contracted to supply or operate vessels servicing the requirements of an offshore field must comply with all relevant regulatory requirements and any project-specific requirements introduced by the titleholder. They are also responsible for developing and implementing an IMO-compliant BFMP.
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specific management obligations that do not apply to other forms of shipping.

While many maritime sectors (e.g. merchant vessels, passenger vessels, etc.) are able to have a single overarching strategy for managing biofouling throughout the in-service period (i.e. between dry-docks), vessels supporting the offshore industry often need to adjust management approaches between projects or between geographical regions. For example, irrespective of previous biofouling management actions, some projects may require vessels to undertake in-water inspections prior to mobilization to demonstrate compliance with project-specific requirements. Alternatively, vessel operators may be required to complete a risk assessment to demonstrate that existing management measures are acceptable for a particular project, and if they are not, to identify adequate management actions to achieve an acceptable standard. Such requirements are typically implemented as a contractual obligation and are thus a core requirement to secure ongoing work.

Vessel operators should also consider potential cost and time savings by using routine processes unrelated to biofouling management to collect relevant information. For example, where maintenance of a vessel's submerged surfaces and equipment are required, or when underwater inspections in lieu of dry-dock are scheduled, vessel operators should consider ensuring the collection of high-quality images and closed-circuit television (CCTV) footage from divers or remote operated vehicles (ROVs – operated remotely by an operator on the surface). Having access to footage and images that document the status of biofouling in all relevant areas and compiling reports within the BFRB is likely to assist in decision-making regarding biofouling management and may result in the avoidance of costly dedicated biofouling inspection requirements.

4.4. Onboard crew

The crew of a vessel is responsible for overseeing and implementing biofouling management tasks and supporting the role of third-party contractors such as commercial divers or biofouling inspectors. The biofouling management obligations of responsible personnel onboard should be clearly outlined in the vessel's BFMP. While the designation of individual responsibility for biofouling-related issues will vary between vessels, this responsibility should be clearly communicated and a process should be in place to ensure that this responsibility is effectively handed over during crew changes.

Figure 12. The crew onboard a vessel has a wide range of roles to play in ensuring that biofouling is effectively managed.
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Onboard biofouling management briefing and education are also a responsibility typically carried out by those onboard the vessel, though in most instances it is the obligation of the vessel operator to provide appropriate material and resources to ensure this can be facilitated effectively onboard. As per the IMO Biofouling Guidelines, training for ships' masters and crews should include:

— Impacts of IAS from ships' biofouling

— Benefits to the ship of managing biofouling and the threats posed by not applying management procedures

— How to use and apply the BFMP

— Maintenance of appropriate records and logs

— Biofouling management measures and associated safety procedures, and relevant health and safety issues.

Training approaches should clearly identify responsible parties and ensure that the full range of biofouling management tasks are addressed, including those to be completed during dry-dock (e.g. cleaning, coating application, general maintenance of relevant systems), whilst underway (e.g. internal seawater system maintenance, tracking operational exposures to biofouling and making appropriate routine observations) and during in-water biofouling inspection and cleaning operations.

4.5. Third parties engaged for biofouling management

Best practice biofouling management involves a range of third-party contractors that are engaged to complete or oversee specific biofouling management actions. While the range of services available to assist in biofouling management is constantly expanding, examples of key services include:

— Antifouling coating manufacturers and applicators

— Dry-docks and ship maintenance facilities

— Commercial divers

— In-water cleaning technology providers

— MGPS technology providers

— Chemical treatment companies (e.g. box-cooler cleaning)

— Professional biofouling inspectors

— ROV service providers (inspection and in-water cleaning)

— Biofouling and biosecurity consultants

— Digital service providers (e.g. biofouling management software, etc.).

Third-party contractors specializing in the delivery of biofouling management services are expected to have a clear understanding of their responsibilities and obligations regarding the implementation of best practice biofouling management. As specialists, these contractors should be aware of all relevant regulations and guidelines and be able to provide pragmatic advice and applied solutions appropriate to the needs of a particular vessel or project. Contractors providing specific biofouling management solutions should also be able to provide clear advice regarding the suitability of their services for particular vessels or structures, and explain any risks or concerns regarding the impact of their services on other shipboard systems. For example, in-water cleaning service providers should be able to advise whether their in-water cleaning tools are compatible with particular coating systems (such as silicone release coatings which are known to be vulnerable to abrasion) and whether the potential exists for cleaning to damage the coating and/or reduce its effective service life. Likewise, antifouling coating representatives have an obligation to provide clear advice regarding the suitability of paint systems

Figure 13. Effective biofouling management requires a wide range of third-party contractors to manage biofouling both in dry-dock and once afloat.
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for a particular vessel and should be able to provide a recommended service life for a particular coating system.

Some third-party contractors provide biofouling management services as part of a broader suite of services for vessel operators. As a result, such contractors may not be able to provide specialized advice and may need clear direction in the form of a scope of works document or other guidance to ensure they perform biofouling management tasks to an acceptable standard. In particular, biofouling management is only one task among many during maintenance in a dry-dock facility. Vessel operators should ensure that established processes and guidance is available to ensure that dry-dock crews and contractors are informed of the need to access all niche areas for maintenance (e.g. sea chest grating and rope-guard covers removed, etc.), to ensure that all biofouling is cleaned from non-toxic surfaces and uncoated areas of the hull (e.g. sacrificial anodes, rope guard voids, propellers, etc.) and that the standard of paint application is of a high quality and applied in all relevant areas (including the interior of sea chests and other voids).

4.6. Other stakeholders

There are a range of other stakeholders that play a direct role in IAS and biofouling management. For example, port authorities may be responsible, as part of their mandate, to protect marine environment in waters under their jurisdiction for managing the risk of IAS transfer within port limits and may imposes specific restrictions on vessel entry, apply port levy fees commensurate with best practice environmental outcomes, or prohibit or otherwise limit the options to implement in-water biofouling management within the port limits. Other maritime stakeholders, such as classification societies and industry or trade associations, are also increasing their focus on biofouling management and in some cases introducing their own standards or guidelines.

5 IAS and biofouling management at the scale of an offshore project

Managing the risk of transfer and establishment of IAS is a core environmental duty of all offshore oil and gas projects. Best practice approaches to managing this risk entail the development and implementation of a targeted management plan that addresses all identified IAS risks and outlines specific management requirements targeting identified IAS transport pathways, including ballast water, biofouling and topside immersible equipment (e.g. workboats, fenders, anchor chains, etc.) (Bax et al., 2003; Cunningham et al., 2019). Procedures for best practice management of biofouling should be integrated within a broader management strategy that

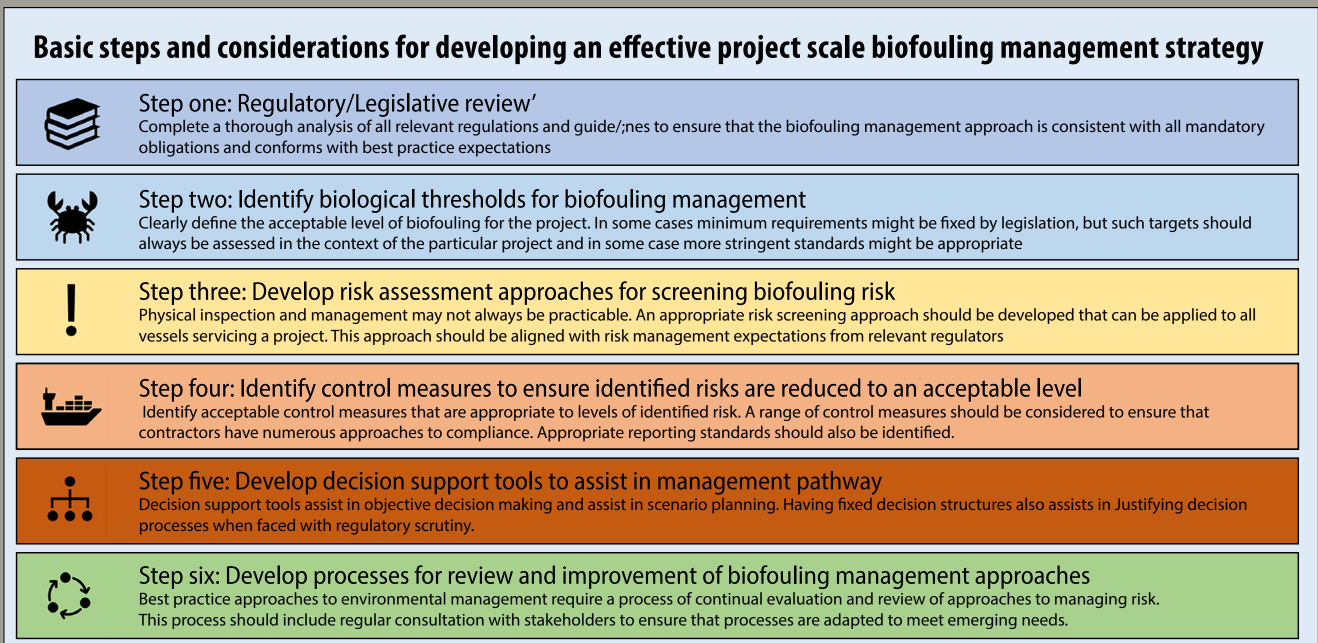

Figure 14. project-scale biofouling management strategy risk-screening approach. Decision-support tools assist in objective decision-making

Source: Patrick N. Lewis, Biofouling Solutions Pty. Ltd.

addresses all regulatory obligations associated with IAS. Ideally, this approach should be framed in the context of a risk reduction strategy that reduces risk to an acceptable threshold (depending on the project, operator and/or the location of the operation) that has been a priori defined for the project.

While any strategy to manage biofouling at the scale of a project should be tailored to the specific needs of the operator and must conform with relevant environmental management regulations and approaches, a number of key steps and considerations should apply to all projects (see Figure 14). This section provides an overview of these considerations.

5.1. Step one: Review of regulations and guidance

The complexity and range of environmental regulations that apply to offshore operations, combined with the operating company's internal sustainability goals and environmental management procedures, means that specific biofouling management requirements frequently vary between projects, even within the same geographical region. Prior to determining an effective management approach to reduce the risk of IAS transfer via biofouling, the offshore project operator should review all relevant legislation and guidelines applicable to the location and the nature of the operation. This includes:

International conventions and guidelines

- Relevant national or federal legislation and guidelines
- Relevant regional, state or territorial legislations and guidelines
- Local, national and port-specific permitting requirements
- Information document and guidance developed by regulators to assist operators in developing compliant biosecurity strategies.

The goal of this review should be to ascertain the minimum requirements for biofouling management that must be implemented to comply with mandatory biofouling and biosecurity obligations, as well as identifying the responsibilities of all entities engaged in the operation. In particular, the review should seek to clearly identify what the definition of acceptable risk is for a particular operation. This should form the basis for all decision-making and should guide all approved measures applied to manage biofouling. Where acceptable risk is defined through the concept of ALARP (i.e. maintaining a risk to levels that are 'as low as reasonably practicable'), acceptable measures may vary according to particular operational and environmental constraints. A detailed overarching management plan is a key tool to justifying the approach adopted by the offshore operator.

While regulations and standards might identify compliance milestones, detailed management plans are required to describe the operational approach needed to meet and maintain these standards. In many cases, environmental compliance is measured in accordance with control measures identified by the offshore operator and subsequently approved by the authority. In this case, it is the responsibility of the offshore operator to develop a best practice approach to reduce risk to an acceptable standard and compliance may be assessed by auditing the implementation and effectiveness of these control measures. Developing a clear decision-support structure to justify the application of identified control measures provides an objective framework to assess compliance in these circumstances.

5.2. Step two: Identifying biological targets for biofouling management

To ensure that reactive biofouling management decisions are simple and objective, an offshore operator should provide contractors with a clear indication of what level of biofouling is acceptable for vessels visiting a project area. Biofouling targets typically fall into two categories: biofouling thresholds and species-specific requirements. While biofouling thresholds are sometimes incorporated into overarching regulations, in some cases offshore operators may choose to adopt more stringent standards (e.g. including a broader range of unacceptable IAS than listed in relevant regulations), or may apply a range of thresholds depending on different classes of operation or geographical areas (e.g. having more stringent thresholds applied to areas identified as particularly vulnerable to IAS or areas with high identified natural values). In other instances, regulatory approaches may be less prescriptive, and as a result the offshore operator may be required to develop a bespoke acceptable threshold for biofouling.

An acceptable level of biofouling might be expressed in a number of ways but should be designed to provide clear and unambiguous advice to assist vessel operators and contractors in making appropriate biofouling management decisions. The threshold should be easily applied by contractors engaged to affect biofouling management and should not, ideally, require specialized expertise to assess and implement. Examples of

Figure 15. A 'species-specific' standard that requires contractors to demonstrate that a vessel is free of IAS such as Japanese kelp (left), Mediterranean fanworm (centre) and the brown mussel (right).
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approaches and their application within the offshore industry include:

a) **A 'species-specific' standard that requires contractors to demonstrate that a vessel is free of a list of undesirable (or 'unacceptable') IAS.**

For example, Woodside Expeditions Limited identifies 'invasive species of concern' within their Invasive Marine Species Management Plan (Peach and Box, 2016). Contractors are required to demonstrate that they represent a 'low risk' of introducing these species within the 'invasive marine species management area'. Where a biofouling inspection is undertaken, the inspection must demonstrate that the vessel is free of these species, or if they are found to be present, in-water cleaning is required to remove them (or alternatively other controls must be applied). While this approach was historically widespread, the difficulties in effectively identifying many pest species combined with the need to manage different types of species in different regions has resulted in a shift of focus towards other approaches. Therefore, the collaboration of sectoral bodies and governments could be a solution to avoid failures in the selection and identification of species of concern.

b) **A 'threshold' approach that defines acceptable biofouling as being below a certain percentage cover value (typically with different values applied to the general hull and niche areas), or alternatively, applies a spatial threshold in addition to a 'functional group' approach that limits the type of biofouling that might be included within the acceptable coverage threshold (e.g. only acorn barnacles, tubeworms, bryozoans, etc.).**

For example, offshore projects operating within New Zealand waters must comply with the New Zealand Craft Risk Management Standard (CRMS) which requires all vessels entering New Zealand waters for less than 21 days to demonstrate compliance with their short-stay threshold (MPI, 2018). While slime and gooseneck barnacles are acceptable on all vessels (as well as some forms of algae), the CRMS sets stringent biofouling thresholds for the general hull and waterline that only allow incidental coverage of other macrofouling (i.e. up to a maximum of 1% which can only be composed of a single species of either tubeworms, bryozoans or barnacles). Likewise, biofouling thresholds for niche areas only allow incidental coverage of macrofouling up to a maximum of 5% which can only be composed of a single species of either tubeworms, bryozoans or barnacles, with the provision for up to a maximum of 1% coverage of a second species of either tubeworms, bryozoans or barnacles.

c) **A 'functional group' approach which limits acceptable biofouling to certain functional groups (e.g. microfouling, gooseneck barnacles, etc.)**

For example, to protect environmental values associated with Barrow Island in Western Australia, Chevron introduced a very stringent biofouling standard requiring that all vessels visiting the vicinity of the island be free of all secondary biofouling (i.e. tubeworms, barnacles and bryozoans) at the point of mobilization (Wells and Booth, 2012). Due to the strong focus on biosecurity, independent verification that biofouling did not exceed this standard was required for all vessels mobilizing to the project. This approach could be an alternative to the species-specific approach, especially if species of concern are not easily identifiable.

Figure 16. A 'threshold' approach that defines acceptable biofouling as being below a certain percentage cover value. *©Biofouling Solutions Pty Ltd.*

Various tiers of government (i.e. local, state and national regulators) as well as other entities (e.g. port authorities, coastal industry representatives, first nations representatives, community groups, environmental NGOs, specialized scientists, etc.) are key stakeholders for the offshore industry, and should be consulted in regard to what represents an 'acceptable level of biofouling' for a particular project area. In some instances, specific natural or cultural values associated with an area or a broader region might result in a case for more stringent rules relating to acceptable biofouling to be applied compared to what might be imposed for other regions or other maritime sectors with a different pattern of operation.

5.3. Step three: Develop risk assessment approaches for screening biofouling risk

Ideally all vessels servicing an offshore project will be able to demonstrate that they meet the acceptable threshold of biofouling through the production of a recent in-water biofouling inspection report. However, this is not always practicable. In some instances, vessels may be transiting between projects regularly and it may not be a reasonable expectation that biofouling inspection reports are produced for every mobilization. In other circumstances, the implementation of best practice biofouling management might provide increased confidence that available documentary evidence of management actions (for example within the BFRB) sufficiently reduces the risk of IAS transfer to within acceptable levels. Considering the complexity of vessel types and the diverse range of operational histories and potential exposure to IAS, an objective approach assessing available information for each vessel is required. This approach can then be utilized to consider the merits of available control measures and ensure that the required management actions are proportional to the perceived risk.

A risk-based approach to managing IAS provides a rigorous framework for decision-making based on an assessment of available data and the theoretical exposure of a vessel to IAS or biofouling. Traditional risk assessment frameworks focus on examining the likelihood of an event (i.e. an IAS introduction) in conjunction with an assessment of the consequences or impacts of such an event occurring. However, many risk-based approaches applied to IAS management assume that the consequence of any identified IAS introduction is unacceptable, or alternatively that any vessels with biofouling exceeding identified thresholds represents an unacceptable risk. As a result, many risk-based models applied to IAS dispense with a detailed analysis of a risk approach focusing on likelihood and consequence, and focus instead on the likelihood that vessel are either contaminated with IAS or biofouling exceeds acceptable thresholds.

5.3.1. Basic informational requirements

Prior to making informed decisions regarding biofouling management and completing risk screening, Titleholders should collect key information about any vessel contracted to provide services for the project. This information should typically be provided within the vessel's BFMP and record book, but where this is not readily available, the information required to make an informed decision on biofouling management (both during the screening and the pre-screening process) should include, at least, the following:

- Antifouling coating certificate (including expected lifespan)
- Voyage history since last dry-dock showing all lay-up periods (when ship is operating outside its normal operating profile)
- Vessel general arrangement
- Vessel docking plan
- Schematics of all internal seawater systems (including records of when they have been inspected, cleaned or treated)
- Information about MGPS (including records of operation and maintenance)

- Details of any previous biofouling inspections or cleaning operations
- Information about niche area configuration, including areas that are vulnerable to biofouling accumulation or difficult to treat or clean in-water (e.g. box coolers).

5.3.2. Overarching vessels and infrastructure screening assessments

Likelihood assessment tools developed to screen contracted vessels for theoretical IAS or biofouling risk are a useful approach to identifying the need to adopt biofouling management actions prior to mobilization. Because the acceptable threshold for risk is likely to vary between projects, companies and regions of operations, such assessment approaches should be devised with clear targets in mind and with sufficient data to support any assumptions underpinning the assessment.

A variety of overarching risk assessment approaches have been widely implemented in the maritime and offshore industry, including approaches focused on habitat similarities between source regions and project areas (Barry et al., 2015) and approaches which focus primarily on the impact of biofouling management actions and vessel history on the exposure of a vessel to IAS or biofouling accumulation. This latter category is more common in the offshore industry and vessel risk assessment score sheets (VRASS) have been developed as commercial models by a range of companies. The VRASS approach allocates numerical weightings to various biofouling management actions and vessel history parameters, and produces a numerical output that must fall within an acceptable range or further management action is required. Project-specific tools similar to VRASS should be developed with consultation with subject matter experts to ensure that the likelihood of IAS transfer is maintained within acceptable boundaries. A VRASS approach should also ensure that operational requirements are not compromised due to excessive management expectations. Overarching assessments should use available information commonly available for all vessels to ascertain the likelihood that a vessel is compliant (or on-compliant) with an acceptable threshold. Currently, this is partly implemented within different countries. For example, New Zealand takes various risk factors into account and allow vessels with varying amounts of biofouling to stay in the country depending on the duration of a vessel's intended stay (Zabin et al., 2018).

In some circumstances, a theoretical assessment showing 'low' risk might be sufficient for a vessel to proceed directly to a project area without further interventions. Alternatively, moderate- or high-risk vessels would likely require intervention or other control measures prior to proceeding. By providing a range of risk assessment outputs, vessel operators and environmental advisors can assess a range of biofouling management approaches or control measures that are proportional to the identified risk.

5.4. Step four: Identify acceptable biofouling control measures

The range of acceptable management actions for an identified biofouling risk will vary according to the regulatory controls in places, the vessel or structure in question and the availability of contractors or equipment to complete the tasks. In particular, the selection of management options should be guided by the specific history of the vessel and a good understanding of the source of any identified risk. Where a vessel has recently been released from dry-dock but has been allocated an unacceptable risk status due to a longer than expected lay-up prior to mobilization, an in-water inspection may be inappropriate because recently recruited IAS are likely to be juveniles and not easily detected by divers or remotely operated vehicles (ROVs). In such an instance, operational controls such as limiting time in-field may be more appropriate or cost effective. A detailed discussion of relevant biofouling control measures is provided in Section 6.0.

5.5. Step five: Develop decision-support tools to assist in management

Decision-support trees (and similar tools) can provide objective decision pathways based on biofouling management scenarios are routinely used in the offshore industry. This approach assists contractors and environmental advisors to identify cost-effective management options, and provides a robust framework to justify decisions and the application of approved control measures. Because the range of consideration and acceptable approaches are likely to vary between projects, any decision-support tools need to be customized for each project but should include some key elements (see Figure 17).

When developing decision-support tools to guide best practice biofouling management, consideration should be given to the relative effectiveness of management measures in relation to identified risk. For example, a dry-dock inspection and clean provides the highest level of confidence in identifying and removing problematic biofouling, and allows access for all niche areas to affect a full clean and/or treatment. In contrast, in-water

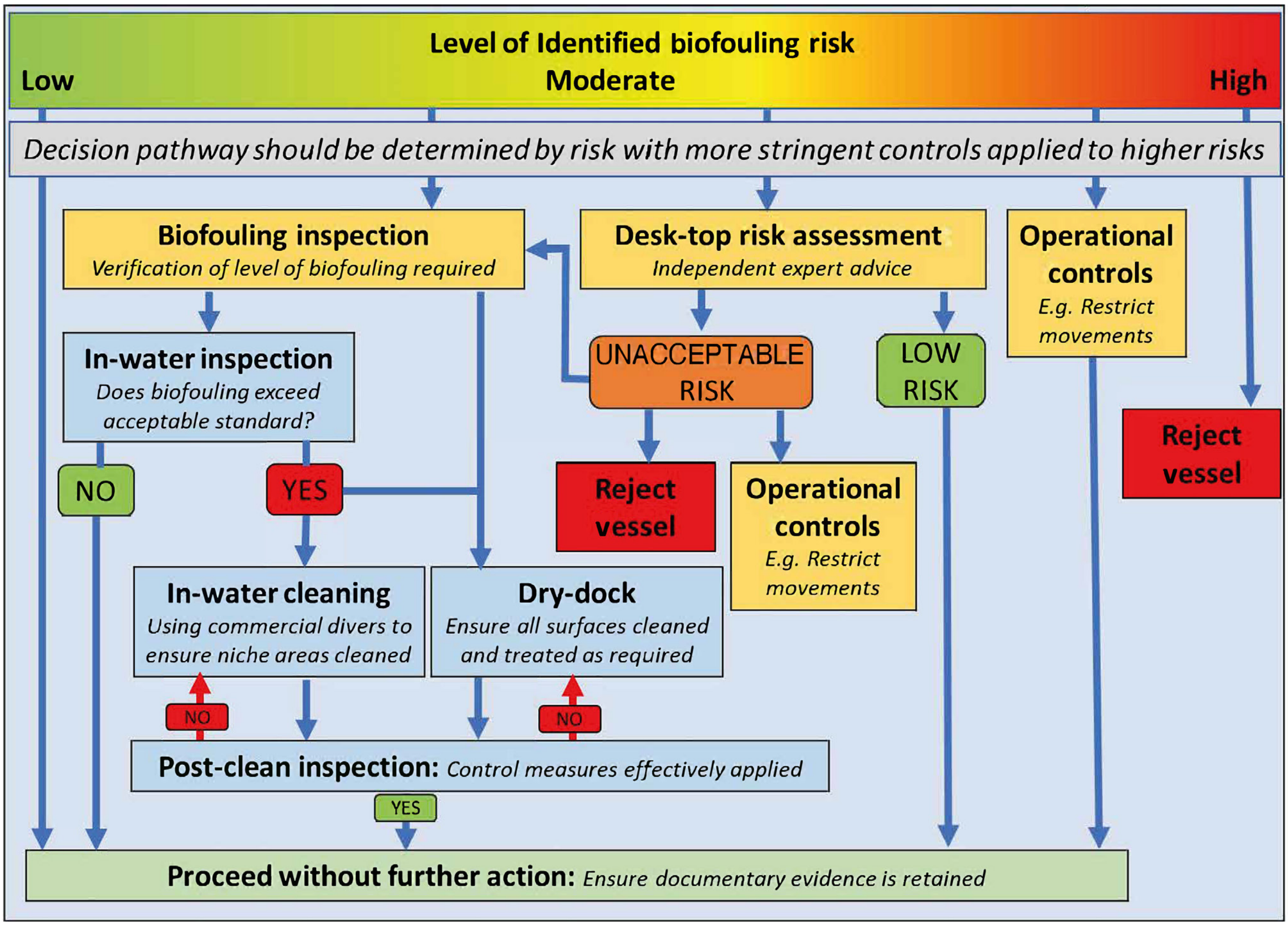

Figure 17. A theoretical example of decision pathways to ensure biofouling is managed to an acceptable standard. Projects should identify appropriate control measures based on risk considerations unique to the project. This example does not attempt to allocate particular actions based on specific risk categories (i.e. low risk/medium risk/ high risk) and titleholders should determine management pathways appropriate to their needs.

Source: Patrick N. Lewis, Biofouling Solutions Pty. Ltd.

inspections provide an effective means of determining the status of biofouling; however, due to potential access limitations to areas like the insides of sea chests, this approach does not provide the same level of confidence and residual biofouling risk may persist despite best efforts. While in-water cleaning may be more attractive due to cost and time considerations, in some instances, high-risk vessels with heavy biofouling might find that dry-dock is a more cost-effective option. For example, where a complete clean is required to remove an identified risk, divers may not be able to access some areas (due to access constraints), some equipment such as box-coolers may not be able to be easily and effectively cleaned in the water, and in some cases the cost of a multi-day commercial clean may exceed that of a dry-dock.

5.6. Step six: Develop review and improvement approaches

To ensure biofouling management arrangements can be continuously implemented effectively over longer time periods, offshore operators should identify a process for continuous review of new information relevant to risk management. This is particularly relevant for offshore project managers with ongoing operations. Continual review and auditing of all responsible parties allows for improvements to be made and to ensure that documented approaches are updated in response to new learnings, technologies and input from relevant stakeholders.


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6 Applying control measures to mitigate biofouling risks

Once an unacceptable biofouling risk is identified, vessel operators need to choose from a range of potential control measures. The biofouling management approach adopted should be guided by best practice management considerations as well as the overarching management approach implemented by the relevant titleholder. In addition to considerations regarding desired environmental outcomes, the selection of control measures to be applied should consider cost and time implications to ensure that the management approach is practicable. Environmental advisors engaged by the titleholder to ensuring compliance should be able to provide decision-support tools or other guidance documents to ensure that biofouling management decisions are straightforward.

6.1. Managing biofouling in dry docks and vessel maintenance facilities

Dry-dock maintenance is a critical element of best practice biofouling management, while it is also considered important for the naval industry. While emersed, vessel managers can assess the performance of previous antifouling coating systems (and consider alternatives if needed), ensure that cleaning and surface preparation removes all residual biofouling, oversee the application of a full antifouling coating system and collect relevant information and reports to ensure that biofouling management records meet the expectations of biosecurity regulators as well as any project-specific requirements that are in force for future projects.

Figure 18. Best practice biofouling management in dry-dock requires coordination between the ship's crew and various contractors.
©Biofouling Solutions Pty Ltd.

6.1.1. Antifouling coating selection

There are a huge number of antifouling coating systems on the market employing a range of physical and/or chemical properties to prevent the accumulation of biofouling on submerged surfaces. While biocidal coatings (i.e. coatings using toxic components to deter settlement) are most prevalent, an increasing focus on environmental stewardship has resulted in many alternative systems (typically referred to as non-toxic coatings) that use physical properties or other mechanisms to deter the settlement of biofouling. This is an area with significant innovation and regular technological advances, and vessel operators should consult subject matter experts and coating representatives when selecting appropriate coating systems for their vessel or fleet. It is important to recognize that more sophisticated (i.e. better performance under certain conditions, though more costly) coating systems are often more expensive than more standards systems, but selection of a coating type should consider much more than cost. For example:

- Dry-docking interval and the required effective life of the coating (i.e. time between full coating applications)
- Operational wear and tear on coating systems (e.g. anchor chain wear, fender damage)
- Planned in-water grooming operations that might result in damage to vulnerable coating systems
- Opportunities to apply touch up coating opportunities during more frequent dry-dockings
- The requirement for regular in-water cleaning operations and the potential impact on coating life
- The consideration of alternative coating systems applied to niche areas experiencing reduced flow

6.1.2. Implementing best practice management in dry-dock

Vessel managers and superintendents should be aware that dry-dock procedures to implement best practice biofouling management require dedicated personnel to oversee a range of biofouling management-related tasks, and to collect relevant information and generate required reports. Some offshore oil and gas operators require third-party oversight by recognized experts (e.g. biofouling inspectors) and inspection reports to be generated during dry-dock so that environmental advisors can make informed and objective decisions on whether a vessel meets regulatory and project-specific requirements. This role, typically referred to as a biofouling inspector, is separate from the role of an antifouling coating representative whose role is to provide advice on the selection of appropriate coating systems for the vessel, to ensure appropriate cleaning and surface preparation and to ensure that the system is applied according to the manufacturer's recommendations.

At the completion of a dry-dock, vessel operators should have a full record of all relevant biofouling management measures that have been implemented, and these should be added to the BFRB. While specific measures completed during a particular docking will vary, records might include:

- Classification Society antifouling coating certificate (demonstrating compliance with the International Convention on the Control of Harmful Anti-fouling Systems on Ships)

— Paint company antifouling certificate (issued by the coating representative and preferentially including a statement regarding the effective life of the coating system)

— Coating application report (issued by the coating company representative and providing details regarding the coating systems applied, film thickness, ambient environmental conditions and other relevant details)

— Dry-dock inspection report providing photographic evidence of the vessel prior to release from dry-dock and demonstrating that all niche areas of the vessel are free of biofouling and managed in accordance with the vessel's BFMP (issued either by designated crew members in charge of by a third-party independent contractor).

— Reports detailing any MGPS system anodes and sacrificial anodes replaced.

— Biofouling treatment report detailing the treatment of any areas that require chemical treatment or other approaches to clean (for example chemical or steam treatment of void areas or box coolers to remove biofouling or render it non-viable).

6.2. In-water inspections

Best practice biofouling management relies upon regular in-water inspections to determine that biofouling does not exceed acceptable standards. Such inspections should include an assessment of the general hull but also must provide detailed photographic evidence of the status of biofouling within niche areas.

Despite many coating systems being designed to provide effective protection from biofouling for extended timeframes (e.g. 60–90 months), the functional designs of these systems are targeted towards limiting the impact

Figure 19. Ensuring that dedicated personnel are available to complete an initial inspection, oversee required cleaning and complete a thorough inspection at the end of the docking is essential. ©Biofouling Solutions Pty Ltd.

Figure 20. Regular in-water inspections are an essential component of ensuring biofouling is effectively managed during the in-service period. ©Biofouling Solutions Pty Ltd.

of biofouling on fuel consumption rather than preventing IAS transfer. Antifouling coating systems are generally designed to perform optimally on the general hull of a vessel where they are exposed to water flow which affects the rate of release of biocides from the leached layer, or where water flow facilitates the action of fouling release coatings. The performance of many coating systems in niche areas such as sea chests and thruster tunnels are typically poorer due to altered water flow conditions. Furthermore, deviations from an expected operating profile such as extended port stays and reduced operating speeds can result in reduced performance of a coating system over the general hull of a vessel while the coating system is still relatively new. Even in ideal circumstances, the performance of an antifouling coating system is expected to decline with time and it is unreasonable to assume that general hull surfaces and niche areas will remain free of biofouling between dry-docks. Finally, some areas of the vessel hull have no protection from biofouling (e.g. sacrificial anodes, propellers) and areas like dry-dock support strips are prone to biofouling accumulation. As a result, even in ideal circumstances in-water biofouling inspections are required to monitor the level of biofouling and to trigger cleaning when required (either in-water or through dry-dock).

A range of potential approaches are presented below to guide vessel operators and offshore project operators when determining the appropriate timing and/or frequency of in-water biofouling inspections:

6.2.1 Inspection obligations fixed by regulatory requirements or recommendations

When operating in some coastal state jurisdictions, vessel operators will be required to comply with overarching mandatory biofouling inspection requirements that are independent of any project specific obligations specific to the offshore industry. For example, the New Zealand Ministry of Primary Industries expect that vessels entering New Zealand territorial waters for less than 21 days will complete an in-water inspection every 12 months in the first two years following the application of a new antifouling coating system, and every six months once the coating system is over two years old (MPI, 2018). Vessel operators and offshore extraction companies should carefully review legislation and other requirements to ensure that vessels meet any mandated or recommended inspection frequencies.

6.2.2. Project-specific inspection obligations prior to mobilization

Vessels contracted to support offshore projects frequently move between projects with different biofouling management requirements and in some instances may be laid up for extended periods between projects. This means that the effectiveness of antifouling systems and the operation of factors contributing to biofouling accumulation and IAS risk can vary dramatically between vessels. To address this risk, some projects adopt a conservative approach and require all vessels to undertake a biofouling inspection prior to mobilization for a particular project. Pre-mobilization biofouling inspections are particularly warranted for the mobilization of large assets such as fuel production storage and offtake units and other infrastructure that is designed to remain in the field for extended periods, and where offshore conditions might limit or eliminate opportunities to facilitate biofouling management upon arrival in the field. Considerations for biofouling inspections when mobilizing large assets are considered in greater detail in Gust et al. (2019).

6.2.3. Regular scheduled inspection frequency

Ideally, a vessel should nominate a regular biofouling inspection frequency that forms part of the scheduled maintenance of the vessel. This enables maintenance routines to be planned in advance to ensure that resources and third-party contractors are available to meet the schedule, and to avoid the need for emergency maintenance due to identified biofouling related risks or compliance action enforced by regulators. Regular biofouling inspection schedules that are clearly identified within a vessel's BFMP form a key part of compliance assessment and risk screening for biosecurity authorities and offshore field operators, and facilitate a simplified approach to assessing best practice biofouling management. Furthermore, this approach ensures that biofouling management is consistently applied through the operation of a vessel and IAS risks are maintained at a relatively low level.

6.2.4. Reactive inspections triggered by exposure to IAS or identified risk

A key expectation of a BFMP is the identification of reactive management measures that need to be implemented in the case of increased exposure to biofouling. Irrespective of past patterns of operation, where a vessel is laid up for an extended period in port, or exposed to significant IAS risk due to operational or geographical consideration (e.g. prolonged proximity to a known IAS population), the BFMP should trigger a reactive biofouling inspection. Expectations for reactive biofouling management should be clearly articulated in a vessel BFMP and also identified within project-specific biofouling management requirements. Where a theoretical risk assessment indicates that biofouling-associated risk is unacceptable, in-water inspections provide a means to validate the assessment and identify required management action.

6.3. In-water cleaning and grooming and treating problematic biofouling

In-water cleaning is frequently the most cost-effective approach to meet a biofouling management requirement. However, vessel operators should consider a range of issues prior to defaulting to in-water cleaning. For example, in some instances design considerations, such as the presence of box-coolers or access constraints, might mean that the required standard of cleaning is not possible to achieve using commercial divers or other in-water techniques. In some instances, a dry dock or alternative (e.g. transportation via a heavy lift vessel) may be more cost-effective and result in a higher degree of certainty in the biosecurity outcome.

6.3.1 Grooming biofouling to manage general hull surfaces

The use of proactive grooming of a vessel to maintain biofouling below a certain threshold can be used by vessel operators to reduce biofouling-related drag and to ensure that fuel costs and also greenhouse gas emissions are minimized. Grooming is a distinct process from in-water cleaning and is designed to minimize drag rather than prevent the transfer of IAS, while its effectiveness is still under evaluation (Hunsucker et al., 2019; Swain et al., 2022). Notably, a recently groomed vessel can be found to be clean in terms of the plating on the general hull, but still include significant levels of biofouling in niche areas and adjacent to features that limit the accessibility for grooming equipment. Because grooming is normally conducted using brush-karts (operated by commercial divers) or specialized ROVs (operated remotely by an operator on the surface), grooming is not capable of cleaning all areas of a submerged hull. While grooming contributes to cleaner hulls in general, to meet biosecurity outcomes, in-water grooming should be completed in conjunction with targeted niche area cleaning.

6.3.2 Physical cleaning to remove biofouling to meet biosecurity standards

Reactive in-water cleaning to achieve a biosecurity outcome is very different to an in-water grooming, operation focused on fuel efficiency. While the latter is typically targeted towards removing slime and light biofouling from general hull surfaces, an in-water cleaning

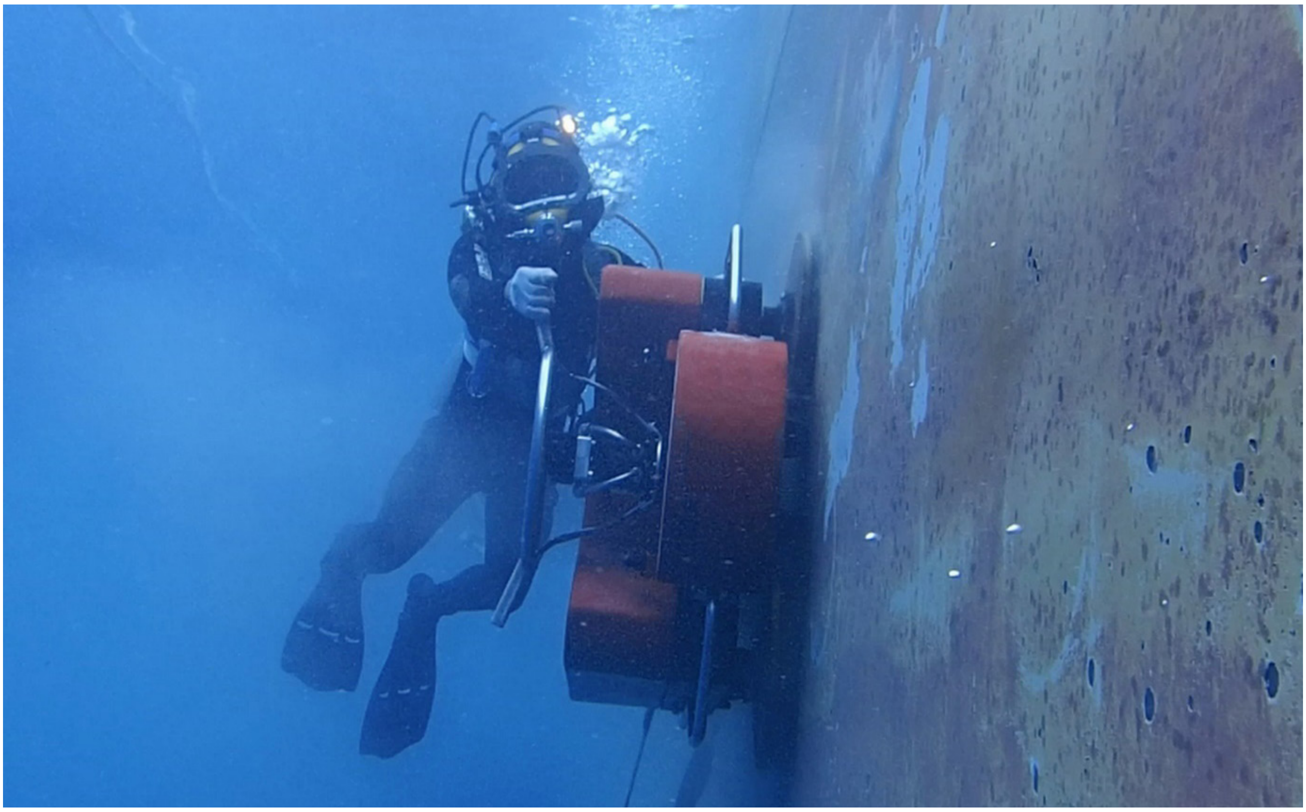

Figure 21. A wide range of equipment is available to facilitate effective in-water cleaning on biofouling. ©Biofouling Solutions Pty Ltd.

operation is designed to meet a biosecurity standard and/or prevent the transfer of IAS and must ensure all niche areas that have unacceptable levels of biofouling can be accessed for cleaning and/or treatment. While grooming equipment such as brush-karts and/or ROVs might be used to clean general hull surfaces, in-water cleaning will also require the use of additional equipment such as hand-scrapers, high-pressure water jets and cavitation wands to clean niche areas as well as hand scraping. In some instances, inaccessible areas may need to be treated during an in-water cleaning operation to ensure all biofouling is rendered non-viable. One example of cleaning and capturing biofouling to prevent its dispersal during cleaning is the in-water cleaning and capturing system, with which different cleaning equipment could be used, such as the Subsea Global Solutions (SGS) Remora plus Whale Shark arrangement (Tamburri et al., 2020). This system works efficiently but it has limitations depending on the biofouling coverage percentage, the types of organisms present and the amount of hull surfaces (Tamburri et al., 2020). It is indeed recognized that some areas may not be able to be cleaned during in-water operations due to access constraints, diver safety or potential damage to equipment; these issues should be considered when assessing the best approach for biofouling management.

To facilitate effective in-water cleaning, vessel operators should be able to provide clear guidance to commercial divers or other contractors regarding the required scope of work. This should include itemization of all niche areas and a diagram or general arrangement schematic showing their location, clear explanation of the expected result of the cleaning operation and guidelines on the acceptable level of biofouling that can remain after the cleaning. Vessel operators should also liaise with contractors to ensure that cleaning techniques are compatible with the coating type used on the vessel and will not cause damage and reduce coating performance. There is also a need to ensure that the commercial dive operator holds the appropriate permits to complete the work and is complying with all national, local and port authority regulations or requirements relevant to biofouling management (e.g. in-water cleaning standards, recapture requirements, regulations pertaining to copper or heavy metal discharges associate with cleaning, etc.). Vessel operators should be prepared to thoroughly brief the dive supervisor when on board and address required diver safety consideration including implementing appropriate safety controls on equipment to prevent diver injury.

Vessel operators need to ensure that in-water cleaning operations are appropriately documented so regulators and third-parties are able to verify the standard of cleaning achieved. Some jurisdictions provide specific guidance on reporting standards for in-water cleaning and where relevant, these should be passed on to the contractor to ensure that this reporting standard is achieved. In some instances, an independent third-party report is required to verify that the standard of clean reported is an accurate representation of the residual biosecurity risk or whether specific biofouling threshold requirements have been achieved. Detailed in-water cleaning report should be appended to the vessel BFRB.

6.4. Treating biofouling to render it non-viable

Some risks associated with biofouling and IAS transfer cannot be adequately managed using in-water cleaning techniques or by dry-docking (or desiccation). For instance, some niche areas of a vessel hull may not be accessible for cleaning, or some features might be vulnerable to mechanical damage during the cleaning process (e.g. box coolers). Sometimes, in-water cleaning is not possible due to national, local and port authority regulations or requirements that prohibit this activity. In other circumstances, emergency reactive management might be required to address an identified risk and immediate measures might be required to eliminate or contain a particular IAS or biofouling-related biosecurity threat.

While a range of techniques have been applied to treat biofouling or otherwise render it non-viable, in most cases vessel operators should engage a suitably qualified subject matter expert to ensure that the treatment is both effective and able to be achieved to an acceptable standard with available resources. Examples of such approaches including wrapping or sealing niche areas such as sea chests (or in some cases the entire vessel) to enable chemical treatment (or de-oxygenation), steam or heat treatment (Piola and Hopkins, 2012; Joyce et al., 2019) or the use of de-scaling chemicals (Piola and Grandison, 2013). Most approaches to treating biofouling in the water require bespoke approaches that need to be adapted to the specific configuration of the vessel and might require engineering input to develop or deploy suitably configured equipment. Where clear empirical evidence is not available to demonstrate the efficacy of a particular approach, treatment might need to be accompanied by dedicated diver surveys to verify that the process has achieved the goal of rendering biofouling non-viable.

6.5. Vessel operational controls

In limited circumstances (i.e. due to costs, operational constraints or the lack of biofouling management capabilities), biofouling management approaches may not be pragmatic or possible to implement for a particular vessel or pattern of operation. Where such limitations exist, the risk of IAS transfer might be reduced by applying operational constraints on the vessel. For example, the risk of IAS transfer might be reduced by applying strict limits on the time a vessel spends within shallow coastal waters where IAS are likely to establish. The justification for such an approach is that the likelihood of successful reproduction and release of larvae, or the dissociation of viable individuals from the biofouling community during a smaller time window will be limited, and the likely scale of release of viable propagules over this shorter time period will be reduced. As a result, the application of time limits ensure that propagule pressure is proportionally reduced and the probability of released individuals, gametes or larvae establishing a successful population in the recipient regions is also reduced. Notably however, this assumption might not apply to species capable of asexual reproduction or regeneration from fragments, so IAS risks should be carefully assessed before adopting or approving such an approach and operational controls should not be applied as an alternative to best practice biofouling management.

Examples of operational controls include applying proximity limits for support vessels interacting with offshore infrastructure and reduced biofouling management requirements for vessels that are sourced from areas that represent a low environmental match for the project area (e.g. vessels mobilized from tropical ports to service temperate projects). Wherever such operational controls are considered, they should be assessed in conjunction with a detailed analysis of the biotic and abiotic factors that contribute to the risk of IAS transfer, and regulators and subject matter experts should be consulted to determine whether such approaches reduce risk to an acceptable level and whether the proposed approach represents an acceptable solution for all stakeholders.

6.6. Desktop risk assessments

Desktop risk assessments refer to comprehensive theoretical risk assessments undertaken by independent third parties. This approach normally requires the collection of significant biological and physical data to supplement the type of information that is readily available for overarching assessments (see Section 5.3.2). There is a broad range of risk assessment models that can be employed to further explore risks associated with biofouling; however all approaches provide less certainty than physically inspecting a vessel and, as a result, should only be employed where inspection is not practicable. Alternatively, desktop risk assessment can be useful to identify the efficacy of proposed management approaches, or to examine whether natural barriers such as seawater temperature and salinity gradients

Figure 22. Lifting equipment out of the water using a heavy lift vessel can facilitate desiccation of biofouling. ©Biofouling Solutions Pty Ltd.

are sufficient to reduce the risk of identified IAS species surviving mobilization and establishing populations in project areas (or adjacent coastal regions).

6.7. Desiccation as a means to manage biofouling

Where vessels or other assets are mobilized to a field as dry cargo aboard heavy lift vessels (see Figure 22), or where vessels spend extended periods in dry docks or vessel maintenance facilities prior to mobilization, desiccation stress may be sufficient to render biofouling non-viable. While desiccation pressure affects different organisms at different rates, and is dependent upon ambient conditions experienced during emersion (i.e. temperature, relative humidity, exposure to sea spray, etc.) some authors claim that periods of emersion in excess of 21 days are sufficient to effectively render most species non-viable (Inglis and Floerl, 2012).

While leaving biofouling intact and relying on desiccation to kill entrained organisms may reduce IAS risk, this is not recommended as best practice biofouling management. This is because the matrix of habitat provided by dead and desiccated organisms provides an ideal settlement surface for new biofouling organisms. This means that the rate of biofouling accumulation once exposed to the marine environment is likely to be rapid. Where a vessel is relying on desiccation stress to manage IAS risk, once release from dry-dock and prior to leaving coastal waters, the risk of contamination with IAS is significantly higher than for vessels that are appropriately cleaned and antifouled. Furthermore, when intact (but presumably dead) biofouling is still attached to the vessel hull, any post-arrival surveillance operations may be compromised due to the difficulty in distinguishing between dead and viable organisms. Therefore, desiccation would only be secondarily and rationally applicable if followed by a thorough biofouling removal. Finally, substantial accumulations of biofouling will contribute to a range of operational consideration such as drag, fuel consumption, greenhouse gas emission and loading stress and should be avoided wherever possible.

6.8. Managing internal seawater systems

Internal seawater systems draw seawater from a sea chest or intake port to provide essential services and cooling functionality to on-board systems. As these systems directly draw seawater from the adjacent ocean, they are also prone to accumulating biofouling organisms as well as free-living species such as crabs, fish and mobile invertebrates.

Best practice management of biofouling within internal seawater systems includes the installation and maintenance of an effective MGPS as well as a regular inspection schedule for all primary seawater strainers to ensure that MGPS systems are functioning effectively (and to ensure that blockages are not affecting the functional operation of the system). Where large crossover trunks or cofferdams are present, the vessel operator should also ensure that MGPS systems are installed and that appropriate antifouling coating systems are applied to internal surfaces.

As access to some features of internal seawater systems are not possible during the in-service period (e.g. flooded crossover trunks, areas of piping upstream of the primary valve, large firefighting systems and other systems without strainers installed, etc.) biofouling management for some elements of internal seawater systems can only be achieved during dry-dock (e.g. antifouling coating applications within crossover trunks; MGPS anode replacement, etc.). In other instances, biofouling management of internal seawater systems should be included as part of the routine scheduled maintenance of the vessel (e.g. MGPS system monitoring or biocidal dosing system checks, seawater strainer inspections, etc.). Where problematic biofouling is encountered during routine maintenance, this biofouling should be removed and disposed of in accordance with appropriate regulations (appropriate means of disposing of biological wastes should be detailed in the vessel's BFMP).

6.9. Topside immersible equipment

Topside immersible equipment refers to items that are typically stored on deck but periodically come into contact with seawater or the seafloor. While this equipment does not typically represent a high risk of IAS transfer, some items of equipment such as anchors and anchor chains have been associated with the transfer of viable IAS between regions, and other equipment such as large fenders (e.g. Yokohama fenders) can be immersed for longer periods and thus accumulate biofouling that might be transferred between locations. A vessels' BFMP should include provisions to ensure that all relevant topside equipment is appropriately cleaned and decontaminated prior to being transported and deployed in a new geographical region. Furthermore, procedures should be itemized to ensure that anchors, chains and chain lockers are thoroughly cleaned during each dry-dock, hose chains are washed down when heaving the anchor and that these actions are recorded in the BFMP.


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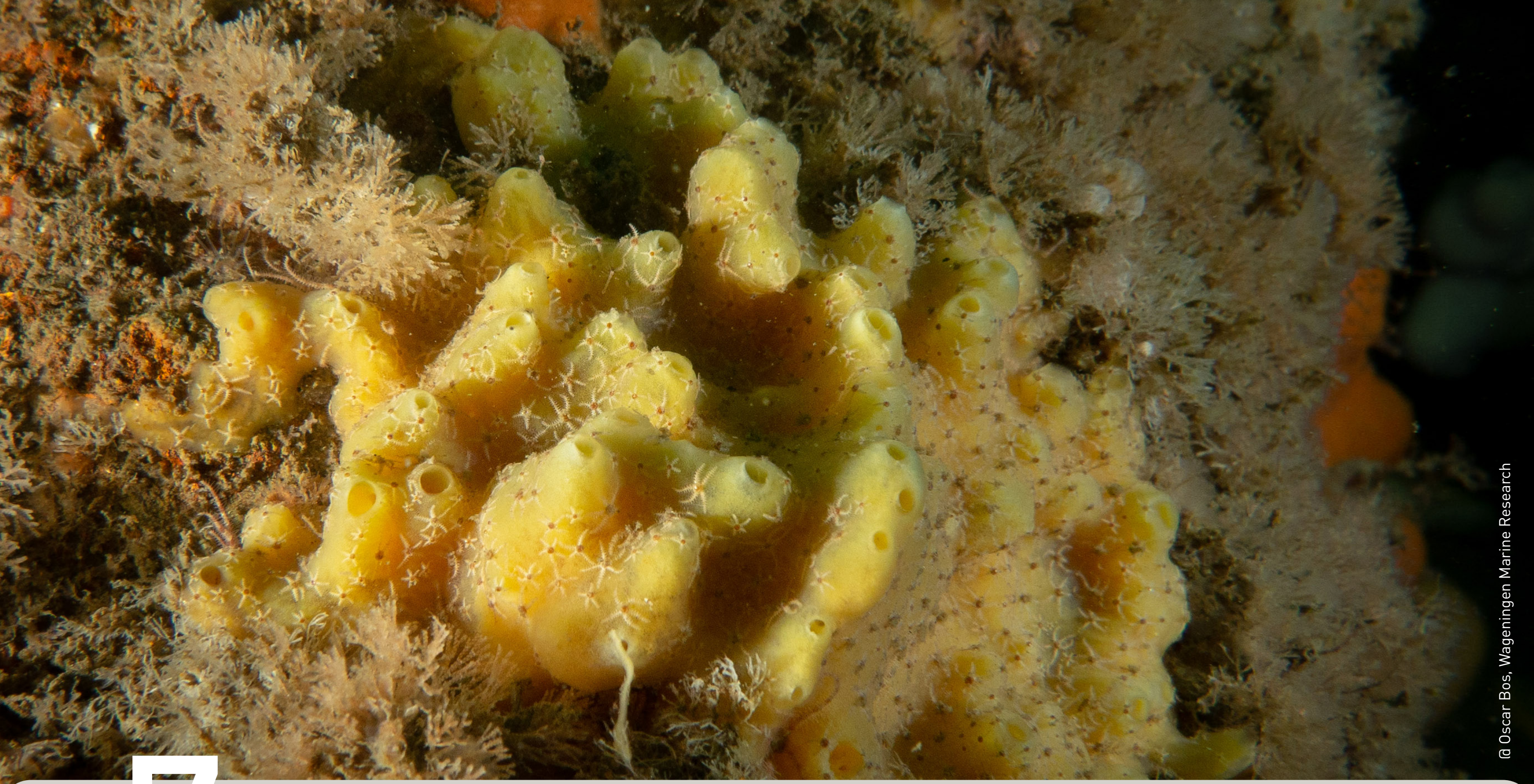

7 Conclusions

Biofouling on offshore oil and gas vessels represents a significant pathway for the introduction of IAS to offshore project areas and also adjacent coastal areas and supply ports. Because patterns of operation within the offshore oil and gas sector create IAS pathways that are significantly different to those facilitated by other forms of maritime traffic, and because some types of offshore infrastructure are prone to supporting significant biofouling assemblages, managing biofouling should be a core environmental obligation for offshore project operators, especially in cases where biofouling management requirements are not mandated.

Acceptable standards of biofouling management are not defined and may vary between operators, projects and locations, making a universal/international management plan difficult to establish. Some general (but not international) conventions for the control and management of biofouling on vessels have been provided by organizations such as the IMO, but they are not mandatory. There are significant legal and regulation differences in biofouling management practices among countries, offshore operators and even equipment used. The management of assets that are designed to be installed for long periods in offshore environments still remains one of the most significant biofouling management challenges. Therefore, it seems that biofouling management procedures should be developed independently for each vessel to address management approaches that are relevant to each vessel's nature, location, route, etc. All these make the achievement of biofouling management best practices and the establishment of a universal array of regulatory biofouling mechanisms challenging.

While there is a broad expectation that all vessels and offshore infrastructure supporting an offshore project implement the IMO Biofouling Guidelines, best practice approaches require that all operators and contractors have access to a detailed overarching plan that supports effective decision-making and outlines acceptable biofouling management approaches. This requires a holistic approach that considers the entire lifespan of the project from exploration, field establishment and ongoing production through to decommissioning operations at the end of a project's life, and considers the different scales of IAS risk associated with specific vessel or infrastructure types, and their patterns of operation. Furthermore, overarching plans should ensure that operators have appropriate guidance in regard to identifying acceptable control measures that need to be implemented prior to mobilization.

References

Alonso A., Castro-Díez, P. 2012. The exotic aquatic mud snail *Potamopyrgus antipodarum* (Hydrobiidae, Mollusca): state of the art of a worldwide invasion. *Aquatic Sciences*, Vol. 74, pp. 375–83.

Anderson, Lars W. J. 2000. California's reaction to Caulerpa taxifolia: a model for invasive species rapid response. *Biological Invasions*, Vol. 7, pp. 1003–1016.

Ashton, G. V., Davidson, I. C., Geller, J. and Ruiz, G. M. 2016. Disentangling the biogeography of ship biofouling: barnacles in the Northeast Pacific. *Global Ecology and Biogeography*, Vol. 25, No. 6, pp. 739–50.

Barry, S. C., Caley, P., Liu, S., Paini, D. R., Carey, J. and Clark, G. 2015. *Development of an Expert-Based Model for Improved Biofouling Risk Assessment*. CEBRA Project No. 1402A. Clayton, Victoria CSIRO.

Bax, N., Williamson, A., Aguero, M., Gonzalez, E. and Geeves, W. 2003. Marine invasive alien species: a threat to global biodiversity. *Marine Policy*, Vol. 27, No. 4, pp. 313–23.

Beermann, J., Hall-Mullen, A. K., Havermans, C., Coolen, J. W., Crooijmans, R. P., Dibbits, B., Held, C. and Desiderato, A. 2020. Ancient globetrotters — connectivity and putative native ranges of two cosmopolitan biofouling amphipods. *PeerJ*, Vol. 8, p. 9613.

Biofouling Solutions. 2015. *An Inspection of the Ocean Monarch for Invasive Marine Species of Concern*. Report for Diamond Offshore Drilling Inc. BFS1350, Version 1.0.

Coma, R., Serrano, E., Linares, C., Ribes, M., Díaz, D. and Ballesteros, E. 2011. Sea urchins predation facilitates coral invasion in a marine reserve. *PLoS ONE*, Vol. 6, No. 7, p. e22017.

Coutts, A. D. and Taylor, M. D. 2004. A preliminary investigation of biosecurity risks associated with biofouling on merchant vessels in New Zealand. *New Zealand Journal of Marine and Freshwater Research*, Vol. 38, No. 2, pp. 215–29.

Creed, J. C., Fenner, D., Sammarco, P., Cairns, S., Capel, K., Junqueira, A. O., Cruz, I., Miranda, R. J., Carlos-Junior, L., Mantelatto, M. C. and Oigman-Pszczol, S. 2017. The invasion of the azooxanthellate coral Tubastraea (*Scleractinia*: *Dendrophylliidae*) throughout the world: history, pathways and vectors. *Biological Invasions*, Vol. 19, pp. 283–305.

Cunningham, S., Teirney, L., Brunton, J., McLeod, R., Bowman, R., Richards, D., Kinsey, R. and Matthews, F. 2019. Mitigating the threat of invasive marine species to Fiordland: New Zealand's first pathway management plan. *Management of Biological Invasions*, Vol. 10, pp. 690–708.

Cuthbert, R. N., Pattison, Z., Taylor, N. J., Verbrugge, L., Diagne, C., Ahmed, D. A., Leroy, B., Angulo, E., Briski, E., Capinha, C., Catford, J. A., Dalu, T., Essl, F., Gozlan, R. E., Haubrock, P. J., Kourantidou, M., Kramer, A. M., Renault, D., Wasserman, R. J. and Courchamp, F. 2021. Global economic costs of aquatic invasive alien species. *Science of the Total Environment*, Vol. 775, p. 145238.

Darling, J. A. and Carlton, J. T. 2018. A Framework for understanding marine cosmopolitanism in the Anthropocene. *Frontiers in Marine Science*, Vol. 5, p. 293.

Davidson, I., Scianni, C., Hewitt, C., Everett, R., Holm, H., Tamburri, M. and Ruiz, G. 2016. Mini-review: assessing the drivers of ship biofouling management – aligning industry and biosecurity goals. *Biofouling*, Vol. 32, No.4, pp. 411–28.

Davidson, I. C., Smitha, G., Ashton, G. V., Ruiz, G. M. and Scianni, C. 2020. An experimental test of stationary lay-up periods and simulated transit on biofouling accumulation and transfer on ships. *Biofouling*, Vol. 36, No. 4, pp.455–66.

de Castro, M. C. T., Fileman, T. W. and Hall-Spencer, J. M. 2017. Invasive species in the Northeastern and Southwestern Atlantic Ocean: a review. *Marine Pollution Bulletin*, Vol. 116, Nos. 1–2, pp. 41–47.

Floerl, O., Inglis, G. J., Dey, K. and Smith, A. 2009. The importance of transport hubs in stepping-stone Invasions. *Journal of Applied Ecology*, Vol. 46, pp. 37–45.

GEF-UNDP-IMO GloFouling Partnerships Project and GIA for Marine Biosafety. 2022*a*. *Analysing the Impacts of Marine Biofouling on the Energy Efficiency of Ships and the GHG Abatement Potential of Biofouling Management Measures*. https://www.glofouling.imo.org/publications-menu.

GEF-UNDP-IMO GloFouling Partnerships Project and GIA for Marine Biosafety. 2022*b*. *Compilation and Comparative Analysis of Existing and Emerging Regulations, Standards and Practices Related to Ships' Biofouling Management*. https://www.glofouling.imo.org/publications-menu

Goodenough, A. E. 2010. Are the ecological impacts of alien species misrepresented? A review of the 'native good, alien bad' philosophy. *Community Ecology*, Vol. 11, pp. 13–21.

Gust, N., Coutts, A., Lewis, P., Tigges, R., Prout, J. and Carter, S. 2019. Biofouling risk management for the importation of a floating production, storage and offloading (FPSO) facility and the central processing facility (CPF); the world's largest semi-submersible platform. *The APPEA Journal*, Vol. 59, p. 596.

Hewitt, C. and Campbell, M. 2010. *The Relative Contribution of Vectors to the Introduction and Translocation of Invasive Marine Species*. Canberra City, Department of Agriculture, Fisheries and Forestry.

Hewitt, C., Campbell, M., Thresher, R. and Martin, R. 1999. *Marine Biological Invasions in Port Phillip Bay, Victoria*. Technical Report No. 20. Clayton, Victoria, CSIRO.

Hewitt, C., Campbell, M., Thresher, R., Martin, R., Boyd, S., Cohen, B., Currie, D., Gomon, M., Keogh, M., Lewis, J., Lockett, M., Mays, N., Macarthur, M., O'Hara, T., Poore, G., Ross, D., Storey, M., Watson, J. and Wilson, R. 2004. Introduced and cryptogenic species in Port Phillip Bay, Victoria. *Marine Biology*, Vol. 144, pp. 183–202.

Hunsucker, K. Z., Ralston, E., Gardner, H. and Swain, G. 2019. Specialized grooming as a mechanical method to prevent marine invasive species, recruitment and transport on ship hulls. C. Makowski and C. W. Finkl (eds), *Impacts of Invasive Species of Coastal Environments: Coasts in Crisis*. New York, Springer International Publishing AG, pp. 247–68.

Inglis, G. and Floerl, O. 2012. *Scenarios of Vessel Biofouling Risk and their Management: An Evaluation of Options*. MPI Technical paper No: 2012/07. Wellington, Ministry of Agriculture and Forestry.

IPIECA. 2010. *Alien Invasive Species and the Oil and Gas Industry: Guidance for Prevention and Management*. London, International Association of Oil & Gas Producers.

Joyce, P. W. S., Cuthbert, R. N., Kregting, L., Crane, K., Vong, G. Y. W., Cunningham, E. M., Dick, J. T. A. and Coughlan, N. E. 2019. Stay clean: direct steam exposure to manage biofouling risks. *Marine Pollution Bulletin*, Vol. 142, pp. 465–69.

Katsanevakis, S., Wallentinus, I., Zenetos, A., Leppäkoski, E., Çinar, M. E., Oztürk, B., Grabowski, M., Golani, D. and Cardoso, A. C. 2014. Impacts of invasive alien marine species on ecosystem services and biodiversity: a pan-European review. *Aquatic Invasions*, Vol. 9, pp. 391–423.

Kochman, J., Buschbaum, C., Volkenborn, N. and Reise, K. 2008. Shift from native mussels to alien oysters: differential effects of ecosystem engineers. *Journal of Experimental Marine Biology and Ecology*, Vol. 364, No. 1, pp. 1–10.

Ministry of Primary Industries (MPI). 2018. *Craft Risk Management Standard: Biofouling on Vessels Arriving to New Zealand*. Wellington, New Zealand Government.

NOPSEMA. 2020. *Reducing Marine Pest Biosecurity Risks through Good Practice Biofouling Management*. NOPSEMA Information Paper. Perth, NOPSEMA.

O'Brien, A., Ross, D. J., Keough, M. 2006. Effects of *Sabella spallanzanii* physical structure on soft sediment macrofaunal assemblages. *Marine and Freshwater Research*, Vol. 57, No. 4, pp. 363–71.

Page, H. M., Dugan, J. E., Culver, C. S. and Hoesterey, J. C. 2006. Exotic invertebrate species on offshore oil platforms. *Marine Ecology Progress Series*, Vol. 325, pp. 101–07.

Peach, D. and Box, T. 2016. Simplicity from complexity: a systematic risk based approach to managing marine biofouling in the petroleum industry. *SPE International Conference and Exhibition on Health, Safety, Security, Environment, and Social Responsibility*. Stavanger (Norway), SPE.

Piola, R. F. and Grandison, C. 2019. *In-Water Treatment of Biofouling in Internal Systems: Field Validation of Quaternary Ammonium Compound (QAC) Chemical Treatment Protocols*. Victoria, Australian Government Department of Defence.

Piola, R. F. and Hopkins, G. A. 2012. Thermal treatment as a method to control transfers of invasive biofouling species via vessel sea chests. *Marine Pollution Bulletin*, Vol. 64, pp. 1620–30.

Reggio Jr, V. C. 1989. *Petroleum Structures as Artificial Reefs: A Compendium*. Fourth International Conference on Artificial Habitats for Fisheries. Rigs-to-Reefs Special Session, Miami, FL, OCS Study/MMS 89–0021. Washington, DC, US Dept Interior, MMS.

Rivas, G., Moore, A., Dholoo, E. and Mitchell, P. 2010. *Alien Invasive Species: Risk and Management Perspectives for the Oil and Gas Industry*. SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production. Rio de Janeiro, OnePetro.

Sakai, A. K., Allendorf, F. W., Holt, J. S., Lodge, D. M., Molofsky, J., With, K. A., Baughman, S., Cabin, R. J., Cohen, J. E., Ellstrand, N. C. and McCauley, D. E. 2001. The population biology of invasive species. *Annual Review of Ecology and Systematics*, Vol. 32, No. 1, pp. 305–32.

Smith, L. D. 2009. The role of phenotypic plasticity in marine biological invasions. G. Rilov and J. A. Crooks (eds). *Biological Invasions in Marine Ecosystems: Ecological, Management, and Geographic Perspectives*. Berlin, Heidelberg, Springer, Berlin, Heidelberg, pp. 177–202. (Ecological Studies, No. 204.)

Swain, G., Erdogan, C., Foy, L., Gardner, H., Harper, M., Hearin, J., Hunsucker, K. Z., Hunsucker, J. T., Lieberman, K. and Nanney, M. 2022. Proactive in-water ship hull grooming as a method to reduce the environmental footprint of ships. *Frontiers in Marine Science*, Vol. 8, p. 808549.

Tait, L. W., Lohrer, A. M., Townsend, M., Atalah, J., Floerl, O. and Inglis, G. J. 2020. Invasive ecosystem engineers threaten benthic nitrogen cycling by altering native infaunal and biofouling communities. *Scientific Reports*, Vol. 10, p. 1581.

Tamburri, M. N., Davidson, I. C., First, M. R., Scianni, C., Newcomer, K., Inglis, G. J., Georgiades, E. T., Barnes, J. M. and Ruiz, G. M. 2020. In-water cleaning and capture to remove ship biofouling: an initial evaluation of efficacy and environmental safety. *Frontiers in Marine Science*, Vol. 7, p. 437.

Thresher, R. 1999. Diversity, impacts and options for managing invasive marine species in Australian waters. *Australian Journal of Environmental Management*, Vol. 6, No. 3, pp. 137–48.

Veldhuizen, T. and Stanish, S. 1999. *Overview of the Life History, Distribution, Abundance and Impacts on the Chinese Mitten Crab,* Eriocheir sinensis. Sacramento, CA, California Department of Water Resources, Environmental Services Office.

Vidal, P. D. C. J., González, M. O. A., de Vasconcelos, R. M., de Melo, D. C., de Oliveira Ferreira, P., Sampaio, P. G. V. and da Silva, D. R. 2022. Decommissioning of offshore oil and gas platforms: A systematic literature review of factors involved in the process. *Ocean Engineering*, Vol. 255, p. 111428.

Wells, F. and Booth, G. 2012. *Setting a New Benchmark in Managing Biofouling on Vessels in a Sensitive Marine Environment*. International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production. Perth, Australia, SPE.

Willan, Richard C., Russell, B. C., Murfet, N. B., Moore, K. K., McEnnulty, F. R., Horner, S. K., Hewitt, C. L., Dally, G. M., Campbell, M. L. and Bourke, S. T. 2000. Outbreak of Mytilopsis sallei (Recluz, 1849) (*Bivalvia: Dreissenidae*). Australia. *Molluscan Research*, Vol. 20, No. 2, pp. 25–30.

Wyatt, A. S., Hewitt, C. L., Walker, D. I. and Ward, T. J. 2005. Marine introductions in the Shark Bay World Heritage Property, Western Australia: a preliminary assessment. *Diversity and Distributions*, Vol. 11, pp. 33–44.

Zabin, C., Davidson, I. C., Holzer, K. K., Smith, G., Ashton, G. V., Tamburri, M. N. and Tuiz, G. M. 2018. How will vessels be inspected to meet emerging biofouling regulations for the prevention of marine invasions? *Management of Biological Invasions*, Vol. 9, No. 3, pp. 195–208.

Acronyms

AFS	Anti-fouling system
ALARP	As low as reasonably practicable
BFMP	Biofouling management plan
BFRB	Biofouling record book
CCTV	Closed-circuit television
CPFs	Central processing facilities
CRMS	New Zealand Craft Risk Management Standard (CRMS)
FLNG	Floating liquified natural gas (FLNG) Facilities
FPSO	Fuel production, storage and offtake facilities
IAS	Invasive aquatic species
IMO	International Maritime Organization
MGPS	Marine growth prevention system
MODU	Mobile offshore drilling unit
ROV	Remote operated vehicle
RSS:	Riser support structure
U-WILD	In lieu of dry-dock (U-WILD)
VRASS:	Vessel risk assessment score sheets

Definitions

(from the 2011 IMO Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species)

Biofouling: The accumulation of aquatic organisms such as micro-organisms, plants, and animals on surfaces and structures immersed in or exposed to the aquatic environment. Biofouling can include microfouling and macrofouling.

Macrofouling: Large, distinct multicellular organisms visible to the human eye such as barnacles, tubeworms, or fronds of algae.

Microfouling: Microscopic organisms including bacteria and diatoms and the slimy substances that they produce. Biofouling comprised of only microfouling is commonly referred to as a slime layer.

Niche areas: Areas on a ship that may be more susceptible to biofouling due to different hydrodynamic forces, susceptibility to coating system wear or damage, or being inadequately, or not, painted, e.g., sea chests, bow thrusters, propeller shafts, inlet gratings, dry-dock support strips, etc.

Ship: 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 units (FSUs) and floating production storage and off-loading units (FPSOs).

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Biofouling Prevention and Management in the Offshore Oil and Gas Industry

Best Practices in Biofouling Management — Volume 2

This report is one of a series covering best practices for biofouling management and addressing Invasive Aquatic Species (IAS) for non-shipping sectors, as part of the GloFouling Partnerships project being undertaken by the International Maritime Organization (IMO), in collaboration with the Global Environment Facility (GEF) and the United Nations Development Programme (UNDP).

The focus of these reports is biofouling management: information about the general processes of biofouling, the ecological and environmental impacts, economics of management, and the costs estimated to be associated with IAS are beyond the scope of these reports.

This report addresses specifically biofouling management in relation to offshore oil and gas industry operations, equipment and infrastructure. It covers offshore vessels, infrastructure, long-term infrastructure, and subsea equipment.

Biofouling on offshore oil and gas vessels represents a significant pathway for the introduction of IAS to offshore project areas and also adjacent coastal areas and supply ports. Patterns of operation within the offshore oil and gas sector create IAS pathways that are significantly different to those facilitated by other forms of maritime traffic, and some types of offshore infrastructure are prone to supporting significant biofouling assemblages, managing biofouling should be a core environmental obligation for offshore project operators, especially in cases where biofouling management requirements are not mandated.

For further information, visit the GloFouling website at https://www.glofouling.imo.org

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