



**Australian Government**  
**Department of Agriculture,  
Fisheries and Forestry**

# **Australian anti-fouling and in-water cleaning guidelines**

Exposure draft



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### **Acknowledgement of Country**

We acknowledge the Traditional Custodians of Australia and their continuing connection to land and sea, waters, environment and community. We pay our respects to the Traditional Custodians of the lands we live and work on, their culture, and their Elders past and present.

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# Introduction

Biofouling is the undesirable accumulation of microorganisms, plants, algae and animals on submerged structures, particularly on vessel hulls and niche areas. Anti-fouling coatings are commonly used to protect submerged surfaces and prevent biofouling accumulation. Application, maintenance and removal of anti-fouling coatings on vessels and movable structures in maintenance facilities or in-water can result in contamination of the aquatic environment.

The release of biofouling and toxicants during in-water cleaning activities can impact the aquatic environment and human health by facilitating the spread of invasive aquatic species and pathogens. It can also impact water quality and sediment, and social, cultural and economic values.

## Purpose and principles

These guidelines provide best-practice approaches for the application, maintenance, removal and disposal of anti-fouling coatings and the cleaning of biofouling on vessels and movable structures in Australia. The guidelines aim to minimise contamination and biosecurity risks associated with shore-based and in-water maintenance of vessels and movable structures.

These guidelines contain the Australian in-water cleaning standards, which provide regulators with a voluntary decision-making framework to support their assessment of the biosecurity and chemical contamination risks of in-water cleaning of biofouling from vessels in Australian territorial seas.

The guidelines and standards are based on the following principles:

- Biofouling should be removed in the location where it was acquired before the vessel departs to a new location.
- The risks posed by biofouling management measures should be balanced against the risks of failing to manage biofouling.
- There is an operational need to manage biofouling on vessels and movable structures.
- The accumulation of biofouling on vessels and movable structures should be minimised.
- The risk of releasing potentially toxic chemicals and invasive aquatic species into the environment should be minimised.
- Where operationally practicable, vessels and movable structures should be removed from the water for cleaning and maintenance.

## Scope

These guidelines apply to vessels and other movable structures in aquatic (marine, estuarine and freshwater) environments, regardless of whether they have an anti-fouling coating.

The guidelines replace the *Anti-fouling and in-water cleaning guidelines*, (Department of the Environment and New Zealand Ministry for Primary Industries 2015). For more information on anti-fouling coatings and biofouling management practices, including in-water cleaning and treatment, see [Factors that influence vessel biofouling and its prevention and management](#).

The practices described in these guidelines align with the following international conventions, guidelines and protocols intended to protect the aquatic environment from invasive aquatic species and contaminants from shipping:

- [International Convention on the Control of Harmful Anti-fouling Systems on Ships](#) (AFC Convention).
- [the 1996 protocol to the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter](#) (London Convention).
- [the 2023 Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species](#) (IMO Biofouling Guidelines).

The IMO Biofouling Guidelines contain guidance on the development and use of biofouling management plans and biofouling record books. Learn more about the [Australian biofouling management requirements](#).

## Out of scope

These guidelines do not address:

- the cleaning of aquaculture equipment (other than vessels)
- how well a vessel is cleaned and any residual biofouling after cleaning
- potential health and safety risks – work health and safety associated with vessel maintenance should be considered prior to undertaking anti-fouling or in-water cleaning activities.

## Structure

The guidelines are divided into 2 sections:

- 1) [Anti-fouling coating guidance](#) – guidance for the application, maintenance, removal, and disposal of anti-fouling coatings at shore-based maintenance facilities to minimise environmental risk.
- 2) [Australian in-water cleaning standards](#) – voluntary decision-making guidance and framework for regulators to assess biosecurity and chemical contamination risks associated with in-water cleaning of biofouling from vessels in Australian territorial seas.

# 1 Anti-fouling coating guidance

## 1.1 Anti-fouling coating types

An anti-fouling coating is a surface coating or paint designed to prevent, repel or facilitate the detachment of biofouling from hull and niche areas that are typically or occasionally submerged. A wide range of anti-fouling coatings are available for owners and operators of vessels and movable structures. For simplicity and relevance to the in-water cleaning risks, these guidelines group anti-fouling coatings into 2 categories:

- 1) biocidal anti-fouling coatings
- 2) biocide-free anti-fouling coatings

Both biocidal and biocide-free anti-fouling coatings may contain harmful substances that pose a contamination risk if released into the environment. See [Appendix A](#) for examples of different types of anti-fouling coatings.

All biocidal anti-fouling coatings must be registered and permitted for use by the [Australian Pesticides and Veterinary Medicines Authority](#) before they can be applied in Australia. The sale and application of unregistered biocidal coatings is prohibited in Australia, as is the addition of any biocidal additive to an anti-fouling coating.

The sale and application of anti-fouling coatings containing tributyltin and cybutryne are prohibited in Australia. However, land-based maintenance facilities may still carry out maintenance on vessels and movable structures that have tributyltin-based anti-fouling coatings beneath barrier coats and compliant anti-fouling coatings, provided the facilities are able to contain waste produced during maintenance and minimise the release of contaminants.

Refer to safety data sheets and relevant product descriptions for advice and information on correct storage, handling and emergency treatment procedures for all anti-fouling coatings and chemicals.

Application, maintenance, removal and disposal of anti-fouling coatings should only be carried out at maintenance facilities that adopt measures to ensure all biofouling, coatings and other physical contaminants removed from vessels and structures are retained and treated in a manner that is compliant with relevant local regulations. The person carrying out the maintenance is responsible for checking that all necessary approvals are in place and ensuring that they are familiar with all conditions specified in such approvals.

## 1.2 Choosing appropriate anti-fouling coatings

Different anti-fouling coatings are designed and developed with different uses in mind. Anti-fouling coatings should be selected based on technical advice, generally from the coating manufacturer, supplier or an independent anti-fouling coating expert. Inappropriate selection, specification and application of anti-fouling coatings may result in increased and unnecessary accumulation of biofouling, increased loadings of biocide in the environment, or a requirement for more frequent maintenance.

## 1.3 Key parameters

The effectiveness of anti-fouling coatings may be impacted by parameters such as vessel speed, activity and environmental factors.

To select suitable biofouling protection for a vessel, owners and operators of vessels and moveable structures should consider the operational and environmental parameters for the intended service life of the coatings, as well as vessel area-specific considerations. For vessels not serving fixed routes (e.g. commercial vessels involved in tramp shipping) it is recommended that an analysis of likely scenarios and the most challenging conditions are taken into consideration to inform selection of anti-fouling coatings.

Assistance from coating manufacturers and third parties should be sought during the selection and specification process to ensure that the selected coatings and the associated specifications are suitable for the vessel's intended operations. Understanding the limitations of the chosen anti-fouling coatings is critical to developing a robust biofouling management strategy.

Factors to consider for optimal selection and specification of anti-fouling coatings and how they may affect coating performance are described in this section.

### 1.3.1 Operating profile parameters

#### Speed

Speed ranges and typical speeds over the intended coating service life are an important factor in the choice of an anti-fouling coating.

Fouling release coatings minimise the adhesion force between the surface and biofouling organisms (Weber & Esmaeili 2023) and facilitate the detachment of such organisms when the vessel is moving. However, as the speed and activity levels required for a vessel to remain free of biofouling may vary across different types of fouling release coatings, these products may not be optimal for all vessel types (Candries et al. 2003; Dafforn et al. 2011).

The speed profile of a vessel is particularly critical for the appropriate specification of polishing anti-fouling coatings. If the product attributes, such as polishing rate and the specified scheme's dry film thickness, are not adequate for the operational and environmental parameters, this can lead to unsatisfactory performance during the intended service life of the coating.

#### Activity

Vessel activity is an indicator for the time spent underway. The effectiveness of anti-fouling coatings may vary with vessel activity. For example, some biocide-free technologies may not offer optimal performance for low activity vessels in challenging environmental conditions. Vessel activity is also a critical parameter for the appropriate specification of polishing anti-fouling coatings.

#### Extended stationary periods

Extended stationary periods are recognised as a significant risk factor for biofouling accumulation (Floerl & Coutts 2009; Sylvester et al. 2011; Davidson et al. 2020; Ruiz et al. 2022). Experimental studies suggest that step increases in biofouling cover can be expected as time progresses compared to the first 7 to 10 days of exposure (Hunsucker et al. 2016; Davidson et al. 2020). Different anti-fouling coatings may tolerate varying periods of inactivity depending on the biofouling control



mechanism, biocide types, content and factors such as environmental conditions, seasonality and species richness and abundance.

### **In-water cleaning regime**

Inappropriate in-water cleaning may lead to issues such as mechanical damages, early polishing of the coating and surface roughness leading to increased rate of biofouling accumulation over time (Swain et al. 2022; Scianni et al. 2023). In-water cleaning approaches, equipment capability and the forces required to remove biofouling organisms at different stages of maturity, vary (Oliveira & Granhag 2016).

To maintain the long-term effectiveness and integrity of anti-fouling coatings, the frequency and type of in-water cleaning should be suitable for the coating, the applied scheme's dry-film thickness, and the level and type of biofouling present. Frequent in-water cleaning can be an effective strategy for controlling biofouling accumulation if suitable cleaning equipment is available when required and the planned frequency and type of cleaning is considered during the coating selection and specification stage.

Generally, the likelihood of damaging anti-fouling coatings is greater while cleaning mature macrofouling unless the coating is mechanically resistant. Cleaning of mature macrofouling is associated with additional biosecurity and water-quality risks, regardless of the coating type and especially with equipment without reliable capture capability (Georgiades et al. 2018).

## **1.3.2 Operating environmental parameters**

Environmental conditions are directly linked to biofouling accumulation. Ocean biogeochemical changes are causing shifts in species composition, abundance and biomass production (Bindoff et al. 2022). However, some environmental parameters may also have a direct effect on an anti-fouling coating's effectiveness and planned in-service period.

### **Sea surface temperature**

An increase in sea surface temperature can lead to an increase in polishing and biocide release rates in some anti-fouling coatings (Dobretsov et al. 2019). Prolonged exposure to sea surface temperatures higher than the anti-fouling coating was specified for can result in premature polishing and biocide depletion, which directly impacts the effectiveness of the coating and its planned service life.

Low sea surface temperatures can also be challenging. Some types of coatings – for example, most fouling release anti-fouling coatings – have low mechanical resistance properties and are prone to abrasion damage in ice conditions (Holm et al. 2011; Stamper & Hasleback 2015).

### **Salinity**

Salinity affects the polishing rate of some coatings (Kiil et al. 2002) and exposure to higher levels leads to increase in the rate of cuprous oxide (Cu<sub>2</sub>O) dissolution (Finnie 2006; Singh & Turner 2009; Ytreberg et al. 2020), a common biocide used in many anti-fouling coatings available on the market (Scianni et al. 2023; Mihaylova et al. 2022).

Prolonged exposure to fresh water can affect film integrity based on coating formulation leading to changes in film properties, blistering or other defects. Some coatings, typically biocidal anti-fouling coatings, may be affected by prolonged freshwater exposure.

### **Trading routes**

Analysing typical trading routes for a vessel helps identify key environmental parameters that inform coating selection and specification. Anti-fouling coatings have some tolerance to most environmental parameters, therefore, understanding the likely exposure to certain conditions in conjunction with the operational profile of the vessel allow for informed decision-making.

It is imperative that potential future changes to trading routes are considered as far as practicable during coating selection.

## **1.3.3 Project related considerations**

### **Active ingredients**

Active ingredients in anti-fouling coatings are the compounds that are released at the coating surface to deter or kill biofouling (Morrissey et al. 2013). These ingredients are the biocides and co-biocides, or booster biocides, found in biocidal anti-fouling coatings. Biocides may affect a broad spectrum of marine organisms or specific organisms. The combination of biocides and co-biocides, the concentration and the biocide release rates are critical and determine the effectiveness of the coating against different biofouling species.

### **Coating application time and location**

Some coatings are more sensitive to environmental conditions during the application stage. Drying times and overcoating intervals can vary significantly with ambient and substrate temperatures and the application may not be recommended under specific ambient temperatures and humidities. Application requirements should be considered in advance of projects, especially if the project time and location are fixed and are likely to present challenging conditions such as low ambient temperatures as well as consideration of humidity and expected rainfall.

### **Surface preparation and coating compatibility**

Areas of coating breakdown should be prepared to the standard specified by the manufacturer. Overcoating of existing primers or anti-fouling coatings should be carried out according to manufacturer's instructions and with compatible coatings.

### **Intended service life before coating system renewal**

Ensuring that coating specification is based on key operational and environmental parameters should result in the coating lasting for the duration of its intended service life. The film thicknesses suitable for the planned in-service periods under the same conditions will vary with coating type.

### **Design and construction of the vessel or movable structure**

The coating must be compatible with construction materials. Use of specific coatings in niche areas and high and low water flow areas should be considered.

## **1.3.4 Typical issues**

Inappropriate coating selection and specification lead to ineffective biofouling management, which can result in increased greenhouse gas emissions, biosecurity and water quality risks. Often the issues stem from lack of understanding of the limitations of different coatings and inadequate planning.

The cost of the coating is not a reliable indication of in-service performance. Additional factors, such as ensuring the coating specification is appropriate and tailored to the vessel's expected operational

profile, typical environmental conditions and project related considerations, are critical in limiting sub-optimal performance.

Poor specification can have a significant impact on anti-fouling effectiveness early in the planned in-service period. A common issue with polishing anti-fouling coatings is premature 'polish through', a phenomenon where the anti-fouling paint has polished away exposing the underlying paint layer with no anti-fouling properties. The presence of polished through areas may be related to several factors associated with the specification stage, such as:

- vessel-specific operational and environmental parameters not considered or not representative
- vessel-specific operational and environmental parameters changed significantly early in the planned in-service period
- unexpected arrival condition at the previous dry docking (additional surface preparation required) but no specification revision followed to account for the changes.

Ensuring appropriate level of surface preparation and compatibility with existing systems during repair and renewal of the anti-fouling is also critical. Poor or inadequate surface preparation can lead to coating defects, such as blistering and delamination. Using a different anti-fouling coating from the one previously applied for example, switching from a polishing biocidal coating to a fouling release coating, may require the relevant areas of the hull to be fully blasted prior to application.

Biofouling management interventions, such as in-water cleaning, should also be taken into consideration as inappropriate or excessive frequency of in-water cleaning may lead to premature polish through, jeopardise the integrity of the coating or lead to surface deterioration and consequently increased rate of biofouling accumulation.

### **1.3.5 Intended service life**

The anti-fouling coating manufacturer should be consulted when choosing an anti-fouling coating to ensure it is capable of meeting or exceeding the intended service life. An anti-fouling coating scheme that has passed the intended service life may not provide adequate protection from biofouling.

For commercial vessels and structures, the type and thickness of anti-fouling coatings (in particular for polishing systems) are generally determined by the planned in-service period and operational profile and associated environmental parameters. The planned in-service period is determined by logistic and economic factors and should be recorded in the vessel's biofouling management plan.

For recreational vessels, the maintenance schedule is not usually determined by operational forecasts and logistical constraints, and anti-fouling coatings are chosen according to other factors.

### **1.3.6 Record keeping**

Records should be kept of anti-fouling coatings chosen and applied.

For commercial vessels and structures, the preferred form of documentation of anti-fouling coating type and service life is:

- a biofouling record book and biofouling management plan (see [Australian biofouling management requirements](#))

- an anti-fouling system certificate or declaration on anti-fouling system.

In addition, any third-party reports that contain information or analysis on anti-fouling coating application, renewal or selection and specification should be available as evidence to support a vessel biofouling management plan.

Where the former documents are not held, original receipts or invoices stating the coating type and the volume purchased; vessel name and date of application, should be kept on board.

For recreational vessels, the preferred form of documentation is either:

- a biofouling record book and biofouling management plan (see [Australian biofouling management requirements](#)), or
- original receipts or invoices stating the coating type and the volume purchased, vessel name (if possible) and date of application, where the former documents are not held.

## 1.4 Requirements for shore-based maintenance facilities

Operators of shore-based maintenance facilities should:

- be familiar with best-practice recommendations set out in these guidelines for application, maintenance and removal of anti-fouling coatings and ensure that all customers are similarly informed
- adopt measures to ensure biofouling waste, coating waste and other contaminants arising during maintenance activities are captured and retained in a manner that minimises their release into the terrestrial and aquatic environment.

Shore-based maintenance facilities should have:

- clearly designated areas where maintenance activities producing debris are isolated from the environment. Facilities that enable customers or other non-professionals to undertake maintenance on their own vessel or movable structure should ensure sufficient information on how to prevent any discharges into the environment is provided
- clear operational rules that facility operators should ensure are followed by supervising non-professional maintenance activities, as appropriate.

Coating and biofouling waste should be disposed of as controlled waste and the method of disposal should comply with relevant local regulations.

## 1.5 Application of anti-fouling coatings

### 1.5.1 General guidance

The way an anti-fouling coating is applied influences its performance. To achieve optimum performance and reduce maintenance:

- Technical advice regarding the correct surface preparation, application and curing time required for maximum performance of the anti-fouling coating should be sought from the manufacturer prior to applying the coating. All elements vary according to the type and brand of coating used and will affect performance.

- All anodes, sensitive fittings and sensors should be removed or heavily taped before application to avoid physical damage.
- Any primers and/or anti-corrosive coatings used must be compatible with the type of anti-fouling coating and appropriately applied to ensure optimal coating adhesion and distribution. Specialist or manufacturer's advice should be sought before new anti-fouling coating is applied over existing anti-fouling coating to ensure the coatings are compatible or that appropriate barrier coatings are used.
- It is important that the manufacturer's recommended coating film thickness be achieved to ensure that the coating provides the expected service life.
- The manufacturer's recommended method of application must be followed to achieve optimal results. Use of non-approved techniques may compromise the anti-fouling and corrosion protection and the service life of the coating system. Spray application of anti-fouling coatings achieves the best coating adhesion, surface consistency and smoothness. Where spray application is not possible, specialist advice should be sought about other application methods.
- Hull locations prone to high water flow and wear (e.g. exposed edges around bilge keels, intake grates and weld joints) should be coated with suitably durable anti-fouling coatings to the specified coating thickness. Housings, recesses (e.g. behind anodes and ladders), draft markers and retractable fittings such as stabilizers, thruster bodies and guards should all be coated with a suitable anti-fouling coating. The anti-fouling coating should be applied to the highest water mark of the vessel (e.g. the load line).
- The position of docking blocks, slings, and other structures used to support vessels or movable structures during out of water maintenance should, where possible, be varied each time new coatings are applied. This ensures that areas under the docking blocks are coated with anti-fouling, at least at alternate dockings. In select cases, docking blocks may be moved during paint application to allow the entire hull to be painted.

### **1.5.2 Specific guidance for non-professionals**

Non-professionals should apply the following guidance:

- Wherever possible, anti-fouling coatings should be applied by experienced professionals. However, non-professional application of anti-fouling coatings is common for small vessels, such as recreational yachts and launches or small fishing vessels.
- Non-professionals should follow manufacturer's recommendations when determining how they intend to apply the anti-fouling coating. The anti-fouling coating industry emphasises that spray application is the preferred method and will achieve the best coating performance. However, spray equipment should only be operated by professionals, or under the supervision of professionals, to ensure optimal application. Spray equipment should never be used outside of screening or other containment to prevent spray drift and contamination of nearby environments and structures.
- Anti-fouling coatings should be mixed (if necessary) in designated areas that are sealed, banded and well ventilated. Preparation and mixing of anti-fouling coatings must never be carried out in intertidal areas.

- Spills should be cleaned up using absorbent material and any residues should be allowed to dry rather than being washed into the wastewater collection system or aquatic environment.
- Coatings should not be allowed to enter water drains, gutters, sewers or the aquatic environment.
- Contaminants should be captured out of run-off water using permeable tarpaulins, screens or filter cloths.
- The area around maintenance areas should be swept or vacuumed frequently to minimise distribution of debris by wind.
- Contaminants such as coatings, pesticides, oils, detergents, paint strippers, etc. should be stored in accordance with safety data sheets and in a manner that complies with any relevant local regulations.
- The recommended drying time of the primer and anti-fouling coatings must be observed to achieve optimal adhesion and coating performance. Premature over-coating or submersion will compromise coating adhesion and/or anti-fouling and anti-corrosion performance.

## 1.6 Shore-based maintenance

Various methods are available for removal and maintenance of anti-fouling coatings. Each requires consideration of different factors. In all cases, disposal of removed material should follow the recommendations set out in [section 1.7](#).

### Blasting

Blasting (including hydroblasting, wet and dry abrasive blasting, and vacuum blasting) to clean surfaces and remove old coatings should consider the following factors:

- Spray drift created during hydroblasting contains anti-fouling residues. The dispersal of spray drift beyond the working area should be minimised by the use of screening and by avoiding spraying during windy conditions.
- Anti-fouling coatings are toxic and hazardous both to people and the environment. The work area where cleaning is carried out should be isolated and people engaged in the blasting should be appropriately protected from contact with all wastewater and spray drift.
- All anodes, sensitive fittings and sensors should be removed or heavily taped before blasting to avoid physical damage.
- Vacuum blasting is recommended over all other abrasive blasting methods.
- Wet abrasive blasting is preferred over dry blasting, as it creates less toxic dust.
- In the absence of vacuum blasting equipment, abrasive blasting operations should be conducted using either:
  - an abrasive blasting chamber vented to the atmosphere via an effective dust collector or fabric filter, or
  - a screening material for outdoor/open-air blasting that is tear-resistant, UV-resistant, fire retardant and of suitable material and construction (preferably fully enclosed) to minimise escape of fine dust.

- Dry abrasive blasting should only be carried out in enclosed areas. Water or a proprietary suppressant agent should be used to minimise dust emissions from the work area.
- If coating removal or maintenance is carried out using small power tools or manual methods, the recommendations for maintenance by non-professionals should be followed.

### **Buffing and scraping**

- Wherever feasible, mechanical or manual buffing and scraping should be used as they create debris that are more easily collected particularly when using wet techniques that further reduce the potential for aerial distribution.
- All waste and debris should be collected using tarpaulins or drop-sheets and by not working during windy conditions.
- Removal of coatings by wet sanding or scraping is preferred to chemical paint stripping as it creates less toxic waste material. The use of a heat gun can make coating removal easier on some surfaces. If chemical paint strippers must be used, consider soy-based or water-based products that are less hazardous. In all cases it is recommended that manufacturer's instructions are sought to determine the safest and most appropriate method for removing coatings.

## **1.7 Disposal of residues and wastes**

To manage biosecurity and contaminant risks associated with shore-based maintenance activities, the following recommendations should be adhered to:

- Any removed material or liquid should not be allowed to enter any body of water or stormwater; and should not come into contact with any land that is below the high-water mark of any tidal body of water.
- All residues, solid coatings, liquid or any other form of waste, including removed biological material and used product containers should be collected and stored for disposal in line with the requirements of the relevant authority.
- Refer to product safety data sheets for specific information about disposal considerations.

## **1.8 Emergency response**

It is recommended that all maintenance facilities have an emergency response plan, whether required by regulation or not. This plan should cover responses to spills of coatings and other hazardous substances, release of organisms, and incidents with potential contamination and work health and safety risks. Any coating spillages should be assumed to contain hazardous substances and be disposed of as controlled waste and in accordance with the requirements of the relevant authority. If an emergency occurs, the relevant authority should be notified.

Spill clean-up equipment, such as absorbent materials, non-toxic dispersants, and booms (physical barriers for containing liquids) should be available for facility users and maintained in good condition. The relevant authority should be contacted for further information on decontamination procedures.

Refer to product safety data sheets for information about accidental release measures of paints.

## 2 Australian in-water cleaning standards

In-water cleaning can manage biofouling to optimise the performance of vessels and other movable structures and to minimise biosecurity risks. However, in-water cleaning can physically damage some anti-fouling coatings, shorten the coating service life and release a pulse of biocide into the environment. In-water cleaning can also facilitate release of invasive aquatic pests into the surrounding environment.

In-water cleaning activities must manage biosecurity and chemical contamination risks. In-water cleaning should only be undertaken if it does not present an unacceptable biosecurity or chemical contaminant risk as determined by the relevant authority.

The objectives of these Australian in-water cleaning standards are to:

- 1) establish a voluntary framework for the assessment and management of biosecurity and chemical contamination risks associated with in-water cleaning to an acceptable level
- 2) support consistent regulatory decision-making across Australia.

These standards are divided into:

- [Assessment of in-water cleaning activities](#) – provides general information on the assessment of in-water cleaning activities.
- [Required outcomes](#) – sets out the required outcomes for in-water cleaning activities. This section provides a capture standard, biosecurity standard and a chemical contamination standard, as well as documentation and in-water cleaning operator requirements.
- [Application of the standards](#) – provides information on the application of the standards. Explanations are provided for the application of the standards to hull cleaning, hull grooming, propeller cleaning or polishing and niche area cleaning.
- [Decision support tools](#) – provides step-by-step decision support tools to identify whether an in-water cleaning activity meets the standards.

### 2.1 Assessment of in-water cleaning activities

The Australian in-water cleaning standards have been developed to support regulatory decision-making. The standards are for use by regulators to inform their assessment of the biosecurity and chemical contamination risks of in-water cleaning of biofouling from vessels in their jurisdiction. The standards are voluntary and do not change the roles or responsibilities of relevant regulators in assessing in-water cleaning activities.

Some regions and locations are more sensitive to the potential impacts of in-water cleaning, including those defined as having high economic, ecological or conservation value. These sites include marine protected areas, such as the Great Barrier Reef Marine Park and Ningaloo Reef, World Heritage sites, sites in or near Ramsar-listed wetlands, areas supporting listed threatened or



endangered migratory species, and areas identified by the Commonwealth, states or territories as ecologically or culturally important. Different requirements to the standards may apply to manage local biosecurity and chemical contamination risks associated with in-water cleaning activities.

The standards can be used to assess a proposed in-water cleaning activity or proposal for ongoing cleaning activities of a service provider (at a single or multiple locations). Regulators may require independent assessment of in-water cleaning equipment and operators as necessary to be satisfied that in-water cleaning activities will meet the standards.

## 2.2 Required outcomes

In-water cleaning activities must manage the biosecurity and chemical contamination risks to meet the Australian in-water cleaning standard. [Section 2.4](#) provides a step-by-step process for applying the following standards to an in-water cleaning activity:

- [capture standard](#)
- [biosecurity standard](#)
- [chemical contamination standard](#).

The [documentation requirements](#) and [in-water cleaning operator requirements](#) apply to all in-water cleaning activities. In-water cleaning operators must be able to demonstrate that in-water cleaning activities comply with the standards and requirements contained in this section.

### 2.2.1 Capture standard

The capture standard is achieved if (1), (2), (3) and (4) are met.

- 1) Concentrations of total suspended solids (TSS) around the cleaning head are not statistically greater than background samples.
- 2) Concentrations of dissolved biocides around the cleaning head are not statistically greater than background samples.
- 3) The cleaning activity is recorded to achieve 360-degree view of the cleaning activity from the cleaning head to assess any cleaning debris not captured by the system.
- 4) All collected cleaning debris is disposed of in compliance with the waste disposal requirements of the relevant regulators.

#### Capture standard note

Statistical significance for the purpose of the capture standard is  $P = \leq 0.05$ .

Multiple cameras can be used to achieve a 360-degree view as an alternative to a 360-degree camera.

Standard operating procedures should detail how the cleaning operator is minimising the release of material during deployment and demobilisation of equipment.

If material is discharged during cleaning activities, cleaning should cease until the issue is rectified.

### 2.2.2 Biosecurity standard

The biosecurity standard is achieved if either (1) or (2) are met.

- 1) Effluent does not contain suspended solids greater than 10 micrometres.
- 2) All biofouling has been exposed to treatment known to render all relevant taxa non-viable to the satisfaction of an independent scientific organisation prior to any in-water cleaning, and effluent does not contain any biological material greater than 1 mm.

#### **Biosecurity standard note**

Treatment(s) known to render all relevant taxa non-viable should be demonstrated through scientific literature.

Relevant taxa are all taxa present on the hull of the vessel that will be treated.

Tertiary treatment for the management of pathogens may be required for the location in which the activity is proposed. Tertiary treatment should be demonstrated by scientific literature as effective at rendering the relevant pathogens non-viable.

Filtration of removed non-viable biofouling to one millimetre reduces risks associated with biological material loads entering the environment and removal should occur within 48 hours.

### **2.2.3 Chemical contamination standard**

The chemical contamination standard is achieved if either (1) or (2) are met.

- 1) Effluent does not contain toxicants in concentrations that exceed the guideline values for the appropriate level of protection listed in the relevant [Australian and New Zealand Guidelines for Fresh and Marine Water Quality](#) (ANZG 2018).
- 2) Environmental concentrations of toxicants in the specified mixing zone for the proposed cleaning location do not exceed the relevant ANZG (2018) guideline values for the appropriate level of protection. This should be demonstrated via a thorough testing regime for water quality in the receiving environment, developed in consultation with the relevant regulator.

#### **Chemical contamination standard note**

For more information about the National Water Quality Management Strategy (NWQMS) and the Water Quality Guideline Framework, including the use and application of Default Guideline Values (DGV) and site-specific values, see [Water Quality Australia](#). Where there are no DGVs, other relevant national or international literature and guidelines should be used.

In most instances the appropriate level of protection is that of a [slightly to moderately disturbed ecosystem](#). However, in-water cleaning proposed in (or adjacent to) undisturbed national parks, World Heritage areas, marine parks or wetlands of outstanding ecological significance would be designated as high conservation value.

The level of protection for some shipping ports and sections of harbours may be that of a [highly disturbed ecosystem](#). Highly disturbed systems should not be regarded as 'pollution havens'. The concepts of adaptive management and continual improvement should always be promoted, to maximise future options for a waterway.

If a toxicant has the potential to be bioaccumulative, the next most protective DGV than the one that would normally be applied based on the appropriate ecosystem condition and associated level of protection should be applied (for example, the 99% species protection DGV instead of the 95% species protection DGV for slightly to moderately disturbed ecosystems).

Guidance should be sought from the relevant regulator if the ambient concentrations exceed the relevant ANZG (2018) guidelines and site-specific guideline values are being considered. Similarly, the NWQMS generally advises against the use of mixing zones for toxicants that bioaccumulate. Consistent with the ANZG (2018) guidelines for toxicants in waters and sediments, the preferred approaches to deriving guideline values are usually through the use of field and laboratory biological-effects (toxicity) data.

The application and determination of mixing zones is developed in consultation with the relevant local jurisdiction. The size of a mixing zone will vary based on site specific characteristics and should be as small as practicable. Advice on [mixing zones](#) is available on the Water Quality Guidelines website.

The [National Assessment Guidelines for Dredging 2009](#), the [National Environment Protection \(Assessment of Site Contamination\) Measure 1999](#), amended May 2013, and the ANZG (2018) guidelines provide guidance on sampling regimes as well as deriving site-specific guidelines.

## 2.2.4 Documentation requirements

The documentation requirements are achieved if (1), (2) and (3) are met prior to in-water cleaning of a vessel.

### Anti-fouling coating

- 1) The vessel's anti-fouling system certificate, or equivalent documentation, demonstrates:
  - a) the vessel has an anti-fouling system certificate compliant with the International Convention on the Control of Harmful Anti-fouling Systems on Ships, or a Declaration on Anti-fouling System (AFS 2001) for a vessel of 24 m or more in length but less than 400 gross tonnage and engaged in international voyages
  - b) the vessel's anti-fouling coatings do not contain diuron, cybutryne, ziram, tributyltin or chlorathonil
  - c) the vessel's anti-fouling coating(s) is within the specified effective coating service life.

### Anti-fouling coating note

A biofouling management plan and record book that is compliant with the International Maritime Organization's 2023 Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species should provide the information and documents required for [section 2.2.4\(1\)](#).

Documentation complies with [section 2.2.4\(1\)](#) if it demonstrates a relevant surface has no anti-fouling coating.

Anti-fouling coating type refers to whether the coating is biocidal or non-biocidal, the active ingredients (if applicable) and the manufacturer and product name.

Areas of the hull where the anti-fouling coating is not in a sound condition should not be cleaned without meeting the [capture standard](#), [biosecurity standard](#) and [chemical contamination standard](#).

An inspection report older than 30 days may be accepted if the inspection occurred in the last port prior to arriving in Australia.

### Assessment of biofouling

- 2) An [inspection report](#) demonstrates:
  - a) the anti-fouling coating type(s) and condition for all surfaces of the vessel to be cleaned is known and documented by an inspection report within 30 days prior to cleaning

- b) the biofouling for all surfaces to be cleaned is assessed consistent with Table 1, Table 2 and Table 3 and documented in an inspection report within 30 days prior to cleaning.

#### Assessment of biofouling note

The biofouling type is defined using a simplified version of the Naval Ships' Technical Manual (2006) fouling rating at [Appendix B](#), which describes the types of fouling in order of increasing severity from soft to hard.

The percentage cover of biofouling is defined using a simplified version of the Floerl et al. (2005) level of fouling scale at [Appendix B](#), which characterises biofouling on the submerged surfaces of vessels.

This assessment of biofouling aligns with Morrisey et al. (2015) and ACT/MERC (2022).

For cleaning of vessels with biofouling of regional origin, the relevant regulator may stipulate alternative information (such as vessel movement logs) to satisfy the [documentation requirements](#).

#### Cleaning method

- 3) An independent scientific organisation assessment report demonstrates that:
- a) an appropriate cleaning method is employed to meet the required outcomes of the [capture standard](#) for the anti-fouling type and condition of the surfaces to be cleaned
  - b) an appropriate cleaning method is employed to meet the required outcomes of the [biosecurity standard](#) for the biofouling type and percentage cover of surfaces to be cleaned
  - c) an appropriate cleaning method is employed to meet the required outcomes of the [chemical contamination standard](#) for the anti-fouling type and condition of the surfaces to be cleaned.

#### Cleaning method note

The cleaning method should not damage the anti-fouling coating and must be in line with the recommendations of the anti-fouling coating manufacturer. This information should be contained in the vessel's biofouling management plan and record book.

In-water cleaning activities related to research and development of in-water cleaning methods, particularly for the purposes of demonstrating compliance with the standards, may be considered to have met the documentation requirements if the relevant regulator is satisfied that:

- an independent scientific organisation assessment report demonstrates a high likelihood of compliance with the [cleaning method requirements](#)
- the in-water cleaning activity complies with all other relevant sections of the [documentation requirements](#) and of the standards, as determined by the relevant regulator.

**Table 1 Determining type of microfouling present**

Biofouling type	Fouling rating	Description
No microfouling (bare/absent)	FR 0	A clean, foul-free surface; red and/or black anti-fouling paint or a bare metal surface.
Light microfouling (thin and light in colour biofilm)	FR 10	Light shades of red and green (incipient slime). Bare metal and painted surfaces are visible beneath the fouling.

Biofouling type	Fouling rating	Description
Full microfouling (thicker and darker in colour biofilm)	FR 20	Slime as dark green patches with yellow or brown coloured areas (advanced slime). Bare metal and painted surfaces may be obscured by the fouling.

**Table 2 Determining the type of biofouling present**

Biofouling type	Fouling rating	Description
Microfouling	FR 20 or less	Slime as dark green patches with yellow or brown coloured areas (advanced slime). Bare metal and painted surfaces may be obscured by the fouling.
Moderate (soft) macrofouling	FR 30	Grass as filaments up to 76 mm in length, projections up to 6.4 mm in height; or a flat network of filaments, green, yellow, or brown in colour; or soft non calcareous fouling such as sea cucumbers, sea grapes, or sea squirts projecting up to 6.4 mm in height. The fouling cannot be easily wiped off by hand.
Moderate (hard) macrofouling	FR 40 to 80	Calcareous fouling in the form of tubeworms and/or barnacles.
Heavy (hard) macrofouling	FR 90 or greater	Dense growth of tubeworms with barnacles, 6.4 mm or greater in height; Calcareous shells brown in colour (oysters and mussels); or with slime or grass overlay.  All forms of fouling present, soft and hard, particularly soft sedentary animals without calcareous coverings (tunicates) growing over various forms of hard growth.

**Table 3 Determining the percentage cover of biofouling**

Description	Estimate of fouling cover (% of visible submerged surface)
Absent	0
Light	1 to 5
Considerable	6 to 15
Extensive	16 to 40
Very heavy	41 to 100

## 2.2.5 In-water cleaning operator requirements

The in-water cleaning operator requirements are achieved if (1), (2), (3) and (4) are met.

- 1) The in-water cleaning operator holds documentary evidence that the [documentation requirements](#) are met prior to commencing in-water cleaning of a vessel.
- 2) The in-water cleaning operator holds all necessary approvals to conduct in-water cleaning at the proposed cleaning location.
- 3) The in-water cleaning operator produces an in-water cleaning report, accompanied by images and video, detailing at a minimum:
  - a) the surfaces of the vessel that were cleaned
  - b) the biofouling type and percent cover pre-clean and post-clean
  - c) the cleaning method(s) used to in-water clean the vessel

- d) the method of collection and disposal of any debris in compliance with the relevant regulator(s).
- 4) The in-water cleaning operator holds copies (may be digital) of documents in (1) and (2) for a period of 3 years.

#### **In-water inspection requirements**

The in-water cleaning operator's inspection requirements are achieved if (5) and (6) are met.

- 5) An inspection report provides documentary evidence, including images and video of sufficient quality to identify the biofouling type and percent cover and the condition of the anti-fouling coating across the entirety of the area to be cleaned.
- 6) An in-water inspection report is provided to the vessel operator for inclusion in the vessel's biofouling record book.

#### **In-water inspection note**

In-water inspections must be conducted to determine the biofouling type and percent cover and the anti-fouling coating condition prior to any cleaning activity proceeding. This is to demonstrate that the cleaning operator is using the appropriate cleaning method for the biofouling type and percent cover.

Videographic and digital photographic images should be used to verify the type and percent cover of biofouling and condition of the anti-fouling coating. Imagery of fouled areas need to be clear to enable broad organism identifications and assessment of biofouling type and percent cover of the area.

Inspection and cleaning reports should include a minimum of 3 images or a video per area inspected (e.g. upper bulbous bow, or midship-port side-sea chest grating) and should be of a quality that ensures biofouling is easily identified and include the date and time stamped on each photo or footage.

To ensure the images taken are of sufficient detail, images should be taken at a distance of approximately 30cm from the vessel surface. Shorter distances can be used in sampling locations with poor visibility. Longer distances can be used to show the extent of fouling over large areas.

These reports should identify the mode fouling rating and range of fouling rating as described at Appendix B.

#### **Equipment and method**

The in-water cleaning operator's equipment and method requirements are achieved if (7), (8) and (9) are met.

- 7) The in-water cleaning equipment has been assessed by an independent organisation to determine that the required outcomes ([section 2.2.1](#), [section 2.2.2](#) and [section 2.2.3](#)) are met by the technology and operations.
- 8) The report of the independent scientific organisation has been submitted to the relevant regulators for assessment.
- 9) The method and procedures for cleaning:
  - a) are compliant with standard operating procedures for the operation of the system, international standards (e.g. [International Organization for Standardization](#) (ISO) standards) and relevant regulator's requirements
  - b) includes shutdown procedures in the event of a system failure, documenting failures and reporting to the relevant regulator, and rectifying failures

- c) includes contingency measures for identifying and reporting to the relevant regulator untreated releases of biofouling and effluent in the environment due to system failure.

#### Equipment and method note

The independent assessment should clearly demonstrate to regulators that the cleaning equipment can meet all aspects of the [capture standard](#), [biosecurity standard](#) and [chemical contamination standard](#), as relevant to the intended use of the technology.

The use of equipment that has not been assessed to meet the [capture standard](#) or the [biosecurity standard](#), may be restricted to cleaning activities of no greater than FR 20. See [decision support tools](#) for hull grooming. The [chemical contamination standard](#) must be met or in-water cleaning should not occur.

The standards require operators to demonstrate through an independent scientific assessment that they meet specified requirements. Cleaning operators must keep records of each clean performed in accordance with these standards for auditing purposes. These records must be retained for a period of 3 years. The approval of technologies and methods utilised by in-water cleaning operators and the process of approving in-water cleaning of specific vessels is outside the scope of these standards. Vessel operators requesting to in-water clean should contact the relevant regulator regarding permission for the proposed activity.

The Alliance for Coastal Technologies and Maritime Environmental Resource Center have published [Guidelines for Testing Ship Biofouling In-Water Cleaning Systems](#) that may be used as a guide for testing in-water cleaning systems.

Any change to the in-water cleaning equipment (not including general maintenance – e.g. changing filters) will require assessment by an independent scientific organisation and be submitted to the relevant regulator.

In-water cleaning activities related to research and development of equipment and methods, particularly for the purposes of demonstrating compliance with the standards, may be considered compliant with the in-water cleaning operator requirements if the relevant regulator is satisfied that:

- the in-water cleaning equipment has been assessed by an independent scientific organisation to determine that the required outcomes ([section 2.2.1](#), [section 2.2.2](#) and [section 2.2.3](#)) have a high likelihood of being met by the technology and operations
- the in-water cleaning activity complies with all other relevant sections of the [documentation requirements](#) and of the standards, as determined by the relevant regulator.

## 2.3 Application of standards

This section provides information on the application of the [capture standard](#), [biosecurity standard](#) and [chemical contamination standard](#) to hull cleaning with capture, cleaning without capture, propeller cleaning or polishing, niche area cleaning and the criteria that must be met before cleaning.

The [documentation requirements](#) and [in-water cleaning operator requirements](#) are required to be met for all in-water cleaning activity.

Further guidance on determining the application of the standards to in-water cleaning activity is provided by the [decision support tools](#).

### 2.3.1 In-water cleaning of the hull with capture

In-water cleaning of the general hull (e.g. flat bottom, sides) may occur if the conditions in (1) and (2) are met.

- 1) The [capture standard](#), [biosecurity standard](#) and [chemical contamination standard](#) are met.
- 2) The [documentation requirements](#) and [in-water cleaning operator requirements](#) are met.

### 2.3.2 In-water cleaning without capture

In-water cleaning may occur without meeting the [capture standard](#) and [biosecurity standard](#), provided the conditions in (1) to (5) are all met.

- 1) The anti-fouling coating is in sound condition and does not contain diuron, cybutryne, ziram, tributyltin or chlorathonil.
- 2) The [chemical contamination standard](#) is met.
- 3) The biofouling is microfouling (FR 20 or less) as assessed using Table 1.
- 4) The cleaning method does not damage the anti-fouling coating.
- 5) The [documentation requirements](#) and [in-water cleaning operator requirements](#) are met.

#### In-water cleaning without capture note

See [Decision support tools](#) to determine the requirements for in-water cleaning without capture.

Evidence that the anti-fouling coating manufacturer approves or accepts the method of cleaning specified may be accepted as evidence that the cleaning method does not damage the anti-fouling coating.

If any of the conditions specified in this section cannot be met, then the [capture standard](#), [biosecurity standard](#) and [chemical contamination standard](#) must all be met for the cleaning activity to meet the standards.

### 2.3.3 Propeller cleaning or polishing

Propeller cleaning or polishing may occur without meeting the [capture standard](#), [biosecurity standard](#) and [chemical contamination standard](#), provided the conditions in (1), (2) and (3) are met.

- 1) Any anti-fouling coating on the propeller is not damaged or removed during cleaning activities.
- 2) An in-water inspection demonstrates that the biofouling type is moderate or low (FR $\leq$ 80) and not more than light cover (1% to 5%) (see Table 1, Table 2 and Table 3).
- 3) The [documentation requirements](#) and [in-water cleaning operator requirements](#) are met.

#### Propeller polishing note

See [section 2.4](#) for guidance on determining relevant requirements for propeller cleaning or polishing.

Propeller cleaning or polishing is limited to the propeller, this does not include the niche areas associated with the propeller such as rope guards etc.

If an invasive aquatic species is detected on the propeller, a regulator may require that the [capture standard](#) and [biosecurity standard](#) be met.

If any of the conditions specified in this section cannot be met, then the [capture standard](#), [biosecurity standard](#) and [chemical contamination standard](#) must be met.

### 2.3.4 Niche areas

In-water cleaning of niche areas may occur if the conditions in (1) and (2) are met.



- 1) The [capture standard](#), [biosecurity standard](#) and [chemical contamination standard](#) are met.
- 2) The [documentation requirements](#) and [in-water cleaning operator requirements](#) are met.

### 2.3.5 Biofouling of regional origin

In-water cleaning activities may occur without meeting the [capture standard](#) and [biosecurity standard](#) provided the conditions in (1), (2) and (3) are met.

- 1) The relevant regulator is satisfied that the biofouling is of regional origin.
- 2) The [chemical contamination standard](#) is met.
- 3) The documentation requirements relating to the [anti-fouling coating](#) and [cleaning method](#) are met for cleaning biofouling of regional origin.

#### **Biofouling of regional origin note**

The [chemical contamination standard](#) must be met when cleaning biofouling of regional origin.

The relevant regulator may require that providers of commercial in-water cleaning services need to meet additional requirements, such as the [in-water cleaning operator requirements](#).

## 2.4 Decision support tools

**Table 4 Checklist for in-water cleaning with capture**

Timing	Criteria	Relevant guideline
Prior to in-water clean	<input type="checkbox"/> Vessel has valid anti-fouling system (AFS) certificate	2.2.4(1)
	<input type="checkbox"/> Vessel AFC does not contain diuron, cybutryne, ziram, tributyltin or chlorathonil	2.2.4(1)
	<input type="checkbox"/> Vessel AFC is within service life	2.2.4(1)
	<input type="checkbox"/> Inspection report – assessed AFC type and condition	2.2.4 (2)
	<input type="checkbox"/> Inspection report – assessed biofouling	2.2.5 (5)
	<input type="checkbox"/> Inspection report – sufficient quality	2.2.5 (6)
	<input type="checkbox"/> Inspection report – provided to vessel	2.2.5 (6)
	<input type="checkbox"/> Evidence that identified cleaning method is appropriate to meet all standards, or evidence that R&D-related cleaning activity is highly likely to meet all standards	2.2.4 (3)
	<input type="checkbox"/> In-water cleaning operator holds all required documents	2.2.5 (1)
	<input type="checkbox"/> In-water cleaning operator holds all approvals, including location approvals	2.2.5 (2)
During clean	<input type="checkbox"/> Capture standard is met	2.2.1
	<input type="checkbox"/> Biosecurity standard is met	2.2.2
	<input type="checkbox"/> Chemical contamination standard is met	2.2.3
After clean	<input type="checkbox"/> In-water cleaning report is completed	2.2.5 (3)
	<input type="checkbox"/> In-water cleaning operator retains documents	2.2.5 (4)

**Table 5 Checklist for in-water cleaning without capture (hull grooming)**

Timing	Criteria	Relevant guideline
Prior to in-water clean	<input type="checkbox"/> Vessel has valid anti-fouling system (AFS) certificate	2.2.4(1)
	<input type="checkbox"/> Vessel AFC does not contain diuron, cybutryne, ziram, tributyltin or chlorathonil	2.2.4(1)
	<input type="checkbox"/> Vessel AFC is within service life	2.2.4(1)
	<input type="checkbox"/> Inspection report – assessed AFC type and condition	2.2.4 (2)
	<input type="checkbox"/> Inspection report – assessed biofouling	2.2.5 (5)
	<input type="checkbox"/> Inspection report – sufficient quality	2.2.5 (6)
	<input type="checkbox"/> Inspection report – provided to vessel	2.2.5 (6)
	<input type="checkbox"/> Evidence that identified cleaning method is appropriate to meet all standards, or evidence that R&D-related cleaning activity is highly likely to meet all standards	2.2.4 (3)
	<input type="checkbox"/> In-water cleaning operator holds all required documents	2.2.5 (1)
	<input type="checkbox"/> In-water cleaning operator holds all approvals, including location approvals	2.2.5 (2)
During clean (Option 1)	<input type="checkbox"/> Capture standard is met	2.2.1
	<input type="checkbox"/> Biosecurity standard is met	2.2.2
	<input type="checkbox"/> Chemical contamination standard is met	2.2.3
During clean (Option 2)	<input type="checkbox"/> Chemical contamination standard is met	2.2.3
	<input type="checkbox"/> Biofouling is microfouling (FR or less) as assessed using Table 1	2.3.2 (4)
	<input type="checkbox"/> Cleaning method does not damage the anti-fouling coating	2.3.2 (5)
After clean	<input type="checkbox"/> In-water cleaning report is completed	2.2.5 (3)
	<input type="checkbox"/> In-water cleaning operator retains documents	2.2.5 (4)

**Table 6 Checklist for niche area cleaning with capture**

Timing	Criteria	Relevant guideline
Prior to in-water clean	<input type="checkbox"/> Vessel has valid anti-fouling system (AFS) certificate	2.2.4(1)
	<input type="checkbox"/> Vessel AFC does not contain diuron, cybutryne, ziram, tributyltin or chlorathonil	2.2.4(1)
	<input type="checkbox"/> Vessel AFC is within service life	2.2.4(1)
	<input type="checkbox"/> Inspection report – assessed AFC type and condition	2.2.4 (2)
	<input type="checkbox"/> Inspection report – assessed biofouling	2.2.5 (5)
	<input type="checkbox"/> Inspection report – sufficient quality	2.2.5 (6)
	<input type="checkbox"/> Inspection report – provided to vessel	2.2.5 (6)
	<input type="checkbox"/> Evidence that identified cleaning method is appropriate to meet all standards, or evidence that R&D-related cleaning activity is highly likely to meet all standards	2.2.4 (3)
	<input type="checkbox"/> In-water cleaning operator holds all required documents	2.2.5 (1)
	<input type="checkbox"/> In-water cleaning operator holds all approvals, including location approvals	2.2.5 (2)
During clean	<input type="checkbox"/> Capture standard is met	2.2.1
	<input type="checkbox"/> Biosecurity standard is met	2.2.2
	<input type="checkbox"/> Chemical contamination standard is met	2.2.3
After clean	<input type="checkbox"/> In-water cleaning report is completed	2.2.5 (3)
	<input type="checkbox"/> In-water cleaning operator retains documents	2.2.5 (4)

**Table 7 Checklist for propellor polishing without capture**

Timing	Criteria	Relevant guideline
Prior to in-water clean	<input type="checkbox"/> Vessel has valid anti-fouling system (AFS) certificate	2.2.4(1)
	<input type="checkbox"/> Vessel AFC does not contain diuron, cybutryne, ziram, tributyltin or chlorathonil	2.2.4(1)
	<input type="checkbox"/> Vessel AFC is within service life	2.2.4(1)
	<input type="checkbox"/> Inspection report – assessed AFC type and condition	2.2.4 (2)
	<input type="checkbox"/> Inspection report – assessed biofouling	2.2.5 (5)
	<input type="checkbox"/> Inspection report – sufficient quality	2.2.5 (6)
	<input type="checkbox"/> Inspection report – provided to vessel	2.2.5 (6)
	<input type="checkbox"/> Evidence that identified cleaning method is appropriate to meet all standards, or evidence that R&D-related cleaning activity is highly likely to meet all standards	2.2.4 (3)
	<input type="checkbox"/> In-water cleaning operator holds all required documents	2.2.5 (1)
	<input type="checkbox"/> In-water cleaning operator holds all approvals, including location approvals	2.2.5 (2)
During clean (Option 1)	<input type="checkbox"/> Capture standard is met	2.2.1
	<input type="checkbox"/> Biosecurity standard is met	2.2.2
	<input type="checkbox"/> Chemical contamination standard is met	2.2.3
During clean (Option 2)	<input type="checkbox"/> Biofouling is moderate or lower (FR $\leq$ 80) and not more than light cover (1% to 5%)	2.3.3 (2)
	<input type="checkbox"/> Cleaning method does not remove or damage anti-fouling coating	2.3.3 (1)
After clean	<input type="checkbox"/> In-water cleaning report is completed	2.2.5 (3)
	<input type="checkbox"/> In-water cleaning operator retains documents	2.2.5 (4)

**Table 8 Checklist for cleaning of regional biofouling**

Timing	Criteria	Relevant guideline
Prior to in-water clean	<input type="checkbox"/> Biofouling of regional origin determined by relevant regulator	2.3.5
	<input type="checkbox"/> Vessel has valid anti-fouling system (AFS) certificate	2.2.4(1)
	<input type="checkbox"/> Vessel AFC does not contain diuron, cybutryne, ziram, tributyltin or chlorathonil	2.2.4(1)
	<input type="checkbox"/> Vessel AFC is within service life	2.2.4(1)
	<input type="checkbox"/> An inspection report or alternative information (such as vessel movement logs) specified by the relevant regulator, used to satisfy the documentation requirements.	2.2.4(2) 2.2.5(5) 2.2.5(6)
	<input type="checkbox"/> Evidence that identified cleaning method is appropriate to meet all standards, or evidence that R&D-related cleaning activity is highly likely to meet all standards	2.2.4 (3)
	<input type="checkbox"/> In-water cleaning operator holds all required documents	2.2.5 (1)
	<input type="checkbox"/> In-water cleaning operator holds all approvals, including location approvals	2.2.5 (2)
During clean	<input type="checkbox"/> Capture standard is met (not required)	2.2.1
	<input type="checkbox"/> Biosecurity standard is met (not required)	2.2.2
	<input type="checkbox"/> Chemical contamination standard is met	2.2.3
After clean	<input type="checkbox"/> In-water cleaning report is completed	2.2.5 (3)
	<input type="checkbox"/> In-water cleaning operator retains documents	2.2.5 (4)

# Glossary

Term	Definition
abrasive blasting	<p>Abrasive blasting (also known as grit blasting) uses air pressure, water pressure or centrifugal force to propel an abrasive material onto a surface to remove contamination, rust and paint, and to create surface profile. Common abrasive materials used include sand, steel shot, steel grit, iron grit, copper slag, garnet and aluminium oxide. Dry abrasive blasting uses compressed air to propel the abrasive material.</p> <p>Wet abrasive blasting (slurry blasting) uses a slurry of water and abrasive material (rather than dry abrasive alone) to suppress dust generation.</p>
anti-fouling coating	A coating applied to submerged surfaces to prevent or reduce accumulation of biofouling.
Australian territorial seas	The waters (including the internal waters of Australia) within the outer limits of the <a href="#">territorial sea</a> of Australia (including every external territory). The territorial sea is a belt of water not exceeding 12 nautical miles in width measured from the territorial sea baseline.
background sample	Sample of water taken at or near the area where in-water cleaning occurs but that is not directly impacted by the cleaning activity.
bioaccumulation	The process by which chemical substances are accumulated by aquatic organisms by all routes of exposures (dietary and the ambient environment).
biocide	A chemical substance incorporated into anti-fouling coatings to prevent settlement or survival of aquatic organisms.
biofouling	The accumulation of aquatic organisms such as microorganisms, plants and animals on surfaces and structures immersed in or exposed to the aquatic environment. Biofouling can include pathogens.
biosecurity	The exclusion, eradication or effective management of pests and diseases that threaten the economy, environment, human health, or social and cultural values.
capture	The collection of removed cleaning debris at the cleaning head.
cleaning debris	Any substance removed from the vessel by the cleaning process. For example, the biofouling, paint flakes or particles and chemical substances (including dissolved chemicals) removed at the cleaning head of an in-water cleaning unit.
cleaning head	The unit that directly interacts with the hull and other areas of the vessel to remove and capture the cleaning debris.
chemical contamination	The presence of chemicals in any environment where they would not usually be found, or at higher concentrations than they would naturally have occurred.
coastal waters	Coastal Waters is a belt of water between the limits of the Australian States and the Northern Territory and a line 3 nautical miles seaward of the territorial sea baseline.
default guideline value	A guideline value recommended for generic application in the absence of a more specific guideline value (e.g., a site-specific guideline value) ANZG 2018.
effluent	Any material or liquid that is discharged into Australian territorial seas as a result of in-water cleaning.
high ecological/conservation value system	Effectively unmodified or other highly valued ecosystems, typically (but not always) occurring in national parks, conservation reserves or in remote or inaccessible locations.
hull grooming	Proactive, regular, and light cleaning of a vessel hull coating to remove microfouling.
hydroblasting	Hydroblasting (also known as hydrojetting, water jetting and water blasting) uses water propelled at high or ultrahigh pressure onto a surface to clean surfaces and remove coatings.
independent scientific organisation	A scientific organisation with the recognised expertise for testing and evaluating in-water cleaning systems with no affiliation to the in-water cleaning company or technology that is being assessed. This group will conduct testing on the equipment and provide a report

<b>Term</b>	<b>Definition</b>
	with the findings to demonstrate if it does or does not meet the criteria specified by these standards. The organisation should have internationally recognised quality management systems in place (E.g., relevant International Organization for Standardization standards or Australian Standards).
invasive aquatic species	Non-native species to a particular ecosystem which may pose threats to human, animal and plant life, economic and cultural activities and the aquatic environment.
in-water cleaning	The physical removal of biofouling or anti-fouling coating surface deposits from submerged surfaces. For the purposes of the standards, 'in-water' refers to the parts of a vessel or movable structure that are either below the load line or normally submerged and/or are coated in anti-fouling coating. In-water cleaning includes hull grooming, propeller cleaning or polishing and cleaning of niche areas.
level of protection	A degree of protection afforded to a water body based on its ecosystem condition.
macrofouling	Biofouling caused by the attachment and subsequent growth of visible plants and animals on structures and vessels exposed to water. Macrofouling is large, distinct multicellular individual or colonial organisms visible to the human eye such as barnacles, tubeworms, mussels, fronds or filaments of algae, bryozoans, sea squirts and other large attached, encrusting or mobile organisms.
microfouling	Biofouling caused by bacteria, fungi, microalgae, protozoans, and other microscopic organisms, that creates a biofilm also called a slime layer.
mixing zone	An explicitly defined area around an effluent discharge where some or all, water quality objectives may not be met.
moveable structure	Structures that can be operated at different locations by the operations of fixing position, floating, sinking and removal. Examples include, but are not limited to, floating breakwater, floating pier, jackup drilling platform, bottom-supported platform, semi-submersible platform and various types of specially designed vessels.
niche area	Submerged surface areas on a vessel that may be more susceptible to biofouling than the main hull due to structural complexity, different or variable hydrodynamic forces, susceptibility to AFC wear or damage, inadequate or no protection by AFS. They include, but are not limited to, waterline, sea chests, bow thrusters, propeller shafts, inlet gratings, jackup legs, moon pools, bollards, braces, and dry docking support strips. The propeller is not considered a niche area for the purpose of the standard.
non-viable	Not capable of living, growing, developing or reproducing.
propeller cleaning or polishing	Cleaning of propellers to restore their propulsion efficiency.
regional origin	Biofouling acquired in the same region as the proposed in-water cleaning activity – as determined by the relevant regulator.
regulator	A body including government agency or port authority responsible for regulating, assessing, or approving an aspect of in-water cleaning.
relevant regulator	The regulator(s) with authority at the proposed cleaning location. For example, a biosecurity agency, Environment Protection Authority or port authority.
sound condition (regarding AFC paint)	The anti-fouling coating does not have paint missing from intact blisters, visible scratch marks exposing underlying coatings, ruptured blisters, paint missing or peeling to expose steel substrate or any corrosion present.
subject to biosecurity control	Means subject to biosecurity control because of the <i>Biosecurity Act 2015</i> (Commonwealth) subsection 191(2) or (4) or subsection 192(2), (3) or (5).
toxicant	A chemical capable of producing an adverse response (effect) in a biological system at concentrations that might be encountered in the environment, seriously injuring structure or function or producing death. Examples include pesticides, trace metals and biotoxins.
vessel	Any kind of vessel used in navigation by water, however propelled or moved, including: <ul style="list-style-type: none"> <li>• a barge, lighter or other floating craft</li> </ul>



Term	Definition
vacuum blasting	<ul style="list-style-type: none"><li>• an air cushion vehicle, or other similar craft, used wholly or primarily in navigation by water</li><li>• installations</li><li>• floating structures.</li></ul> Vacuum blasting has vacuum technology added to dry abrasive blasting to capture used abrasive material and cleaning debris.
windy conditions	Wind greater than 20 km/h or 11 kn.

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# Appendix A: Types of coatings

Anti-fouling coatings evolve as a result of research and development efforts. A non-exhaustive list of types of coatings available to end users is presented below.

## Biocidal anti-fouling coatings

Biocidal anti-fouling coatings contain active ingredients that aim to prevent the settlement and growth of biofouling organisms.

The main types of biocidal coatings are:

- Insoluble matrix – contact leaching, long-life or diffusion anti-fouling coatings use an insoluble binder that contains a high concentration of biocide released from the coating through a diffusion process.
- Soluble matrix – controlled depletion polymer (CDP) or ablative anti-fouling coatings contain a binder that is slightly soluble in seawater. Hydration causes the coating to surface to slowly dissolve, releasing the freely associated biocide.
- Self-polishing copolymer (SPC) – anti-fouling coatings release biocides as a result of chemical reaction with the seawater to form a water-soluble polymer which polishes away due to movement of the vessel through water, releasing the biocide(s).
- Hybrid (ablative) polishing systems – combine the properties of CDPs and SPC paints, bringing together SPC technology with the rosin-based CDP technology.
- Fouling release coatings containing biocides – have low surface energy which impairs the adhesive attachment of biofouling and facilitates the detachment of biofouling when the vessel is moving in combination with biocide(s).
- Metallic anti-fouling coatings – use copper or copper nickel alloy as either metal sheathing or metal particles mixed into a coating.

## Biocide-free anti-fouling coatings

Biocide-free anti-fouling coatings rely on their physical nature to either impair the attachment of biofouling or to withstand regular in-water cleaning. The main categories are:

- Fouling release coatings – have low surface energy which impairs the adhesive attachment to biofouling and facilitate the detachment of biofouling when the vessel is moving.
- Biocide-free self-polishing copolymers – rely on a chemical reaction with the seawater to form a water-soluble polymer, which polishes away due to movement of the vessel through water, effectively creating a surface that is too unstable for biofouling to remain attached.
- Mechanically resistant coatings (using epoxy, vinyl ester resin combined with pigments, such as glass flakes) are tough, highly durable coatings without specific anti-fouling properties. They allow biofouling organisms to accumulate and are designed to withstand regular in-water cleaning (including abrasive methods).

# Appendix B: Guidance for assessment of biofouling

**Table 9 Naval Ships' Technical Manual fouling rating scale**

Type	Fouling rating (FR)	Description
Soft	0	A clean, foul-free surface; red and/or black AF paint or a bare metal surface.
	10	Light shades of red and green (incipient slime). Bare metal and painted surfaces are visible beneath the fouling.
	20	Slime as dark green patches with yellow or brown coloured areas (advanced slime). Bare metal and painted surfaces may be obscured by the fouling.
	30	Grass as filaments up to 3 inches (76 mm) in length, projections up to 1/4 inch (6.4 mm) in height; or a flat network of filaments, green, yellow, or brown in colour; or soft non calcareous fouling such as sea cucumbers, sea grapes, or sea squirts projecting up to 1/4 inch (6.4 mm) in height. The fouling cannot be easily wiped off by hand.
Hard	40	Calcareous fouling in the form of tubeworms less than 1/4 inch in diameter or height.
	50	Calcareous fouling in the form of barnacles less than 1/4 inch in diameter or height.
	60	Combination of tubeworms and barnacles, less than 1/4 inch (6.4 mm) in diameter or height.
	70	Combination of tubeworms and barnacles, greater than 1/4 inch in diameter or height.
	80	Tubeworms closely packed together and growing upright away from surface. Barnacles growing one on top of another, 1/4 inch or less in height. Calcareous shells appear clean or white in colour.
	90	Dense growth of tubeworms with barnacles, 1/4 inch or greater in height; Calcareous shells brown in colour (oysters and mussels); or with slime or grass overlay.
Composite	100	All forms of fouling present, soft and hard, particularly soft sedentary animals without calcareous covering (tunicates) growing over various forms of hard growth.

Source: Naval Ships' Technical Manual 2006

**Table 10 Level of fouling scale**

Rank	Description	Estimate of macrofouling cover (% of visible surface)
0	No slime layer. No macrofouling. Only clean surfaces.	0
1	Slime layer on some or all surfaces. No macrofouling.	0
2	Macrofouling present in small patches or a few isolated individuals or small colonies.	1 to 5
3	Considerable macrofouling on surfaces.	6 to 15
4	Extensive macrofouling present but more than half of surfaces without biofouling.	16 to 40
5	Very heavy macrofouling present covering substantial portions of visible surface.	41 to 100

Note: The Floerl et al. 2005 level of fouling scale provides visual estimates for assisting in the assessment of the amount of biofouling present.

## Method for allocating fouling rating and fouling cover

The method for allocating fouling rating and fouling cover ranks is based on the method proposed by Georgiades & Kluza (2020).

During an in-water inspection, the fouling rating and the estimate of fouling cover should be allocated for each area ( $\leq 1 \text{ m}^2$ ) within the hull transect or niche area. For example, for a propeller where the total surface area is estimated to be  $\leq 1 \text{ m}^2$ , the fouling rating and fouling cover rank is allocated for the entire structure, including the blades, boss and shaft. Where the surface area of the propeller is  $> 1 \text{ m}^2$ , separate fouling rating and fouling cover ranks are allocated for each  $1 \text{ m}^2$  area. Similarly, each  $1 \text{ m}^2$  area along a transect is to be given a separate fouling rating and fouling cover rank. For above water surveys (i.e. on-vessel or topsides surveys), a fouling rating and fouling cover rank is allocated for each area ( $\leq 2 \text{ m}^2$ ) under survey.

For each transect and niche area surveyed, the mode of the fouling rating and fouling cover rank (i.e. the most frequent ranking) and the fouling rating and fouling cover range (i.e. the highest and lowest ranking) is to be used to report the overall fouling rating and fouling cover of that area. It is inappropriate to use the mean (e.g. average) and standard deviation to report the results derived from ordinal data. For cases where the survey data is multimodal (i.e. more than one mode), report each of the modes for overall fouling rating and fouling cover and the fouling rating and fouling cover range. For cases where there is no mode, report the highest fouling rating and fouling cover for overall fouling rating and fouling cover and the fouling rating and fouling cover range.

A minimum of 3 digital images should be taken for each surveyed area (i.e. a minimum of 3 images should be taken for each allocation of fouling rating and fouling cover).

It is advised that vessel surveyors should be trained in the use of the fouling rating and the level of fouling rank scale.

**Table 11 Example of assessment of biofouling table**

Location on vessel	Fouling rating (FR)		Fouling coverage (%)	
	Mode	Range	Mode	Range
Propeller blade 1	60	40 to 70	5	0 to 10
Portside fire intake grate	80	30 to 100	60	5 to 100

# References

- ACT/MERC 2022, [Guidelines for Testing Ship Biofouling In-Water Cleaning Systems](#), TS-788-22, CBL/UMCES 2023-017, accessed July 2023.
- ANZG 2018, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand governments and Australian state and territory governments, Canberra.
- Bindoff, NL, WWL Cheung, JG Kairo, J Arístegui, VA Guinder, R Hallberg, N Hilmi, N Jiao, MS Karim, L Levin, S O'Donoghue, SR Purca Cuicapusa, B Rinkevich, T Suga, A Tagliabue & P Williamson 2022, Changing Ocean, Marine Ecosystems, and Dependent Communities, In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 447–587, DOI: [org/10.1017/9781009157964.007](https://doi.org/10.1017/9781009157964.007).
- Candries, M, Atlar, M & Anderson, CD 2003, 'Estimating the impact of new-generation antifoulings on ship performance: the presence of slime', *Journal of Marine Engineering & Technology*, 2:1, pp. 13–22.
- Dafforn, KA, Lewis, JA, & Johnston, EL 2011, 'Antifouling strategies: History and regulation, ecological impacts, and mitigation', *Marine Pollution Bulletin*, vol. 62, pp. 453–465.
- Davidson, IC, Smith, G, Ashton, GV, Ruiz, GM, & Scianni, C 2020, 'An experimental test of stationary lay-up periods and simulated transit on biofouling accumulation and transfer on ships', *Biofouling*, vol. 36, pp. 455–466, DOI: [org/ 10. 1080/ 08927014. 2020. 17696 12](https://doi.org/10.1080/08927014.2020.1769612).
- Department of the Environment and New Zealand Ministry for Primary Industries 2015 '*Anti-fouling and in-water cleaning guidelines*' Department of Agriculture, Canberra.
- Dobretsov, S, Coutinho, R, Rittschof, D, Salta, M, Ragazzola, F & Hellio, C 2019 'The oceans are changing: impact of ocean warming and acidification on biofouling communities', *Biofouling*, vol. 35:5, pp. 585–595, DOI: [10.1080/08927014.2019.1624727](https://doi.org/10.1080/08927014.2019.1624727).
- Finnie, AA, 2006, 'Improved estimates of environmental copper release rates from antifouling products', *Biofouling* vol. 22, pp. 279–291.
- Floerl, O, Coutts, A 2009, 'Potential ramifications of the global economic crisis on human-mediated dispersal of marine non-indigenous species', *Mar Pol Bul* vol. 58, pp. 1,595–1,598, DOI: [org/10. 1016/j.marpo lbul.2009.08.003](https://doi.org/10.1016/j.marpolbul.2009.08.003).
- Floerl, O, Inglis, G, & Hayden, B 2005, '[A Risk-Based Predictive Tool to Prevent Accidental Introductions of Nonindigenous Marine Species](#)', *Environmental Management*, vol. 35, pp. 765–778, DOI: [10.1007/s00267-004-0193-8](https://doi.org/10.1007/s00267-004-0193-8).
- Georgiades, E, Growcott, A, and Kluza, D 2018, 'Technical Guidance on Biofouling Management for Vessels Arriving to New Zealand', Ministry for Primary Industries, [mpi.govt.nz/dmsdocument/27726-](https://mpi.govt.nz/dmsdocument/27726-)

technical-guidance-on-biofouling-management-for-vessels-arriving-to-new-zealand (accessed October 2023).

Georgiades, E, & Kluza, D 2020, 'Technical Advice: Conduct of In-Water Biofouling Surveys for Domestic Vessels', Biosecurity New Zealand Technical Paper No: 2020/04, Ministry for Primary Industries, New Zealand.

Hearin, J, Hunsucker, KZ, Swain, G, Stephens, A, Gardner, H, Lieberman, K & Harper, M 2015, 'Analysis of long-term mechanical grooming on large-scale test panels coated with an antifouling and a fouling-release coating', *Biofouling*, vol. 31, no. 8, pp. 625–638.

Holm, ER, Curran, JR, Stephens, AP, Swain, GW & Haslbeck, EG 2011, 'Effect of repeated cleaning on condition and performance of a fouling-release coating', NSWCCD-61-TR-2011, 11 July 2011.

Hunsucker JT, Hunsucker KZ, Gardner H, Swain G 2016, 'Influence of hydrodynamic stress on the frictional drag of biofouling communities', *Biofouling*, vol. 32, pp. 1,209–1,221, DOI: 10.1080/08927014.2016.1242724.

IMO 2023, *2023 Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species*, MEPC.378(80), International Maritime Organization, London, United Kingdom, accessed 7 July 2023.

Kiil, S, Weinell, CE, Pedersen, MS, Dam-Johansen, K 2002 'Mathematical modelling of a self-polishing antifouling paint exposed to seawater: a parameter study', *Chemical Engineering Research and Design*, vol. 80, pp. 45–52.

Mihaylova, R, Barnes, C 2023, 'The importance of hull coating specifications', *Journal of Protective Coatings and Linings*, vol. 40(4), pp. 17–21.

Mihaylova, R, Barnes, C, Porsbjerg, M 2022, 'Energy Efficiency: Data-driven Approaches to Hull Coating Specification and Selection', *Scaling Decarbonisation Solutions: Reducing Emissions by 2030*, Rotterdam, The Netherlands.

Morrisey, D, Gadd, J, Page, M, Floerl, O & Woods, C 2013, 'In-water cleaning of vessels: Biosecurity and chemical contamination risks', Ministry for Primary Industries, Wellington, New Zealand.

Morrisey, D, Inglis, G, Tait, L, Woods, C, Lewis, J, & Georgiades, E 2015, 'Procedures for Evaluating in-Water Systems to Remove or Treat Vessel Biofouling' MPI Technical Paper No: 2015/39, Ministry for Primary Industries, New Zealand.

Naval Ships' Technical Manual 2006, 'Waterborne underwater hull cleaning of Navy ships', Publication No. S9086-CQ-STM-010/CH-081, Revision 5, Naval Sea Systems Command, Washington DC, USA, pp. 68.

Oliveira, DR & Granhag, L 2020, 'Ship hull in-water cleaning and its effects on fouling-control coatings', *Biofouling*, vol. 36, no. 3, pp. 332–350, DOI: 10.1080/08927014.2020.1762079.

Ruiz, GM, Galil, BS, Davidson, IC, Donelan, SA, Miller, AW, Minton, MS, Muirhead, JR, Ojaveer, H, Tamburri, MN & Carlton, JT 2022, 'Global marine biosecurity and ship lay-ups: Intensifying effects of trade disruptions', *Biological Invasions*, DOI: org/10.1007/s10530-022-02870-y.

Scianni, C, Georgiades, E, Mihaylova, R, Tamburri, MN 2023, 'Balancing the consequences of in-water cleaning of biofouling to improve ship efficiency and reduce biosecurity risk', *Frontiers in Marine Science*, vol. 10, DOI: 10.3389/fmars.2023.1239723.

Singh, N, Turner, A, 2009, 'Leaching of copper and zinc from spent antifouling paint particles', *Environmental Pollution*, vol. 157, pp. 371–376.

Stamper, DM, Hasleback, EG 2015, 'An Analysis of U.S. Navy Arctic and Ice Operations With Regard to Ship Hull Coating Systems', Technical report accession no. AD1068072, Naval Surface Warfare Center, Carderock Division, Bethesda, Maryland, DOI: apps.dtic.mil/sti/citations/AD1068072.

Swain, G, Erdogan, C, Foy, L, Gardner, H, Harper, M, Hearin, J, Hunsucker, KZ, Hunsucker, JT, Nanney, M, Ralston, E, Stephens, A, Tribou, M, Walker, B & Wassick, A 2022, 'Proactive in-water ship hull grooming as a method to reduce the environmental footprint of ships', *Frontiers in Marine Science*, vol. 8, DOI: 10.3389/fmars.2021.808549.

Sylvester, F, Kalaci, O, Leung, B, Lacoursière Roussel, A, Clarke Murray, C, Choi, FM, Bravo, MA, Therriault, TW & MacIsaac, HJ 2011, 'Hull fouling as an invasion vector: can simple models explain a complex problem?', *Journal of Applied Ecology*, vol. 48, pp. 415–423.

Weber, F, Esmaili, N 2023 'Marine biofouling and the role of biocidal coatings in balancing environmental impacts', *Biofouling*, vol. 39, pp. 661–681, DOI: 10.1080/08927014.2023.2246906.

Ytreberg, E, Lagerström, M, Holmqvist, A, Eklun, B, Elwing, H, Dahlström, M, Dahl, P, Dahlström, M 2017, 'A novel XRF method to measure environmental release of copper and zinc from antifouling paints', *Environmental Pollution*, vol. 225, pp. 490–496, DOI: org/10.1016/j.envpol.2017.03.014.