Southland Regional Marine Invasive Species Surveillance and Compliance Plan

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Prepared for Environment Southland

Envirolink Grant # 2027-ESRC292

03 April 2020

University of Otago researcher Gaby Keeler-May controlling the spread of the invasive seaweed *Undaria pinnatifida* in Breaksea Sound, Fiordland, 2019. Photo credit: Louise Bennett-Jones

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Executive Summary

Marine pests pose a major threat to biodiversity, fisheries and ecosystems of coastal areas. In Southland (Murihiku), formal active surveillance of marine pests is limited to biannual surveys in Bluff Harbour and parts of the Fiordland (Te Moana o Atawhenua) Marine Area. The Southland Regional Pest Management Plan (RPMP, 2018, ES) highlights 7 marine pests which are managed with the goal of exclusion (6) or progressive containment (1, *Undaria pinnatifida*). Of particular concern is the continued spread of *Undaria* into Fiordland's pristine marine ecosystem and the significant costs incurred by the ongoing response to prevent further spread. The Fiordland Marine Regional Pathway Management Plan (2017) established clean hull standards to reduce new incursion risks to Fiordland's marine area. However, this management initiative does not contribute to the monitoring and surveillance requirements for the rest of Southland. For these reasons the University of Otago was contracted by Environment Southland (ES) to develop a surveillance and compliance plan to reduce the spread and ensure early detection of marine pests in the Southland Coastal Marine Area (CMA).

A literature review identified and summarised basic biological data on 21 potential marine pest species of concern to Southland, 14 of which are already established within New Zealand (Aotearoa). A detailed review of the life history of the 7 pest species named by ES under the RPMP revealed that most species (excluding the Asian paddle crab (*Charybdis japonica*)) were benthic, sessile and establish colonies on artificial structures. Most of these pests reproduce in the spring/summer and recruit in late summer/early fall, although *Undaria* thrives in cold water and can have multiple recruitment events throughout the winter.

High risk sites and pathways for marine pest incursions were identified for the Southland CMA. The highest risk pathways were:

- Vessel movements (especially hull fouling of fishing vessels, but also private yachts and powerboats of international and national origins);
- Aquaculture (stock and equipment transport);
- Fishing gear (such as crayfish pots stored in the subtidal)

The highest risk sites for marine pest incursions in Southland are those with large submerged artificial structures and frequent traffic of large vessels. High-risk structures include docks, wharves, moorings, stern lines, wrecks, helicopter landing pads and aquaculture facilities. Fourteen high-risk areas were identified and mapped (7 in Fiordland, 5 in Stewart Island and 2 on the south Coast).

A Southland-wide Surveillance plan was developed to target the 7 marine pests identified by the Southland RPMP. Annual surveys (diver searches, shore searches and crab traps) of artificial structure and the adjacent seafloor should be done at each of the high-risk areas during the late spring/early summer (November onward). This timing will capture the largest visible life stages of each pest prior to reproduction and will coincide with the best weather conditions for field work. **Estimated annual costs for operation of the plan were ~$150,000**.

In order to start the annual pest marine monitoring plan next steps, include:

- Secure financial resources and staffing to run the programme
- Develop capability and capacity to survey for pest species, including recruitment or training of skilled staff and adapting survey methods to local conditions;
- Engage with stakeholders/those with jurisdiction over all structures to be surveyed; and
- Baseline surveys at each location to determine which invasive species are present and to gather information on local weather and sea conditions, hazards, habitat distribution and focal points for marine pest incursions.

In this report we recommend that ES:

1. Implements an annual monitoring plan for marine pests at high-risk sites in several areas throughout Southland (including Fiordland and Stewart Island/Rakiura), with surveys done in the spring of each year (3.1, p.32).
2. Implements a surveillance programme with a focus on spring and summer to check the hulls of predominantly in-water vessels for marine pests at all major harbours throughout Southland. (3.2.1 p. 36)

3. Consider implementing a Southland Pathway Management Plan requiring clean hulls for all vessels moving into or between harbours throughout the region (Section 3.2.2, p.36).

Secondary recommendations include that ES:

4. Consider reviewing the status of the Asian Paddle Crab/*Charybdis japonica* and Australian droplet tunicate/*Eudistoma elongatum* in the RPMP's exclusion programme since they are unlikely to be reproductive in the water temperatures in Southland (Section 2.1, p.6).

5. Consider doing a risk assessment for the inclusion of the Carpet sea squirt/*Didemnum vexillum*, Light bulb ascidian/*Clavelina lepadiformis*, Vase and Pacific tunicates (*Ciona intestinalis/Ciona savigny*) and Devils tongue seaweed (*Grateloupia turuturu*) as exclusion programme species as they are invasive species that are present in New Zealand and could thrive in Southland as noted by Page (2018) (Section 2.1, p.6).

6. Consider doing a risk assessment for adding Japanese skeleton shrimp (*Caprella mutica*) as a species for progressive containment since they are already present within Southland and present a potential risk to aquaculture operations (Section 2.1, p.5).

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1. INTRODUCTION AND OBJECTIVES

New Zealand/Aotearoa's marine environment is an important resource for both commerce and recreation. In Southland (Murihiku), marine ecosystems are culturally, ecologically and economically significant. Southland holds many marine areas and species of significance to Ngai Tahu acknowledged and protected under the Deed of Settlement (1997). This includes sites of importance to mahinga kai (practices of traditional wild food harvesting) cultural keystones and taonga like Pāua (*Haliotis iris*), Toheroa (*Paphies ventricosa*) and Tītī (*Puffinus griseus*) (McCarthy et al. 2013), Rimurapa (*Durvillaea spp*.) and Karengo (*Porphyra spp.*). Southland is also home to critically endangered Hoiho/Yellow-eyed penguin (*Megadyptes antipodes*); threatened species including Tūpoupou/Hector's dolphin (*Cephalorhynchus hectori*), Terehu/Bottlenose dolphins (*Tursiops truncatus*), Tawaki/Fiordland crested penguins (*Eudyptes pachyrhynchus*) and protected cold-water corals (e.g. *Antipathes fiordensis*) (Cunningham et al. 2019). Diving and marine wildlife tourism is popular in the Fiordland (Te Moana o Atawhenua) Marine Area and Stewart Island (Rakiura), and many marine resources are harvested by commercial and recreational fisheries. The most important fishery species include Raawaru/Blue cod (*Parapercis colias*), Pāua, Tio paruparu/Bluff oysters (*Tiostrea Chilensis*) and Kōura/Rock lobster (*Jasus edwardsii*) with a seafood export value of > $145 million (Williams et al. 2017). This is the second highest catch value overall of all New Zealand's Fishery Management Areas (FMAs) and the most valuable inshore FMA. Hāmana/King Salmon (*Oncorhynchus tshawytscha*), Kuku/Green Lip mussels (*Perna canaliculus*) and Pāua are farmed in aquaculture facilities based in Stewart Island and Bluff (Motu-pōhue), and Bluff Harbour provides a major port for commercial shipping as well as a ferry service to Stewart Island.

Marine pest species have the potential to introduce disease, outcompete native species and alter benthic structure and biodiversity, posing a significant risk to the health of Southland's marine ecosystem and the economic, cultural, recreational and myriad other services it provides (Environment Southland 2019[A]). Thus, Environment Southland (ES) has identified a need for a comprehensive marine biosecurity plan that will implement surveillance, compliance and monitoring of all the major pathways and potential incursion sites for marine pests throughout Southland's marine region.

1.1 Current Marine Biosecurity Initiatives in Southland

While some initiatives are currently in place for surveillance, compliance and monitoring of marine pests in Southland (as of 2020), they cover limited areas and/or do not occur every year. Current marine biosecurity management efforts are discussed below.

1.1.1 Surveillance - Monitoring

Monitoring for marine pests is formally done on an annual basis throughout New Zealand by the Ministry of Primary Industry, Biosecurity New Zealand's Marine High Risk Site Surveillance programme (MHRSS). MHRSS is a national programme that targets the early detection of high-risk marine non-indigenous species at ports and marinas that are identified as high risk for invasion (Woods et al. 2019). At Bluff Harbour MHRSS uses several survey methods biannually (summer and winter) at 225 locations to create an annual synopsis report on invasive species. Occasional (every 3 -5 years) monitoring of Southland's secondary ports (Waikawa, Bluff, Riverton (Aparima), Cosy Nook (Pahi), Stewart Island and Port Craig) are done as part of a summer studentship with the University of Otago (Subritzky and Pullman 2014). Quadrat surveys are done across slipways or nearby rocky substrate and wharf pylons and the general area is searched at low tide for invasive species. Mooring lines are also checked for pests by ES during bi-annual compliance and DOC on biological monitoring trips to Fiordland.

1.1.2 Surveillance – Hull Inspections

Diver surveys of boat hulls throughout Bluff Harbour and Stewart Island (Halfmoon Bay and Horseshoe Bay) are conducted on a monthly basis between November and April on boats known to enter Fiordland and by request between May and October under a contract with Biosecurity New Zealand. Joint agency (Biosecurity New Zealand, Fisheries, Department of Conservation (DOC) and ES) compliance trips to Fiordland are conducted bi-annually at peak use times in January and April and include hull inspections and snorkel surveys of artificial structure and natural habitat (Environment Southland 2018). Although all of Fiordland is targeted, sites from Doubtful Sound south to Preservation Inlet are most often visited.

1.1.3 Compliance

The Southland Regional Pest Management Plan (RPMP) identifies marine pest species which may not be held in Southland (unless within a specified exemption area) and outlines their management programme (progressive containment or exclusion (Environment Southland 2019[A])). The Southland Biosecurity Strategy identifies the Council's approach to biosecurity (Environment Southland 2019[B]). Additionally, the Fiordland Marine Pathways Management Plan (Environment Southland 2017) requires that all boats entering the Fiordland Marine Area must hold a Clean Vessel Pass (CVP), comply with clean hull, clean gear and residual seawater standards and maintain evidence of compliance efforts. Compliance with the CVP is enforced by ES staff through inspections of all vessels encountered on bi-annual trips to Fiordland on dates when boat use is expected to be high (New Years and Easter).

1.2 Statement of Problem

There is no comprehensive plan for marine biosecurity surveillance, monitoring and compliance in Southland. Compliance efforts are limited to parts of Fiordland. Only one port is monitored for establishment of new species on a bi-annual basis and few vessels are surveyed for fouling or marine pests. And much of Southland's coast is remote and rugged making it difficult to detect incursions. Thus, there is a high risk of invasive species establishing themselves without being discovered.

1.3 Statement of Purpose

The purpose of this plan is to allow for the early detection of invasive species incursions in Southland's Coastal Marine Area (CMA) at high risk sites and to actively exclude marine pests by targeted surveillance and compliance efforts for high risk pathways.

1.4 Statement of Objectives:

1.4.1 Primary Objectives

1. To detect incursions of new-to-Southland non-indigenous marine organisms listed as Pest Species by the RPMP at High Risk Sites throughout Southland.
2. To detect range extensions of established non-indigenous organisms listed as Pest Species by the RPMP at High Risk Sites throughout Southland (i.e. *Undaria*).
3. To ensure compliance with the RPMP and the Fiordland Marine Regional Pathway Management Plan.

1.4.2 Secondary Objectives

1. To detect incursions of all potentially threatening non-indigenous organisms, such as those listed on the "Unwanted Organisms Register" by the Ministry for Primary Industries or as Organisms of Interest by the RPMP at High Risk Sites throughout Southland.

1.5 Geographic Extent of the Plan

This management plan will target high risk sites within Southland's marine area, which extends from Awarua Point, Fiordland in the West to Waiparau Point, Catlins in the east, including Stewart Island/Rakiura and nearby islands (**Figure 1**).

Figure 1.1 Boundary map of coastal areas managed by Environment Southland

2. MANAGING INVASIVE MARINE SPECIES

2.1 Current and potential invasive marine species

As of 2017, 214 non-indigenous species have been recorded within New Zealand's marine environment at locations throughout both the North and South Islands (Ministry for Primary Industries, 2019[A]). Several of these are considered highly invasive marine pests by Biosecurity New Zealand (Ministry for Primary Industries, 2019[B]). These include organisms from multiple phyla such as algae, bivalves, crabs, polychaetes, sea stars and sea squirts. Information on marine pests and incursion locations are updated on Biosecurity New Zealand's "Marine Biosecurity Porthole" website (Seaward et al. 2015). A non-indigenous species is classified as an invasive "marine pest species" by ES if it is considered to pose significant risk to economic, environmental, social and cultural values in Southland's CMA (Environment Southland 2019[A]). Southland has had fewer pest incursions than other parts of New Zealand, with only one known established marine pest (*Undaria*) as of July 2020.

Non-indigenous species other than *Undaria* have been recorded by MHRSS surveys in Southland, but they are not currently identified as pest species by Environment Southland. For example, the non-indigenous amphipod from Asia, *Caprella mutica* (2018), the non-indigenous tubular hydroid, *Ectopleura crocea* (2018) and the vase tunicate, *Ciona intestinalis* (2014) have all been detected in Bluff Harbour during MHRSS surveys (Woods et al. 2018). *Caprella mutica* is a long thin marine amphipod, similar to a stick insect in appearance, that was first noted in Timaru (Te Tihi-o-Maru) in 2006 (Fenwick 2006) but has since been found in several parts of the South Island including on aquaculture structures in Big Glory Bay, Stewart Island (pers. obs, C. Hepburn). *Caprella mutica* is aggressive, can outcompete native amphipods and quickly forms dense masses on floating artificial structures in New Zealand (Boos et al. 2011, Willis et al. 2009). But it is less abundant on natural near-bottom habitat due to predation by fishes (Page et al. 2007), and thus may prove less of a threat to local biodiversity in New Zealand. Further research is required to understand the effects of its invasion on local native and non-native species. A site-led programme is currently under consideration by Environment Southland for the containment of *C. mutica*.

High risk pest species to be monitored by Environment Southland

Numerous marine pest species pose a threat to Southland, including those established in other parts of New Zealand as well as from international waters. A report prepared for Environment Southland by NIWA identified 18 potential high-risk marine species to Southland including the main risk species to New Zealand already identified by MPI (Ministry for Primary Industries 2019[B]) as well as other non-indigenous organisms that pose a risk to Southland based on their potential environmental impacts, rate of spread and their proximity to the region (Page 2018) (Appendix A, Table 1). In addition to the organisms identified by the NIWA report, highly invasive seaweeds in the Sargassum family (*Sargassum muticum* and *Sargassum horneri*) should also be considered risk species, since they have established in similar temperate ecosystems along the pacific coast of North America and have the capacity to outcompete native kelps (Marks et al. 2018).

A subset of seven marine pest species was identified by Environment Southland's RPMP as high-risk based on their life history, geographic range and habitat preferences (**Appendix**, **Table 1**) (Environment Southland 2019[A]). Four of these species overlap with those identified in the report by NIWA's Mike Page (2018) as Southland's top high risk species but they do not include the others on that list; the light bulb ascidian (*Clavelina lepadiformis*), the vase tunicate and Pacific tunicate (*Ciona intestinalis* and *Ciona savigny*) or the devil's tongue weed (*Grateloupia turuturu*). All of these are non-indigenous species with potential negative impacts that are established in New Zealand and could flourish in the ocean conditions in Southland. Further, some species included on the RPMP list may be less pertinent, like the Asian Paddle Crab (*Charybdis japonica*) and the Australian droplet tunicate (*Eudistoma elongatum*) which pose a very low invasion risk in Southland since reproduction only occurs in warm waters at >20°C and >14°C respectively. Average water temperatures only peak at 12-15°C during the summer months in most of Southland, though warming trends in southern New Zealand could make conditions more suitable for these species in the future (Shears & Bowen 2017).

Information on the life history and biology of the pest species listed by the RPMP will be essential for defining the scope of this plan's monitoring design, but the other invasive species discussed (**Appendix, Table 1**) could pose similar or greater risks, and thus should also be targeted for presence/absence monitoring in all surveys. The following seven species were identified by the RPMP as pest species:

1. *Undaria*, *Undaria pinnatifida*
2. Asian paddle crab, *Charybdis japonica*
3. Mediterranean fan worm, *Sabella spallanzanii*
4. Australian droplet tunicate, *Eudistoma elongatum*
5. Clubbed tunicate, *Styela clava*
6. Australian cunjevoi, *Pyura doppelgangera*
7. Carpet sea squirt, *Didemnum vexillum*

MANAGED UNDER THE PROGRESSIVE CONTAINMENT PROGRAMME:

2.1.1 Asian kelp (Undaria pinnatifida)

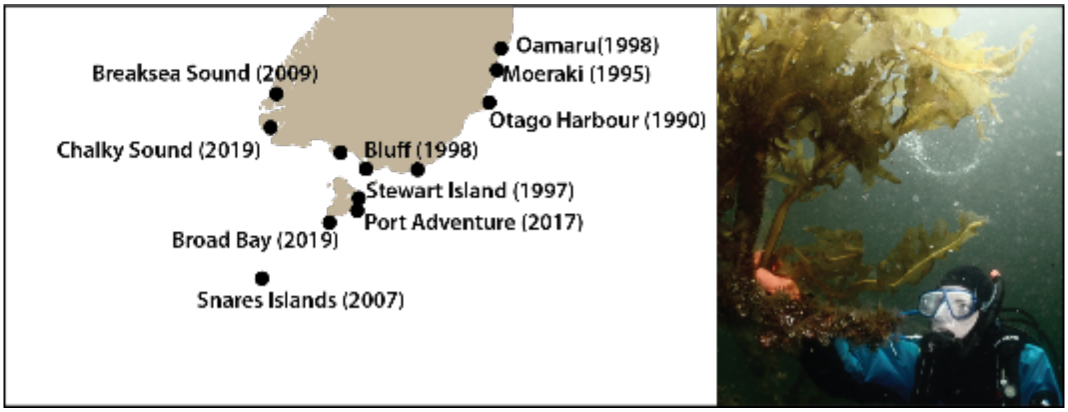


Figure 2.1 Dates of incursion of *Undaria pinnatifida* in southern South Island, New Zealand (left); and diver with mature *U. pinnatifida* in sporophytes in Breaksea Sound (2019) (right).

Description: *Undaria pinnatifida (Undaria)* is a golden-brown seaweed with a central midrib, divided frond and a fleshy, frilly reproductive structure at its base.

Geographic Range: Native to the Northwest Pacific (Japan and Korea), *Undaria* was first observed in New Zealand in 1987 in Wellington Harbour. It has since established in parts of Stewart Island/Rakiura (1997), Waikawa (2014), Bluff Harbour (1998), Breaksea Sound/ Te Puaitaha (2009) and Chalky Inlet/Taiari (2019).

Life history: *Undaria* is a winter annual laminarian kelp that first appears in early spring in its native home range. In New Zealand populations can persist and recruit throughout the year, especially in cool areas (SST <20 °C year-round) (James et al. 2015). *Undaria* has a high growth rate with sporophytes reaching maturity in 40 to 50 days with the potential to release up to 700 million zoospores per plant (Schiel and Thompson 2012). In its native habitat sporophytes form in winter, 20-30 days after zoospores germinate (Hewitt et al. 2005), but in New Zealand bi-annual recruitment events can occur in autumn and spring in Moeraki (Schiel and Thompson 2012) and variable recruitment occurs between inner harbour and outer coast populations in Dunedin/ Ōtepoti (Leahy 2018). Recruitment from microscopic life stages can persist for up to 2.5 years after plants are removed (Hewitt et al. 2005).

Habitat: *Undaria* can grow on almost any hard, intertidal or subtidal substrate (artificial or natural), with peak populations found in 4-6 m depth in New Zealand (Russell et al. 2008). Founding populations typically occur in intertidal rockpools. Plants have been observed at 0-20 m depth in southern New Zealand (Hepburn et al. unpub.) but more research is needed to confirm the vertical distribution of *Undaria* within New Zealand waters (South et al. 2017).

Impact: *Undaria* can substantially modify natural habitats changing the native ecology of those areas (Suarez-Jimenez et al. 2017). It can dominate space and change species composition by outcompeting seasonal or opportunistic macroalgae (South et al. 2017).

MANAGED UNDER THE EXCLUSION PROGRAMME:

2.1.2 Asian paddle crab (Charybdis japonica)

Figure 2.2 Photo of *Charybdis japonica* and its distribution within New Zealand. Viewed 14/04/20 at https://marinebiosecurity.org.nz/search-for-species/

Description: *Charybdis japonica* (*Charybdis*) is a large crab with six prominent spines on each side of the carapace (distinguishing it from native paddle crab species), which is up to 12 centimetres across. There are five prominent spines on the upper surface of each claw. The swimming paddles on the back legs are flattened. Colour ranges from off-white and pale green, through olive-green to a deep chestnut brown with purplish markings.

Geographic Range: Native to central and southeast Asia, the Asian paddle crab was first detected in New Zealand in 2000 and as of 2020 it can be found in Waitamata, Whangarei and Waikare Inlet in Northland/ Hiku-o-te-ika. Crabs can tolerate temperatures ranging from 4 – 34 °C.

Life history: Each female crab can produce one brood of more than 400,000 eggs between austral spring and autumn, with reproduction peaking in summer (Fowler and McLay 2013). Larvae can survive in the plankton for three to four weeks before reaching recruitment size and settling into estuaries (Fowler and McLay 2013). Larvae can survive in temperatures from 12 – 34 °C, though survival is best above 16 °C (Fowler et al. 2011) and reproduction occurs in water temperatures between 17 and 22 °C (Wong and Sewell 2015).

Habitat: They inhabit the sand and mud of coastal estuaries and harbours from the low tide mark out to 15 metres depth.

Impact: It is highly detrimental to shellfish aquaculture, as it is an aggressive predator and displaces native and fisheries species (Fowler et al. 2013). Also, it can carry diseases that affect crab, lobster, shrimp, and prawn fisheries (PIRSA 2019).

2.1.3 Mediterranean fan worm (Sabella spallanzanii)

Figure. 2.3 Mature *Sabella spallanzanii* (Mediterranean fan worm) Photo credit: CSIRO and a map of its distribution in New Zealand. Viewed 14/04/20 at https://marinebiosecurity.org.nz/search-for-species/

Description: *Sabella spallanzanii* (*Sabella*) is a large tube worm that secretes a tough, flexible tube 10 – 30 cm and up to 80 centimetres long. Tentacles at the top form a spiralled fan, up to 15 centimetres across. Fans vary in colour, from dull white, to brightly banded with stripes of orange, purple and white.

Geographic Range: Native to the Mediterranean and Atlantic coast of Europe, *Sabella* was first detected in Lyttleton/ Ōhinehou, New Zealand in 2008 and as of 2020 it has established in a number of ports throughout the country as far south as Timaru, but more commonly in the Auckland/Ākarana region.

Life history: *Sabella* is a dioceous (worms of both sexes are present) broadcast spawner and populations in Port Phillip Bay, Australia reproduce annually during autumn/winter in water temperatures of ~ 11 °C (Currie et al. 2000). Females reach maturity at a minimum size of 50 mm and they can release >50,000 eggs annually but the duration of larval development is undetermined. Life history characteristics appear to differ substantially by geographic region however, even within Australia (Lee et al. 2018), and further information on populations from New Zealand is required to inform management. Based on research from the Mediterranean *Sabella* may have a life span of up to 5 years.

Habitat: *Sabella* prefers sheltered, shallow subtidal areas (1 to 30 metres deep). It attaches to hard substrates such as shells, jetty pylons, wrecks and rocks and boat hulls, but can also be found in sand. In Australia it is found in highest abundance on pier pylons (~7 m depth) and less commonly over shallow sediments (~7 m depth), declining rapidly in abundance in deeper sediments (17 - 22 m) (Currie et al. 2000).

Impact: These fast-growing worms can form vast, dense meadows and are likely to compete with native suspension feeders for food and interfere with their life cycle (Holloway and Keough 2002). They can also alter infaunal communities (O'Brien et al. 2006).

2.1.4 Australian droplet tunicate (Eudistoma elongatum)

Figure 2.4 A colony of *Eudistoma elongatum* (Australian droplet tunicate) Photo credit: Mike Page, NIWA and a map of its distribution in New Zealand. Viewed 14/04/20 at https://marinebiosecurity.org.nz/search-for-species/

Description: *Eudistoma elongatum* (*Eudistoma*) forms large colonies that attach to hard surfaces and look like clusters of white or cream-coloured cylindrical tubes. Each colony contains numerous small individuals and they can appear orange flecked due to the colour of the larvae within them. The species is firm and gelatinous to the touch and the cylindrical colonies are generally 5-30 cm long but can occasionally reach 1.5 metres in length. Colonies are generally 5-20 mm in diameter and regress and over winter as small (approx. 10 millimetres) cream buds, re-growing the following spring to larger colonies.

Geographic range: Native to Australia, *Eudistoma* was first found in New Zealand in 2005 and established in areas throughout Northland within the next few years.

Life history: Populations of *Eudistoma* in Northland are reproductive from October to June, with output decreasing following high rainfall events and cooler sea surface temperatures (Morrisey et al. 2009). Embryos are present at water temperatures above 14 °C and larval survival is best at conditions above 20 °C and 20 psu though they can withstand conditions down to 10 °C and 10 psu (Page et al. 2011). Recruitment occurs from late summer through autumn (February – May) in Northland (Morrisey et al. 2009).

Habitat: *Eudistoma* is found in sheltered soft-bottomed tidal habitats and on hard structures such as wharf piles, aquaculture equipment and mangrove roots. It prefers submerged habitats just below the waterline but can survive in the intertidal (Morrisey et al. 2009).

Impact: *Eudistoma* competes with native species for both space and food and occupies space on oyster farm stock, increasing cleaning requirements prior to sale (Morrisey et al. 2009). It is also may ingest and kill the eggs and larvae of native species.

2.1.5 Clubbed tunicate (Styela clava)

Figure 2.5 *Styela clava* (Clubbed tunicate). Photo credit: Matthieu Sontag, Licence CC-BY-SA and a map of its distribution in New Zealand. Viewed 14/04/20 at https://marinebiosecurity.org.nz/search-for-species/

Description: *Styela clava* (*Styela*) has a long, club-shaped body on a tough stalk. Its surface is leathery, rumpled, and yellow, red or brown in appearance. It is sometimes referred to as a 'solitary' sea squirt because each individual has its own stalk and adheres separately to the substrate. Underwater it appears to have a fuzzy secondary growth and two short siphons are visible at the top. *Styela* can grow rapidly, reaching densities of 500-1500 individuals m^{-2}, but it has only been found at densities of 100 individuals m^{-2} within New Zealand.

Geographic range: Thought to be native to the Pacific Northwest, Styela was first discovered in Auckland's Viaduct Basin and in Lyttelton Harbour in 2005. It was found soon after on the hull of a vessel that had sailed from Auckland to Picton/Waitohi and as of 2020 it is established in harbours throughout the North and South Island.

Life history: *Styela* can live for up to two years and grow up to 160 millimetres long. They are potentially self-fertilising and are capable of reproducing throughout the year in water temperatures above 15°C with peaks in early spring and late summer (McClary et al. 2008).

Habitat: Common on artificial habitats in shallow (<5 m) turbid water, especially piles, pontoons and ropes (Gust et al. 2009). They are also present, but in lower abundance at 5 – 13 m.

Impact*:* *Styela* competes with other filter feeders for food and space. As a result, it disrupts native ecosystems and aquaculture (Soliman and Inglis 2018).

2.1.6 Australian cunjevoi (Pyura doppelgangera)

Figure 2.6 *Pyura doppelgangera* (Australian cunjevoi) and a map of its distribution in New Zealand. Viewed 14/04/20 at https://marinebiosecurity.org.nz/search-for-species/

Description: *Pyura doppelgangera* (*Pyura)* is a large, solitary, short, chalice-shaped sea squirt with two large mounds representing siphons set in the depressed upper surface of the body. When the *Pyura* is inflated, cruciform or cross-shaped siphons are visible by the bright reddish orange body wall. Individuals can be very large and often form dense aggregates on intertidal platforms, sometimes occupying 100% cover.

Geographic range: Native to Australia, Pyura was first detected in New Zealand in 2007 (Hayward and Morley 2009). As of 2020 Pyura is found in ports throughout New Zealand's North Island and as far south as Christchurch on the South Island.
Life history: Information from other Pyura species suggests that larvae spend a maximum of only 12 hours in the water column, limiting natural dispersal (Fletcher 2014). Microsatellite data on Pyura show high levels of larval retention at the parent site (Teske et al. 2015) and new recruits are often found in clusters or on top of adults. Spawning is probably dependent on water temperature thresholds, but no information is currently available on reproductive season or duration (Fletcher 2014).

Habitat: *Pyura* forms large aggregations on rock platforms in the mid-intertidal to shallow subtidal down to depths of 12 m. Populations can be limited by wave action and sand smothering (Fletcher 2014).

Impact: *Pyura* is an ecosystem engineer capable of altering local population structure and displacing important native New Zealand species, including green shell mussels (Davis et al. 2018).

2.1.7 Carpet sea squirt (Didemnum vexillum)

Figure 2.7 Close-up of *Didemnum vexillum* zooids and siphons and Photo credit: Dann Blackwood USGS and a map of its distribution in New Zealand. Viewed 14/04/20 at https://marinebiosecurity.org.nz/search-for-species/

Description: *Didemnum vexillum* (*Didemnum*) colonies form extensive sheets on vertical surfaces. Cylindrical or frond-like outgrowths can often arise off the main colony. These can form extremely long dripping tendrils, sometimes metres long. Outgrowths of the colony encrusts algae, hydrozoans, tube worms and mussels. The colonies are pale yellow to cream coloured and firm yet gelatinous to the touch. Common exhalent openings are obvious at the end of lobes and a fine open network of canals can be seen below the surface. Spicules are sparse throughout most of the pest; making it more gelatinous than other *Didemnum* species.

Geographic range: Potentially native to Japan, *Didemnum* was first detected in New Zealand in 2001 in Whangamata harbour but it is now present throughout the country, detected as far south as Dunedin.

Life history: Capable of rapid growth and expansion *Didemnum* can reproduce both sexually and asexually. They are reproductive 9 months of the year in the Marlborough sounds, and may be able to recruit year-round but the lowest levels of recruitment occur over winter (July – September) (Fletcher et al. 2013). Larval recruitment has not been detected at temperatures below 12 °C.

Habitat: *Didemnum* has been found on artificial structures in New Zealand (barges, recreational vessels, moorings, salmon cages and wharf piles) (Coutts and Forrest 2007), and these offer the most likely vectors for establishment. In the north-eastern U.S.A *Didemnum* are also present on artificial structures, but they are most abundant on natural cobble reefs in deep offshore waters (40 – 65 m) that offer stable temperatures and higher salinity (Valentine et al. 2007).

Impact: Dense colonies of *Didemnum* displace native and fisheries species and smother beaches, rocks and tidepools. They also foul boat hulls, the undersides of floating structures and marine farm lines and sea cages (Coutts and Forrest 2007).

2.2 High risk sites, structures and pathways

Marine pests are introduced to new environments accidentally by transport vectors such as shipping, canals, aquaculture, fisheries, tourism, research or restoration efforts (Minchin et al. 2009). Vessel movements are the primary vector as a result of biofouling (attachment to boat hulls, anchors or fishing gear) or water and sediment transport in bilge water, dive equipment or other gear (Hulme 2009). Since vessels are the primary mode of transport for pests, the highest risk sites and structures for marine invasions are berths, wharfs and moorings. The risk of new invasions in New Zealand will continue to rise as international and local trade routes expand, so strong national and regional biosecurity plans that target high-risk pathways and structures are needed to protect local biodiversity and fisheries. It is especially important to manage pathways since eradication efforts on established species are costly, resource and labour intensive (Hewitt et al. 2005) and often unsuccessful (Hewitt and Campbell 2007).

Southland maintains a relatively pristine marine area with few pest incursions (other than *Undaria*) since it is distant from international ports and has less traffic of large pleasure vessels compared to warmer areas like Northland. The biggest issue with maintaining a pest-free environment in Southland is that many areas are remote and therefore not well monitored. Any potential incursion may spread well beyond the initial settlement site before being detected (Brunton 2019). An annual surveillance and compliance plan targeting high-risk structures and moorings will help ensure incursions are detected as early as possible. The following sites, structures and pathways represent the most important high-risk focal points for surveillance and management of marine pests in Southland.

2.2.1 Pathways in Southland

Vessel movements

Recreational vessels are a major threat to biosecurity in Northland, New Zealand (NRC 2017) and other regions (Floerl et al. 2015) but far fewer visit Southland (Griffiths et al. 2018), so commercial fishing vessels are probably the main vector for invasive species. However, any vessel that is predominantly in-water (only dry docking for maintenance) poses a risk for introducing marine pests since they are prone to fouling (Cunningham et al. 2019). This includes charter boats, cruise ships, navy or recreational vessels and yachts. Cruise ships visit Bluff, Stewart Island and Fiordland between October and April and tourism boats including ferries, sightseeing, fishing and diving boats regularly move through many areas in Southland. In Fiordland alone, over 200 vessels visited annually in 2018 and 2019 (ES Clean Vessel Pass Data, 2020). Recreational power boats <10 m and commercial fishing vessels were the most commonly encountered vessels inside the southern Fiords on the annual surveillance trips by ES (~50% and 20% respectively) as most commercial fishing vessels operate in the coastal parts and only moor in the sounds in the evenings so they are not encountered often.

The dominant mode of transport for marine pests in Southland is hull fouling (Cranfield et al. 1998, Dodgshun et al. 2007). There are already strict regulations on bilge water discharge for cruise ships (Environment Southland 2008) and any vessel arriving from international waters (Ministry for Primary Industries 2016) making this vector of lower likelihood. High-risk fouling species such as *Undaria* have been found on the hulls of fishing vessels, throughout New Zealand's South Island despite active control programmes (Stuart 2002). For example, vessels in Bluff and Stewart Island that regularly visit Fiordland have repeatedly harboured *Undaria* when subject to hull checks and cleaning. Following implementation of the Clean Vessel Pass (CVP) by ES in 2017 (Environment Southland 2017), two boats have been found without CVPs in the Fiordland Marine Area that were harbouring pest species on their hulls (*Undaria* and suspected Mediterranean Fan Worm, respectively) (ES Surveillance data, 2020).

Fishing Gear

Since fishing vessels are a primary vector for pest transport in Southland, any associated fishing gear that is submerged for long periods of time should also be considered a primary vector for pest transport. Recent surveys by staff at the University of Otago discovered that *Undaria*, which was previously confined to Oban, was introduced to Broad Bay Stewart Island via crayfish pots stored in shallow water (internal ES report, Keeler-May & Hepburn 2020). Any fishing equipment that is submerged for long periods of time and transported should be considered a high-risk pathway and prioritised for inspection or subject to further compliance measures.

Aquaculture

A third important pathway to monitor in Southland is aquaculture. Aquaculture fisheries for pāua, salmon and mussels operate in Big Glory Bay, Stewart Island and Bluff Harbour. Aquaculture can introduce pest species, parasites, pathogens and predators since stock and equipment are often transported from other areas (Grosholz et al. 2015).

Mussel and Salmon are delivered to Bluff on a daily basis from Big Glory Bay and delivery of aquaculture equipment (e.g. barges), feed and/or spat present marine biosecurity risks. For example, *Bonamia ostreae*, which is a parasite of flat oysters (*Ostrea* spp.) throughout Europe (Culloty et al. 1999) was introduced to Big Glory Bay, Stewart Island in 2017 potentially via *Ostrea chilensis* seed stock from a Marlborough marine farm (Lane 2018). This event infected *Ostrea chilensis* farms in Big Glory Bay resulting in a moratorium on oyster farming in the area. As a result, all 4000 tonnes of farmed oysters were removed from Stewart Island, resulting in the end of the industry and a 2.4-million-dollar compensation package (which included farm removal costs) from Biosecurity New Zealand. The introduction of this parasite to the wild population could collapse the fishery, so wild populations continue to be monitored for infection by Biosecurity New Zealand. Further, in 1997 the invasive seaweed *Undaria pinnatifida* (*Undaria*) was accidentally introduced to Big Glory Bay through the transfer of fouled aquaculture equipment (Hunt et al. 2009). Finally, the invasive amphipod *Caprella mutica* has been found in high densities on aquaculture equipment in Big Glory Bay (pers obs. Chris Hepburn, 2019), though the source of this incursion is unknown and has not been recorded in any formal reports.

Biosecurity New Zealand provides a handbook of best management practices for biosecurity in aquaculture facilities in New Zealand, but there are no formal regulations in place (Ministry for Primary Industries 2016). Thus, aquaculture fisheries represent high risk pathways for invasive species, that should be a focus for management in Southland.

2.2.2 Sites and structures in Southland/Murihiku

Sites and structures associated with vessel traffic that are high-risk for the establishment of marine pests include frequently used berths, wharves and moorings. Aquaculture operations also provide structure for fouling species including barges, net pens, cages, ropes, moorings and pontoons. Bluff Harbour is the most heavily used, and thus high risk, port in Southland but it is already monitored for pest species by Biosecurity New Zealand’s MHRSS programme (Woods et al. 2019). However, many vessels, especially fishing boats and recreational yachts, frequent other locations in Southland. Thus, secondary ports and aquaculture facilities should be monitored for comprehensive biosecurity management.

Local harbourmasters and commercial fishermen were consulted by the authors of this report to determine the locations of permanently submerged structures, anchorages and mooring areas frequently used by in-water vessels throughout the Southland CMA. These areas will form the core survey sites for the surveillance programme. To assist with project planning, and to accurately identify the scope of the programme, an up-to-date GIS map of all active moorings and high-risk sites in Southland should be created for Environment Southland.

Before any monitoring takes place all stakeholders with jurisdiction over each facility (wharf, marina, aquaculture facility) should be notified of the monitoring plan. Additional information on local oceanographic conditions, locations of all suitable pest habitats at each location and constraining issues (e.g. health and safety) are also required prior to monitoring (Australian Government 2010). These consultations are outside the scope of this report.

South Coast - Bluff Harbour/ Motu-pōhue

Figure 2.8 Bluff Harbour, Southland. Photo credit: Pavel Špindler

Bluff Harbour is a 5,500 ha shallow inlet south of Invercargill that faces the Foveaux strait (**Figure 2.12B**). The port contains high-risk structures for incursion including commercial vessel berths, channel markers, boat ramps, berths, aquaculture facilities, slip ways, bridges and shipwrecks. Major structures are found in Island Harbour, Town Wharf, fishing boat berths, Ferry Wharf, Tiwai Wharf, the Pilot launch jetty and the Oyster Boat wharf. The ferry for Stewart Island and commercial fishing boats operate out of this harbour, and a wide range of cargo are imported and exported both nationally and internationally, much of which is associated with the Tiwai aluminium smelter. Bluff Harbour is surveyed for marine pests bi-annually (summer and winter) by Biosecurity New Zealand's MHRSS programme using diver surveys, shore searches, benthic sled tows and crab traps at 225 locations during each visit (Woods 2019). Survey locations include all major structures such as Tiwai Wharf, Town Wharf, Island Harbour and Fishing Boat Wharves. The marine pest seaweed *Undaria* is present in Bluff Harbour and other non-indigenous species including the amphipod *Caprella mutica* and the tubular hydroid *Ectopleura crocea* have been detected here (Woods 2019).

South Coast – Riverton/Aparima and Waikawa

Figure 2.9 Wharf and fishing vessels in Riverton and the primary wharf at Wakawa.

On the south coast mainland, the only area with consistent traffic of large vessels outside of Bluff is Riverton/Aparima (**Table 2.1**, **Figure 2.12B**). In Riverton two wharves in the Aparima river mouth (east and west side) provide moorings for several fishing vessels and some pleasure yachts that visit Stewart Island and Fiordland. In the east, Waikawa is at the entrance to the Catlins coastline and has a small wharf and boat ramp. Though no large boats moor here, it does represent an important area to monitor for pest incursions since the Catlins remains pest free as of 2020. he marine pest seaweed *Undaria* is present in Riverton

Fiordland/Te Moana o Atawhenua

Figure 2.10 Wharf in Deepwater Basin, Piopiotahi/Milford Sound and anchorage in Deep Cove, Doubtful Sound/Patea, Fiordland.

In Fiordland anchorages, stern lines, permanent moorings, barges, water hoses, cray pot storage points and helicopter landing pads are high-risk areas for marine pest incursions. Based on previous mapping of high-risk areas by ES and consultation with commercial fishermen (Fiordland Marine Guardians- Jerry Excell and Pete Young) frequently visited high-risk structures are found in Preservation Inlet, Chalky Inlet, Dusky Sound, Breaksea Sound, Doubtful Sound/Patea, Charles Sound and Piopiotahi/Milford Sound (**Table 2.1**, **Figure 2.12A**). Major wharves that service fishing vessels and the commercial tourism industry are found in Doubtful Sound / Patea and Piopiotahi/Milford Sound.

Stewart Island/Rakiura

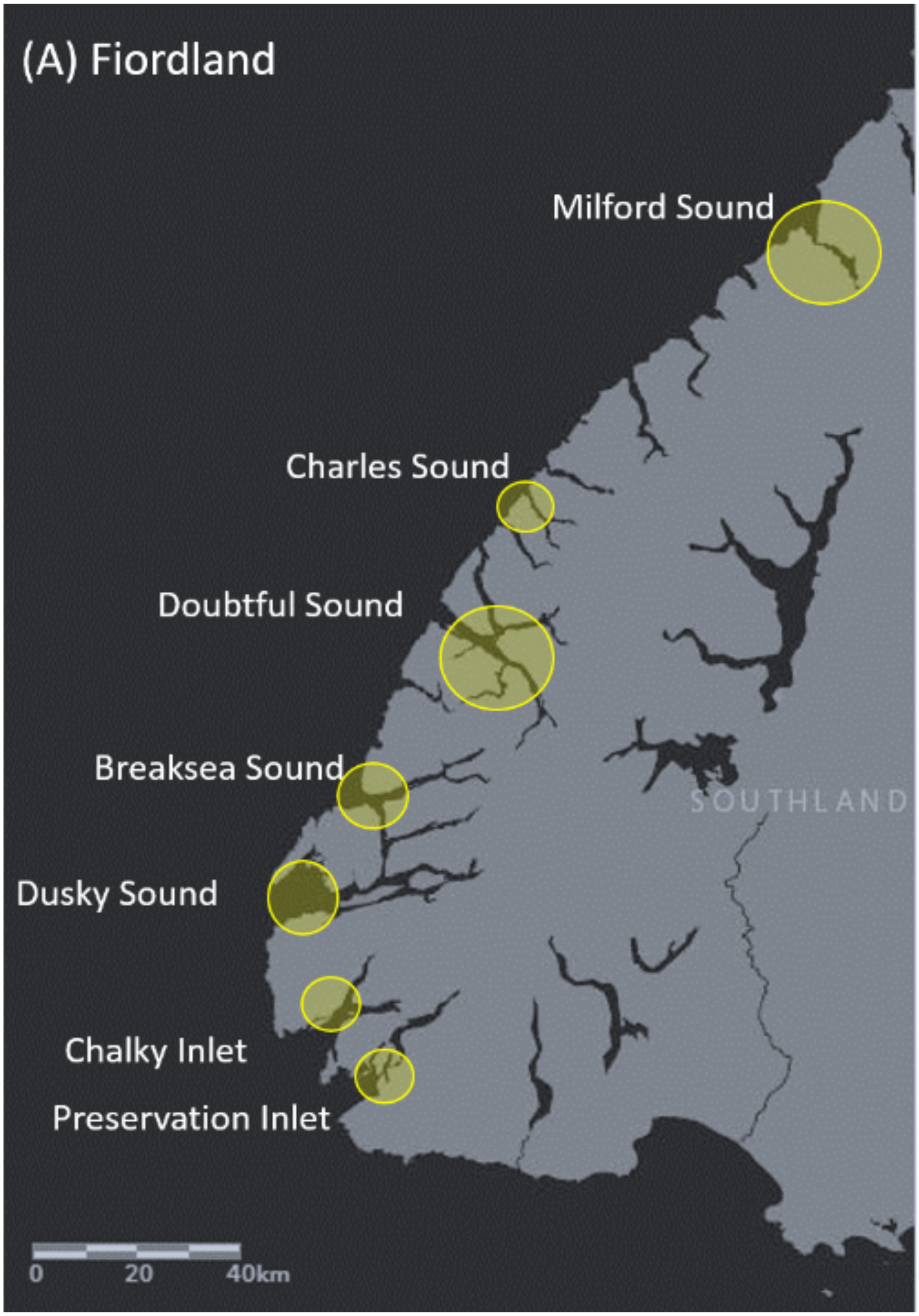
Figure 2.11 Golden Bay and Halfmoon Bay wharf and moorings, Stewart Island/Rakiura.

Many vessels move around Stewart Island to transport groups associated with marine farming, fishing, hunting, conservation and tourism. Several bays on the island serve as all-weather anchorages for recreational and fishing vessels visiting from the mainland or internationally, and moorings, wharves and crayfish pot storage points are present. Biosecurity New Zealand completed baseline surveys for non-indigenous species in 2006 at forty sites in the area around Paterson Inlet/ Whaka ā Te Wera and Big Glory Bay including aquaculture farms, shipping berths, anchorage areas and shipping approach channels (Stuart et al. 2009). Wharf pilings and pontoons supporting salmon cages were the main structures where non-indigenous marine species were found, with non-indigenous or cryptogenic species found at 47% of sites surveyed. Based on prior studies and local knowledge (pers. comm. Zane Smith) potential high-risk sites include Halfmoon Bay wharf and moorings, Golden Bay wharf and moorings, Port Pegasus/ Pikihatiti (stern lines, pot storage and moorings), Sealers Bay, Codfish Island/Whenua Hou (all-weather anchorage for trawlers), Port William (all-weather anchorage and wharf for Rakiura track) and Big Glory Bay (Salmon farming pontoons, mussel farming longlines, floating housing and processing facilities) (**Table 2.1**, **Figure 2.12C**).

Table 2.1 High-risk locations and structures to be included in regional monitoring for marine pest species in Southland.

Site	Region	Location	High-risk Areas
1	Fiordland	Milford Sound	-**Harrison's** Cove moorings -Harrison's Cove underwater observatory -Wharves and moorings in **Freshwater Basin** for tourism vessels and Deepwater Basin for tourism and fishing vessels - Cray pot storage
2	Fiordland	Charles Sound	-Helipad -Anchorage - Cray pot storage
3	Fiordland	Doubtful Sound	-**Deep Cove** wharves and moorings for tourism and fishing vessels -**Blanket Bay** helipad, structure, mooring lines, water line and cray pot storage
4	Fiordland	Breaksea Sound	-**Sunday Cove** barge, moored vessel, moorings and cray pot storage -**Beach Harbour** moorings and cray pot storage -**Stevens Cove** stern line -**Broughton Arm** mooring line -**Vancouver Arm**- mooring line
5	Fiordland	Dusky Sound	- **Anchor Island- Luncheon Cove** barges including a heli pad, moorings, stern lines and cray pot storage
6	Fiordland	Chalky Inlet	-**North Port** Stella wreck, stern line mooring lines and cray pot storage
7	Fiordland	Preservation Inlet	-**Weka Island** barge mooring and cray pot storage -**Kisbee Bay** heli pad and barge
8	South Coast	Riverton	-Wharves, moorings and boat ramps for commercial fishing and rec vessels
9	South Coast	Waikawa	-Small wharf and boat ramp. No permanent moorings for large vessels
10	Stewart Island	Port William, Halfmoon Bay and surrounds	**Port William** – New wharf, daily Rakiura track use and safe all-weather anchorage **Horseshoe Bay** – Low use only Stewart Island Based cray vessels and 10-15 boat moorings in north corner, old structures from closed oyster and paua farming. **Halfmoon Bay** - Main port with ferry service and 30-40 permanent moorings, freight boat from Bluff, rental moorings there and surrounding bays **Golden Bay** – water taxi to Ulva Island and ~12 dinghy longlines for rec. fishermen

			Thule Bay – Mussel farmers and Salmon farmers from BGB private wharf **Vaila Voe Bay** – Jet boat to Sanford, yachts and pleasure boats **Kaipipi** – Recreational moorings, stern line or anchorage **Prices Inlet** – Small wharf **Freds Camp Hut** – Small jetty for hunters and occasional DOC workers
11	Stewart Island	Big Glory Bay	-Pontoons for salmon farming -Mussel lines -Floating processing and living facilities -North BGB mooring for barge (only leaves to bluff for maintenance) -**Glory Cove** to the east - Kiwi Spotting Boat visits there
12	Stewart Island	Port Adventure	-Fishermen mooring in **Abraham's Bosom** -**Tikotahahi Bay** mooring -**Little Kuri Bay** potential pot storage -**Lords River/ Tūtaekāwetoweto** anchorage and mooring
13	Stewart Island	Port Pegasus	- DOC hut and mooring west of **Anchor Island** -**Albion Inlet** water hose -**Islet Cove** stern lines and mooring lines for scalloping boats -**Disappointment Cove** stern line and all weather anchorage -**Ernest Island** stern lines and mooring lines for commercial fishing boats - **Burial Cove**/**Broad Bay-** cray pot storage
14	Stewart Island	Codfish Island	-**Sealers Bay** a commonly used overnight anchorage for trawlers from many different ports. Often first landing point on the Stewart Island. No permanent structure to survey.


(A) Fiordland
Milford Sound
Charles Sound
Doubtful Sound
Breaksea Sound
Dusky Sound
Chalky Inlet
Preservation Inlet
SOUTHLAND
0
20
40km

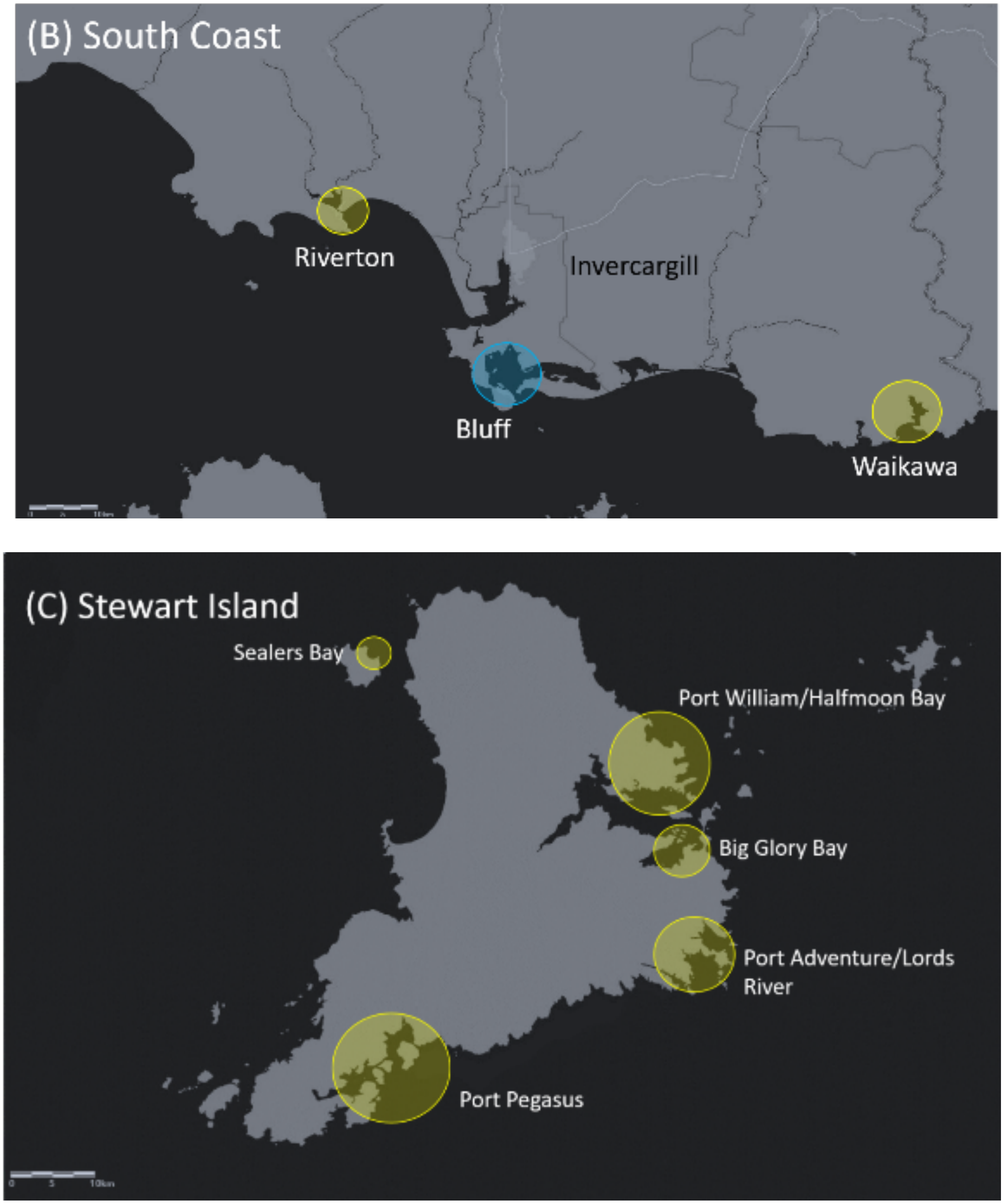


Figure 2.12 Monitoring locations with high-risk sites for the introduction of marine pests in Southland including (A) Fiordland Marine Area/Te Moana o Atawhenua, (B) South Coast and (C) Rakiura/Stewart Island. Yellow areas show regions prioritized for monitoring while the blue location (Bluff/ Motu-pōhue) is already monitored by Biosecurity New Zealand.

2.3 Methods for surveillance

New Zealand's economy depends on the health of its natural environment and its native resources are constantly under threat from pest species introduced by global trade. As a result, New Zealand's biosecurity programmes are some of the most advanced, with an entire sector of the Ministry for Primary Industries (MPI) devoted to biosecurity issues (Biosecurity New Zealand. Biosecurity New Zealand manages marine biosecurity at a national scale by encouraging New Zealanders to clean maritime equipment and vessels and by implementing stringent requirements for hull fouling and ballast water discharge for vessels entering New Zealand from international waters (Ministry for Primary Industries 2016, Ministry for Primary Industries 2018). Biosecurity New Zealand has done baseline surveys throughout New Zealand to assess which pests are already present and helps implement responses for pest eradication. Biosecurity New Zealand also inspects high-risk locations annually through the Marine High Risk Site Surveillance (MHRSS) programme (Woods et al. 2019).

Biosecurity New Zealand surveys major harbours, which are high-risk sites for marine pest incursions at a national level, but many secondary ports and facilities present marine biosecurity risks that would benefit from local management. Some regional partnerships for marine pest management already exist, such as the Top of the South Biosecurity Partnership for Tasman, Nelson (Whakatū) and Marlborough (Te Tau Ihu o te Waka-a-Māui) (Top of the South Marine Biosecurity Partnership 2013), the Top of the North marine biosecurity partnership (which includes Auckland Council, Northland Regional Council, Bay of Plenty Regional Council, Waikato Regional Council, Hawke's Bay Regional Council, Gisborne District Council, Biosecurity New Zealand and DOC), and the Fiordland Marine Regional Pathway Management Plan (FMPP) developed by DOC, ES, Biosecurity NZ, Te Rūnanga o Ngāi Tahu and the Fiordland Marine Guardians (Environment Southland 2017). These partnerships aim to prevent the spread of marine pests through coordinated response efforts to incursions and regional guidelines for clean vessels and hull inspections.

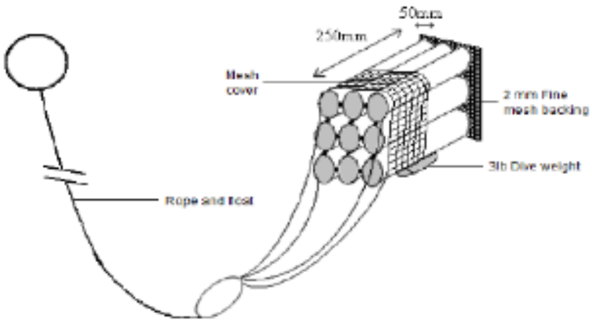
In Southland, current initiatives for marine pest management include management of pathways the Fiordland Marine Area through the FMPP, annual surveillance of Bluff Harbour by

Biosecurity New Zealand's MHRSS, and hull monitoring at Bluff and Rakiura/Stewart Island for vessels visiting Fiordland. These initiatives represent valuable methods for preventing and/or detecting marine pests in Southland, but their scope remains narrow. The aim of this plan is to identify cost-effective methods for the annual surveillance of the most high-risk pathways and structures throughout Southland's CMA. Monitoring and compliance methods should be chosen based on the local conditions, safety and feasibility of sampling, the pest species of interest and their ecology and cost-effectiveness (Willis et al. 2008).

2.3.1 Surveillance – Monitoring for marine pests

Annual or seasonal monitoring (depending on pest life cycles) is essential for the timely detection of marine pests (Lehtiniemi et al. 2015). Surveillance for marine pests at high-risk sites and structures can be done using common marine survey methods such as diver searches (including visual searches, substrate sampling and video recording), trapping, benthic grabs, settlement plate monitoring, rope sentinels and plankton sampling. More novel methods are also being explored. For example, testing eDNA from seawater samples is being trialled for detecting marine pests, but it is not effective enough to replace diver surveys at this time (Wood et al. 2019). Remotely Operated Vehicles (ROV) or drop cam surveys may also be useful in areas where conditions are unsafe for diving (Cook and Coutts 2017) but they require additional equipment and skilled staff to operate them.

In New Zealand, the MHRSS programme run by Biosecurity New Zealand uses several survey methods to monitor for marine pests at national high-risk sites including crab traps, diver searches and benthic sled tows (Willis et al. 2008) (**Figure 2.13**). These monitoring methods were chosen based on their applicability to target species, cost effectiveness and feasibility in a range of conditions. After reviewing the literature, these methods still appear the most relevant for targeting marine pest species in Southland and are well suited to the needs of the Southland surveillance and compliance plan. Many of the species targeted by MHRSS overlap with those identified as pest species by ES. Justification for the applicability of each method to the pest species identified in the RPMP is provided in **Table 2.2**.



A


B


C


D

Figure 2.13 Examples of sampling methods for marine pest species including (A) crab condos (photo credit: Hewitt & McDonald 2013), (B) diver searches (NIWA) (C) benthic sleds (Robert Win, ES) and (D) crab traps.

Table 2.2 Potential survey methods for surveillance of targeted marine pests at high-risk sites in Southland. Table adapted from MHRSS report (Woods et al. 2019) Note: underlined species have been collected using this method in previous surveillance programs in New Zealand (Woods et al. 2019). * Denotes target species for each method.

Method	Species	Habitat	Coverage	Effectiveness	Cost	Feasibility
Crab traps (baited)	**C. japonica*	Next to wharf pilings/artificial habitats. Intertidal and shallow subtidal rocky shores	Dependent on dispersion of bait scent	Effective for C. Japonica (Fowler et al. 2013)	High replication at low cost	Most conditions/locations
Crab condos (unbaited)	**C. japonica*	Intertidal and subtidal banks of rivers and areas with complex habitat and vegetation	Easy replication	Effective for smaller herbivorous or omnivorous crabs	High replication at low cost	Most conditions/locations
Benthic sled tows	**D. vexillum,* **E. elongatum,* **S. spallanzanii* *C. japonica* *U. pinnatifida* *S. clava*	Subtidal soft sediments next to artificial structure (marinas/wharves etc.)	Narrow width, 50 m tow length, but easy to do high replication	Consistent collection of macroalgae and other epifaunal and infaunal species	Time consuming post processing of sled contents	Feasible in most weather on soft sediment. Limited in very soft sediment or macroalgae choked areas.
Diver searches	**D. vexillum,* **E. elongatum,* **S. spallanzanii,* **S. clava* **U. pinnatifida,* **P. doppelgangera* *C. japonica*	Wharf and marina piles, berth walls, breakwaters pontoons and other artificial structures and shallow subtidal reefs	Good coverage, can cover large areas accurately	Depends on visibility and level of fouling	Time consuming in poor conditions	Dependent on currents, visibility and weather conditions
Shore searches	**C. japonica,* **D. vexillum,* **E. elongatum,* **S. Spallanzanii,* **U. pinnatifida,* **P. doppelgangera* *S. clava*	Intertidal sandy or rocky shorelines, wharves or areas where drift is likely to accumulate	Wide, easy to sample a large area	Effective for most intertidal dwellers	High replication and low cost	High, site access could be limiting depending on local geography

2.3.2 Surveillance - Hull inspections for marine pests

Hull inspections - Potential methods

Boat hull surveys are used to prevent the introduction or spread of marine pests due to biofouling. In Southland these surveys can be used to confirm that boats visiting Fiordland are complying with the Clean Vessel Pass standards (Environment Southland 2017) and that boats are not harbouring marine pest species outside of the Southern and Breaksea Sound exemption areas (Environment Southland 2019[A]).

Hull surveys are typically done by certified SCUBA divers or snorkellers but can also be done using an ROV or pole camera with a high-resolution camera and lights (Cook and Coutts 2017). SCUBA divers are better at recording all species present and inspecting cryptic areas, while autonomous video surveys are useful for collecting general information like the degree of biofouling (Zabin et al. 2018). Depending on the size of the vessel and the degree of biofouling, diver assessments could include quadrat sampling, opportunistic sampling of niche areas using visual searches and waterline to keel video transects (Piola and Conwell 2010). Other potential methods include predictive tools based on the level of fouling and interviews with operators on the condition of their vessel (Floerl et al. 2005, Davidson et al. 2019).

Current Hull Inspection Programme – Biosecurity New Zealand and ES

Contractors for Biosecurity New Zealand carry out hull inspections at Bluff Harbour (various locations) and Stewart Island (Halfmoon Bay, Horseshoe Bay), with regular monthly checks in Nov-April of vessels known to visit Fiordland (based on local knowledge), and additional on-request inspections available throughout the year for vessel owners planning a trip to Fiordland. In the past, monthly targeted checks were also done over the winter period (but not in the past 2 years). During the inspection divers check the antifoul condition, the level of fouling and the presence of any marine organisms. The presence/absence of *Undaria* and any other pests and the associated level of fouling is reported for each vessel. If any marine risk organisms are found they are reported and removed or the owner is informed that further action is required before travelling to Fiordland. Hull inspections are also done on the biannual compliance trips by ES staff on all vessels encountered throughout Fiordland.

2.4 Methods for compliance

The Clean Vessel Pass (CVP) provides a key part of a strategy to protect Fiordland from marine pests, but compliance with this regulation can only be enforced sporadically due to the remoteness of the target area. A NIWA report "Tools and infrastructure for responding to marine pest incursions in Southland" recommended that free divers be deployed by helicopter to check for compliance (Page 2018), but the logistics and health and safety requirements involved with this method would make it difficult to implement. Compliance initiatives that target all vessels are more effective than those targeting incursions of a particular species (e.g. limited areas/vessels) (Sinner et al. 2009). Clean hull standards might be simpler to enforce and less confusing to vessel owners if the same rules were applied on a regional or even national scale. For example, in Northland, New Zealand boat hulls must be free of any marine pests and no more than "light fouling" when you travel to and within the region (NRC 2017). Any moving vessels in Northland found to be carrying marine pests are required to be cleaned at the owners' expense, and the owners may also be subject to a $500 fine.

3. MANAGEMENT RECOMMENDATIONS AND BUDGET

3.1 Survey Design for Surveillance of Marine Pests

Based on the information collected in the prior sections of this report we present a sampling design to effectively monitor and detect incursions of marine pests in Southland. The timing, methods and sample size reflect the biology of targeted marine pests, feasibility under local conditions and habitat characteristics of the areas to be surveyed. The surveys are designed to detect the presence/absence of marine pest species targeted by ES. If a new pest species is found, further action would be required to assess the extent of the population and initiate removal. Recommendations are summarised at two levels for (1) a basic surveillance plan tailored to ES's target species, and (2) a more inclusive plan for detecting all potential marine pests (**Table 3.1**).

Table 3.1 Summary of survey methods recommended for Southland's marine pest surveillance plan

Scope	Target species	Method	Depths	Habitat	Sampling period
Minimum required	ES named marine pests	Crab traps, shore searches, diver searches	Intertidal shore, 0-5, 5-10, 10-15 m	Soft bottom and artificial structure	Annual – late spring (Nov - Dec)
Broad	All potential marine pests	Add: Crab condos, benthic tows, Replace diver searches with: drop cams or ROV streaming video	Add 15-20 m depth strata	Soft bottom, artificial and natural structure	Seasonal – Autumn (March – May) and late spring (Nov - Dec)

3.1.1 Survey methods

Primary survey methods

Only one target pest species (Asian Paddle Crab (*Charybdis)*) is mobile, requiring trapping methods. *Charybdis* is an aggressive omnivorous crab found on mud or sand down to depths of 15 m. We recommend baited traps be deployed on mud and sand substrate adjacent to structures at each high-risk site to detect Charybdis. The remaining pests (*Undaria*, tunicates and sea squirts) are sessile and found on artificial and natural structures. Thus, a combination of diver and shore-based visual surveys of structures and adjoining intertidal habitat should be done at each site, dependent on visibility and sea conditions. Video or photographic records of any suspected pests recorded on visual surveys should be taken for verification of species ID. Continuous video imagery may be collected along wharves using a high-quality camera set up for underwater photography. Detailed protocols for the suggested sampling methods can be found in Hewitt and Martin (2001) and the Australian Marine Pest Monitoring Manual (Australian Government 2010).

Additional survey methods

Though marine pests typically establish on hard substrate (i.e. rocky reefs) and artificial structures (e.g. jetties, wharves, pilings and floating docks or aquaculture equipment), *Sabella* and *Eudistoma* can also invade soft sediment areas so a comprehensive monitoring plan should include benthic diver searches (if visibility allows) or sled tows to sample the benthos in the areas adjacent to structure at each high-risk site. Unbaited crab condos would increase the scope of the surveys to detect non-target marine pests that are smaller or herbivorous. An ROV or drop cam would provide a valuable alternative to diver surveys, if this equipment were available.

3.1.2 Depth of surveys

All target pest species are observed in abundance in the intertidal or in shallow waters < 12 m, though some are found down to 30 m. The deeper extent of some species is poorly understood, for example new recruits of *Undaria* could occur in waters below 15 m (pers obs C. Hepburn) and *Didemnum* can form parent colonies in deep sea areas below 40 m. Further information on organism distribution would be required however to justify surveys at greater depths.

Shore searches should be done along the intertidal zone of each site at low tide where viable. Diver surveys and crab traps deployed at 0-5 m, 5-10 m and 10-15 m depths at each site will sample the common distribution of all targeted pests. The number of depths sampled will vary depending on habitat distribution and bathymetry at each location.

3.1.3 Timing of sampling

The reproductive seasonality for some of the pest species such as *Pyura* is unknown. *Undaria* has the potential to recruit multiple times throughout the colder months with peaks in density observed during both autumn and spring in southern New Zealand (Schiel and Thompson 2012), though populations in sheltered areas may only have a single autumn recruitment event (Leahy 2018). The remaining pest species including *Charybdis* and most listed tunicates and sea squirts appear to reproduce in summer and recruit in late summer and autumn. Based on the known reproductive seasonality of the target species, annual monitoring surveys would be most effective during the late spring and early summer season when most adult life stages should be visible, but not yet reproductively mature and when weather would be most suitable for field work. If viable, biannual surveys during autumn and spring would best cover potential recruitment events of a broad array of pest species.

3.1.3 Sampling effort

The sampling effort at each location will be primarily limited by the scope of the project (target species, funding, staff hours). Initial surveys should focus on areas most likely to be influenced by ballast water discharge or hull fouling transfers (i.e. areas nearest to where mobile vessels are commonly moored or anchored). From these surveys, maps should be produced to focus future surveys. Careful record keeping of where observations/surveys have occurred will be essential. Baseline surveys at each site may require more sampling effort initially to determine the highest risk areas for non-indigenous species incursions and any constraints due to local conditions. Sampling locations and effort should be revised following baseline surveys to increase efficiency and reduce costs of surveys.

Marine invasive species are typically in low abundance before they become well established, so high replication is required for detection. The largest area possible should be sampled at each site to increase the likelihood of detection. Calculation of sampling effort for different types of structures can be done based on the size of the area to be sampled, sample method area, sampling efficiency and the population size to be detected ($n = 1$) through a monitoring design Excel template (MDET) provided by the Australian government (Australian Government 2010). Further information from baseline surveys on the size of each structure and surrounding habitat/bathymetry will help fine tune the sample size at each of the high-risk locations. Depending on the cost and availability of funding at a minimum sampling the highest risk locations could be monitored on an annual basis, while lower risk sites may potentially be done less frequently (by rotating through different sites each year).

3.2 Compliance initiatives

3.2.1 Hull inspections

A more comprehensive hull inspection programme could be done on all vessels on permanent moorings at heavily frequented harbours including Bluff, Riverton, Golden Bay and Halfmoon Bay, Stewart Island. This would expand on work currently contracted by Biosecurity New Zealand at Bluff and Stewart Island, and it would bring ES in line with hull monitoring programmes already implemented by the Northland Regional Council and Bay of Plenty Regional Council. For consistency, hull inspections done by ES in Fiordland should be revised to collect the same information as those done by Biosecurity New Zealand (level of fouling, presence of *Undaria* or other marine pests and antifoul condition). Hull inspections should continue to be done during high season for recreational craft (November – April) and during winter in anticipation of commercial fishing seasons in the Fiordland Marine Area. Quarterly inspections may be more economically viable given the expanded surveillance area suggested here. These inspections will ensure that boats visiting Fiordland are complying with the CVP requirements (if a list of such boats can be established) while reducing the likelihood that new marine pests go undetected before creating established populations in Southland.

3.2.2 Compliance

A minimum of bi-annual compliance trips to Fiordland to enforce the CVP will be critical to assess the effectiveness of the Pathways Plan. In the future ES should consider introducing a Southland-wide clean-hull requirement for any vessel moving into or between harbours within the region, as in Northland. This type of regulation could reduce confusion and reduce disparity among vessel owners over who must clean their hulls. With this type of regulation exemption areas could be reviewed so that all vessels would be subject to the same requirements. This regulation would effectively control the spread of all marine pests throughout Southland, rather than only in a targeted area (Fiordland). It could be enforced more easily (in non-remote areas), reducing surveillance costs and increasing the likelihood of compliance. In the future, consistent biosecurity measures at a national level will provide the best defence against marine invasions.

3.3 Budget

A minimum budget for the implementation of a marine pest monitoring programme was determined based on estimated staff salary and costs associated with similar trips (**Table 3.2**). Costs were estimated based on a plan using the minimum amount of staff and resources required to effectively detect marine pests targeted by ES. We estimate that Stewart Island sites would take 5 days, South Coast sites would take 2 days and Fiordland sites would take 10 days to survey. Stakeholder engagement, trip planning, site exploration, data entry and database updates are estimated to take an additional 15 days per year.

Table 3.2 Estimated minimum budget for an annual monitoring plan for marine pests in Southland.

Item	Function	No.	Unit	Cost	Total Cost
Staff hours (Based on 4 staff members) 1 dive technician 1 compliance officer, 1 monitoring officer and 1 team leader)	Field work	600	hours	$80/hr	$48,0000
Boat hire (Southern Winds or contract)	Fiordland and remote Stewart Island locations	20	days	$4000/day SW $6000/day contract	$90,000
Boat hours (ES Harbour master small vessel including skipper)	Riverton, Waikawa and non-remote Stewart Island locations	3	days	$200/hr	$4800
Meals/Accom	During monitoring	20	days	$23pp/day Based on 5 people	$2300
Transport of staff and equipment to/from locations	During monitoring (ES to Te Anau or Milford for Fiordland surveys, to Riverton and Bluff)	650	vehicle kilometres	$77c/km	$500
Equipment purchase and maintenance	2 sets of dive gear, 6 tanks and compressor and filters servicing	1	service	$2000/yr	$2000
	Crab traps	12	Traps	$360	$360
	Underwater video camera (go pro)	2	Cameras	$600	$600
	Still camera with lights	1	Cameras	$2000	$2000
	Quadrats	3	Quadrats	$100	$100
Lab costs	Species ID	3	Samples	$100/yr	$300
Public Awareness programme flyers or signs	Increase likelihood of pest detection	100	Flyers	$300/yr	$300
				Total	**$151,260**

4.CONCLUSIONS

Southland's marine resources are a vital part of the community and local economy. The risk of marine pest incursions throughout New Zealand will continue to rise due to our global economy and the associated demand for new shipping routes, tourism activities and aquaculture facilities. Since much of the Southland's coastline is relatively remote and only one identified pest species has become established, ES has a unique opportunity to protect its marine environment before it is too late. By adopting a formal marine biosecurity monitoring and compliance plan, ES can take a major step towards reducing the risk of invasion by new marine pests and controlling the spread of *Undaria*. Implementation of this plan will require additional resources, including expansion of the marine biosecurity programme, but this would be well justified given the value of Southland's marine environment. Next steps for adopting a formal monitoring and compliance plan include:

- Secure financial resources and staffing to run the programme
- Develop capability and capacity to survey for pest species, including recruitment or training of skilled staff and adapting survey methods to local conditions;
- Engage with stakeholders/those with jurisdiction over all structures to be surveyed; and
- Baseline surveys at each location to determine which invasive species are present and to gather information on local weather and sea conditions, hazards, habitat distribution and focal points for marine pest incursions.

4.1 Recommendations

To summarise, we recommend that ES:

1. Implements an annual monitoring plan for marine pests at high-risk sites in several areas throughout Southland (including Fiordland and Stewart Island), with surveys done in the spring of each year (3.1, p.32).
2. Implements a surveillance programme with a focus on spring and summer to check the hulls of predominantly in-water vessels for marine pests at all major harbours throughout Southland.
3. Considers reviewing the Fiordland Regional Pathway Management Plan to include all of

Southland by requiring clean hulls for all vessels moving into or between harbours throughout the region (Section 3.2.2, p.36).

Secondary recommendations include that ES:

4. Consider reviewing the status of the Asian Paddle Crab/*Charybdis japonica* and Australian droplet tunicate/*Eudistoma elongatum* in the RPMP's exclusion programme since they are unlikely to be reproductive in the water temperatures in Southland (Section 2.1, p.6).
5. Consider doing a risk assessment for the inclusion of the Carpet sea squirt/*Didemnum vexillum*, Light bulb ascidian/*Clavelina lepadiformis*, Vase and Pacific tunicates (*Ciona intestinalis/Ciona savigny*) and Devils tongue seaweed (*Grateloupia turuturu*) as exclusion programme species as they are invasive species that are present in New Zealand and could thrive in Southland as noted by Page (2018) (Section 2.1, p.6).
6. Consider doing a risk assessment for adding Japanese skeleton shrimp (*Caprella mutica*) as a species for progressive containment since they are already present within Southland and present a potential risk to aquaculture operations (Section 2.1, p.5).

ACKNOWLEDGEMENTS

We would like to thank Robert Win and Ali Meade for their involvement with the grant proposal and for guidance with this report. Thanks to Rebecca McLeod, Rich Kinsey and Elizabeth Green for helpful review of the draft plan. Thanks also to Jerry Excell, Pete Young, Ian Coard and Zane Smith for expert advice on high-risk sites.

GLOSSARY

Active surveillance: a planned process targeted to find and identify a particular new pest.

Biological control: a means of controlling pests using other living organisms that relies on predation (animals killing other animals for food), herbivory (animals eating plants) or parasitism (using other animals or plants for food, but not killing them outright).

Biosecurity: the protection of a country's economy, environment and peoples' health from biological threats such as pests and diseases.

Buffer zone: an area surrounding or directly beside a pest population, that is not infested with that pest. It is often treated, or has other special control measures applied to it in order to reduce the likelihood of the target pest spreading.

Containment: keeping an invasive species within a defined area.

Control: reducing the population of an invasive species.

Delimiting: determine the boundary of something. With respect to marine pest invasion, delimiting the invasion means finding out how far the species has spread.

Effective management: achieving operational success (e.g. reducing the pest to defined levels) and desired outcomes (reduced impact and recovery of impacted values) of invasive species management.

Environmental Impact Assessment (EIA): EIA is an analysis of the potential non-target effects of a management plan or activity on the environment.

Eradication: the removal of every individual of a species from the infested country, such that the only way the species could re-establish is to re-enter the country from another country. Eradication should be demonstrated by surveillance.

Impact(s): a routinely used term in invasion ecology and management that refers to the negative effects of an invasive species on resident native organisms (biodiversity), agriculture, economy, health or lifestyle.

Incursion: a single arrival event of an invasive species in a new environment. Typically, an incursion is identified at the time of arrival (or first detection), and an incursion response plan developed. The arrival of an organism within a country or region after it has crossed the border.

Incursion response plan: effectively an emergency response plan to deal with a newly detected incursion of an invasive species. Incursion response plans include a number of steps including: 1) initial detection and response; 2) delimiting survey and; 3) draft management plan, including a surveillance plan, a plan for treatment and eradication (if possible), a communications strategy, specifications for movement controls, monitoring progress, a budget, and an organisational plan.

Infestation: a single discrete area where the invasive species is localised. An incursion consists of one or more infestations.

Invasive species: introduced species that become destructive to the environment or human interests.

Management: reducing or eliminating the impacts of established invasive species, by eradication, containment, exclusion, or population reduction by physical, chemical or biological control.

Monitoring: programmes to detect change, e.g. in the distribution of invasive species, the success of management projects etc.

Movement Control: preventing an invasive species from spreading by Controlled Area Notices and Restricted Place Notices and their conditions.

Organism: any individual entity that embodies the properties of life.

Passive surveillance: the detection of exotic species through haphazard, unplanned and unsolicited observations by the general public, fishermen, farmers, and others.

Pathway: a unique means by which a living organism may enter a region or country.

Pest: a prion, virus, microbe, fungus, plant or animal capable of causing adverse effects to a country's natural and introduced biodiversity.

Risk: the chance of something happening that will have an impact upon objectives. It is measured in terms of likelihood and consequences.

Surveillance: a systematic programme of inspection and examination to determine the presence of risk organism.

Vector: a vector is the object that moves an invasive species from one place to another. In the marine sense this may be on boat hulls, ballast water, fishing gear, a commodity (fish, mussels); or other method of movement (natural spread on water currents).

LITERATURE CITED

Australian Government. 2010. Australian Marine Pest Monitoring Manual. Australian Government Department for Agriculture Fisheries and Forestry. Australia.

Brunton, J. 2019. Future recommendations for *Undaria pinnatifida* in Breaksea Sound/Te Puaitaha, 15 August 2019. Biosecurity New Zealand. 27 pp.

Boos, K., Ashton, G. V. and Cook, E. J. 2011. The Japanese skeleton shrimp *Caprella mutica* (Crustacea, Amphipoda): a global invader of coastal waters. In the Wrong Place-Alien Marine Crustaceans: Distribution, Biology and Impacts, Springer: 129-156.

Cook, J. and Coutts, A. 2017. The growing role of underwater robotics as a first line of defence for protecting Australia's marine ecosystems. Australasian Coasts & Ports 2017: Working with Nature: 268.

Coutts, A. D. and Forrest, B. M. 2007. Development and application of tools for incursion response: lessons learned from the management of the fouling pest Didemnum vexillum. Journal of Experimental Marine Biology and Ecology 342(1): 154-162.

Cranfield, H., Gordon, D., Willan, R., Marshall, B., Battershill, C., Francis, M., Nelson, W., Glasby, C. and Read, G. 1998. Adventive marine species, National Institute of Water and Atmospheric Research, Wellington, New Zealand.

Culloty, S., Novoa, B., Pernas, M., Longshaw, M., Mulcahy, M., Feist, S. W. and Figueras, A. 1999. Susceptibility of a number of bivalve species to the protozoan parasite *Bonamia ostreae* and their ability to act as vectors for this parasite. Diseases of Aquatic Organisms 37(1): 73-80.

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

Currie, D. R., McArthur, M. and Cohen, B. 2000. Reproduction and distribution of the invasive European fanworm *Sabella spallanzanii* (Polychaeta: Sabellidae) in Port Phillip Bay, Victoria, Australia. Marine Biology 136(4): 645-656.

Davidson, I., Floerl, O., Fletcher, L. and Cahill, P. 2019. Level of Fouling rank scale an updated guideline. Prepared for Auckland Council, Auckland, New Zealand. 14pp.

Davis, A. R., Walls, K. and Jeffs, A. 2018. Biotic consequences of a shift in invertebrate ecosystem engineers: Invasion of New Zealand rocky shores by a zone-forming ascidian. Marine ecology 39(3): e12502.

Dodgshun, T. J., Taylor, M. D. and Forrest, B. M. 2007. Human-mediated pathways of spread for non-indigenous marine species in New Zealand. Science & Technical Pub. Department of Conservation.

Environment Southland. 2008. Deed of Agreement Between The New Zealand Cruise Ship Industry and Environment Southland Regional Council. Invercargill, New Zealand.

Environment Southland. 2017. Fiordland Marine Regional Pathway Management Plan. Environment Southland Regional Council. Invercargill, New Zealand.

Environment Southland. 2018. Operational Plan: Fiordland Marine Regional Pathway Management Plan 2018-19. Environment Southland Regional Council. Invercargill, New Zealand.

Environment Southland. 2019[A]. Southland Regional Pest Management Plan 2019 - 2029. Publication No 2019-03. Environment Southland Regional Council. Invercargill, New Zealand.

Environment Southland. 2019[B]. Southland Biosecurity Strategy 2019 - 2024. Environment Southland Regional Council. Invercargill, New Zealand.

Fenwick, G. 2006. Notes on the amphipod *Caprella (Caprella) mutica* Schurin, 1935 identified from ports survey samples. NIWA, Christchurch, New Zealand.

Fletcher, L. 2014. Background information on the sea squirt *Pyura doppelgangera* to support regional response decisions. Cawthron Institute, report prepared for Marlborough District Council, Nelson, New Zealand.

Fletcher, L. M., Forrest, B. M., Atalah, J. and Bell, J. J. 2013. Reproductive seasonality of the invasive ascidian *Didemnum vexillum* in New Zealand and implications for shellfish aquaculture. Aquaculture Environment Interactions 3(3): 197-211.

Floerl, O., Inglis, G. J. and Hayden, B. J. 2005. A risk-based predictive tool to prevent accidental introductions of nonindigenous marine species. Environmental management 35(6): 765-778.

Floerl, O., Fletcher, L. and Hopkins, G. A. 2015. Tools and Infrastructure for Managing Biosecurity Risks from Vessel Pathways in the Top of the South Region. Cawthron Institute. Nelson, New Zealand.

Fowler, A. E., Gerner, N. V. and Sewell, M. A. 2011. Temperature and salinity tolerances of Stage 1 zoeae predict possible range expansion of an introduced portunid crab, *Charybdis japonica*, in New Zealand. Biological invasions 13(3): 691-699.

Fowler, A. E. and McLay, C. L. 2013. Early Stages of a New Zealand Invasion by *Charybdis Japonica* (Brachyura: Portunidae) from Asia: Population Demography. Journal of Crustacean Biology 33(2): 224-234.

Fowler, A. E., Muirhead, J. R. and Taylor, R. B. 2013. Early Stages of A New Zealand Invasion By *Charybdis Japonica* (A.)(Brachyura: Portunidae) from Asia: Behavioral Interactions with A Native Crab Species. Journal of Crustacean Biology 33(5): 672-680.

Green, R. H. and Young, R. C. 1993. Sampling to detect rare species. Ecological Applications 3(2): 351-356.

Griffiths, R., Dodd, J. and Karkaria, Y. 2018. 2018 Recreational Boating Participation Research. Ipsos. Auckland, New Zealand.

Grosholz, E. D., Crafton, R. E., Fontana, R. E., Pasari, J. R., Williams, S. L. and Zabin, C. J. 2015. Aquaculture as a vector for marine invasions in California. Biological Invasions 17(5): 1471-1484.

Gust, N., Inglis, G., Floerl, O., Peacock, L., Denny, C. and Forrest, B. 2009. Assessment of population management options for *Styela clava*. Biosecurity New Zealand Technical Paper No: 2009/04. Ministry for Primary Industries and Biosecurity New Zealand. Wellington, New Zealand.

Hayward, B. W. and Morley, M. S. 2009. Introduction to New Zealand of two sea squirts (Tunicata, Ascidiacea) and their subsequent dispersal. Records of the Auckland Museum: 5-14.

Hewitt, C. and Martin, R. 2001. Revised protocols for baseline port surveys for introduced marine species–design considerations, sampling protocols and taxonomic sufficiency. Centre for Research on Introduced Marine Pests Technical Report(22). CSIRO Marine Research. Hobart, Australia.

Hewitt, C. L., Campbell, M. L., McEnnulty, F., Moore, K. M., Murfet, N. B., Robertson, B. and Schaffelke, B. 2005. Efficacy of physical removal of a marine pest: the introduced kelp *Undaria pinnatifida* in a Tasmanian Marine Reserve. Biological Invasions 7(2): 251-263.

Hewitt, C. L. and Campbell, M. L. 2007. Mechanisms for the prevention of marine bioinvasions for better biosecurity. Marine Pollution Bulletin 55: 395 - 401.

Holloway, M. G. and Keough, M. J. 2002. An introduced polychaete affects recruitment and larval abundance of sessile invertebrates. Ecological Applications 12(6): 1803-1823.

Hulme, P. E. 2009. Trade, transport and trouble: managing invasive species pathways in an era of globalization. Journal of applied ecology 46(1): 10-18.

Hunt, L., Chadderton, L., Stuart, M., Cooper, S. and Carruthers, M. 2009. Results of an attempt to control and eradicate *Undaria pinnatifida* in Southland, New Zealand, April 1997-November 2004. Department of Conservation, Invercargill, New Zealand. ISBN: 978-0-478-14582-3

James, K., Kibele, J. and Shears, N. T. 2015. Using satellite-derived sea surface temperature to predict the potential global range and phenology of the invasive kelp *Undaria* pinnatifida. Biological invasions 17(12): 3393-3408.

Lane, H. S. 2018. Studies on Bonamia parasites (Haplosporidia) in the New Zealand flat oyster *Ostrea chilensis*, PhD thesis, Department of Zoology, University of Otago. Dunedin, New Zealand.

Lee, A. L., Dafforn, K. A., Hutchings, P. A. and Johnston, E. L. 2018. Reproductive strategy and gamete development of an invasive fanworm, *Sabella spallanzanii* (Polychaeta: Sabellidae), a field study in Gulf St Vincent, South Australia. PloS one 13(7): e0200027.

Lehtiniemi, M., Ojaveer, H., David, M., Galil, B., Gollasch, S., McKenzie, C., Minchin, D., Occhipinti-Ambrogi, A., Olenin, S. and Pederson, J. 2015. Dose of truth—monitoring marine non-indigenous species to serve legislative requirements. Marine Policy 54: 26-35.

Marks, L., Reed, D. and Holbrook, S. 2018. Life history traits of the invasive seaweed *Sargassum horneri* at Santa Catalina Island, California. Aquatic Invasions 13(3).

McCarthy A., Hepburn C.D., Scott N., Schweikert K., Turner, R, Moller H. (2013) Local people see and care most? Severe depletion of inshore fisheries and its consequences for Māori communities in New Zealand. Aquatic Conservation. Marine and Freshwater Ecosystems 24 (3), 369-390. DOI: 10.1002/aqc.2378

McClary, D. J., Phipps, C. and Hinni, S. 2008. Reproductive behaviour of the clubbed tunicate, *Styela clava*, in northern New Zealand waters. Ministry of Agriculture and Forestry.

Minchin, D., Gollasch, S., Cohen, A. N., Hewitt, C. L. and Olenin, S. 2009. Characterizing vectors of marine invasion. Biological invasions in marine ecosystems, Springer**:** 109-116.

Morrisey, D., Page, M., Handley, S., Middleton, C. and Schick, R. 2009. Biology and ecology of the introduced ascidian *Eudistoma elongatum*, and trials of potential control options. MAF Biosecurity New Zealand Technical Report(2009/21): 63.

Ministry for Primary Industries. 2016[A]. Import Health Standard: Ballast Water from All Countries. Ministry for Primary Industries. Wellington, NZ

Ministry for Primary Industries. 2016[B]. Aquaculture Biosecurity Handbook Assisting New Zealand's commercial and non-commercial aquaculture to minimise on-farm biosecurity risk. Ministry for Primary Industries and Aquaculture New Zealand. Wellington, NZ

Ministry for Primary Inudstries. 2018. Craft Risk Management Standard: Biofouling on Vessels Arriving to New Zealand. Ministry for Primary Industries. Wellington, New Zealand

Ministry for Primary Industries. 2019[A]. Marine non-indigenous species. NIWA, Ministry for Primary Industries. Webpage: https://www.stats.govt.nz/indicators/marine-non-indigenous-species.

Ministry for Primary Industries. 2019[B]. New Zealand Marine Pest ID Guide. Biosecurity New Zealand, Wellington. 32pp.

Te Rūnunga o Ngāi tahu and Her Majesty the Queen. 1997. Deed of Settlement. New Zealand.

NIWA. 2020. Marine Biosecurity Porthole Website. Accessed at: https://marinebiosecurity.org.nz/search-for-species/.

NRC. 2017. Northland Regional Pest and Marine Pathway Management Plan 2017-2027. Northland Regional Council. Northland, NZ

O'Brien, A. L., Ross, D. J. and Keough, M. J. 2006. Effects of *Sabella spallanzanii* physical structure on soft sediment macrofaunal assemblages. Marine and freshwater research 57(4): 363-371.

Page HM, Dugan JE, Schroeder DM, Nishimoto MM, Love MS, Hoesterey JC (2007) Trophic links and condition of a temperate reef fish: comparisons among offshore oil platform and natural reef habitats. Marine Ecology Progress Series 344: 245–256, http://dx.doi.org/10.3354/meps06929

Page, M. J., Morrisey, D. J., Handley, S. J. and Middleton, C. 2011. Biology, ecology and trials of potential methods for control of the introduced ascidian *Eudistoma elongatum*(Herdman, 1886) in Northland, New Zealand. Aquatic Invasions 6(4): 515-517.

Page, M. J. 2018. Tools and infrastructure for responding to marine pest incursions in Southland. NIWA Project: ELF18401. National Institute of Water & Atmospheric Research Ltd. Nelson, New Zealand.

Piola, R. and Conwell, C. 2010. Vessel biofouling as a vector for the introduction of non-indigenous marine species to New Zealand: Fishing vessels. MAF Biosecurity New Zealand.

PIRSA. 2019 Asian Paddle Crab *Charybdis japonica* Factsheet. https://www.pir.sa.gov.au/__data/assets/pdf_file/0008/348155/2019_Asian_Paddle_crab_factsheet.pdf

Russell, L. K., Hepburn, C. D., Hurd, C. L. and Stuart, M. D. 2008. The expanding range of *Undaria pinnatifida* in southern New Zealand: distribution, dispersal mechanisms and the invasion of wave-exposed environments. Biological invasions 10(1): 103-115.

Seaward, K., Acosta, H., Inglis, G.J., Wood, B., Riding, T., Wilkens, S., Gould, B. (2015) The Marine Biosecurity Porthole - a web-based information system on non-indigenous marine species in New Zealand. Management of Biological Invasions, 6: 177-184. doi: http://dx.doi.org/10.3391/mbi.2015.6.2.08.

Schiel, D. R. and Thompson, G. A. 2012. Demography and population biology of the invasive kelp *Undaria pinnatifida* on shallow reefs in southern New Zealand. Journal of Experimental Marine Biology and Ecology 434: 25-33.

Shears, N. T., & Bowen, M. M. (2017). Half a century of coastal temperature records reveal complex warming trends in western boundary currents. Scientific Reports, 7(1), 14527. http://doi.org/10.1038/s41598-017-14944-2

Sinner, J., Roberts, B. and Piola, R. 2009. Pride of the South: Risk Analysis for Marine Biosecurity in Fiordland.

Soliman, T. and Inglis, G. J. 2018. Forecasting the economic impacts of two biofouling invaders on aquaculture production of green-lipped mussels *Perna canaliculus* in New Zealand. Aquaculture Environment Interactions 10: 1-12.

South, P. M., Floerl, O., Forrest, B. M. and Thomsen, M. S. 2017. A review of three decades of research on the invasive kelp *Undaria pinnatifida* in Australasia: An assessment of its success, impacts and status as one of the world's worst invaders. Marine Environmental Research 131: 243-257.

Stuart, M. 2002. Translocation of *Undaria pinnatifida* by vessel fouling: Analysis of the Department of Conservation vessel monitoring database, May 1999 to May 2001. Draft report prepared for the Ministry of Fisheries, Wellington. Project ZBS2001-04.

Stuart, M., Jones, E. and McClary, D. 2009. Stewart Island Non-Indigenous Species Port Survey Baseline Surveys of New Ports and Marinas. ISBN No: 978-1-98-857171-3, ISSN No: 2624-0203.

Suárez-Jiménez, R., Hepburn, C. D., Hyndes, G. A., McLeod, R. J., Taylor, R. B. and Hurd, C. L. 2017. The invasive kelp *Undaria pinnatifida* hosts an epifaunal assemblage similar to native seaweeds with comparable morphologies. Marine Ecology Progress Series 582: 45-55.

Subritzky, P. and Pullman, K. 2014. Invasive marine organism surveys at secondary ports along the Southland Coast. University of Otago summer studentship report. Department of Marine Science. Dunedin, New Zealand.

Teske, P. R., Sandoval-Castillo, J., Sasaki, M. and Beheregaray, L. B. 2015. Invasion success of a habitat-forming marine invertebrate is limited by lower-than-expected dispersal ability. Marine Ecology Progress Series 536: 221-227.

Top of the South Marine Biosecurity Partnership. 2013. Top of the South Island Marine Biosecurity Strategic Plan Summary 2013.

Valentine, P. C., Collie, J. S., Reid, R. N., Asch, R. G., Guida, V. G. and Blackwood, D. S. 2007. The occurrence of the colonial ascidian *Didemnum sp*. on Georges Bank gravel habitat—ecological observations and potential effects on groundfish and scallop fisheries. Journal of Experimental Marine Biology and Ecology 342(1): 179-181.

Williams, J., Stokes, F., Dixon, H. and Hurren, K. 2017. The economic contribution of commercial fishing to the New Zealand economy. Ref No: 5643. Business and Economic Research Ltd. Wellington, New Zealand.

Willis, K., Morrisey, D., Inglis, G., Johnston, O. and Peakcock, L. 2008. Targeted surveillance for non indigenous marine species in New Zealand: Design report for Bluff. MAF Biosecurity Technical Paper No: 2018/63. Biosecurity New Zealand.

Willis, K. J., Woods, C. M. and Ashton, G. V. 2009. *Caprella mutica* in the Southern Hemisphere: Atlantic origins, distribution, and reproduction of an alien marine amphipod in New Zealand. Aquatic Biology 7(3): 249-259.

Wong, N. A. and Sewell, M. A. 2015. The reproductive ecology of the invasive Asian paddle crab, *Charybdis japonica* (Brachyura: Portunidae), in northeastern New Zealand. Invertebrate Biology 134(4): 303-317.

Wood, S. A., Pochon, X., Ming, W., von Ammon, U., Woods, C., Carter, M., Smith, M., Inglis, G. and Zaiko, A. 2019. Considerations for incorporating real-time PCR assays into routine marine biosecurity surveillance programmes: a case study targeting the Mediterranean fanworm (*Sabella spallanzanii*) and club tunicate (*Styela clava*). Genome 62(3): 137-146.

Woods, C., Seaward, K., Pryor Rodgers, L., Buckthought, D., Carter, M., Lyon, W., Neill, K., Olsen, L., Smith, M., Tait, L. and Inglis, G. 2019. Marine High Risk Site Surveillance Annual Synopsis Report for all High Risk Sites 2018–19 (SOW18048). Biosecurity New Zealand Technical Paper No: 2019/31. Biosecurity New Zealand.

Zabin, C., Davidson, I., Holzer, K., Smith, G., Ashton, G., Tamburri, M. and Ruiz, G. 2018. How will vessels be inspected to meet emerging biofouling regulations for the prevention of marine invasions? Management of Biological Invasions 9(3): 195-208.

APPENDIX 1

Table 1 Guide to marine species established or at risk of invasion to the Southland region and their presence or absence (P/A) in New Zealand. The listed species are identified as marine pests (bold print) or organisms of interest (asterisk) by the *Environment Southland Regional Pest Management Plan (2019-2029)*. All others are potential invasive species identified by ES or the Ministry for Primary Industries. This table was adapted from Page (2018).

Species	Common Name	Pathway	Impact	Habitat	Temp/Salinity/ Depth range	P/A NZ
Undaria pinnatifida	**Wakame or Asian kelp**	Vessel fouling, aquaculture, marine structures, Drifting sporophytes	Restructuring subtidal communities, fouling	Intertidal and subtidal structure	0.1-30 °C >18 S_A 0-15 m or deeper	P
Charybdis japonica	**Asian paddle crab**	Ballast water, vessel fouling	Predation on small estuarine bivalves	Intertidal, subtidal, estuarine sand and mud	4-34 °C 14-33 S_A 1-15m	P
Sabella spallanzanii	**Mediterranean fan worm**	Aquaculture stock, vessel fouling, ballast water	Competition, predation, fouling	Low intertidal, shallow subtidal structure	4-29 °C 26-39 S_A 0-30 m	P
Eudistoma elongatum	**Australian droplet tunicate**	Vessel fouling	Displacement of native species	Sheltered bays, intertidal to shallow subtidal on structure	>10 °C > 10 S_A 0–2 m	P
Styela clava	**Clubbed tunicate**	Aquaculture stock, vessel fouling, ballast water	Competition, predation, fouling	Low intertidal, Subtidal artificial structure	-2-24 °C >20 S_A 0-40 m	P
Pyura	**Australian cunjevoi**	Aquaculture, vessel	Competition,	Low intertidal,	>12 °C	P

doppelgangera		fouling, attached to drift	changes benthic structure and diversity	Subtidal rock platforms	>26 S_A 0-12 m	
Didemnum vexillum	**Carpet sea squirt**	Aquaculture stock, vessel fouling, ballast water	Competition, fouling	Shallow sub-tidal artificial structure	1-24 °C 20-45 S_A 0-80 m	P
*Theora lubrica**	Asian Semele/fragile clam	Ballast water	Research needed	Muddy subtidal and lower intertidal flats	9–27 °C 18-40 S_A Unknown	P
*Arcuatula senhousia**	Asian date mussel	Ballast water, vessel fouling, aquaculture stock	Competition, habitat loss	Intertidal and subtidal soft sediment	1–31 °C but 22.5-28 °C for spawning 18 - 36 S_A < 20 m	P
*Amanthia verticillata**	Spaghetti bryozoan	Vessel fouling	Fouling, habitat loss, competition	Sheltered coastal habitats	>20 °C but endures 11 °C 20 – 30 S_A but up to 56 S_A 1–4 m	P
Clavelina lepadiformis	Light bulb ascidian	Aquaculture, vessel fouling	Competition	Shallow littoral, preference for vertical substrates	10-17 °C 14-35 S_A <50 m, commonly ~3 m	P
Ciona intestinalis	Vase tunicate	Aquaculture and fisheries, vessel fouling, ballast water	Competition, predation, fouling	Shallow subtidal	10-20 °C 11-42 S_A 1-100 m	P
Grateloupia turuturu	Devil's tongue seaweed	Aquaculture, vessel fouling, ballast	Competition for space and light with native	Estuarine, low intertidal,	4-29 °C 22–37 S_A	P

		water	species	shallow sub-tidal	0-2.5 m	
Ciona savignyi	Pacific transparent tunicate	Aquaculture and fisheries, vessel fouling, ballast water	Competition, predation, fouling	Shallow subtidal	10-20 °C 11-42 S_A 1-100 m	P
Asterias amurensis	Northern Pacific seastar	Ballast water, aquaculture, vessel fouling	Generalist predator	Soft sediment, reef, artificial structure	10-35 °C 12-36 S_A 1-200 m	A
Carcinus maenas	European green crab	Ballast water, aquaculture, vessel fouling larval dispersal	Generalist predator	Soft sediment, intertidal, estuaries, shallow bays	3-26 °C 20-35 S_A <10 m	A
Caulerpa taxifolia	Aquarium weed	Ballast water, aquaculture, hull fouling, natural dispersal, aquarium trade	Aggressive competitor for space	Soft sediment, Intertidal, estuaries, Shallow subtidal	15-30 °C 15-30 S_A 1-100 m	A
Eriochier sinensis	Chinese mitten crab	Hull fouling, ballast water	Competition, predation, habitat loss	Soft sediment, Intertidal, estuaries	0-31 °C 1-35 S_A 0-14 m	A
Potamocorbula amurensis	Asian clam	Ballast water	Competition for space and food, habitat loss	Subtidal and intertidal creeks and estuaries in freshwater to brackish	0-28 °C 1-33 S_A 0-17 m	A
Sargassum muticum	Sargassum/Japanese wireweed	Rafting fragments, hull fouling, aquaculture	Fouling, competition and habitat loss	Hard substrate in the lower intertidal to upper subtidal	10-30°C 6.4-34 S_A 0-20 m	A

Sargassum horneri	Sargassum/Devil weed	Rafting fragments, ballast water and hull fouling	Fouling, competition and habitat loss	Hard substrate especially boulders in intertidal to upper subtidal	18-22°C 0-30 m	A