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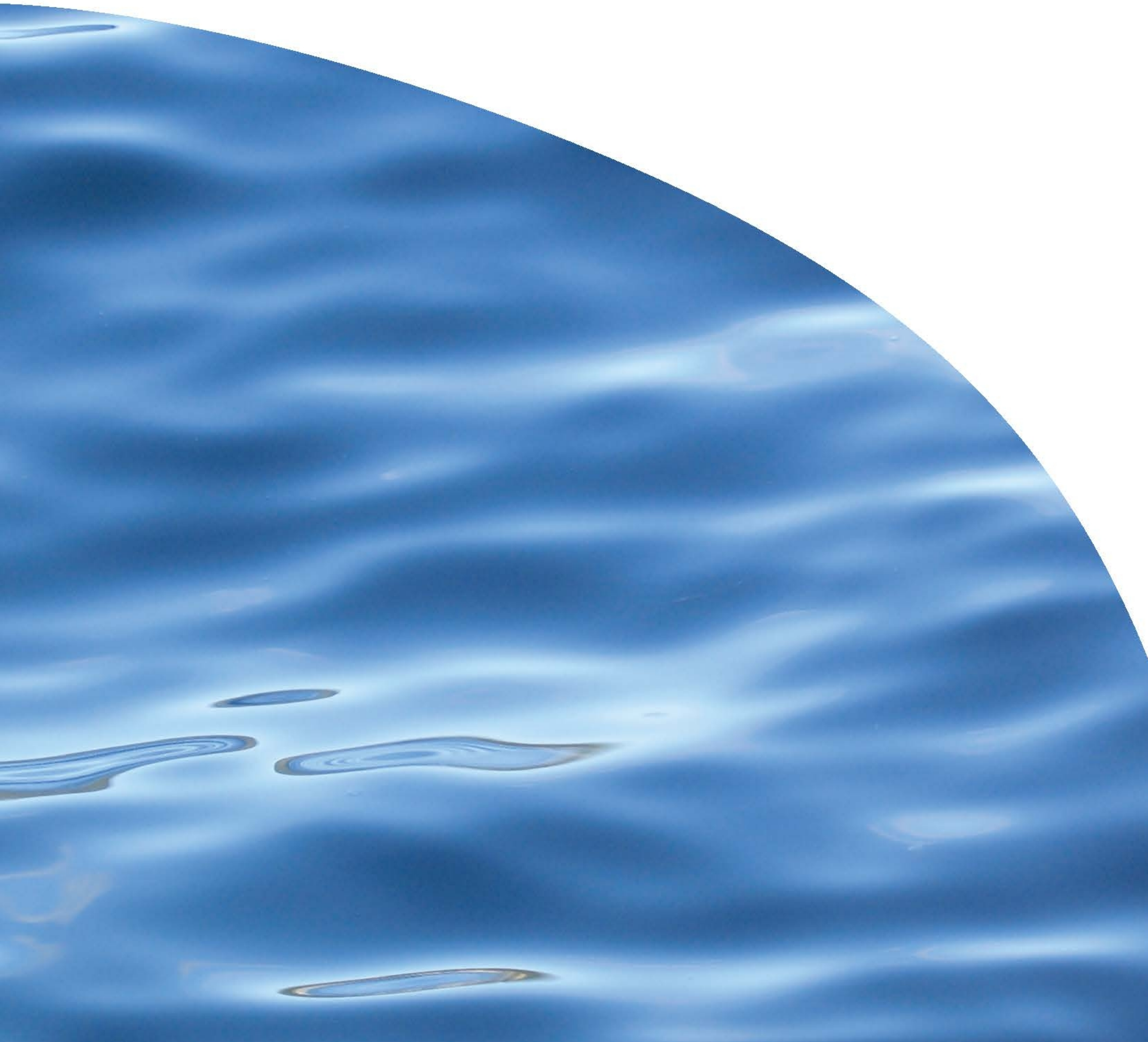
BILGE WATER RISK TO THE FIORDLAND MARINE AREA



BILGE WATER RISK TO THE FIORDLAND MARINE AREA

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Prepared for Environment Southland via Envirolink Small Advice Grant 1608-ESRC160

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EXECUTIVE SUMMARY

Marine non-indigenous species (NIS) can spread domestically by natural dispersal mechanisms and through human-mediated transport vectors such as vessel movements between coastal regions. Vessels can transport marine organisms as part of biofouling communities on the hull, in ballast water, or in water or debris entrained in bilge spaces. Compared to other modes of infections, the risk of species transfer via bilge water is relatively unknown. Any microscopic life-stages (*e.g.* larvae or spores) present will be difficult to detect without specialist techniques and equipment, raising the risk of inadvertent transfer of propagules.

One location particularly at risk from the anthropogenic transfer of marine NIS is the Fiordland Marine Area (FMA). The FMA is well recognised for its pristine natural character and biodiversity, and supports a range of regionally important coastal industries, including commercial fishing and tourism. The FMA is frequently visited by vessels from both domestic and international origins, including those where populations of NIS not currently found in the region are known to occur. As such, Environment Southland is currently developing a Fiordland Marine Pathways Management Plan. The Plan proposes that clean vessel, clean gear and clean residual seawater standards be adopted and complied with to minimise the risk of marine pests spreading to Fiordland. Bilge water has been recognised as a pathway that needs to be considered and potentially included into the standards.

Cawthron Institute has been contracted by Environment Southland, via a Ministry of Business, Innovation and Employment's Envirolink small advice grant, to advise on biosecurity risks posed by bilge water with regards to transport of marine NIS into the FMA. An overview of recent research describing the type of biological material commonly found in bilge water is presented here, as well as the results of lab-based experiments investigating the effects of voyage duration and discharge on the viability of this material. A summary of existing guidance on managing risks (domestic and international) is presented along with consideration of bilge water treatment using chlorine.

Experimental assessment of biological material contained in bilge water suggests these discharges pose a biosecurity threat to the FMA. Vessel bilge water samples were shown to contain a number of planktonic species, including larvae and juveniles of several invertebrate groups. These findings support the only previous research of bilge water biosecurity risks, a survey of recreational and commercial vessels in eastern Canada. In addition, propagules of three key biofouling species were shown to survive 1-3 day holding periods with no aeration, with successful settlement or fragment reattachment possible after discharge.

Mitigation measures for biosecurity risks posed by bilge water include: restrictions on the location of discharge (*i.e.* discharge in the source region or areas of low-risk), retention of bilge water for subsequent disposal, and treatment of bilge water prior to discharge. Requiring discharge within the source region was identified as the most practical option

available, with no associated costs and minimal logistic constraints. However, the use of chemical treatments should be considered when discharges can't be managed or for high-risk vessels. Chlorine provides a cost-effective and efficient biocide option, however constraints with regards to contaminant discharge regulations and health and safety considerations exist.

Regulation of bilge water discharge or treatment is likely to be difficult to enforce. However, good management can be promoted through codes of practice as well as general communications-based measures to educate boaters about possible risks from bilge water. Encouraging operators to empty their bilge before entering the FMA or within the same fiord where seawater entered the vessel is recommended. Any specific treatment measures instigated would need to be simple and practical to ensure a high uptake. Guidance provided in previous documents (in particular the earlier advice document regarding seawater discharges in Fiordland[1]) is recommended at this stage for chemical treatment options. Further research is needed to develop standard operating procedures for the use of chlorine to treat bilge and other seawater discharges.

[1] Cawthron Institute 2013. Biosecurity guidelines for managing seawater discharges from vessels operating in the Fiordland (Te Moana o Atawhenua) Marine Area. Advice document prepared by the Cawthron Institute on behalf of the Ministry for Primary Industries. Version 1.0 (FINAL). 15 p.

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1. INTRODUCTION

1.1. Background

The spread of non-indigenous species (NIS) in the marine environment can have widespread ecological and economic impacts (Colautti *et al.* 2006; Molnar *et al.* 2008). Almost 200 marine NIS are believed to have been introduced into New Zealand, the majority into international ports via ballast water and ship-hull fouling (Hayden *et al.* 2009; Gordon *et al.* 2010). Although preventing NIS introductions into New Zealand is the primary goal of marine biosecurity, restricting subsequent domestic spread can reduce potential negative impacts of any organisms that do establish in New Zealand.

Marine NIS can spread domestically by natural dispersal mechanisms, which are difficult or impossible to counteract, and via anthropogenic transport vectors (Dodgshun *et al.* 2007; Inglis *et al.* 2010). Vessel movements between coastal regions are considered the primary anthropogenic vector for domestic spread, transporting marine organisms as part of biofouling communities on the hull, in ballast water, or in water or debris entrained in bilge spaces. NIS can also be translocated with contaminated fishing equipment, aquaculture stock, and discarded dredge spoil.

The potential for biofouling to transfer NIS is reasonably well-explored (*e.g.* Gollasch 2002; Fofonoff *et al.* 2003; Coutts & Taylor 2004; Bell *et al.* 2011), as are ballast water risks (*e.g.* Carlton 1985; Ruiz *et al.* 2000; Gregg *et al.* 2009). In comparison, bilge water is an unknown quantity with little research conducted in this area. The potential for bilge water to harbour microscopic life-stages, such as invertebrate larvae or algal spores, is particularly worrying. Microscopic life-stages are difficult to detect without specialist techniques and equipment, raising the risk of inadvertent transfer.

1.2. Fiordland Marine Area

One location particularly at risk from the anthropogenic transfer of marine NIS is the Fiordland Marine Area (FMA). The FMA is approximately 882,000 ha and is well recognised for pristine natural character and biodiversity, incorporating 10 marine reserves within its boundary (see Figure 1). In addition to its ecological value, the FMA supports a range of regionally important coastal industries, including commercial fishing and tourism.

The introduction of NIS into the FMA poses a severe threat to the ecology of the area, commercial industries, and key cultural and amenity values (*i.e.* impacts on food harvesting, recreational fishing and native biodiversity). The primary biosecurity risks to the region arise from vessel movements into and within the FMA (including from overseas). The majority of vessel movements are associated with recreational boating, commercial fishing and tourism (Sinner *et al.* 2009; Cawthron Institute 2013).

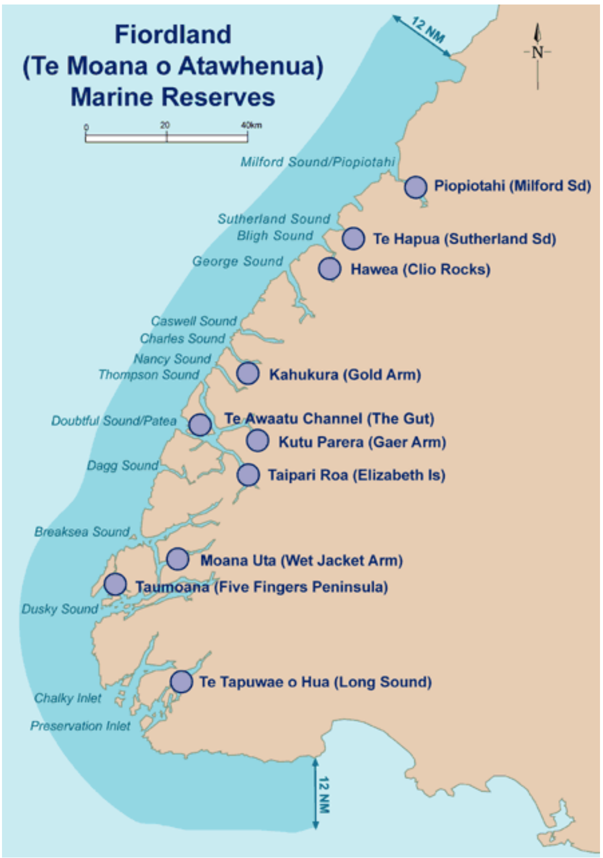


Figure 1. Fiordland Marine Area with the location of marine reserves within the region indicated. Source: Department of Conservation.

Given the remoteness of the FMA and the corresponding difficulties of surveillance and response, preventing NIS introductions must be a key consideration of any biosecurity management initiatives. Fouling associated with hulls, sea chests and other niche areas on vessels will likely be the dominant mechanism for the transfer of invasive marine organisms into the region (Sinner *et al.* 2009). Nevertheless, seawater discharges associated with ballast and bilge water may also pose a biosecurity risk to the FMA. Given that bilge water risks are not well understood, this mechanism has potential to compromise the overall effectiveness of a management plan.

1.3. Project scope

Cawthron Institute (Cawthron) has been contracted by Environment Southland under the Ministry of Business, Innovation and Employment's Envirolink small advice grant scheme to advise on biosecurity risks posed by bilge water with regards to transport of marine NIS into the FMA. Specifically, this document provides:

- an overview of recent field- and lab-based research describing the type of biological material commonly found in bilge water, as well as the effects of voyage duration and discharge on the viability of this material
- a summary of existing guidance on managing risks (domestic and international) with recommendations of practices which could realistically be adopted by vessels entering the FMA
- consideration of bilge water treatment using chlorine, including possible discharge-related mitigation measures (*e.g.* neutralisation prior to discharge).

Information provided will be incorporated into the Fiordland Marine Pathways Management Plan that is currently under development. The Pathways Plan proposes that clean vessel, clean gear and clean residual seawater standards be adopted and complied with to minimise the risk of marine pests spreading to Fiordland. Bilge water is another pathway that needs to be considered and potentially included into the standards. Best practice guidance on hull cleaning and antifouling technologies, cleaning of vessels and ways to treat residual seawater will be incorporated. The advice provided in the current document will also be of benefit to other regional councils, particularly those developing their own pathway management plans for vessel traffic (*e.g.* the top of the South Island and Northland regions).

2. BIOSECURITY AND BILGE WATER DISCHARGES

2.1. Bilge water

For the purposes of this report, bilge water is defined as any seawater that accumulates within the hull of a vessel, including in the engine room of larger vessels (*i.e.* seawater that enters the vessel via the stern glands), in the bilge sumps of smaller vessels, and uncontained water on the deck area of a vessel (Cawthron Institute 2013). Seawater can enter the vessel in a number of ways; common mechanisms include waves, leaks, use of a deck hose, and equipment transfer (*e.g.* during diving, fishing, aquaculture operations and scientific research) (see Appendix 1). Bilge water commonly contains materials other than seawater; for instance marine debris, oil, dirt, terrestrial vegetation, and detergents. This accumulated water is removed via pumps (manual and automatic operation) and is not commonly treated prior to discharge.

2.2. Biosecurity risks posed by bilge water

Internationally, Darbyson *et al.* (2009) has provided the only dedicated biosecurity assessment of bilge water. The authors surveyed commercial and recreational vessels operating around Prince Edward Island, Canada. They identified a total of 31 different taxa in the bilge water of 35 vessels. Results showed a wide diversity of zooplankton, including crab and bivalve larvae and juvenile sea stars. These findings demonstrate the potential for any species with a planktonic life-stage (*i.e.* most invasive marine species) to be transported via this method.

Fragments of colonial organisms and those capable of asexual reproduction are also likely to be transported via bilge water. Bilge water has previously been listed as a potential transport mechanism for invasive algae (Sant *et al.* 1996; Schaffelke & Deane 2005). Algae are often capable of surviving long emersion periods when kept in protected, high-humidity areas of a vessel, for instance entrapped in fishing nets or within anchor well compartments. In a similar manner, bilge water discharges have previously been identified as a possible spreading mechanism for the invasive ascidian *Didemnum vexillum* (Acosta & Forrest 2009).

Bilge water discharges have been implicated in the spread of several aquatic invasive species within the Great Lakes region of the USA. Although these are freshwater systems, the principle of species' spread among lakes and rivers through human-mediated transport vectors has many parallels to the marine environment. The introduction of invasive quagga mussels (*Dreissena bugensis*) to Lake Mead on the border of Nevada and Arizona is believed to have been via bilge water (specifically bait or live wells) (McMahon 2011; Wong and Gerstenberger 2011). Likewise, zebra mussel (*Dreissena polymorpha*) larvae have been found in live wells, bilges, bait buckets and engine spaces of recreational boats in Michigan, USA (Johnson *et al.* 2001).

2.3. Bilge water and the Fiordland Marine Area

A recent survey of boat operators within the FMA found that most vessels < 10 m length, including recreational, research and tourism vessels, are likely to have approximately 1 L of bilge water on board during usual operations. Larger vessels are believed to carry greater volumes, with 100 - 300 L estimated for commercial fishing boats and large research vessels (Cawthron Institute 2013). As such, bilge water is a common feature of vessels operating in the FMA. Vessels often travel between the FMA and other domestic and international locations but the associated biosecurity risk posed by bilge water is not known. The research outlined in Section 2.2 suggests some risk exists, but the relevance of this risk to biosecurity in New Zealand and the FMA is poorly understood. Cawthron has recently carried out the first quantitative assessment of bilge water risks in New Zealand. Key findings of this research are discussed in Section 3.

3. ASSESSMENT OF BILGE WATER AS A POTENTIAL VECTOR

Cawthron has ongoing projects investigating transport pathways for marine NIS, with research outcomes intended to support international and domestic pathway management initiatives. A preliminary study investigating the biosecurity risks associated with bilge water was recently completed. Project outcomes include assessment of the abundance, diversity and viability of biological material contained in bilge water from a range of vessel types. The relationship between voyage duration and survival of propagules within discharged bilge water was also investigated. Key findings and their implications for Environment Southland are discussed below.

3.1. Characterisation of biological material contained in bilge water

3.1.1. Vessel sampling and sample analysis

Approximately 50 boats were sampled between December 2014 and May 2015; however, only 31 of these vessels contained bilge water. A mixture of opportunistic and systematic sampling was employed. Opportunistic sampling involved one-off collection of vessel bilge water following completion of a particular trip. In contrast, systematic sampling involved collection of each bilge water discharge during an entire vessel trip. At the time of sampling, all vessel operators were asked several key questions about their bilge system, voyage history and usual methods of operation.

Bilge water was collected from 16 yachts and 13 motorboats during opportunistic sampling. Yachts sampled ranged from around 9 - 18 m length. Ports of origin were regional (Picton and Waikawa Bay), national (Wellington, Auckland, Dunedin) and international (Brisbane, Sydney, Hobart, United States). Bilge water volumes ranged from 150 ml (from a medium-sized yacht) to 27.3 L from a large catamaran. Considerably more bilge water was present within the hull of the catamaran at the time of sampling (> 200 L estimated); however, it was not logistically feasible to sample it in entirety. All motorboats sampled were < 10 m in length and of local or regional origin (*i.e.* Nelson and Picton). Bilge water volumes sampled from these vessels ranged from 900 ml to 5.5 L.

Two small (< 8 m length) research vessels, Cawthron's vessel *Waihoe* and NIWA's vessel *Tito*, were systematically sampled over the duration of routine trips. All bilge water was collected at the point of discharge, with samples filtered and preserved on board. In total, 9 bilge water discharges were collected during 4 vessel trips. Bilge water volumes ranged from 2.4 to 28.8 L.

Samples were assessed microscopically for the presence of any biological material. Genetic analyses were also undertaken to provide a snapshot of the biological diversity of the samples, but these analyses are still ongoing and are not discussed further in this report.

3.1.2. Preliminary results

Microscopic analyses identified 13 taxa in the 29 bilge water samples from yachts and motorboats, and 23 taxa from the 9 samples from two research vessels (Table 1). Taxa were generally only identified to major taxonomic groups due to difficulties in identifying zooplankton to species level.

Table 1. Marine vegetation, zooplankton and benthic organisms found in bilge water from vessels sampled at Nelson, New Zealand. Bilge water discharges (n=38) were collected from yachts, motor boats and research vessels. In some instances the same vessel was sampled multiple times over the course of the sampling period.

Taxon	Opportunistic sampling		Systematic sampling
	Yachts (*n* = 16)	Motorboats (*n* = 13)	Research vessels (*n* = 2)
Plants:			
Filamentous algae			X
Diatoms			X
Cnidaria:			
Hydrozoa		X	X
Viatrix sp.			X
Crustacea:			
Copepoda		X	X
Ostracoda			X
Amphipoda	X	X	X
Isopoda	X	X	
Caprellidae		X	X
Cirripedia			
Halicarcinus sp.			X
Pontophilus sp.	X	X	X
Anthuridae			X
Polychaeta:			
Syllidae			X
Polynoidae			X
Polynoidae larvae			X
Unidentified polychaete	X	X	X
Mollusca:			
Perna canaliculus			X
Unidentified juvenile bivalve	X	X	X
Gastropoda juvenile			X
Xenostrobus neozelanicus (juvenile)			X
Other taxa:			
Foraminifera		X	X
Nematoda		X	X
Unidentified encrusting bryozoan		X	
Unidentified egg		X	X
Unidentified fish			X

3.1.3. Sources of bilge water and common discharge practices

Water sources reported included seawater from waves and that used to wash down decks and equipment after on board activities such as fishing. Several yachts reported seawater entering the vessel as leakage or cooling of the propeller shaft. Recreational vessels sampled reported freshwater (*i.e.* rainwater, freshwater tanks, condensation) as a large component of their bilge water which may mitigate the risk of marine species transfer to some extent. The research vessels reported use of a deck hose along with scientific equipment (*e.g.* grab samplers, video sleds, survey traps) as the primary water sources.

The majority of vessels sampled had both automatic and manual bilge systems, with the ability to override the automatic activation if desired. Motor boat operators often reported using the bilge system prior to arrival at the boat ramp at the conclusion of their journey (after washing down equipment and decks). The remaining bilge water then drained once the boat was on land. Similarly, most yacht operators reported emptying the bilge as part of their standard operations upon arriving in a new location.

3.2. Assessment of propagule survival

A series of lab-experiments were conducted to investigate what proportion of biological material makes it through the bilge pump and whether this material is viable. Propagules of three common non-indigenous biofouling species were assessed; larvae of the bryozoan *Bugula neritina* and the solitary ascidian *Ciona* sp., and fragments (~3 mm^2) of the colonial ascidian *Didemnum vexillum* (see Figure 2).

3.2.1. Experimental procedure

The three test species were added to an experimental bilge sump fitted with an 1100 GPH bilge pump (a common model used on recreational vessels). The delay between adding organisms to the sump and discharging through the pump ranged from 0 to 72 hours, to test whether time spent in the bilge sump affected discharge success of propagules. A ‘no pump’ control was included to investigate potential pumping effects. The viability of larvae and fragments post-pumping was assessed by their capacity to successfully settle (larvae) or reattach (fragments) within 48 hours.

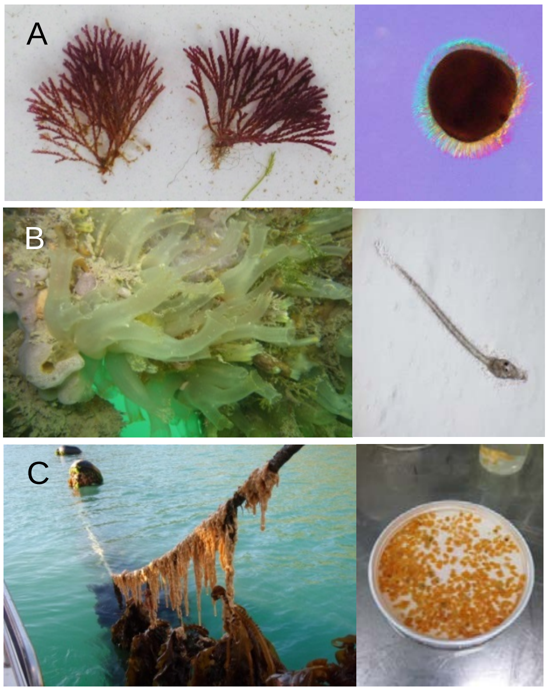


Figure 2. Adults and larvae of (A) the bryozoan *Bugula neritina*, and (B) the solitary ascidian *Ciona* sp., and (C) adults and fragments of the colonial ascidian *Didemnum vexillum*.

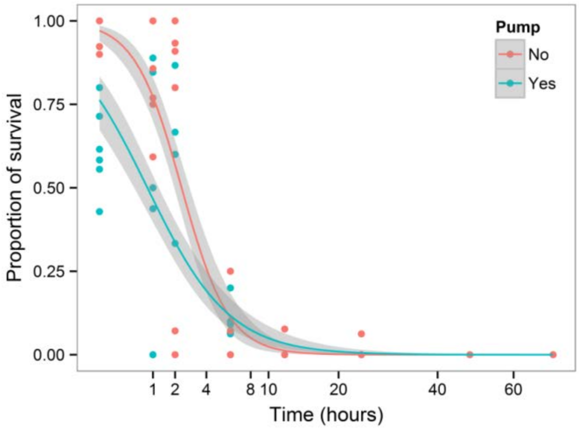
3.2.2. Results

Each of the three species behaved differently when passed through the simulated bilge sump and pump (Figure 3). Although the pump itself had no effect, *Bugula* larvae were not discharged when left in the sump for > 24 hours. Bryozoan larvae are very short-lived and as such settled within the sump during this time period. In contrast, *Ciona* was little affected by time spent in the sump; viable larvae still made it through the pump after 72 hours. The pumping process had a significant effect on overall discharge success for *Didemnum*, with most fragments not being picked up or becoming stuck in the pump itself. Regardless, some fragments were still viable after pumping for all time periods investigated.

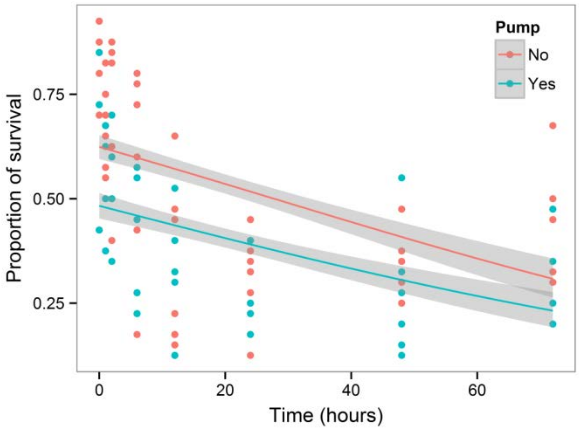
3.2.3. Conclusions

The larvae and fragments of biofouling species can pass through a bilge pump system relatively unharmed. Time spent in the bilge sump is likely to affect discharge success, particularly of short-lived and sensitive larvae, but survival for 3 days is possible (and potentially greater for other groups of taxa not tested here). Larvae are more likely to be discharged as they are small and buoyant and easily picked up by the pump's impeller mechanism. In contrast, fragments of colonial organisms are more likely to remain in the bilge sump but those that are discharged are capable of reattachment and colony growth.

Bugula neritina



Ciona sp.



Didemnum vexillum

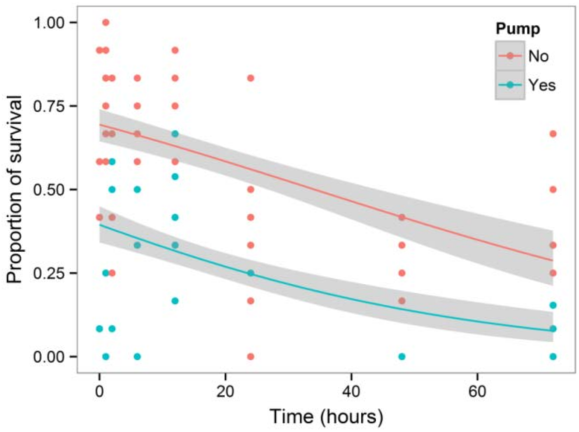


Figure 3. Probability of survival of propagules or fragments of three key biofouling species (*Bugula neritina*, *Ciona* sp. and *Didemnum vexillum*) for varying durations of time spent within a simulated bilge sump.

4. EXISTING GUIDANCE ON MANAGING BILGE WATER RISK

4.1. Regional and national guidance

There is currently no specific legislation on bilge water discharge that addresses potential biosecurity risks. The Biosecurity Act (1993) and the Southland Regional Pest Management Strategy provide a generic framework for managing biosecurity risks to the FMA but do not specifically consider bilge water. Previous legislative focus has been limited to addressing pollution rather than biosecurity risks. The risk from oil contained in bilge water (*i.e.* from engine rooms of larger vessels) is managed under the Resource Management Act (Marine Pollution) Regulations 1998. In addition, the Clean Boating Programme[2] provides guidance on bilge water management for reducing pollution.

The Fiordland Marine Biosecurity Risk Management: Operational Plan Recommendations (Sinner *et al.* 2009) was the first regional or national level document to provide guidance for addressing seawater discharge risks with reference to the spread of marine pests. Proposed options for management included washing down bilge water reservoirs with an on-board deck hose while *en route* to a new location, or alternatively with freshwater while in port. Treatment of high-risk vessels with chemicals was recommended to ensure adequate disinfection. Environmentally friendly chemicals such as acetic acid (4% solution) and bleach (0.5% solution) are suggested, with the bilge area thoroughly immersed for an extended period of time (~10 minutes to 1 hr). The recommendations found in Sinner *et al.* (2009) are summarised in Table 2 below.

Table 2. Recommended procedures for the treatment of bilge water by owners and operators of vessels and gear entering Fiordland. Modified from (Sinner *et al.* 2009).

Pathway	**Actions**
Bilge water	Prior to entry to FMA, vessel operators to: i. *(preferred)* Treat bilge areas and decks with eco-friendly chemicals (*e.g.* using backpack or handheld sprayer), especially if vessel has been in a known infected area; OR ii. *(if (i) is not practical)* Flush bilge areas with freshwater when in port or when vessel is out of water (*e.g.* trailered vessel); OR iii. Wash down bilge areas with seawater while *en route* between regions, preferably soon after departure when clear of infected area

[2] Administered by the Marina Operators Association of New Zealand. More information is available at http://www.cleanboating.org.nz/index.html

The Operational Plan Recommendations also proposed the development of a code of practice to manage both bilge and ballast water discharges in the FMA. This was subsequently achieved through development of the Biosecurity Guidelines for Managing Seawater Discharges from Vessels Operating in the Fiordland (Te Moana o Atawhenua) Marine Area (Cawthron Institute 2013). The default position specified is to avoid discharging water where possible. If this is not possible, the Guidelines propose the following.

1. **Prior to entering the Fiordland Marine Area (FMA)**:

    a. Pump bilge water into purpose-built collection tanks for disposal on land (**Preferred**)

    OR

    b. Discharge bilge water overboard, in accordance with current marine pollution regulations (**Preferred**)

    OR

    c. Add bleach to the bilge water at recommended dosage (1 part bleach to 100 parts of seawater) and leave it for at least 1 hour, after which it may be discharged within the FMA, in accordance with health & safety and marine pollution regulations

2. **While operating within the FMA:**

    a. Pump bilge water into purpose-built collection tanks for disposal on land (**Preferred**)

    OR

    b. Discharge bilge water overboard in the same fiord where the seawater entered the vessel, in accordance with current marine pollution regulations (**Preferred**)

    OR

    c. Add bleach to the bilge water at recommended dosage (1 part bleach to 100 parts of seawater) and leave it for at least 1 hour, after which it may be discharged within the FMA, in accordance with health & safety and marine pollution regulations

Additional guidelines are available for the discharge of seawater holding tanks and containers, as well as other compartments where seawater may accumulate.

In a national context, guidance is provided in two reports produced following a Ministry for Primary Industries (MPI) commissioned review of practical measures for reducing the spread of potentially harmful marine organisms via human transport pathways within New Zealand (see Inglis *et al.* 2013; Sinner *et al.* 2013). Four options were identified for treatment of bilges and water in other contained spaces to reduce biosecurity risks:

- discharge and emptying of water before departing from a location
- retention and storage of water for discharge to shore-based treatment
- regular flushing with freshwater or an approved treatment as a preventative measure to keep the spaces clean
- treatment of water spaces with an approved treatment.

The most practical and cost-effective risk reduction measure identified was discharge of all non-oily bilge and retained seawater in the area where it was taken on-board, and washing down all deck areas (with freshwater if possible) prior to departure for other areas. Chemical treatment was identified as a non-preferred option because of contaminant concerns (see Inglis *et al.* 2013). Prohibitions on discharge of bilge in specified high-value areas were also suggested; an option of particular relevance when addressing risks to the FMA. This would require regulation via the Regional Coastal Plan for Southland.

4.2. International guidance

As in New Zealand, there does not appear to be any specific legislation on bilge discharges that address potential biosecurity risks internationally. Guidance documents are available regarding disinfection of boats and boating equipment for several coastal regions (*e.g.* Ireland[3]), but these are not regulatory. Legislation exists preventing the transport of water and live fish within several US States, in particular with regards to preventing spread of invasive mussel larvae, spiny water fleas and fish diseases within the Great Lakes region. The recent Drain Campaign[4] in Wisconsin was implemented to encourage anglers to drain all livewells and buckets before leaving an area. Similarly, guidance documents are available for preventing the transport of invasive species by seaplane (*e.g.* McNeil 2010). Suggested procedures include the treatment of all internal spaces with bleach; one cup of bleach for each gallon of water is suggested (yields a 6% bleach solution) (McNeil 2010).

[3] http://invasivespeciesireland.com/cops/water-users/leisure-and-industrial-crafts/
[4] http://dnr.wi.gov/lakes/invasives/drainingcampaign.aspx

5. BILGE WATER MANAGEMENT OPTIONS

The default position should be to avoid discharge of bilge water (and other seawater) within the FMA unless it is necessary for safety or operational activities. However, in instances where discharge is required, several options exist for mitigating the risks associated with bilge water to the FMA:

- discharge in the source region only or discharge in areas of low-risk (*e.g.* offshore)
- collect bilge water and dispose of on land or in a low-risk area
- treatment of bilge water prior to discharge.

The application and practicalities of these mitigation measures are further explored below.

5.1. Bilge water discharge in source region or low-risk areas

Discharge of bilge water in the same fiord where the seawater entered the vessel is likely to be relatively low-risk from a biosecurity perspective. This is the preferred option for mitigating biosecurity risks. Discharge of bilge water in areas perceived to be of low-risk (*e.g.* offshore) is advised where discharge within the source region is not logistically feasible.

The previous advice document for managing seawater discharges in the FMA (Cawthron Institute 2013) recommends discharge at least 1 km from a fiord's entrance or outside of the FMA boundaries[5]. The area encompassed by the FMA is considerable (see Figure 1), and includes all the sea area from mean high water springs out to the 12 nm territorial limit. As such, any discharge complying with the 1 km minimum distance from a fiord's entrance will still likely be discharging within the FMA boundaries. Coastal invertebrate species often have restricted planktonic life-stages, and as such restricted natural dispersal potential, so discharge at this distance from the shoreline will likely be appropriate for preventing transport and subsequent establishment of most marine pest species.

Requiring discharge in the source region does not incur any additional costs and presents minimal logistical constraints in terms of time or effort required. However, this option relies heavily on stakeholder buy-in and compliance would be difficult to enforce.

[5] The minimum distance from a fiord's entrance (1 km) to discharge seawater from within the FMA was arbitrarily taken from the Department of Conservation's proposed regional plan for Kermadec and the sub-Antarctic Islands.

5.2. Collection and disposal of bilge water

Bilge water retention may be appropriate while operating within high-value areas or when water was taken on board in areas of increased risk (*e.g.* ports and marinas). This option is best suited to small volumes of bilge, including that found on most recreational vessels. Bilge water can be retained within the bilge sump of a vessel, or collected and stored within containers or tanks, until the vessel returns to port. Some FMA operators already report vacuuming the bilge out or using dedicated sponges or mats rather than pumping bilge water overboard (pers. comm. A. Castinel, Cawthron). In most instances, disposal on land will involve complete drainage of the vessel following haul-out (trailered craft only). Bilge water containing pollutants such as engine oil, fuel, antifreeze, and transmission fluid should not be discharged to land (*i.e.* within parking lots, vessel-cleaning stations, or to storm drains) where it could contaminate groundwater. Any contaminated water (*e.g.* oil at > 15 mg per L) should be disposed of at an appropriate shore-based facility. All ports and marinas have facilities for disposal of oily liquid waste[6]. The nearest official collection point to the FMA is at Bluff Harbour; however, this is a mobile facility (truck-based collection) so collection could theoretically occur elsewhere in the region.

Retaining large volumes of water is likely to be somewhat difficult and cumbersome in practice. Vessels carrying large volumes of bilge are likely to include commercial fishing vessels, large (> 10 m length) research vessels, and cruise ships. Commercial fishing vessels and research vessels operating in the FMA have been estimated to hold between 100 and 300 L of bilge water in some instances. In addition, these vessels often carry 200 L drums of seawater for holding and transporting organisms and carrying out operations. Vessel operators have previously reported using chlorine or household detergent (*e.g.* EnviroClean) to mitigate any risk associated with stagnant water or within holding tanks (pers. comm. A. Castinel, Cawthron). Bilge water discharge by cruise ships operating in the FMA is presently governed by a deed of agreement between Environment Southland and Cruise New Zealand on behalf of the cruise ship industry. The agreement requires vessels to implement a 'zero discharge' to water regime while in the FMA.

As bilge water retention would likely require over-riding any automatic bilge system, not compromising vessel safety would need to be paramount. This option may be the most difficult in terms of stakeholder buy-in although it may be useful in certain situations.

[6] Details of port reception facilities are available on the International Maritime Organisation (IMO) website at: https://gisis.imo.org/Public/PRF/Browse.aspx

5.3. Treatment of bilge water prior to discharge

As identified in Section 4.1, biosecurity risks posed by the discharge of bilge water can be mitigated through chemical treatment prior to discharge. Suggested treatment agents have included acetic acid, disinfectants, bleach or other chlorine-based products. Chlorine seems the most widely accepted chemical for use in the marine environment and has been suggested by several sources as a potential candidate for treating bilge water (McNeil 2010; Sinner *et al.* 2012; Cawthron Institute 2013).

Chlorine is currently used for control of a range of marine and freshwater organisms, in particular with regards to mussel fouling in water treatment plants (*e.g.* Jenner *et al.* 1998; Rajagopal *et al.* 2003). This chemical has been shown to be effective against adults of a range of biofouling species (Rajagopal *et al.* 2002; Coutts & Forrest 2005; Anderson 2007 and references therein; Lewis & Dimas 2007). Relatively low concentrations are expected to be lethal for early life stages due to increased vulnerability. Chlorination at concentrations of 0.5 - 0.6 mg/L has been shown to be lethal against mussel embryos, even at very short exposures of between 30 and 120 minutes (Klerks *et al.* 1993; Verween *et al.* 2009).

Two viable methods to administer chlorine to bilge water exist, namely household bleach and swimming pool chlorination products, with both products discussed in more detail below.

5.3.1. Bleach

The active ingredient in bleach is sodium hypochlorite, with commercial bleach typically containing 3–10% free available chlorine (FAC). Bleach is widely used as a disinfectant, including trials for the control of biofouling organisms (Carver *et al.* 2003; Piola *et al.* 2010). The chlorine in bleach is in a relatively unstable and easily degraded form that quickly breaks down in seawater and becomes benign rapidly with dilution (Clarkson *et al*. 2001; OSU 2011; Morrisey 2015). Bleach is commonly found on fishing vessels as it used to treat ropes for fouling. It is also readily available at supermarkets, dairies and service stations. Bleach is considered relatively safe to handle, providing general health and safety procedures are followed.

Treatment of large volumes of bilge water will require relatively large volumes of bleach. Treatment of a 200 L drum will require 2 L bleach at the recommended 1:100 ratio. It may also be difficult to ensure adequate mixing for large volumes of seawater. All internal compartments treated will have some residual salt from the breakdown of the bleach, which may lead to corrosion of the materials. Corrosion proofing products are available and may be beneficial in this context.

5.3.2. Swimming pool chlorination products

Treatment of very large volumes of bilge water may be more appropriate through use of swimming pool chlorination granules or tablets. Sodium dichloroisocyanurate (dichlor) is a stabilised chlorination product commonly used for the treatment of swimming pools. Commercial grades of dichlor are generally available in granule form and contain 55-56% FAC by weight (Morrisey 2015). Granules can be added directly to seawater to be treated, or a solution can be made prior to treatment to ensure adequate mixing. The most common unstabilised chlorination product is calcium hypochlorite tablets (generally 200 g). This product contains about 65% FAC by weight.

Due to the high FAC concentration present in pool chlorination products, the treatment of bilge water will only require relatively small amounts of either product. Both stabilised and unstabilised chlorination products are relatively inexpensive, with dichlor granules retailing at around $10/kg and calcium hypochlorite tablets at around $20/kg. Stakeholders may perceive the use of chlorination tablets as easier as no measurement is required.

Calcium hypochlorite tablets act in the same way as household bleach when added to water; the chlorine present quickly breaks down and becomes benign rapidly with dilution. Due to the stabilising agent present, dichlor reacts with water to produce hypochlorous acid and cyanuric acid. Cyanuric acid is not readily biodegradable and is stable in water, however, toxicity to aquatic life is believed to be low (Morrisey 2015 and references therein).

Both pool chlorination products are likely to result in treated water with a final concentration considerably higher than allowable for discharge (see Section 5.3.3). This will be somewhat mitigated by treatment time as well as dilution with ambient seawater following discharge. High final chlorine concentrations may also lead to corrosion of materials.

5.3.3. Discharge-related issues

The discharge of chlorine is restricted under the Resource Management Act 1991:

> The discharge of water or contaminants from a ship or offshore installation into water is prohibited unless permitted or controlled by regulations in the Act, a rule in a regional coastal plan, a resource consent or if, after reasonable mixing, the water or contaminant discharged is not likely to give rise to significant adverse effects on the receiving environment, including aquatic life.

Limits on chlorine discharge are generally set at < 0.5 mg/L of free or residual chlorine (*e.g.* Tasman Resource Management Plan). Northland Regional Council has recently issued a resource consent for treatment of fouled vessel hulls using a combination of encapsulation and dosing with chlorine. In this situation the consent requires the discharged water to have < 0.2 mg/L FAC.

Three options are available for reducing the residual chlorine present in bilge water prior to discharge (Morrisey 2015):

- allow the treated water to sit for longer to allow natural degradation of FAC
- neutralise using a chemical agent
- further dilution by mixing with ambient water.

Household bleach and unstabilised chlorination tablets will degrade relatively quickly, therefore leaving treated bilge water for as long as possible before discharge is the best option for these two products. In contrast, stabilised chlorination granules will need neutralisation unless the treated water is left for a long period (> 24 hours).

Sodium thiosulphate has been previously recommended as a neutralising agent as it is not classified as a hazardous substance and it is of relatively low toxicity (see Morrisey 2015). This chemical is used for the dechlorination of swimming pool water before discharge to the stormwater system so is readily available from retailers of swimming pool supplies. The use of sodium thiosulphate will produce hydrochloric acid as a result of the neutralisation reaction. As such, it is important that only the minimum amount required is used.

6. SUMMARY AND CONCLUSIONS

Results of recent field and laboratory-based experiments, along with previous international work, demonstrate that bilge water discharges pose a biosecurity threat to the FMA. Bilge water discharges were shown to contain a number of planktonic species, including larvae and juveniles of several invertebrate groups. Propagules of three key biofouling species can survive 1–3 day holding periods with no aeration, with successful settlement or fragment reattachment possible after discharge.

Mitigation measures for biosecurity risks posed by bilge water include restrictions on the location of discharge (*i.e.* within the source region or areas of low-risk), retention of bilge water for subsequent disposal, and treatment of bilge water prior to discharge. Bilge water discharge within the source region is the most practical option available, with no associated costs and minimal logistic constraints. The use of chemical treatments is also a promising option when discharges can't be managed or for high-risk vessels. Chlorine provides a cost-effective and efficient biocide option, however constraints with regards to contaminant discharge regulations and health and safety considerations exist. More research is needed to develop standard operating procedures for the use of chlorine to treat bilge and other seawater discharges.

It is probably impractical to regulate the discharge and / or treatment of bilge, but good management practices can be promoted through codes of practice. Any specific treatment measures instigated would need to be simple and practical to ensure a high uptake. Previous consultation undertaken by Cawthron has highlighted that most vessel operators in Fiordland perceive bilge water as unimportant from a biosecurity perspective (Sinner *et al.* 2013). This belief may lead to low compliance with any treatment measures initiated. General communications-based measures to educate boaters about possible risks from bilge water are recommended; for example, encouraging boaters to empty their bilge before entering the FMA. With regards to chemical treatment options, following guidance provided in previous documents (*e.g.* Cawthron Institute 2013) is recommended at this stage.

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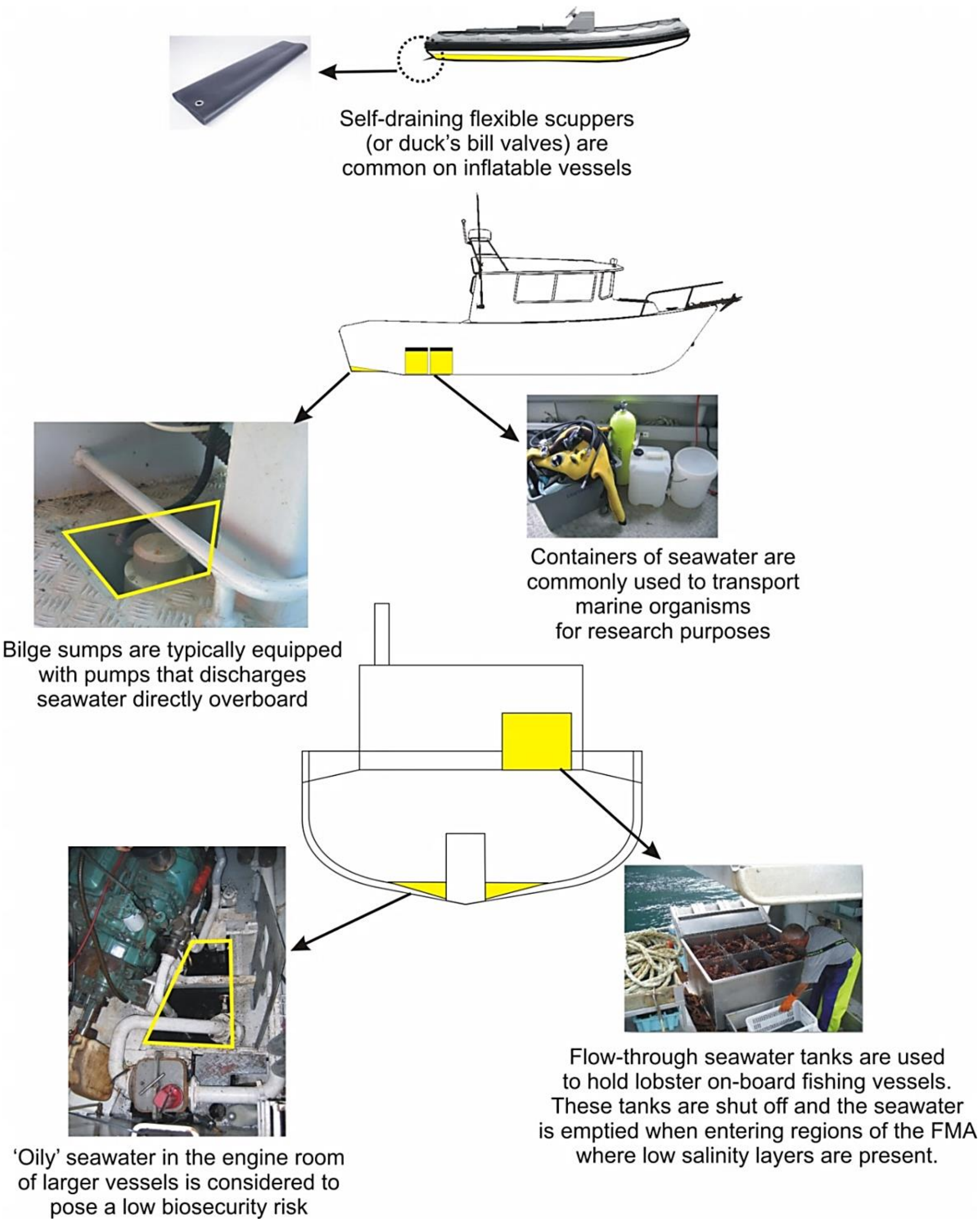
9. APPENDIX

Appendix 1. Regions of a vessel where seawater is held or may accumulate. Taken from the Ministry for Primary Industries funded advice document regarding seawater discharges in Fiordland[7].



[7] Cawthron Institute 2013. Biosecurity guidelines for managing seawater discharges from vessels operating in the Fiordland (Te Moana o Atawhenua) Marine Area. Advice document prepared by the Cawthron Institute on behalf of the Ministry for Primary Industries. Version 1.0 (FINAL). 15 p.