Review of Best Practice Treatment Methods and Current Educational Efforts for Marine Pests

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Abstract

Marine pests can cause huge detrimental effects on the native environment and marine industries if they are introduced in a natural environment by different marine activities. This report overviews different methods to clean fishing gear, boats, and bilge for educational purposes and for the aim of stopping the spread of marine pests throughout Southland, New Zealand. It also touches on marine biosecurity education methods in New Zealand and overseas.

Introduction

Environment Southland (ES) has a leadership role under the Biosecurity Act 1993 and powers to manage harmful marine species. Under the Southland Regional Pest Management Plan (SRPMP) 2019-2029 and the Fiordland Marine Regional Pathway Management Plan (FMRPMP) 2017, the aim is to slow the spread of marine pests in Southland, through regulation, education, control, and surveillance. These aims need to be targeted, complementary and aligned with international best practice.

There have been several Envirolink funded projects for Environment Southland related to marine biosecurity. To date, work has focused on vessel pathways, bilge water risk, anti-fouling application and tools for responding to incursions. This report 2330-ESRC300 is complementary as it will address another of the primary marine biosecurity risks and inform education programmes.

A Southland Regional Marine Invasive Species Surveillance and Compliance Plan 2020 mapped high-risk sites and pathways. Nationally, boats are the highest risk vector, but in Southland, fishing gear that has been submerged for a long period is also a high risk. At present, the Council relies on passive education such as signs at ramps, web information and the *Clean Boats – Living Seas* brochure as well as verbal education during inspections.

This Envirolink report summarises the best practice and preventative measures available in literature in New Zealand and internationally that can be implemented or adapted to assist marine users' compliance with the SRPMP rules.

Best practice treatment methods for marine species

The SRPMP lists nine marine species considered as pests in Southland. Asian paddle crab, sea squirts and Mediterranean fan worm are listed as exclusion pests and *Undaria*, an algae, is a progressive containment pest. Mediterranean fan worm is a Notifiable Organism and *Undaria* is an Unwanted Organism. Notifiable

Organisms must be reported to the Ministry of Primary Industries (MPI). Unwanted Organism status means that the organisms cannot be sold, propagated, or distributed.

Online search engines such as Google Scholar, PubMed, Science Direct and UC Library were used to locate published literature. Key words such as each pest's scientific name, mortality, removal, cleaning methods and best practices were used, and references in published documents were also searched.
The best practice for each species is summarised below, and references of the literature used are highlighted in the references section and PDF files are attached to this report.

Previous New Zealand guidelines for cleaning fishing gear include: freshwater immersion for at least 72 hours with water changed every 12 hours, hot water (>40°C) immersion for at least 20 minutes, 5% dishwashing detergent solution for 60 minutes, 5% acetic acid solution or undiluted household vinegar for 10 minutes, 2% bleach solution for 30 minutes, 2% Decon 90 solution for 30 minutes and 1% antiseptic solution for 60 minutes. Sprays such as 5% acetic acid solution or undiluted vinegar left on for 10 minutes and 1% antiseptic left for 60 minutes are also used. Items are dried after these treatments and items not treated beforehand are left to dry for one month [1].

Asian Seaweed *(Undaria pinnatifida)*

Asian seaweed or *Undaria* is an invasive seaweed which can grow and spread rapidly through New Zealand's marine environment. It grows from spores that are released into the water and attach to surfaces such as vessel hulls. They are easily transported to other areas by vessels and marine equipment. *Undaria* has the potential to substantially impact the unique marine environment and fishing economy of Fiordland due to its ability to quickly establish and outcompete native species. It was first discovered in Fiordland in 2010 and since then Environment Southland, MPI and the Department of Conservation (DOC) have been trying to eliminate it from Te Puaitaha/Breaksea Sound [2].

Undaria is a persistent pest and several methods have been trialed to kill it on marine equipment such as fishing gear. Promoted methods currently used in Australia include drying, immersion in 2% detergent solution for 8 hours, immersion in hot water (40°C) for at least an hour and immersion in 3% sodium hypochlorite for 2 hours. Ropes, buoys, traps, etc. can be cleaned with high pressure water blasting (2000 psi) followed by immersion in 3% sodium hypochlorite for at least 2 hours, followed by rinse and air dry [3].

For internal water systems, immersion in 2% bleach solution for at least an hour, freshwater at 20°C for at least 48 hours and water at 35°C for at least 45 minutes are effective treatments. Other possible methods which may be effective include immersion with 5% industrial detergent for 14 hours, chlorine 24mg/L for 90 hours and 1 mg/L copper sulphate solution for 38 hours. These methods are also safe for mussels [3].

Methods that have been trialed in laboratory conditions that successfully caused 100% mortality of *Undaria* include freshwater immersion (18°C for 8 hours, 35°C for 10 minutes, 45°C for 45 seconds, 55°C for 5 seconds), acetic acid at 4% for 1 minute, air drying (55–85% humidity; 3 days at 10°C or 1 day at 20°C, >95% humidity; 8 weeks at 10°C or 6 weeks at 20°C), bleach at 2% for 1 hour and detergent at 2% for 30 minutes at >18°C [4] [5].

Asian Paddle Crabs *(Charybdis japonica)*

The Asian paddle crab or *Charybdis japonica* is a swimming crab that is native to Southeast Asia, found in the waters around Japan, Korea, and Malaysia. They were first discovered in New Zealand in 2000 and are currently found in the Waitematā and Whangārei Harbours and Waikare Inlet in Northland. They are a pest as they are aggressive and compete with native crabs for habitat and food. They may also eat shellfish species which are culturally and economically important to New Zealand. Adult crabs can produce thousands of offspring. The larvae can survive for three to four weeks, and the adults can swim large distances, so they have a high potential to spread to new areas through ballast water and hull fouling [6].

Fowler, et al 2011 investigated survival of Asian paddle crab larvae at different salinities and temperatures. Larvae can be carried in bilge water. They found that at temperatures greater than 36°C with exposure for 24 hours there was complete mortality. They also found that Asian paddle crabs have a low tolerance for salinities below 15% even for short exposure times which makes freshwater a possible option for cleaning [7].

Visual inspections of boats and marine equipment, particularly in areas that retain water, are important. Asian paddle crabs can be removed physically and should be disposed of on land [8] [9].

Mediterranean Fanworm *(Sabella spallanzanii)*

Mediterranean fanworm or *Sabella spallanzanii* is a large tube dwelling worm which is native to the Mediterranean and Atlantic coast of Europe. They attach to solid structures in the water such as wharf pilings and shells. It was first discovered in New Zealand in 2008 and is now found in a number of New Zealand harbours. Mediterranean fanworm can form dense colonies which stop the settlement of other organisms and can compete with mussels and oysters for food. They can survive in a range of water temperatures and salinities and can be spread by vessel biofouling and movement of marine equipment [10] [11].

Killing Mediterranean fanworm with chlorine was investigated by Morrisey, et al 2013. They found that chlorine exposure for 4 hours at a concentration of 160 mg FAC l^{-1} killed 99% of Mediterranean fanworm in laboratory tests. This method can be used as a quick method to clean hull fouling [12]. Hull fouling can also be removed physically by scraping. Anything removed must be disposed of on land to avoid it continuing to grow in the sea. Antifouling paint can help avoid hull fouling and hulls should be cleaned twice a year. For Mediterranean fanworm removed from vessels or equipment in the water, a bag placed over the top will avoid the release of larvae and fragments into the environment although it is recommended that cleaning should be done out of the water [13] [14].

It has been found that immersion in 1% solution of acetic acid for 4 minutes will give 100% mortality [15]. It is predicted that immersion in freshwater for 90 minutes would also be effective [16]. On its own, air exposure would not be effective as it can survive for longer than 24 hours when exposed to air [15].

Clubbed Tunicate *(Styela clava)*

Clubbed tunicate or *Styela clava* is a sea squirt native to the northwest Pacific around Japan, Northern China, and Korea. It grows mostly in shallow water, ports, and harbours. It competes with other native species for food and habitat and can increase aquaculture harvesting and processing costs due to biofouling. It can survive in a range of water temperatures and can be spread by hull fouling on vessels and marine equipment [17].

Methods investigated for the eradication of clubbed tunicate include air drying and acetic acid. Hillock and Costello 2013 found that exposure to air was effective after two weeks at 10°C. Drying time can be less if it is in direct sunlight and at higher temperatures [18] [17] [19]. This is a cheap method for fishers, but the length of time required may not be the most feasible. Acetic acid has also been found to kill clubbed tunicates [20]. Immersion in 5% acetic acid for 30 seconds and 2 minutes has been tested [21]. It has also been found that sodium hydroxide sprays and immersion in hot water are effective. These methods are better for rapid removal [18]. Any remaining biomass can be scraped off and disposed of on land.

Australian Droplet Tunicate (Eudistoma elongatum)

The Australian droplet tunicate or *Eudistoma elongatum* is a sea squirt which is native to Australia. It forms large colonies which attach to hard surfaces such as wharf piles and marine equipment. It was first discovered in New Zealand in 2005. The dense colonies of tunicates smother beaches, tide pools and rocks displacing native marine species, and they also foul boats and marine structures. It can be spread by biofouling on boats, buoys, and other marine equipment [22] [23].

For Australian droplet tunicate the most effective method of elimination is concentrated acetic acid. Hydrated lime, ammonium sulphate solution and heat treatments are also possible methods [24].

Pyura *(Pyura doppelgangera)*

Pyura or *Pyura doppelgangera* is a sea squirt native to Australia. It is mostly found on rocky platforms, in rock pools and on the underside of rock overhangs. It can also grow on aquaculture equipment and wharf piles. They are aggressive competitors for space and can alter the structure of intertidal communities. Pyura forms dense mats which displace and engulf native species such as the green-lipped mussel. It can be spread by biofouling on vessels or in ballast water [25].

So far, no literature has been found on the best methods for cleaning gear of Pyura. Current methods in educational sources are cleaning and drying gear [25]. It is predicted that treatments for other marine pests may be successful such as air drying, hot water, freshwater immersion, Ultraviolet (UV) light, bleach, and acetic acid [26].

Carpet Sea Squirt *(Didemnum vexillum)*

Carpet sea squirt or *Didemnum vexillum* is a sea squirt which grows on surfaces such as rocks, seaweed, and seagrass. In New Zealand, it is more commonly found on artificial structures such as wharves, vessel hulls and mooring lines. Carpet sea squirt can survive in a variety of environmental conditions, has a high reproductive ability and a high population growth rate. It has no natural predators and has an ability to grow over other organisms. It also has the ability to grow from broken off fragments. This makes it hard for native species to compete with it. The larvae can be spread by water currents and ballast water while the adults can be transported by hull fouling and marine farming activities [27].

Several methods have been trialed for killing and cleaning gear of carpet sea squirt. These methods include freshwater and saltwater immersion, acetic acid, bleach, lime, and sodium hydroxide at various concentrations as well as only mechanical cleaning. McCann, et al., 2013 found that freshwater was successful at killing carpet sea squirt after 4 hours of exposure and brine solution with salinity at least twice that of seawater was successful after 24 hours of exposure [28]. However, Denny 2008 found freshwater immersion to be ineffective at controlling it as mortality was only 87% after a 10-minute immersion [20]. These both provide relatively easy and cheap methods for fishers to clean their gear with low environmental impacts. Acetic acid and dilute bleach offer faster options, with acetic acid taking 2 minutes of exposure to accomplish complete mortality and dilute bleach taking 10 minutes of immersion. The acetic acid and bleach solutions can be made up with seawater and do not require freshwater [28]. Denny 2008 tested acetic and found that it had a 77% mortality rate at concentrations of 2% but mortality increased with longer exposure times. They also found bleach at a concentration of 0.5% for 2 minutes to be 100% effective [20]. The efficacy of acetic acid, lime and hypochlorite has also been investigated as a spray to remove tunicates as an alternative to immersion. Acetic acid at 5% and 10% were the most effective, with short 1 minute exposure times and repeat spraying achieving high mortality [29].

Caulerpa *(Caulerpa taxfolia, Caulerpa brachypus and Caulerpa parvifolia)*

Exotic Caulerpa seaweeds are highly invasive and have been found in the Hauraki Gulf and in the Bay of Islands. It can smother the ocean floor, crowding out native marine life such as sponges, mussels and scallops. This can have detrimental effects on commercial and recreational fishing and diving in New Zealand. The biggest threat for spreading Caulerpa is boat anchors and chains as the seaweed can get tangled in them. Once it is established it is very difficult to eradicate [30].

Successful methods trialed to eliminate it from vessels and fishing gear include chlorine bleach, temperature shock, drying, salinity changes, and copper. No herbicides were found to be effective, however, all other methods had some level of success. Chlorine bleach was successful at 125 ppm when exposed for 30 minutes and semi successful at 50 ppm. Chlorine is currently used to eradicate Caulerpa in Southern California. Water at 72°C was successful at killing Caulerpa when exposed for 60–120 minutes [31]. Creese, et al 2004 found that 3 days of air drying killed Caulerpa even if it was in large clumps. They also found that copper at a concentration higher than 10 ppm when exposed for 30 minutes was successful at completely killing Caulerpa. This is lower than the concentration of potassium or sodium ions required to produce a similar result [32]. It has also been reported that exposure to reduced salinity of 10 ppt ($1x10^{-5}$ ppm) for 180 minutes will eliminate Caulerpa [33].

NIWA has previously used a strong soap solution for cleaning diving gear to kill/remove fragments of Caulerpa. Coarse salt may also be able to remove some species of Caulerpa [34] [35]. Lapointe & Bedford, 2010 report that low temperatures (<15°C) can be lethal to *C. brachypus* (<15°C) and *C. taxfolia* (<10°C) [36].

Flat Oyster Parasite *(Bonamia ostreae)*

Flat oyster parasite or *Bonamia ostreae* is a parasite that affects flat oysters such as New Zealand's Bluff oyster. It is a tiny organism that is two to five thousands of a millimetre in size. It was first discovered in New Zealand in 2015. It is carried in water and enters the oyster's blood through its gut, mantle and gills. It can cause the oyster to develop sores or lesions which can lead to death. This can have a significant impact on farmed flat oysters. Bonamia is spread through water currents and on marine equipment, vessel hulls and other shellfish [37].

Contamination can be reduced by immersion in peracetic acid at concentrations of 0.001% and 0.005% [38]. Studies have found that 58% of parasites from infected oysters are able to survive after a week in 15°C seabed bore water. Survival was higher in higher salinities, [39] so this is not an optimal choice for cleaning gear. To avoid the spread of the flat oyster parasite MPI recommends keeping boat hulls clean, cleaning fishing gear and disposing of shells on land [40].

Bilge and on-board seawater

Bilge water is water which accumulates within a vessel at sea, at the lowest point of the vessel. It is not deliberately pumped on-board but can accumulate due to leaks, waves, loading of wet equipment or washing surfaces and gear on-board. It commonly contains more than just seawater such as oil, dirt, and vegetation. A study by Fletcher, et al, 2017 found that discharged bilge water can contain marine pests which can pose a biosecurity risk [41]. Ballast water is water held on-board larger vessels in tanks constructed for holding water. They add structural support to ships and studies show that a large range of marine organisms survive transport in ballast water making it a threat for the spread of pests [42].

Most literature for treating bilge and on-board water is not specific to each marine pest but gives overall methods to prevent the spread of all pests. Bilge and ballast water should be discharged in open water or at an onshore facility. Ballast water discharged in open water should be more than 200 nautical miles from land and in water at least 200 metres deep. If that is not practicable then it should be discharged as far out as possible at a minimum of 50 nautical miles from land and in water that is at least 200 metres deep [43]. Water in bilge and ballast can be treated with chemicals, heat or UV [44] [45] [46] to eliminate pests in the water. Freshwater above 49°C can also be used to clean bilge tanks [47] [48] [49]. UV light at 0.2 m^3/h–2 m^3/h has been proven to be effective at removing some marine organisms [44].

Electrochlorination (EC) and chlorine dioxide have been shown to decrease biofouling in ballast water. EC generates hypochlorite by electrolyzing seawater and chlorine dioxide is created by adding sulfuric acid, sodium chlorite and hydrogen peroxide together. The EC method requires neutralizing with sodium bisulfate before the water can be discharged [46].

Other methods that have been used to treat bilge and ballast water include heat treatments of 55°C–80°C with a flow rate of 85 L/min, biocides, chlorine at 2mg/L–5mg/L, sodium hypochlorite at 2 mg/L–5 mg/L, NaOCl and ozone at 400 L/h. Methods such as biocides are easy as they can simply be added to water but pose bigger environmental risks than other treatments [44].

It is not recommended that it be cleaned physically in water as some pests can release spores, larvae and fragments which can continue to grow in the water [50].

Table 1. Best methods of removal and treatment of marine pests from fishing gear and bilge water

Pest	Effective methods of removal	Treatment of bilge and on-board seawater
Undaria (*Undaria pinnatifida*)  [1]	• 4% acetic acid exposure for 1–10 min • 2% Hydrogen peroxide (H_2O_2) or bleach for 1 hour • 3% sodium hypochlorite for 2 hours • 2% detergent solution for 8 hours • Chlorine (24mg/L) for 90 hours • Freshwater immersion (18°C–55°C) for 1 min to 8 hours followed by at least 12 hours of drying	• 2% bleach solution for 1 hour • Freshwater (20°C–35°C) for 45 min to 48 hours • 5% industrial detergent for 14 hours • 24mg/L chlorine for 90 hours • 1mg/L copper sulphate for 38 hours • Biocides • Ozone at 400 l/h • Electrochlorination and electrolysis • 2–5 mg/L sodium hypochlorite • Chlorine dioxide
Asian Paddle Crab (*Charybdis japonica*)  [2]	• Exposure to temperatures above 36°C for 24 hours • Immersion in freshwater	• Wash with freshwater • Temperatures greater than 36°C for 24 hours • Electrochlorination and electrolysis • 2–5 mg/L sodium hypochlorite • Chlorine dioxide • 2–5 mg/L chlorine • Biocides • Ozone at 400 l/h
Mediterranean Fanworm (*Sabella spallanzanii*)  [3]	• Chlorine (160 mg FAC l−1) exposure for 4 hours • 1% acetic acid immersion for 4 min • Freshwater immersion for 90 min	• Chlorine (160 mg FAC l−1) • Wash with freshwater • Hot water (>49°C) • Electrochlorination and electrolysis • 2–5 mg/L sodium hypochlorite • Chlorine dioxide • Biocides • Ozone at 400 l/h

[1] [2]
[2] [8]
[3] [10]

Pest	Effective methods of removal	Treatment of bilge and on-board seawater
Clubbed Tunicate (*Styela clava*)  4	•4–5% acetic acid exposure for 1 min •Drying for 2 weeks •Sodium hydroxide spray •Hot water immersion	•Wash with freshwater •Hot water (>49°C) •Electrochlorination and electrolysis •2–5 mg/L sodium hypochlorite •Chlorine dioxide •2–5 mg/L chlorine •Biocides •Ozone at 400 l/h
Australian Droplet Tunicate (*Eudistoma elongatum*)  5	•Concentrated acetic acid exposure •Possibly hydrated lime, ammonium sulphate and heat treatments	•Wash with freshwater •Hot water (>49°C) •Electrochlorination and electrolysis •2–5 mg/L sodium hypochlorite •Chlorine dioxide •2–5 mg/L chlorine •Biocides •Ozone at 400 l/h
Pyura (*Pyura doppelgangera*)  6	•Air drying •Possibly hot water, freshwater immersion, UV light, bleach, and acetic acid	•Wash with freshwater •Hot water (>49°C) •Electrochlorination and electrolysis •2–5 mg/L sodium hypochlorite •Chlorine dioxide •2–5 mg/L chlorine •Biocides •Ozone at 400 l/h
Carpet Sea Squirt (*Didemnum vexillum*)  7	•0.5% bleach exposure for 2–10 min •2% acetic acid exposure for at least 2 min •5%–10% acetic acid spray with repeat spraying •1–5% lime exposure for 5–10 min •Possibly freshwater immersion for 4 hours •Brine solution (double seawater salinity) immersion for 24 hours	•Wash with freshwater •Hot water (>49°C) •Electrochlorination and electrolysis •2–5 mg/L sodium hypochlorite •Chlorine dioxide •2–5 mg/L chlorine •Biocides •Ozone at 400 l/h

[4] [58]
[5] [23]
[6] [25]
[7] [59]

Pest	Effective methods of removal	Treatment of bilge and on-board seawater
Aquarium Caulerpa (*Caulerpa taxfolia, Caulerpa brachypus* and *Caulerpa parvifolia*)  [8]	•Chlorine bleach 125ppm for at least 30 min •72°C seawater for 60–120 min •Copper >10ppm for 30 min •Air drying for 3 days •Freshwater (<15°C) or high salinity water for at least 1 hour •10 ppt salinity water for 180 min •Strong soap solution •Coarse salt	•Wash with freshwater •Hot water (>49°C) •Electrochlorination and electrolysis •2–5 mg/L sodium hypochlorite •Chlorine dioxide •2–5 mg/L chlorine •Biocides •Ozone at 400 l/h
Flat Oyster Parasite (*Bonamia ostreae)*  [9]	•Peracetic acid at concentrations of 0.001% and 0.005%	•Wash with freshwater •Hot water (>49°C) •Electrochlorination and electrolysis •2–5 mg/L sodium hypochlorite •Chlorine dioxide •2–5 mg/L chlorine •Biocides •Ozone at 400 l/h

Best method for all pests

From current sources in New Zealand and literature elsewhere, a first step for cleaning fishing gear of any pest is removal of any pests and debris. Any pests removed should be contained and disposed of correctly. The gear should be cleaned by soaking in acetic acid or bleach which have the greatest potential for effectively killing marine pest species. This can be done at lower concentrations as it is still effective and is safe for the public to use. It should be soaked for a minimum of 10 minutes and then left to dry for at least 12 hours until it is dry to the touch. Air drying alone is not enough to kill all pests.

Physical removal is also good for boats and fishing gear but is best done out of the water and in conjunction with other methods.

The best method for cleaning bilges is with hot freshwater (>49°C). This method is the easiest and safest as it does not use any chemicals which can pose dangers to the users and the environment.

Marine biosecurity education

[8] [30]
[9] [60]

A key component of addressing marine biosecurity is communicating effectively with the target audience. Existing education resources in New Zealand and overseas were looked at briefly to get an idea of what kind of resources are currently available and their effectiveness.

A selection of boat ramp signs and lists of some online marine biosecurity education sites is provided in the Appendix. Most education sources and programmes for marine biosecurity in New Zealand are through councils, MPI and marinas. They mainly focus on identifying marine pests and how to clean biofouling off boats. Most information around cleaning gear is 'clean and dry'. Those that are specific say to soak or rinse with freshwater and let dry until it is dry to the touch.

A New Zealand report tested different methods for spreading messages about cleaning gear for two lakes in the Auckland region. The report tested directional and informational signs, cleaning kits and stations, checking stations and commitment boards. It found that instructional signs and cleaning kits were the most successful and compliance was better when done on site rather than at home [51]. Another report found that most reasons for non-compliance were not knowing what to use for decontamination, not having time (particularly in relation to drying) and not having a good place to wash gear [52]. Further research of the literature around marine education is warranted and will be explored in depth in a further Envirolink study.

Discussion

Most existing methods in New Zealand are clean and dry after use and when moving between locations. Cleaning is done with freshwater or detergent on site, and it is left to dry until it is dry to the touch. Most sources do not specify how cleaning should be done or with what, so it is assumed to be with freshwater. Methods implemented overseas include clean and dry with vague instructions. Some sources specify cleaning with bleach or potassium chloride. Most literature was specific to one or two pests looking into what methods can be used to kill and remove marine pests on fishing gear, structures, and mussels.

Conclusion

According to literature, each marine pest species requires a different method of cleaning for effective removal and mortality. Overall, the best practice of cleaning fishing gear for all pests involves removing any debris, soaking in low concentrations of acetic acid or bleach and air drying for a minimum of 12 hours until it is dry to the touch. This method will have the best effect against most pests while still being safe and not too difficult for the pubic to carry out. It also fits well with other methods currently in New Zealand as it follows the clean and dry practice, with the addition of specifications for the best way to clean and dry. The best method for cleaning bilges is with hot freshwater.

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Appendix

Below is an overview of some online marine biosecurity resources, as well as a selection of boat ramp signs used for educating users on aquatic and marine pests. As mentioned above, the communication element of marine biosecurity best practice will be explored in a further Envirolink study.

New Zealand

MPI has good online resources on basic best practices to clean boats and fishing gear, laid out in an easy-to-read manner. It has a guide to identifying pests and the impact they can have as well as guidelines for cleaning boats and recreational gear.

Northland Regional Council, Bay of Plenty Regional Council, Environment Canterbury and Auckland Council had information on how to identify and clean boat fouling.

Clean below? Good to go had educational resources for teaching about marine pests and best practices for schools as well as information on how to clean boats, boat trailers and other recreational gear.

Overseas

Stop Aquatic Hitchhikers has information on marine pests and best practices for different recreational users with information on how to clean boats, scuba gear and angler gear. It has resources for signage to encourage the use of clean, drain, dry and dispose, which are used by several states in America.

Figure 1. Michigan Signage [53]

Figure 2. Michigan Cleaning Station [53]

Take action

to stop the spread of invasive species in the Broads

CHECK CLEAN DRY

Broads Authority

Anglers

Waders, landing and keep nets are great hiding places for invasive freshwater species including killer shrimp. Take special care to Check, Clean and Dry these items when moving between waterways. Peg out nets to dry or soak them in hot water (above 45°C) for 15 minutes to ensure they are pest free. Don't take water mixed ground bait from place to place.

Boaters, Canoeists, Kayakers and Windsurfers

Please follow Check, Clean, Dry actions when moving between waterways.
Cruiser owners – not all Check, Clean, Dry actions are practical for your vessel, but you can help prevent the spread of invasive pests by lifting and cleaning your hull once per year. However, Check, Clean, Dry actions can be carried out on clothing, equipment and tenders.

Following the simple procedures in this leaflet will help prevent the further spread of freshwater invasive species like killer shrimp and floating pennywort throughout the Broads and other UK waterways. It is everyone's responsibility to help protect and preserve our waterways for future generations to enjoy.

Remember to **Check, Clean, Dry** everywhere, every time to protect the Broads, Britain's Magical Waterland.

There is more information about freshwater invasive species online:
www.nonnativespecies.org/checkcleandry

To find out more about what is being done in Norfolk to reduce the impacts of these species, and other ways you can help, please visit:
www.norfolkbiodiversity.org/nonnativespecies

To report a suspected find of freshwater pests or invasive species please email a photograph to:
alert_nonnative@ceh.ac.uk

We all have a part to play in protecting the Broads, from the harmful effects of freshwater invasive species.

The Facts

Unwanted non-native plants and animals are invading our waterways and pose a serious threat to our broads, lakes, rivers and streams. Once in a waterway these invasive species can disperse rapidly, adversely affecting recreational facilities, reducing fish populations and restricting navigation.

Some freshwater pests are microscopic and can be spread by a single drop of water. Even if you can't see the danger, you could be spreading it. To stop the spread of invasive species you must Check, Clean and Dry your clothing and equipment when you are moving from one waterway to another, anywhere in the UK.

Invasive non-native freshwater plants can grow rapidly, blocking out light and removing oxygen from the water, rendering waterways unsuitable for wildlife and our own recreational activities. Floating pennywort (pictured below) was first found in the UK in 1990. It is able to grow 20cm per day and is now causing widespread problems.

Invasive non-native invertebrates such as the killer shrimp, zebra mussels and signal crayfish can also have a harmful effect on our freshwater environment. These organisms can reproduce rapidly, compete with or eat our native species and spread diseases and parasites.

Killer shrimp feed on native shrimp, damselfly larvae, water boatmen, fish fry and fish eggs.

We all have a part to play.
Individual river, broad and lake users are being asked to take care not to transport plants, fish and other organisms from one waterway to another. It is everyone's responsibility to slow the spread of invasive species. Please remember to follow these simple steps.

Check

Before you leave a waterway, check your equipment and clothing for any organisms or debris that may have been in contact with the water. Leave anything you find on the bank side. If you find any later, put it in your rubbish bin, do not wash down drains.

Clean

Clean and wash all equipment, footwear and clothes thoroughly. Soaking fishing nets and equipment in hot water (above 45°C) for 15 minutes will kill any invisible pests.

Dry

Drying will kill all freshwater pests, but even slightly damp items can harbour killer shrimp and other microscopic pests for several weeks. To ensure pests are dead by drying, the items must be completely dry to the touch, inside and out.

Figure 3. Broads Authority UK Leaflet [54]

Version 1

Version 2

Figure 4a. Lake Rototoa Instructional Sign Options [51]

Version 3

Version 4

Figure 4b. Lake Rototoa Instructional Sign Options [51]

Version 5

Version 6

Figure 4c. Lake Rototoa Instructional Sign Options [51]

Figure 5. Pennsylvania Clean Drain Dry Poster [47]

FACTSHEET

November 2018
Biosecurity SA Aquatic Pests (08) 8303 9620

BIOSECURITY SA
PIRSA

Cleaning marine equipment

Your marine equipment should be regularly cleaned, especially prior to moving to a new location. Marine equipment includes boat anchors, ropes, moorings, buoys, wetsuits, dive flags, fishing gear, aquaculture equipment and structures (e.g. racks, sea cages, longlines).

Cleaning assists in preventing the spread of marine pests and aquatic diseases such as Pacific Oyster Mortality Syndrome (POMS). See best practice methods for cleaning marine equipment below.

DRYING OUT

Most marine organisms, with some exceptions such as Asian Green Mussel (*Perna viridis)*, Dead Man's Fingers (*Codium fragile spp.*) and Japanese Seaweed (*Undaria pinnatifida)*, cannot tolerate prolonged desiccation. This can therefore be an effective way of reducing the risk posed by marine pests. As a general guide, most marine organisms exposed to the air will die within seven days but some will survive for longer. Survival will be affected by:

- the type of species
- the life cycle of the species
- temperature
- humidity
- sunlight

Suitable treatment times need to be considered on a case-by-case basis. Further advice can be sought from the Biosecurity SA Aquatic Pests team.

FRESHWATER TREATMENT

A freshwater bath is a simple treatment, particularly for silt trap residue, and is an effective way of destroying many marine pests that have infested seed stocks and equipment. Freshwater can also be used to treat some species and equipment to reduce the threat from marine pests.

Immersion for more than three hours in freshwater (less than 0.5 per cent salinity) is the minimum time needed to kill some species, such as *Caulerpa taxifolia* but not all marine pests. For example, up to two days of immersion is necessary to completely kill all life stages of Japanese Seaweed or Green-lipped Mussels.

The European Green Shore Crab (*Carcinus maenas*) can also survive prolonged immersion in freshwater. In this case, other treatments should be used at the same time and all treatments should be followed by a visual inspection for any remaining live crabs.

Figure 6. South Australia Fact Sheet [55]

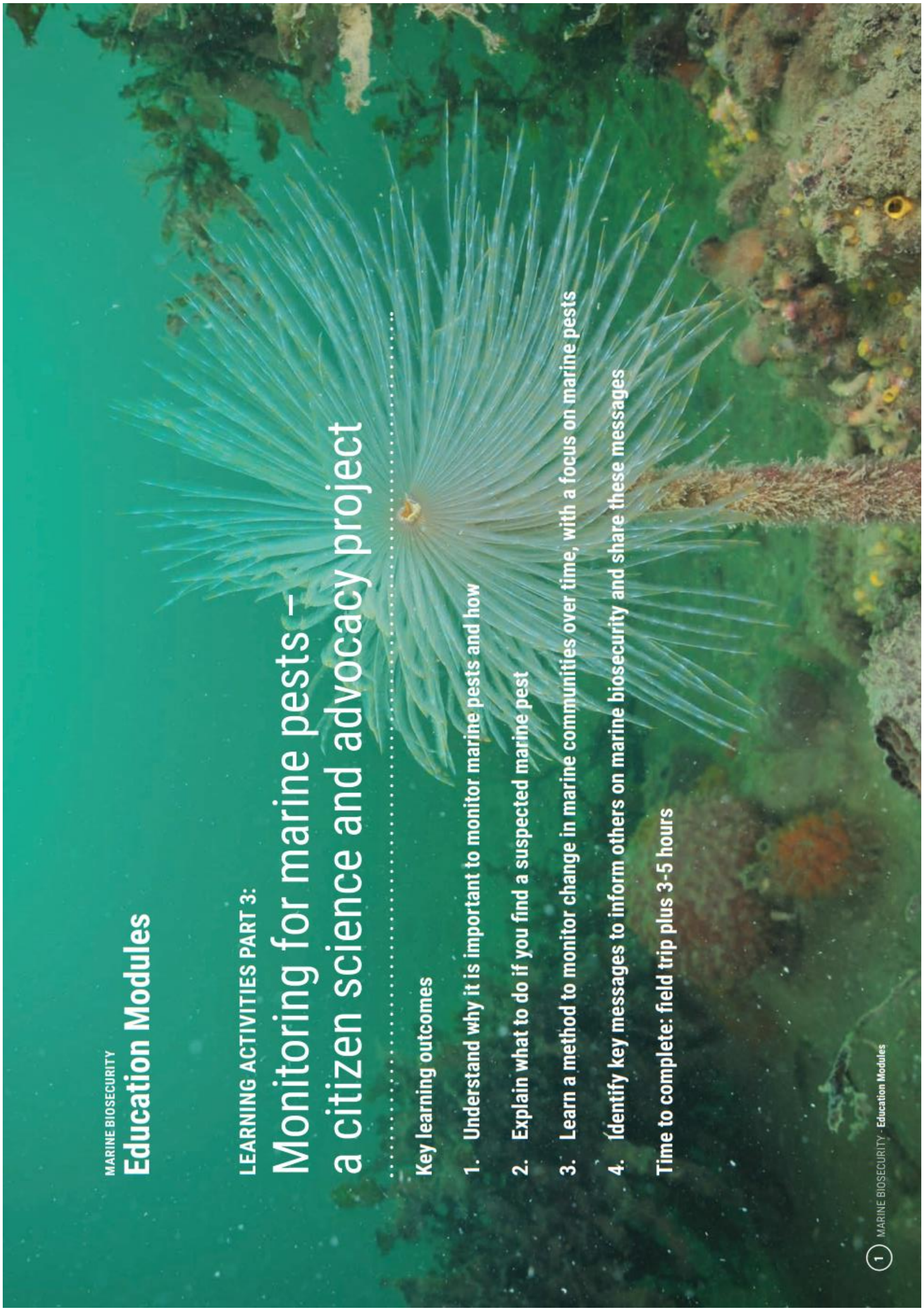
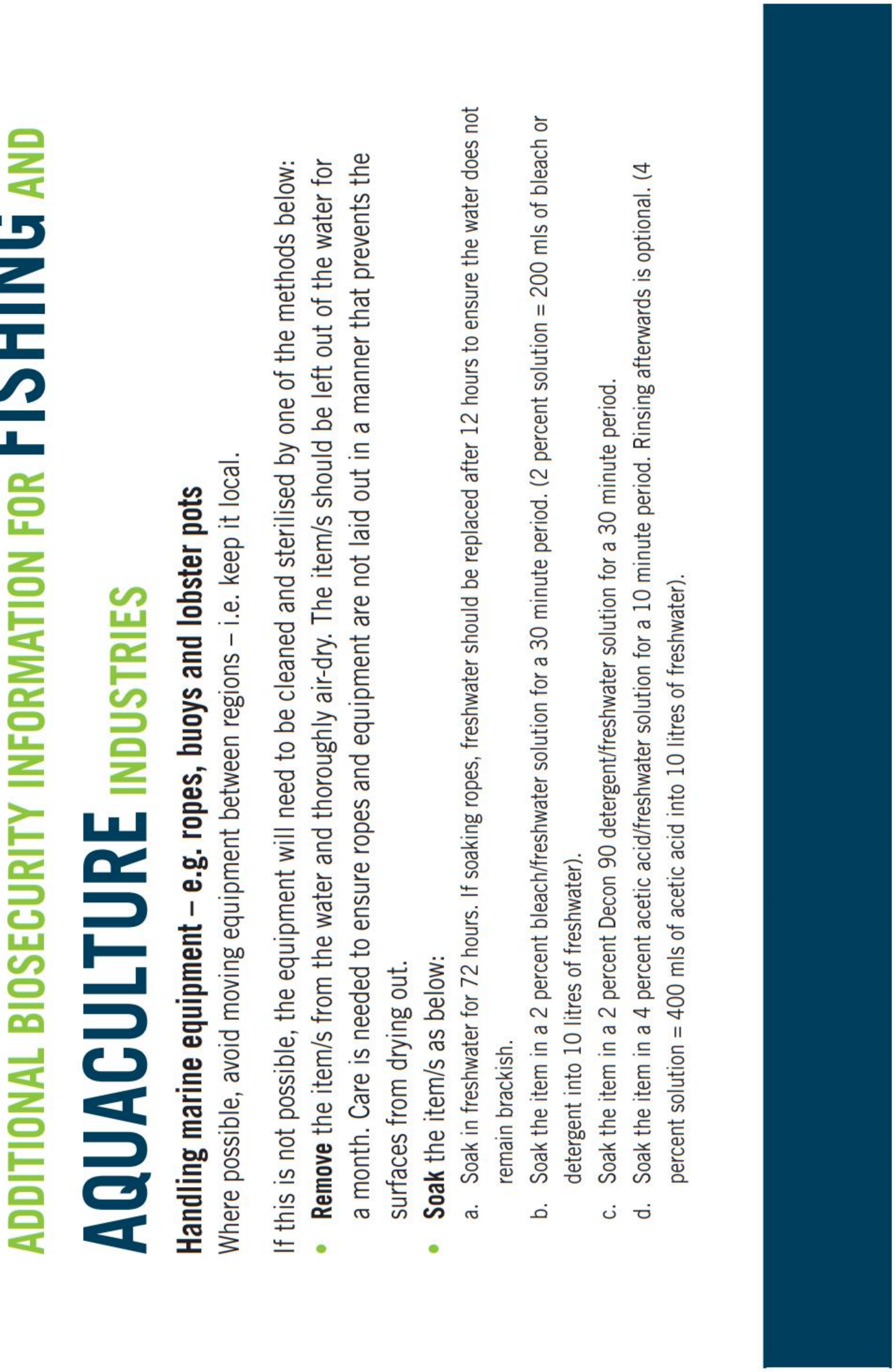


Figure 7. NZ Clean Below? Good to Go Education Module [56]



ADDITIONAL BIOSECURITY INFORMATION FOR FISHING AND AQUACULTURE INDUSTRIES

Handling marine equipment – e.g. ropes, buoys and lobster pots
Where possible, avoid moving equipment between regions – i.e. keep it local.

If this is not possible, the equipment will need to be cleaned and sterilised by one of the methods below:

- **Remove** the item/s from the water and thoroughly air-dry. The item/s should be left out of the water for a month. Care is needed to ensure ropes and equipment are not laid out in a manner that prevents the surfaces from drying out.
- **Soak** the item/s as below:
  a. Soak in freshwater for 72 hours. If soaking ropes, freshwater should be replaced after 12 hours to ensure the water does not remain brackish.
  b. Soak the item in a 2 percent bleach/freshwater solution for a 30 minute period. (2 percent solution = 200 mls of bleach or detergent into 10 litres of freshwater).
  c. Soak the item in a 2 percent Decon 90 detergent/freshwater solution for a 30 minute period.
  d. Soak the item in a 4 percent acetic acid/freshwater solution for a 10 minute period. Rinsing afterwards is optional. (4 percent solution = 400 mls of acetic acid into 10 litres of freshwater).

Figure 8. Part of MPI's Guide [57]