Regional Recreational Vessel Fouling and Marine Pest Survey 2017/18

Top of the South Marine Biosecurity Partnership

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June 2018

Prepared for

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Technical Report 2018/01

ISSN: 2324-4925 (print), 2324-4933 (online)
ISBN: 978-0-473-44618-5 (print), 978-0-473-44619-2 (online)

Published by:
Top of the South Marine Biosecurity Partnership
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EXECUTIVE SUMMARY

Background

This report describes a summer survey of biofouling and marine pests on recreational vessels and structures across the Top of the South (TOS) region. The survey focused on locations outside the main vessel hubs, and included areas commonly visited by boaters from other regions. The scale of the survey was considerably greater (17 days) than in the two previous summers (5-6 days), reflecting increased surveillance effort for the Mediterranean fanworm *Sabella spallanzanii*. The regional programme described here supports fanworm surveillance and control activities being undertaken in and around the main hubs where this organism has been found to date (Picton marina, Nelson marina, Port Tarakohe).

The survey was conducted from December 2017 to April 2018, with an intensive period of effort during peak boating activity over Xmas and January. Biofouling on boats was assessed by snorkel diving, using a level of fouling (LOF) scale that describes categories of fouling ranging from no macrofouling (LOF ≤ 1) to very heavy macrofouling (LOF 5). As well as LOF assessment, boats and associated structures were simultaneously checked for the presence of six target marine pest species. When boaters were present, they were asked questions about their home port and their vessel maintenance habits.

Key findings and implications

In total we surveyed 544 vessels (mainly recreational yachts and power boats) and 546 coastal structures (mainly swing moorings and jetties), and engaged with 232 active boaters. **Although no Mediterranean fanworm was detected during the surveys, other marine pests were recorded.** The key findings described below **reinforce the role of recreational vessels in the spread of marine pests, and highlight the importance of managing this pathway effectively**.

The fouling (LOF) status of boats was similar to previous surveys. Overall, hull fouling was the greatest on vessels from Nelson, less on vessels from Marlborough, and least on vessels visiting from outside the region. The long-established marine pests, *Undaria pinnatifida* and *Didemnum vexillum*, were widespread. The most notable change since 2016/17 was the increased prevalence and relatively widespread distribution of the sea squirt *Styela clava*. This species was present on >5% of vessels and >7% of structures. New populations were recorded in Kenepuru Sound, which added to new populations found in Okiwi Bay during the concurrent SCUBA survey. The disjointed distributional pattern of *Styela* is consistent with human-mediated spread rather than natural dispersal. The current prevalence and wide distribution of *Undaria* and *Didemnum* likely reflects the future distribution (e.g. over the next 10-20 years) of *Styela*, and also of the fanworm in the absence of comprehensive management.

Survey results illustrate that intensive population control for target pests in vessel hubs is an effective way to reduce vessel colonisation and subsequent vessel-mediated spread. The fanworm has been managed to low densities in Picton/Waikawa, Nelson, and

Tarakohe, and was not recorded anywhere outside of these hubs. By contrast, the more abundant unmanaged pests in these hubs were the ones that were prevalent on vessels. In the absence of *Styela* population control, or continued fanworm control, it can be expected that vessels in TOS hubs will increasingly act as vectors for the within-region spread of multiple marine pests. In addition, the proportion of boats from Wellington was high (17%), illustrating the potential importance of Wellington marinas as source regions for pests to the TOS. Wellington marinas are not currently thought to have fanworm, but if it did establish, those locations would become significant sources for fanworm spread, especially to Marlborough.

The above results reinforce the importance of direct management of vessel fouling as an integral part of effective biosecurity. Achieving effective vector management is not straightforward, as it requires means to address the risk from vessels coming into the TOS from other regions. For this purpose, the TOS Coordination Team is already working with Wellington marina managers, and is considering the best ways to address potential risks from Northland and Auckland.

A significant challenge for effective vessel management is reducing "niche" area fouling on the bottom of vessel keels, especially in situations where the main hull appears well-maintained and free of visible fouling. The Coordination Team is continuing to explore the potential for development of effective antifouling practices for keels. A related challenge, and critical issue to address, is the lack of capacity at haul-out facilities in Nelson, to enable boaters to be lifted from the water for cleaning or maintenance. The risk profile of recreational vessels plying the region's waters is probably going to worsen unless this issue is addressed. Exacerbating this situation is the likelihood that some boaters will scrape these pests to the seabed while they are moored or anchored in high-value areas. Arguably, it is futile to be advocating or regulating improved hull hygiene without systems in place to support best practice.

Considerations for future surveillance

Future surveillance needs are discussed, including the need for further investigation of options for ensuring that visiting vessels: (i) arrive in the TOS with a clean hull, (ii) get cleaned upon arrival if they weren't cleaned before departure, or (iii) are subsequently detected if the first two measures fail. Gaps in regional surveillance are also discussed, and recommendations made for the allocation of effort among snorkel-based and SCUBA-based surveys. It is important that these two separate activities are well-aligned. SCUBA-based surveys within the key hubs need to be systematic and comprehensive, with snorkel-based surveys filling in the regional gaps and maintaining a broader data collection and boater interaction focus. Simultaneously, efforts to integrate other stakeholders (e.g. marine farmers, mooring service providers) into the surveillance programme should be continued. With all of these elements in place, the programme has the best chance of managing the ongoing threat from fanworm to the TOS region's values.

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1 INTRODUCTION

The Top of the South (TOS) Marine Biosecurity Partnership (the Partnership) was formed in 2009 to improve marine biosecurity management in the top of the South Island. The Partnership includes representation from the three TOS councils (Nelson City Council, and Marlborough and Tasman District Councils), the Ministry for Primary Industries (MPI), the aquaculture industry, other stakeholders, and iwi. The Coordination Team that operationalises the Partnership's activities has an ongoing programme of marine biosecurity engagement with vessel owners and operators. A key focus of that engagement has been to promote the need for regular and effective antifouling and cleaning of vessel hulls, in order to reduce levels of biofouling. This focus reflects that biofouling is a significant mechanism for the spread of potentially harmful organisms into and within the TOS region, with recreational vessels being of particular significance (see Box 1).

As part of engagement activities, regional field surveys were undertaken by the Coordination Team in the summers of 2015/16 (Forrest 2016) and 2016/17 (Forrest 2017a), whose purpose was to: (i) collect data on the fouling status of recreational vessels, (ii) check for the presence of key marine pests (Table 1) on vessels and associated moorings, and (iii) further engage with boaters regarding marine biosecurity risks and management. Together with analysis of vessel hull fouling and boater questionnaire data collected from regional haul-out facilities (Forrest 2017b), these recent surveys have revealed a gradual spread of established marine pests in the region, and confirmed the significant risk presented by recreational vessels under current management practices.

As part of efforts to better understand and manage risk, regional field surveys were again undertaken in the summer of 2017/18, but the effort and scope was expanded to support a broader programme of regional surveillance and management for the Mediterranean fanworm *Sabella spallanzanii* (see Table 1). The goal of the broader programme is to prevent the establishment of the fanworm beyond its known distribution in three regional vessels hubs (Picton and Nelson marinas, Port Tarakohe).

A major element of the broader programme currently underway is intensive SCUBA-based fanworm surveillance within the three infected hubs, as well as Waikawa Bay (where infected vessels have been detected) and a few other locations (Table 2). These other locations include areas adjacent to the hubs (e.g. Shakespeare Bay near Picton), or remote areas that have not already been comprehensively checked (e.g. Port Underwood, Okiwi Bay). The expanded survey by the Coordination Team in the summer of 2017/18 had the additional purpose of filling in regional knowledge gaps of fanworm distribution outside of these intensively-surveyed areas, while also continuing the boater engagement and data collection activities of the earlier surveys.

This report summarises the methods and key findings from the 2017/18 survey, compares results with the earlier surveys, provides insights gained from the collective survey effort to date, and makes recommendations for future work.

Box 1. Recreational vessel biofouling – why all the fuss?

Biofouling is a key focus of marine biosecurity management internationally. Marine pests and other potentially harmful organisms can be spread via biofouling associated with a wide range of vessel types (e.g. recreational, barges, merchant ships) and other activities (e.g. aquaculture). Although mechanisms such as ballast water and bilge water discharge also have the potential to transport harmful species, vessel biofouling is the main mechanism implicated in most (c. 87%) of the marine pest introductions into New Zealand. Biofouling is also a key mechanism for domestic spread, which is where recreational vessels become really important.

The first reason is that recreational vessels are numerous, and widely scattered across the region. For example, there are almost 2,000 vessels in marina berths in the TOS alone, and around 3,500 consented swing moorings, most of which (c. 3,100) are in Marlborough (Floerl et al. 2015). A second key reason is that recreational vessels are susceptible to the accumulation of biofouling, due to the following:

- Antifouling is undertaken at intervals that are too infrequent (typically 24-30 months) to prevent fouling accumulation on the hull (Forrest 2017c).
- Boats may spend long periods of time idle between use (i.e. at berth or on swing moorings). This situation means that the effectiveness of their antifouling coating is reduced, and fouling can easily accumulate.
- Recreational vessels are not always antifouled to a high standard, or their owners may implement cleaning practices that reduce coating efficacy.

In addition, the voyage profiles of recreational vessels can lead to elevated biosecurity risk for the following main reasons:

- Some vessel types (e.g. yachts) move at slow speeds, meaning much of their biofouling growth can survive transport among regions. In general, it requires vessel speeds of around 10 knots or greater before fouling becomes physically dislodged (Coutts et al. 2010a; Coutts et al. 2010b).
- Perhaps most significantly, recreational vessels operate in relatively isolated and picturesque coastal areas; often travelling directly to these areas from transport hubs where marine pests occur. In the case of out-of-region vessels, TOS boater surveys reveal that 75-80% of boats visiting the TOS region do not necessarily travel to a main hub (e.g. port, marina) during their visit, so it is possible that some marine pest introductions are occurring without even being detected (Forrest 2017c).

Recreational vessels often get heavily fouled

Some vessels have a hull that appears clean, but which is fouled in niche areas below the water-line

Table 1. Marine fouling pests targeted during regional field surveys. All are MPI-designated marine pests (see MPI 2015) except for *Didemnum vexillum*, which is of regional interest. Specific management programmes in the TOS are currently in place for Mediterranean fanworm.

Scientific name	Common name and/or group	Reported NZ distribution	Example
Didemnum vexillum	Colonial sea squirt	Widespread in many ports and harbours nationally, including around the **Top of the South**	
Eudistoma elongatum	Australian droplet tunicate/ Colonial sea squirt	Northland east coast	
Pyura doppelgangera	Solitary sea squirt	Northland west coast and Opua (Bay of Islands)	
Sabella spallanzanii	Mediterranean fanworm / Tubeworm	Whangarei, Auckland, Coromandel, Tauranga, **Tarakohe, Nelson, Picton,** Lyttelton	
Styela clava	Clubbed tunicate / Solitary sea squirt	Whangarei, Tutukaka, Auckland, Tauranga, Wellington**, Tarakohe, Nelson, Picton, Waikawa, Marlborough Sounds,** Lyttelton, Dunedin	
Undaria pinnatifida	Japanese or Asian kelp / Large brown seaweed	Widespread nationally, including parts of **Tasman, Nelson** and **Marlborough Sounds**	

Table 2. Locations where intensive SCUBA-based surveys have been undertaken (or are planned) as part of regional Mediterranean fanworm control efforts. These locations were excluded from the regional survey undertaken by the TOS Coordination Team.

Region	SCUBA-based survey area
Marlborough	Picton Marina, swing moorings & wider harbour, Shakespeare Bay, Waikawa marina, Waikawa Bay swing moorings, Okiwi Bay, Port Underwood
Nelson	Nelson marina and swing moorings in wider harbour
Tasman	Port Tarakohe, including swing moorings

2 FIELD SURVEY METHODS

2.1 General approach

The 2017/18 regional programme encompassed: (i) recreational vessels in active use in the TOS region (including vessels visiting from elsewhere in New Zealand); (ii) recreational vessels that appeared to be idle on swing moorings; and (iii) swing moorings themselves, or other structures associated with hotspots of regional recreational vessel activity (e.g. pontoon and pile jetties).

The survey was conducted over 17 days (16 full days and two part-days) between 16 December 2017 and 26 April 2018, focusing on the peak period of boater activity over Xmas and January. The area surveyed covered four main sub-regions in the Top of the South: the Abel Tasman National Park coastline, Nelson Harbour, Pelorus Sound, and Queen Charlotte Sound (Figure 3). The locations surveyed were coordinated with the SCUBA-based fanworm control programme described above (see Table 2), in order to avoid duplicated effort.

Moorings were checked to depths up to 8m

In the regional survey described here, biofouling and/or pest checks were made on recreational vessels and associated structures using snorkel. For structures, the main area checked was across the 0-5m depth range. In good water clarity, some swing moorings were checked to depths up to 8m (which at times included the mooring chain and block).

Snorkelling is particularly useful as a rapid assessment method and has proven effective for pest detection in the TOS. However, in situations of reduced water clarity (e.g. Nelson marina) or in the case of extensive fouling, snorkelling is unlikely to be as effective as SCUBA for detecting the presence of pests (especially when juvenile or at very low density). Snorkelling is also restricted in terms of safe diving depth.

A quiet day at Anchorage on the Abel Tasman coast

The largest vessel checked was 40m long, from Malta

Vessels and skippers for the 2017/18 survey were provided by the Tasman Harbour Master (Tata Beach & Abel Tasman coastline), the Marlborough Harbour Master (Pelorus and Queen Charlotte Sound), and Department of Conservation Picton office (Queen Charlotte Sound). Most of the monitoring was restricted to periods of fine weather when boaters were more likely to be on the water.

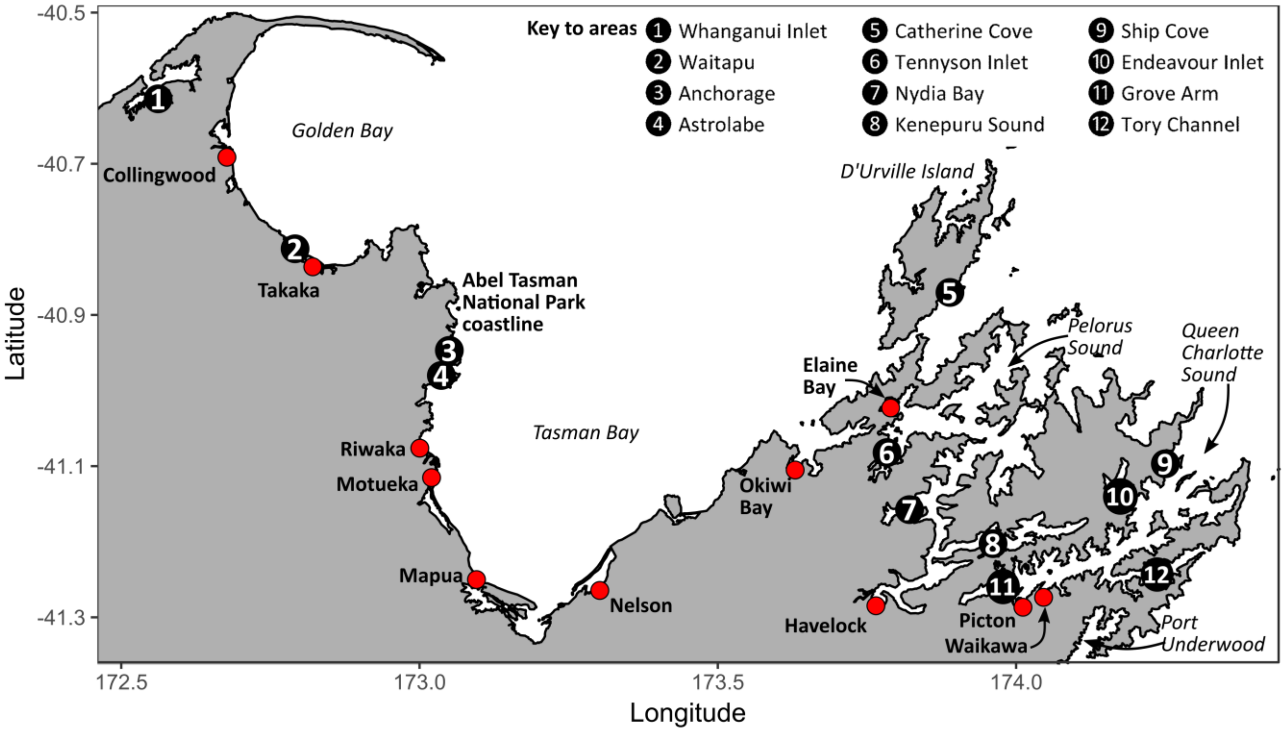


Figure 1. General region covered during the 2017/18 summer biofouling and marine pest survey. The main place names mentioned in the text are shown.

Example of pontoon and pile jetty

Typical biofouling visible on a pile jetty at low tide

2.2 Prioritisation of survey locations

The general snorkel survey locations shown in Figure 3 above included known high density areas for recreational vessel activity, especially boats visiting the region from outside the TOS. They also included high use jetties and moorings belonging to various boating clubs. Identification of such areas was facilitated by the vessel skippers, most of whom had an extensive knowledge of boater voyage habits in the different regions. Key areas surveyed included the following:

The out-of-region boats were often found on club moorings in idyllic bays

- High density mooring areas outside the main hubs (e.g. Grove arm of Queen Charlotte Sound, Tennyson Inlet in Pelorus Sound). Also, a cursory check was made of about half of the structures in Elaine Bay, as this represent an important aquaculture hub for Pelorus Sound.
- Commonly used boat anchorages along the Abel Tasman coast (Anchorage, Astrolabe Roadstead at Adele Island); environs of Ship Cove, Pickersgill and Motuara Islands in Queen Charlotte Sound.
- Bays with boat-club swing moorings known to often be used by visiting vessels.
- Hot-spots where vessels are known to aggregate during the holiday season (e.g. Endeavour Inlet in Queen Charlotte Sound, Anchorage on the Abel Tasman).
- Localities where significant marine pest finds have been reported (e.g. Duncan Bay in Tennyson Inlet, where the sea squirt *Styela clava* is present).

Vessels and structures were also checked in locations visited by an out-of-region vessel (Aquasition) that had cruised the Marlborough Sounds during 2017 with fanworm on its hull. These locations were: Catherine Cove (D'Urville Island), St Omer (Kenepuru Sound), and Onahau and Lochmara Bays (Queen Charlotte Sound). Finally, above-water checks were made of wharf areas in Whanganui Inlet and Waitapu (see Figure 1), and random checks were made of occasional vessels or structures in areas perceived as being lower use, in order to increase geographic coverage.

The derelict wharf at Whanganui Inlet

2.3 Boater engagement and in-water hull checks

2.3.1 General

During the peak holiday season, the greatest emphasis was placed on locating boats in active use, so that boaters could be interviewed. As well as using the opportunity for general boater education about marine biosecurity and biofouling, boaters were asked key questions about their antifouling and cleaning habits, and their home region (Appendix 1). Unless consent was denied by the boater (when present), the hull of each vessel was checked in-water on snorkel. Particular attention was given to "niche" areas where fouling tends to accumulate. Depending on vessel type, such areas may include the keel, rudder, trim tabs (power boats), propeller shaft, pipe outlets, bow-thruster tunnels, and hard-stand support strips.

2.3.2 In-water level of fouling assessment

Each vessel was assigned an overall "level of fouling" (LOF) score based on categories described by Floerl et al. (2005) and shown in Table 3. The LOF approach has been used in many hull fouling studies in New Zealand, including in the TOS (Lacoursière-Roussel et al. 2012; Forrest 2016; Forrest 2017a). It is evident from such studies that the likelihood of vessel biofouling including marine pests increases with increasing LOF.

Table 3. Level of fouling (LOF) categories and descriptions based on Floerl et al. (2005). The Floerl et al. category of LOF 0 (no visible fouling) was not used in the present study; LOF 1 is taken to represent slime layer[1] fouling or less (i.e. absence of visible macrofouling).

LOF	Description	Macrofouling cover (%)
1	**Slime layer** fouling only. Submerged hull areas partially or entirely covered in biofilm, but absence of any macrofouling.	Nil
2	**Light fouling**. Hull covered in biofilm and 1-2 very small patches of macrofouling (only one taxon).	1 – 5
3	**Considerable fouling**. Presence of biofilm, and macrofouling still patchy but clearly visible and comprised of either one or several different taxa.	6 – 15
4	**Extensive fouling**. Presence of biofilm, and abundant fouling assemblages consisting of more than one taxon.	16 – 40
5	**Very heavy fouling**. Diverse assemblages covering most of visible hull surfaces.	41 - 100

[1] Slime layer fouling described by LOF 1 contains no visible macrofouling, but may contain the early or microscopic life-stages of such organisms.

In some instances, the number of species groups (referred to by the term "taxa" in Table 3) did not match the descriptors for the percent cover thresholds. For example, at times LOF 2 fouling of 1-5% cover comprised many species (i.e. consistent with LOF 3), whereas the Table 1 criterion allows only one species. In those instances, the percent cover thresholds were given priority (i.e. in that case, LOF 2 would be assigned). Examples of the LOF categories are shown in Figure 2. Video examples of LOF categories can be viewed at the following link: http://youtu.be/LMJKZSs8Arg.

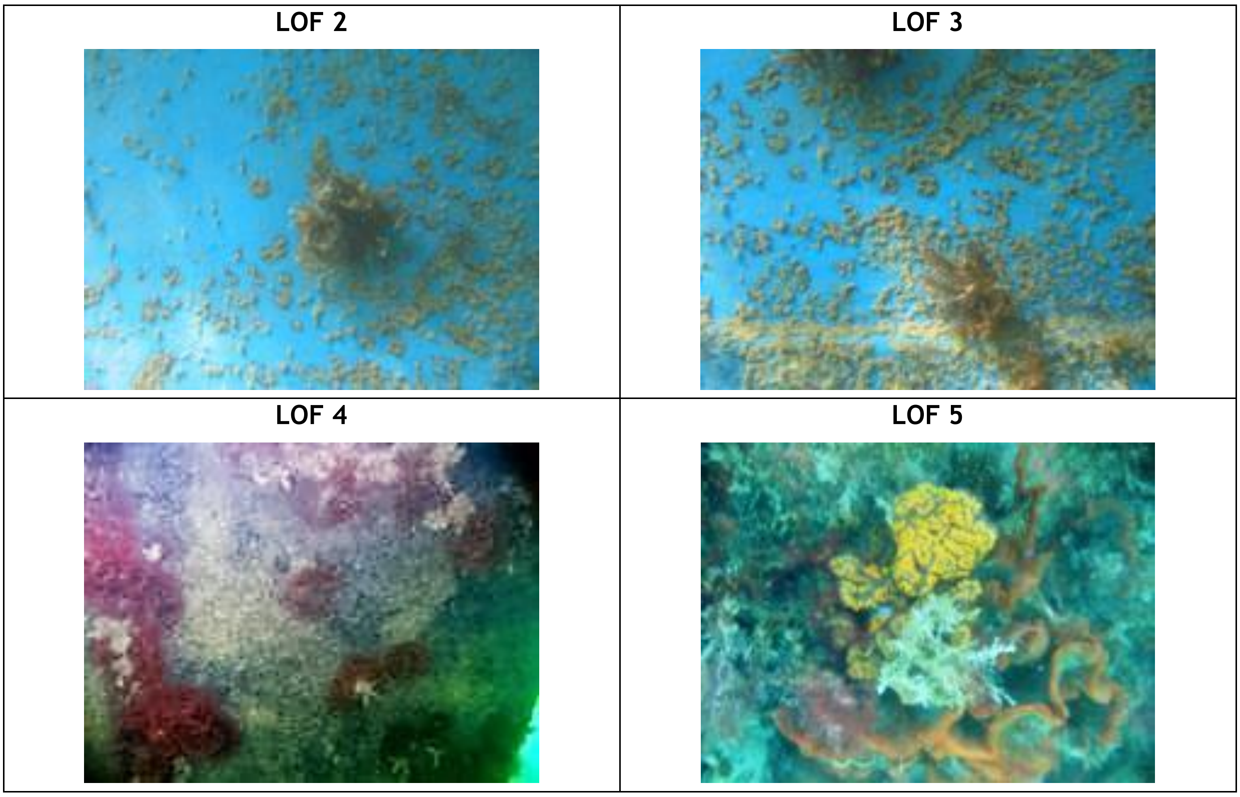


Figure 2. Level of fouling (LOF) examples. The photographs are close-up rather than depicting "whole boat" hence should be considered as illustrative only. For a better impression see video at: http://youtu.be/LMJKZSs8Arg

2.3.3 Marine pests

In addition to LOF scores, the presence of known marine pests was recorded, based on the target list of six species in Table 1. With the exception of the sea squirt *Didemnum vexillum*, which is of interest as a pest of potential regional significance, five of the target species are designated as marine pests by the Ministry for Primary Industries (MPI 2015). Of these five, the fanworm was of special interest as already outlined. Also of interest was the clubbed sea squirt *Styela clava*. This species has been the subject of limited small-scale or intermittent management in the TOS, and has been found in only a few locations outside the main vessel hubs.

Two of the MPI-designated sea squirt pests, *Pyura doppelgangera* and *Eudistoma elongatum*, are not thought to have established in the TOS, but exist in northern New Zealand in locations connected to the TOS by vessel movements (see Table 1). The Asian kelp *Undaria pinnatifida* has been established in many areas of the TOS for several decades, and is a useful indicator of the future long-term spread of any new or more recent biofouling incursions that are not effectively managed. Despite being regionally widespread, *Undaria* is also of interest in that there remain susceptible locations (e.g. parts of the remote outer Marlborough Sounds) at risk from vessel-mediated introductions. Without human transport, *Undaria* would be unable to get to such areas due to its limited natural dispersal capacity (Forrest et al. 2000).

2.4 Data recording and analysis

2.4.1 Recording

Field data were recorded in a tablet-based reporting template developed with software available at www.fulcrumapp.com. Among other things, the template was used to record the location and type of each vessel surveyed (sail or power boat), vessel LOF, the occurrence of any of the target pests on vessels or structures, and boater responses to questions regarding home port and maintenance habits (Appendix 1). The software automatically recorded GPS position and linked any photographs that were taken to the unique record number assigned to each location. Intermittently during each field day, the data were uploaded to the fulcrumapp website and later exported to Excel for quality assurance checks and backup.

Given that one of the goals was to understand the fouling status of vessels in active use in the region, boats were categorised as “active” in situations where: (i) someone was on-board or on-shore; or (ii) the boat was unattended but at anchor or on a boat club mooring. The activity status of the remaining boats was categorised as “unknown”. Although the latter category includes some boats that appeared relatively derelict (i.e. they were clearly not in use), others were on private moorings adjacent to dwellings and may have been in use around the time of the survey. As such, the number of boats classified as active is likely to be an underestimate of the true situation.

2.4.2 Analysis

For the present report, tabulated and graphical displays of the LOF and pest data are provided. Distributional maps and summary data for LOF and pest occurrence were generated using the software R 3.4.0. The LOF scores for boats surveyed are compared to the results from the two previous summer surveys (Forrest 2016; Forrest 2017a) as well as other studies conducted in New Zealand outside the TOS (e.g. Brine et al. 2013). The relationship between pest occurrence and LOF is described, and information on boater habits is presented. Limited analyses are undertaken to explore levels of fouling in relation to boat maintenance (time since last antifouling, cleaning), to provide a comparison with comprehensive analyses described in Forrest (2017b).

3 KEY FINDINGS

3.1 Field survey effort

The regional distribution of vessels and structures surveyed is shown in Figure 3. In total, 544 vessels and 546 structures were checked, which is considerably greater than in previous surveys (186 boats & 73 moorings in 2016/17; 226 vessels & 135 moorings in 2015/16). The high numbers achieved in the latest survey reflected not only the greater effort (17 days c.f. 5-6 previously), but also that fine weather during the holiday season meant a lot of boaters were on the water. Of the 546 structures, 85% were swing moorings. The distribution of vessels surveyed across the council jurisdictions was: Marlborough (410 vessels; 323 Queen Charlotte, 87 Pelorus), Nelson (43 vessels), and Tasman (89 vessels; 84 Abel Tasman coastline, 5 Golden Bay).

The far greater count in Marlborough reflects the greater boater activity in that region (especially Queen Charlotte Sound), and the substantially greater number of moorings (see above) and other coastal structures. In turn this situations reflects that the Marlborough Sounds covers a vast area (c. 4,000 km^2) and 1,500 km of coastline which represents about 10% of New Zealand's total.

3.2 Origin of boats surveyed

Of the 544 vessels, 232 had people of board, although not all knew the history of the vessel (e.g. some were hire boats). The home port was determined for 231 of the vessels. Approximately 23% were from locations outside the TOS, of which only two were of international origin (Table 4). Of the New Zealand boats originating outside the TOS, 39 (17% of total vessels) came from Wellington; mainly from Mana Marina. Only six vessels were from Auckland and Northland localities where the fanworm is well established; however, no fanworm was found on these boats (see Section 0).

Figure 4 shows a breakdown of vessel origin for the two main TOS sub-regions – Marlborough and Nelson/Tasman. The Nelson and Tasman council jurisdictions were pooled together, as very few boaters were interviewed in Nelson (most were on the Abel Tasman coastline in the Tasman district). Figure 4 shows that, for each sub-region, the majority of boats originated from within that the same sub-region. Most boats on the Abel Tasman coastline came from Nelson marina, and most Marlborough boats came from Queen Charlotte Sound (Picton and Waikawa marinas). However, Marlborough had the greatest proportion of boats from outside the region (33%), most notably from Wellington. By contrast, only 19% of Nelson/Tasman boats originated from elsewhere.

3.3 Levels of fouling

Figure 5 shows that the incidence of "heavily fouled" (LOF ≥ 4) vessels was slightly greater in 2017/18 (19%) than in the two earlier TOS regional surveys (15-16%). However, the proportion of boats in 2016/17 with "conspicuous" fouling; defined here as LOF of ≥ 3, which reflects a fouling cover exceeding 5%, was similar to that in

2015/16. At LOF 3, fouling is usually quite noticeable to a surface observer (e.g. from a boat), as it often extends beyond submerged niche areas and may be visible in patches around the water-line. Clearly, despite progress being made within the TOS Partnership, the overall fouling status of vessels is not appreciably changing.

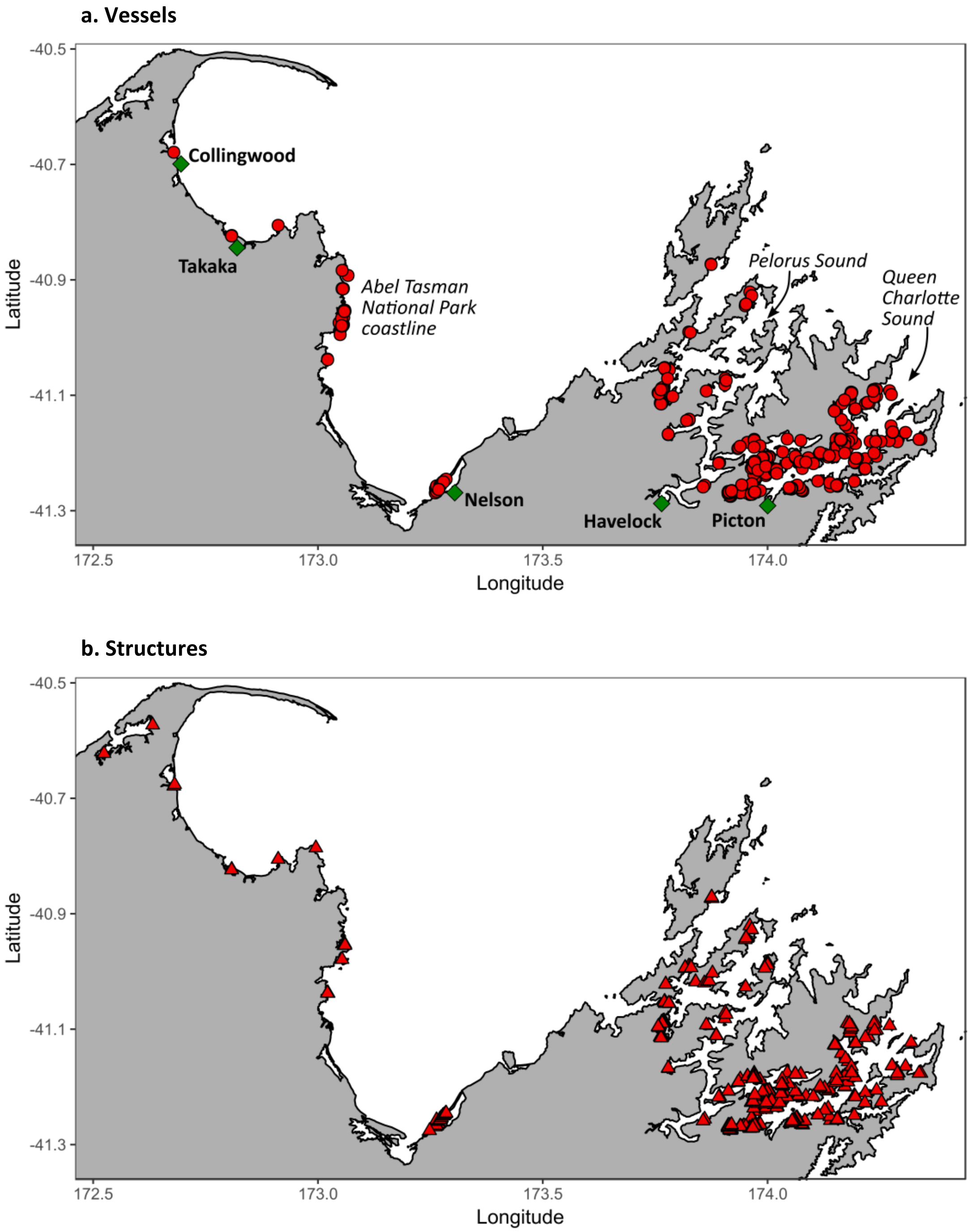


Figure 3. General localities of 544 vessels and 546 structures surveyed for biofouling and marine pests between December 2017 and April 2018. Symbols overlap or are obscured due to survey points close to each other. As part of a Mediterranean fanworm control programme, additional surveillance (using SCUBA) is being undertaken in areas not shown on this map (see text).

Table 4. Home region information obtained from boaters during the 2017/18 summer survey.

Home region	No. boats	% boats
TOS		
Nelson/Tasman (including Golden Bay)	66	29
Pelorus Sound	8	3
Queen Charlotte Sound	103	45
Total boats from TOS	177	77
Elsewhere in New Zealand		
Auckland	4	2
Bay of Plenty	1	< 1
Lyttelton	5	2
Northland	2	1
Otago	1	0
Wellington	39	17
Total boats from elsewhere NZ	52	22
International		
Malta & Cayman Islands	2	< 1

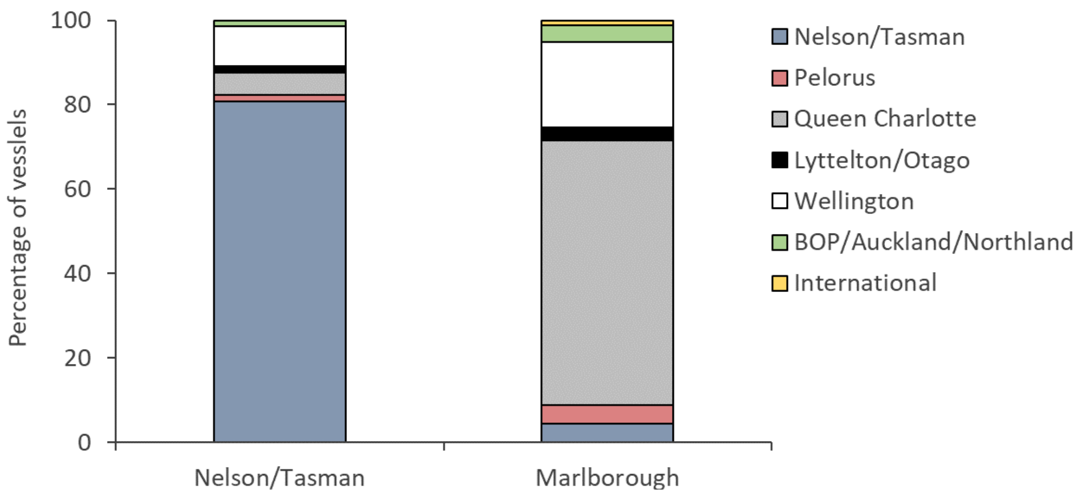


Figure 4. Proportion of vessels active within either Nelson/Tasman or Marlborough that came from different locations within and outside the TOS. Summary derived from the survey responses of 231 boaters across the two main areas. BOP = Bay of Plenty

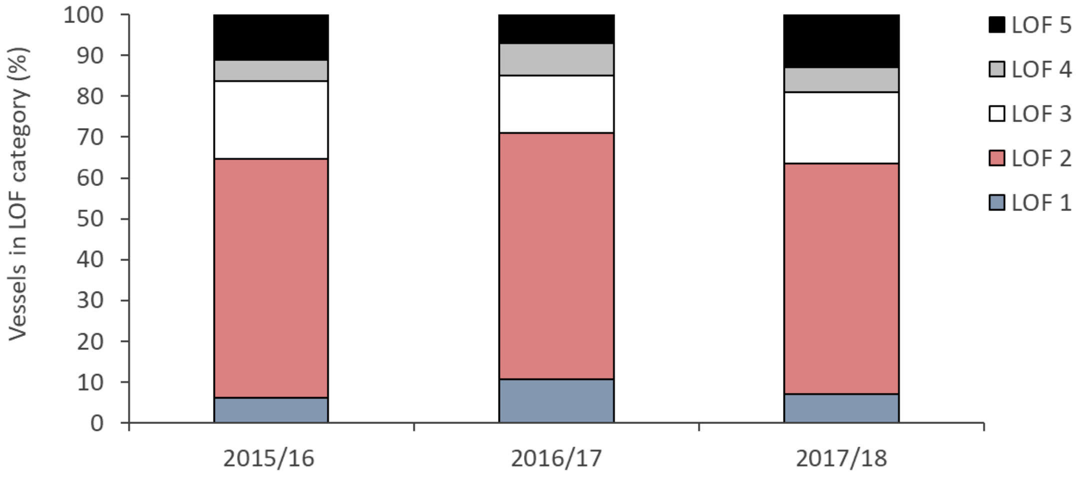


Figure 5. Proportion of vessels in each LOF category comparing the summer 2017/18 survey data with two previous summer surveys.

The slightly greater incidence of heavily fouled vessels in the latest survey probably reflects that some of the increased effort for fanworm surveillance was directed at boats that were idle on swing moorings across entire region (i.e. reflecting vessels that were poorly maintained). Boats that were in active use were noticeably better maintained and less fouled than those whose activity status was unknown (Figure 6), which is consistent with the findings of the previous surveys. In 2017/18, approximately 8% of active boats were heavily-fouled (LOF ≥ 4), compared with 28% for the remaining boats of unknown activity status.

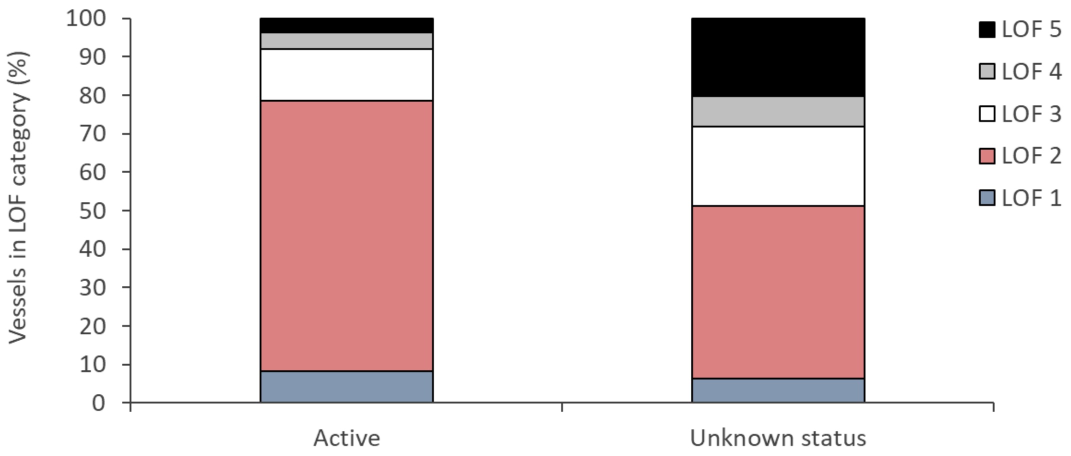


Figure 6. Proportion of vessels in each LOF category, comparing boats from the summer 2017/18 survey classified as being in active use (n=242) with boats whose activity status was unknown (n=302).

When hull fouling was considered in relation to the home region of the vessels (see Table 2), it is apparent that Nelson/Tasman vessels (which originated mainly from Nelson marina) were more heavily-fouled than boats from anywhere else (Figure 7). Around 14% of Nelson/Tasman boats were LOF ≥ 4, whereas for Marlborough this figure was 6%, and was 4% for vessels originating from outside the TOS. This finding is consistent with earlier TOS studies showing that boats in Nelson marina had higher LOF scores than boats from Waikawa (Forrest 2014).

Consistent with the 2016/17 data, most Wellington boats were well-maintained and had only light fouling (LOF 2). Boaters from this region were reasonably aware of marine biosecurity issues; the TOS Coordination Team has been working with Wellington marina managers to encourage vessel maintenance before departure for the TOS. The most heavily-fouled out-of-region vessel originated from the Bay of Islands where the fanworm is widespread. This boat was very-heavily fouled (LOF 5) and was anchored in Chance Bay in inner Pelorus Sound, directly adjacent to mussel farms in Nydia Bay (see Figure 3). Although no fanworm was detected, this situation illustrates how easily marine pests could be transported directly to the heart of the country's most significant aquaculture region.

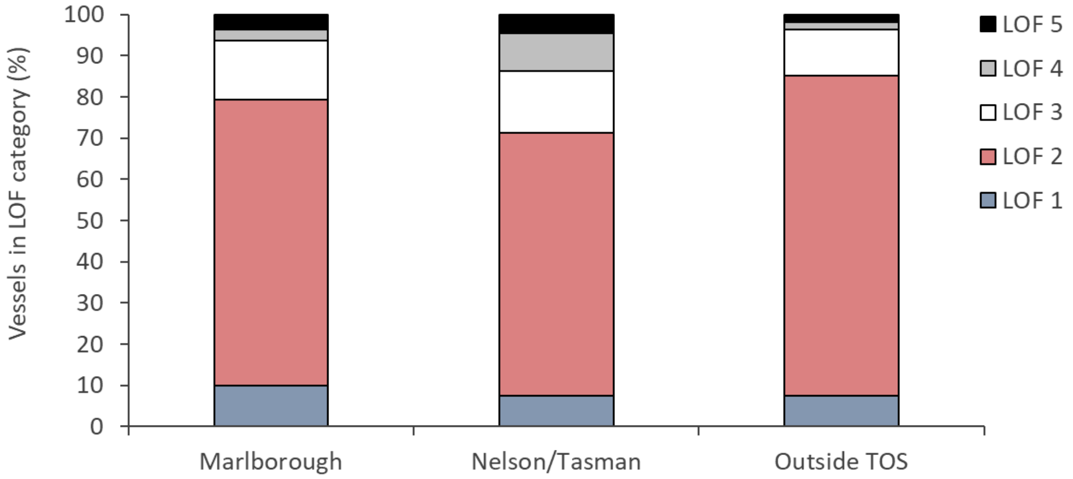


Figure 7. Proportion of vessels in each LOF category, comparing boats whose home port was from either Marlborough (n=111), Nelson/Tasman (n=66) or outside the TOS (n=54).

3.4 Occurrence of marine pests

A total of 22% of boats had at least one of the target pests listed in Table 1 present, which is within the range (19-30%) recorded in previous surveys. No pests were found that were new to the TOS region. Furthermore, among the target pests already present in the TOS, the fanworm was not recorded. This situation conceivably reflects that the known populations of this species (i.e. in Picton, Nelson, Tarakohe) are being periodically removed by divers as part of the SCUBA-based control programme. This approach would be expected to limit the reproductive reservoir, hence reduce the risk of vessels being colonised.

By contrast with the fanworm, the sea squirt *Styela* appeared to be more regionally widespread in 2017/18 than in previous surveys (Table 5, Figure 8a, Figure 9a). Although the effort was increased in the latest survey, *Styela* was found on a greater overall percentage of boats and structures (5.2% & 7.1%, respectively) compared with previous years. However, Nelson Harbour vessels and moorings were a particular hot-spot and skew the data somewhat; just over half of the infected vessels and structures were in Nelson, and these were not checked in the two earlier surveys. In the latest survey, *Styela* was found to be widely established in Kenepuru Sound on mooring lines, and was also noted on mussel farms there, as well as moorings and mussel farms in Nydia Bay. Additionally, the SCUBA-based programme concurrently underway recorded *Styela* in Okiwi Bay.

Sea squirt *Styela* on a swing line mooring in Tennyson Inlet

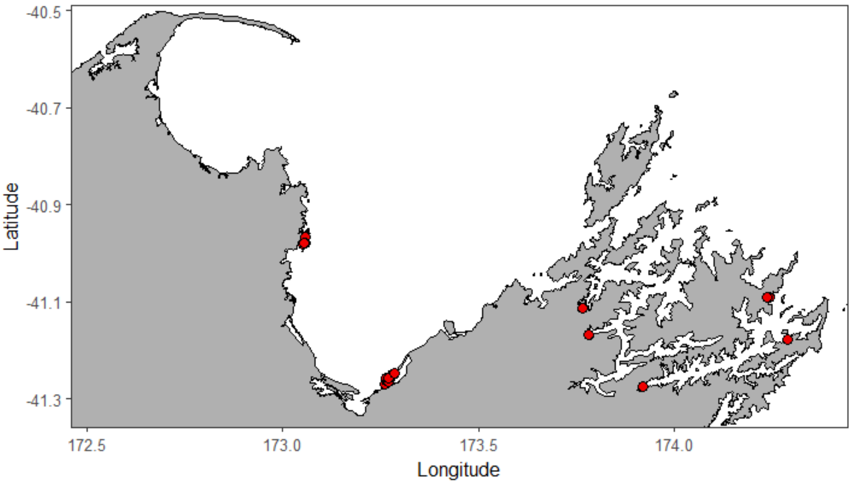
Among eight active vessels carrying *Styela*, all were yachts, with the sea squirt in most cases on the bottom of the keel. Hence, as with previous TOS surveys, as highlighted by overseas studies (Clarke Murray et al. 2013), the 2017/18 work highlights the need for better maintenance practices for this key niche area. Six of these vessels originated from Nelson marina, one from Waikawa marina and one from Auckland. Interestingly, the Auckland vessel had been dived in Auckland and apparently “certified” as pest-free.

The importance of Nelson as a source hub for *Styela* reflects that the species has been established there for more than 10 years, but the population has never been extensively controlled. Only a small amount of *Styela* removal work has been undertaken, confined to Nelson marina and conducted as part of fanworm searches. The reason *Styela* was never comprehensively managed in Nelson is that at the time of first discovery it was already quite widespread across the Port, including in the natural habitats of the harbour area. This distribution, coupled with the poor water clarity in Nelson, make effective population control impractical.

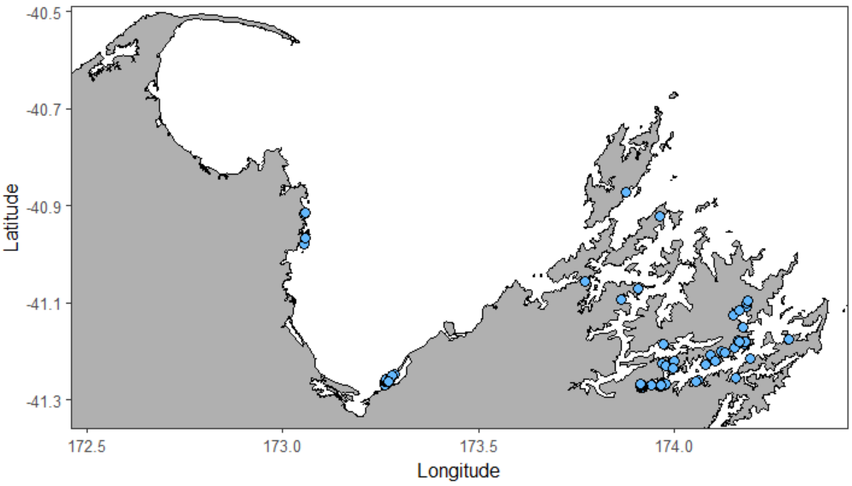
Table 5. Change in regional prevalence of the sea squirt *Styela clava* over time, based on results of three summer snorkel surveys. The 2015/16 survey included Port Tarakohe, and the 2017/18 survey included vessels and swing moorings in Nelson Harbour.

Survey	Boats with *Styela* # (%)	Structures with *Styela* # (%)
2015/16	4 (1.8%)	3 (2.2%)
2016/17	6 (3.3%)	2 (2.7%)
2017/18	28 (5.2%)	39 (7.1%)

a. *Styela* on vessels (n=28, 5.2%)



b. *Undaria* on vessels (n=86, 15.8%)



c. *Didemnum* on vessels (n=50, 9.2%)

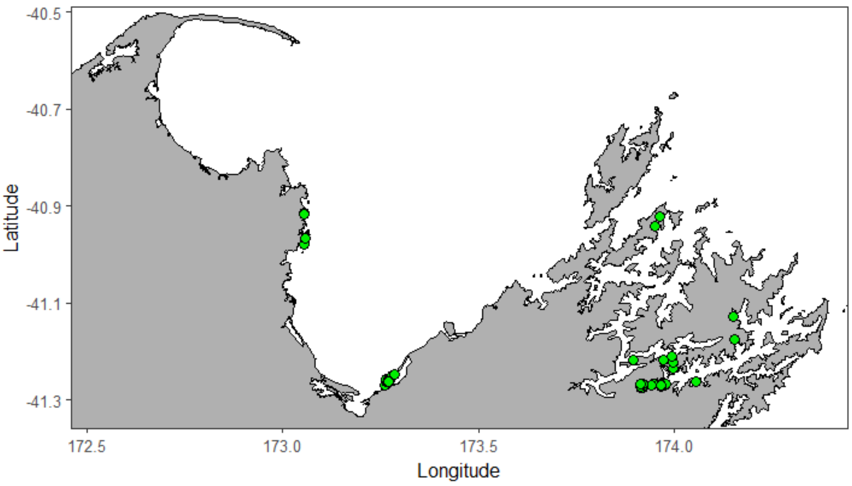


Figure 8. Locations of the 544 vessels surveyed in summer 2017/18 that were fouled by: a. *Styela*, b. *Undaria* or c. *Didemnum*. Bracketed numbers indicate the number of vessels infected by each species, and the percentage of total boats. Some symbols overlap due to survey points close to each other.

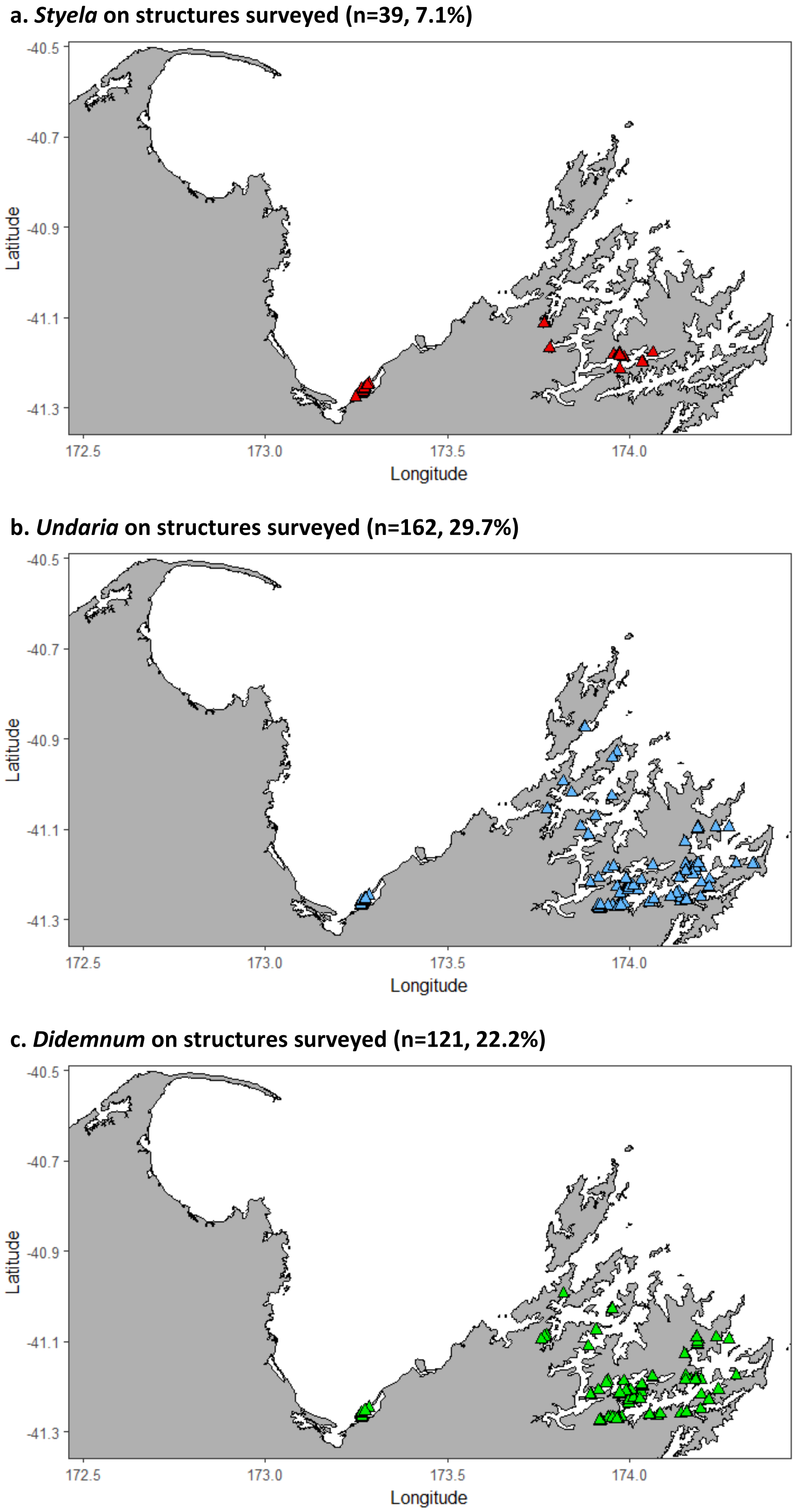
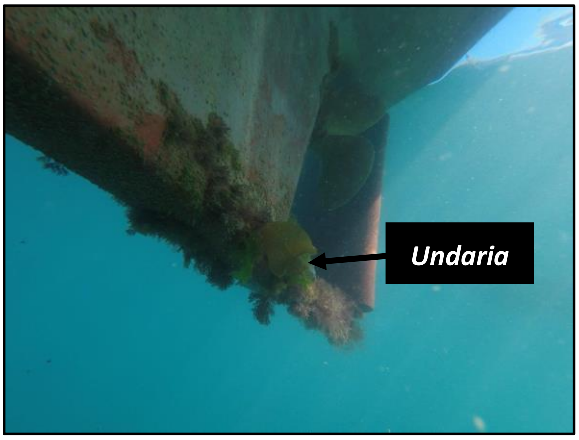


Figure 9. Locations of the 546 structures surveyed in summer 2017/18 that were fouled by: a. *Styela*, b. *Undaria* or c. *Didemnum*. Bracketed figures indicate the number of vessels, and percentage of total, infected by each species. Some symbols overlap due to survey points close to each other. Note that all three species occurred in the main vessel hubs.



The bottom of the keel, especially in the case of yachts, can be heavily-fouled even when the main hull is clean and well-antifouled

In addition to *Styela*, the survey again highlighted the widespread occurrence of the two longest-established pests – the kelp *Undaria* and sea squirt *Didemnum* (Figure 8b,c; Figure 9b,c). The base of the keel was also an important niche area for these two species. *Undaria* was first recorded in the TOS in Picton in 1991 and Nelson in 1997. Despite its long-time presence, there remain more remote parts of the TOS from which *Undaria* has not yet been reported (e.g. islands on the north side of the Sounds), and whose biodiversity values *Undaria* still threatens. Recreational vessels are a potentially significant vector for *Undaria*'s spread to such areas.

Didemnum is a more recent arrival than *Undaria*, being first detected in the TOS in 2001 in Shakespeare Bay (Coutts and Forrest 2007). By 2008, regional surveys conducted during two separate *Didemnum* management programmes revealed >100 new populations of the species throughout the Marlborough Sounds, with further populations in Nelson and Tarakohe (Forrest and Hopkins 2013). Both *Undaria* and *Didemnum* illustrate that, without effective vector management, marine pests can become well-entrenched regionally, relatively quickly. Based on the most recent results, *Styela* appears to be following a similar pattern.

3.5 Occurrence of marine pests in relation to vessel activity and levels of fouling

Figure 10 highlights the clear trend previously reported, that as LOF increases, so does the proportion of vessels carrying marine pests. Pests were notably less prevalent on active vessels (13% infected), than vessels whose activity status was unknown (29% infected). Active vessels also had a lower prevalence of pests in the higher LOF (3-5) categories. Pests were slightly more common on sail boats (24% infected) than power boats (19% infected). These differences are consistent with research findings that marine pests may be physically dislodged or damaged on active vessels, especially those whose speeds exceed c. 10 knots (yachts would typically travel at c. 7-8 knots). For active vessels, it is probably also the case that maintenance is often conducted before planned voyages (see next section).

Figure 10 highlights that vessels with even light fouling (LOF 2) can harbour marine pests; for example, c. 7% of LOF 2 vessels had pests (21 of 306 LOF 2 vessels). As noted above, this situation arose due to the occurrence of *Styela* and other pests on the bottom of the keel, or in other niche areas (e.g. rudder, pipe outlets, trim tabs) that lacked an effective antifouling coating.

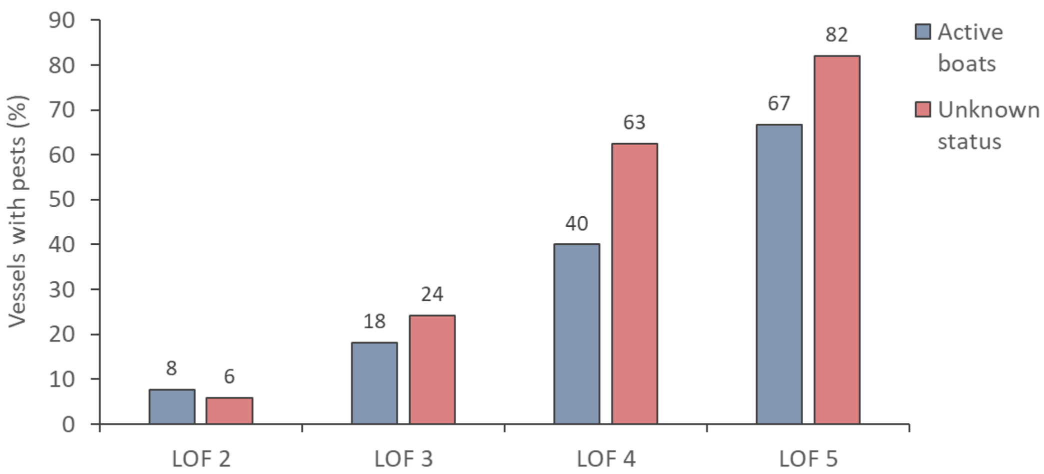


Figure 10. Percentage of recreational boats with any of the designated pests from Table 2 present in each LOF category, with boats categorised as being in active use or of unknown activity status. By definition, no visible pests can be present at LOF 1 (no macrofouling, see Table 1). Numbers at top of each bar are percentages.

The bottom of vessel keels is difficult to antifoul, and is a problem area for pests

The TOS Coordination Team has been investigating solutions for improving effective coating application in such niche areas. In the case of vessel keels, a key challege is that the bottom of the keel can be difficult to access while the boat is on hard-stand. While it is technically feasible to have the boat lifted (e.g. by travel-lift) so the keel can be coated, the cost increases and the lift itself may be unavailable. Many boaters therefore paint the keel bottom when their vessel is lifted off the hard-stand for placement back into the water. However, due to insufficient drying time it can be expected that most of this paint would soon wash off. Hence keel antifouling will be ineffective, and pulses of antifouling contaminants like copper will be released.

3.6 Boater antifouling and cleaning habits

Based on 221 boaters who knew their vessel's maintenance history, just over a third said that antifouling had been undertaken in the three months prior to the fouling survey, with almost half of vessels having been antifouled within the preceding six months (Figure 11). The median time since last antifouling was eight months (mean 9 months ± SE 0.04). Approximately 57 (26%) of boaters had cleaned their vessel since last being antifouled, 84% of whom had cleaned within three months of the survey. Based on this figures, the incidence of cleaning as a hull maintenance method is with the range reported from other recreational boat studies in New Zealand and overseas (Lacoursière-Roussel et al. 2012; Brine et al. 2013; Clarke Murray et al. 2013; Forrest 2017b).

Of interest from the present survey is that about a quarter of the 57 boaters that had cleaned (equating to 6% of total boaters interviewed in 2017/18) had cleaned their vessel in the few days before our survey (i.e. cleaned in-water while on holiday). For this subset, the mean time since last antifouling was 12 months (range 3-30 months). As such, while not all of these boats would necessarily have been heavily fouled, marine pests would conceivably have been present and dislodged to the seabed during cleaning. More generally, the TOS boater questionnaire data reported by Forrest (2017b) indicate that nearly a third of boats may be cleaned in locations outside the main vessel hubs. Hence, it is not just fouled vessel movements, but also cleaning habits, that are likely contributing to regional biosecurity risk.

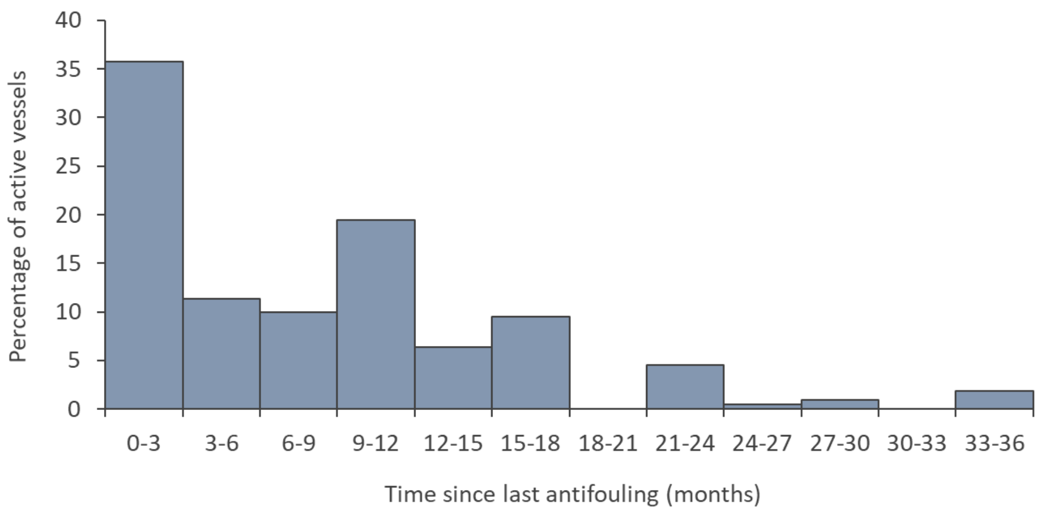


Figure 11. Months since last antifouling (i.e. antifouling paint age) reported by boaters (n=221) during the 2017/18 survey.

In fact, the relationship between LOF and time since last antifouling is highly variable (Inglis et al. 2010; Forrest 2017b), reflecting that a range of risk factors work together to determine the fouling status of a vessel's hull. These include cleaning habits, vessel speed during travel, the amount of time the vessel sits idle (which enables fouling to accumulate) and the type of antifouling coating used. The TOS report by Forrest (2017b) describes a comprehensive analysis of the relationship between fouling accumulation and these types of risk factors, based on aggregated data from in-water snorkel surveys and surveys conducted out-of-water at haul-out facilities (Waikawa and Nelson).

In the present report, a comprehensive analysis is not undertaken, but summary data are presented for the regional snorkel surveys conducted over the last three summers. The data are displayed in Figure 12 as box-and-whisker plots. Figures 12a & 12b illustrate the distribution of antifouling paint ages (i.e. boater responses on months since last antifouling) for each LOF category, partitioned into boats that had either been cleaned or not cleaned since last being antifouled. Time since last cleaning is shown in Figure 12c.

For boats not cleaned (Figure 12a), increases in vessel LOF are characterised by clear increases in time elapsed since last antifouling (i.e. antifouling paint age). For example, vessels categorised as having light fouling (LOF 2) had a median paint age of c. 4 months, moderately to heavily fouled vessels (LOF 3 & 4, respectively) had median paint ages of c. 13-14 months, while for very heavily-fouled vessels (LOF 5) the median paint age was almost 30 months.

For cleaned boats (Figure 12b), the contrast in median paint age across LOF

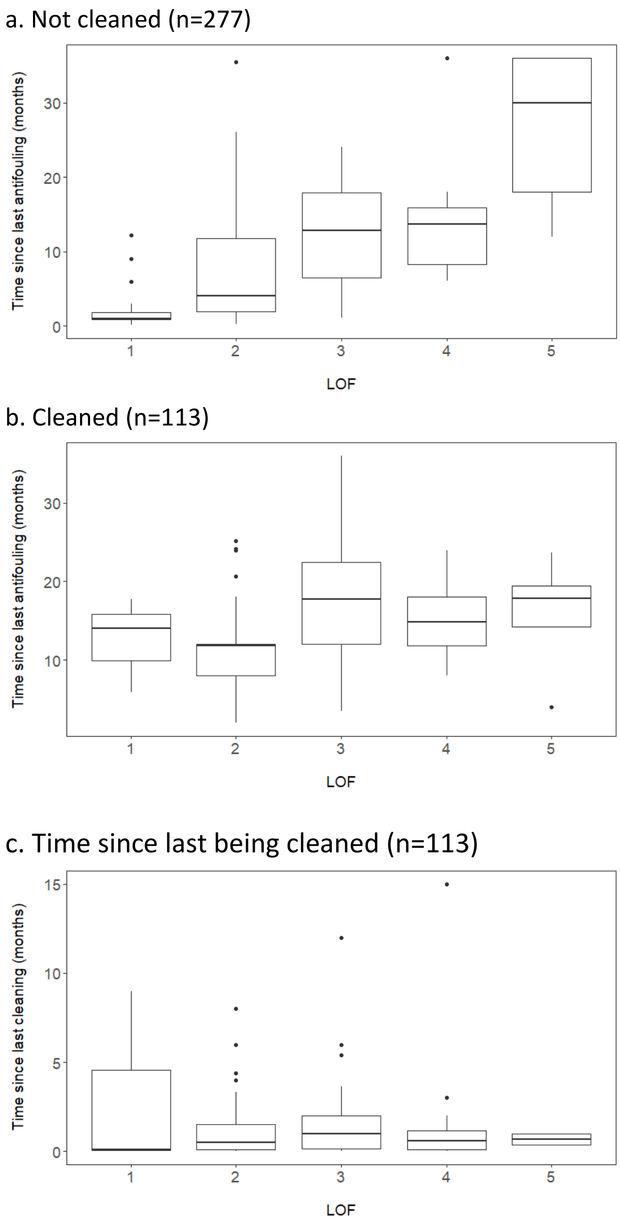


Figure 12. LOF scores and maintenance data aggregated over three summer snorkel surveys. (a) & (b) show the distribution of antifouling paint ages (i.e. time since last antifouling) for vessels grouped by LOF according to whether they had been cleaned (n=113) or not (n=277) since last being antifouled. For cleaned vessels, the distribution of months since last being cleaned is shown in (c). These graphs are based on vessels antifouled with the previous 36 months (outliers are excluded. Horizontal bars in the boxes represent medians, the top and bottom ends the upper (75th) and lower (25th) quartiles respectively, and extending lines (and dots) are the extremes.

1-5 is less apparent. As many of the vessels had been cleaned in the days or a few months prior to the survey, there were vessels that had either no macrofouling (i.e. they were LOF 1) or only light macrofouling (LOF 2) despite their median paint ages being c. 12-14 months. By contrast, there existed vessels with antifouling coatings <24 months old that were scored as being very heavily fouled (LOF 5; Figure 12b) despite having been cleaned a short time before the survey (Figure 12c). A probable explanation for the latter result is that vessels become heavily fouled in the first instance because their antifouling coating is no longer effective. As such, despite being cleaned, the vessel is quickly recolonised by biofouling.

One of the unresolved questions is whether antifouling paint efficacy is being reduced by cleaning practices. LOF values for cleaned boats overall slightly exceeded that for boats not cleaned, which is counterintuitive, but was also described by Forrest (2017b). A possible explanation is that boaters who clean their vessel hull between antifouling intervals are in some instances using methods (e.g. brooms, scrubbing brushes) that are too harsh for the “soft” ablative or semi-ablative biocidal coatings that are typically applied to the hulls of recreational boats (data in Forrest 2017b indicate that soft biocidal coatings are used on c. 83% of boats in the TOS). Such cleaning methods are likely to damage the antifouling coating and reduce its effectiveness. However, there may be other explanations, and clarification of this situation would require further investigation; e.g. a more rigorous experimental approach to assess cleaning effects on paint integrity, as well as systematic collection of information on cleaning methods used by boaters.

4 SYNTHESIS OF FINDINGS AND FURTHER CONSIDERATIONS FOR REGIONAL SURVEILLANCE

4.1 Key findings and implications

The 2017/18 study builds on previous summer surveys and highlights the importance of managing recreational vessels in order to prevent or slow the spread of marine pests. Although the Mediterranean fanworm was not detected, the fouling status of boats remains similar to previous surveys. Overall, hull fouling was the greatest on vessels from Nelson, less on vessels from Marlborough, and least on vessels visiting from outside the region. However, in most cases, the fouling status on most of these vessels was such that they have the potential to transport marine pests into or within the TOS region, if pest populations become well-established in their source regions.

The long-established marine pests, *Undaria pinnatifida* and *Didemnum vexillum*, were widespread. The most notable change since 2016/17 was the increased prevalence and relatively widespread distribution of the sea squirt *Styela clava*. The disjointed distributional pattern of this species is consistent with human-mediated spread rather than natural dispersal. The current prevalence and wide distribution of *Undaria* and *Didemnum* likely reflects the future distribution (e.g. over the next 10-20 years) of *Styela*, and also of the fanworm in the absence of comprehensive management.

Survey results illustrate that intensive population control for target pests in vessel hubs is an effective way to reduce vessel colonisation and subsequent vessel-mediated spread. The fanworm has been managed to low densities in Nelson, Picton and Tarakohe, and was not recorded anywhere outside of these hubs. By contrast, the more abundant unmanaged pests in these hubs were the ones that were prevalent on vessels. In the absence of *Styela* population control, or continued fanworm control, it can be expected that vessels in TOS hubs will increasingly act as vectors for the within-region spread of multiple marine pests. Similarly, the high proportion of boats from Wellington highlights the potential importance of Wellington marinas as source regions for pests to the TOS. Wellington marinas are not currently thought to have fanworm, but if it established those locations would become significant sources for fanworm spread into the TOS.

The above results reinforce the importance of direct management of vessel fouling as an integral part of effective biosecurity. The limitation of population control is that it addresses only the target pest. It is also expensive to achieve effective target pest control across anything but very local scales (e.g. within marinas). Achieving effective vector management is not straightforward either, as it requires means to address the risk from vessels coming into the TOS from other regions. With this in mind, the TOS Coordination Team is already working with Wellington marinas to develop effective management approaches for vessels planning to visit the TOS. As part of ongoing work, the Team is considering the best ways to address potential risks from other regions, especially Northland and Auckland where the fanworm is established.

A significant challenge for effective vessel management is niche area fouling on the bottom of vessel keels, especially in situations where the main hull appears well-maintained and free of visible fouling. As well as being a biosecurity risk, the niche area issue has implications for determination of compliance with management standards, such as a Nelson marina berth agreement requiring that: "The Berth-holder shall keep hulls clean of designated marine pests and free of conspicuous bio-fouling…". To reliably determine the occurrence of pest organisms would require an in-water assessment method (e.g. diving, surface-operated camera). The Coordination Team will continue to explore the potential for development of effective antifouling practices for keels.

A related challenge, and critical issue to address, is the lack of capacity at haul-out facilities (especially in Nelson) to enable boaters to be lifted from the water for cleaning or maintenance. As well as lack of facilities, hard-stand cost in Nelson has been an ongoing complaint from boaters, with some going further afield (Motueka, Waikawa) for maintenance. In the 2017/18 peak-summer period we encountered a vessel from Nelson marina with *Styela clava* on its hull, which was anchored along the Abel Tasman coast. The owners were embarrassed about the state of their vessel; they had made a travel-lift booking the previous October, but had been unable to arrange a haul-out until the following February. As such, they went on holiday knowing they had a dirty hull. According to the latest Fiordland Marine Guardians newsletter (June 2018), the same issue of infrastructure shortage has arisen in Bluff, subsequent to the implementation of the Fiordland Marine Regional Pathway Management Plan.

Until the TOS infrastructure issue is resolved, the risk profile of recreational vessels plying the region's waters is probably going to worsen; e.g. more-recent pests including *Styela* and the fanworm will occur at greater prevalence on active boats. Exacerbating this situation is the likelihood that boaters may scrape these pests to the seabed while they are moored or anchored in high-value areas. Arguably, it is futile to be advocating or regulating improved hull hygiene without systems in place to support best practice. In the meantime, promoting the recently-developed guidance on acceptable in-water cleaning in the TOS may assist discouraging undesirable practices (see: http://www.marinebiosecurity.co.nz/downloads/4741190/in-water+cleaning.pdf).

4.2 Considerations for enhancing surveillance and management

4.2.1 Plugging holes in the TOS "border"

In terms of the chain of events that lead to risk to the TOS from external vessels, the three key points of management intervention are:

- **Before the vessel leaves home port:** As noted, the Coordination Team, is working with other regions to try and develop effective ways to ensure the vessels bound for the TOS arrive with a clean hull. As well as working directly with other councils and marinas, the Team is investigating the use of biosecurity messaging via social media (e.g. messaging on smartphone apps used by boaters).

- **Upon arrival:** Biosecurity messaging as above could also target vessels that were not cleaned before leaving home port, to promoting cleaning or inspection upon arrival. More could also be done to get advanced notice of vessels arriving from outside the TOS; e.g. via trip reports on marine radio or via more formalised liaison re slipway/boatyard bookings.

- **During the visit:** There is scope to improve detection and *ad hoc* risk profiling of out-of-region vessels that are encountered during their visit to the TOS. One of the several benefits of working with the Harbour Masters and Department of Conservation is that the skippers typically recognise unfamiliar vessels from outside their district. During our field surveys, such vessels are inspected when encountered, but there are likely to be many more that go undetected but which may be high risk. An option to consider would be to enlist the ongoing support of the Harbour Masters and DOC to assist with risk-profiling such vessels when they encounter them during their routine business. This profiling could include:

  - Approaching the vessel and asking questions regarding port of origin, time since last antifouling, and intended duration of stay.

  - Recording LOF from surface observations.

  - Passing the information to the relevant council or the Coordination Team, who could decide whether an in-water inspection was warranted.

4.2.2 Regional surveillance gaps

It is important that the snorkel-based work integrates closely with the other surveillance activities, while maintaining the broader data collection and boater interaction focus. The discussion below covers these two aspects.

Snorkel-based surveillance

Queen Charlotte Sound: In 2017/18 the greatest intensity of TOS effort was focused on Queen Charlotte Sound. This is justified from a risk perspective in that this area has the greatest number of moorings and other structures, and is arguably at greatest risk due to the relatively high proportion of visiting vessels. The same type of survey approach for this area is recommended for summer 2018/19, covering the same general areas.

Pelorus Sound: Coverage was relatively low in Pelorus Sound in 2017/18, reflecting that high-risk boating activity is relatively low in that area; it includes many fizz boats, boats from Havelock marina, and marine farming vessels. Nonetheless, surveillance could be enhanced in 2018/19 by including at least one survey day targeted at vessels that are active during the busy Xmas/New Year period. A more comprehensive SCUBA-based assessment of Elaine bay is also recommended (see below).

Outer Sounds: Outside the confines of Queen Charlotte and Pelorus Sound, there are outer bays worth checking that are known to be used by visiting boaters (e.g. Anakoha Bay). Visiting vessels also frequent Greville Harbour and Port Hardy on D'Urville Island. It is difficult to justify going to the D'Urville sites due to cost, weather dependency, and the "hit and miss" nature of the work (i.e. we may encounter very few vessels). However, French Pass is an area that warrants checking, given that some boats transit there to/from Nelson.

Nelson: The original intention was that Nelson would be covered as part of the SCUBA-based assessment. As this did not happen over the summer period as expected, the snorkel survey was an add-on the original scope of that work. However, as that survey was conducted outside peak season, the opportunity was lost to interact with visiting vessels. For 2018/19 it is recommended that all vessels and swing moorings are checked using SCUBA (see below), but that it may be worth intermittent snorkel-based checks of boats visiting during the peak season.

Tasman Bay and Abel Tasman: The Abel Tasman snorkel survey is worth continuing, but the Team would ideally time one of the days to coincide with the annual peak on New Year's eve or day. Consideration should also be given to checks in Mapua and the parts of Motueka marina that are not exposed at low tide. Motueka should be checked on SCUBA due to the (generally) low water clarity. At Mapua, boats could be screened for general fouling status using snorkel (at high neap-tide slack water), to determine whether there was any value in a comprehensive SCUBA survey.

Golden Bay: Port Tarakohe is part of the SCUBA-based fanworm survey programme. In 2017/18 very few boats were picked up outside the Abel Tasman coast (e.g. two at Tata beach), and surface checks of boats and structures at Whanganui Inlet and Waitapu revealed very little fouling. As such, there is no great need for snorkel checks, assuming the Tarakohe work continues. However, to ensure that wide surveillance is adequate, a further consideration is to get the marine farming industry more formally involved in fanworm checks at places like Wainui Bay and the Golden Bay "ring road" area (see below).

Broader fanworm surveillance activities

To align with the snorkel-based surveys, and maximise the chance of fanworm detection, key considerations for broader surveillance activities are:

- **SCUBA checks and infilling of existing gaps:** The SCUBA programme should aim to ensure that the areas where fanworm is most likely to be found are comprehensively checked. SCUBA provides a better method than snorkelling in areas of low water clarity, where heavy fouling is present, and where water depths >5m need checking. SCUBA checks would ideally be more comprehensive than at present; for example, they should:

- Target all vessels, structures and seabed in the key hubs. In 2017/18, SCUBA coverage of boats, swing moorings and adjacent seabed was incomplete in the areas checked (Waikawa Bay, Picton, Nelson Harbour, Tarakohe).
- Be conducted at a frequency (at least twice per year) that maximises the chance that fanworm not detected in one survey will be detected in the next (before becoming reproductively mature).
- Consider covering potentially at-risk areas outside main hubs, including: (i) areas which fanworm-infected vessels have visited, (ii) anchorages for out-of-region vessels (e.g. Anchorage, Adele Island, Ship Cove), (iii) secondary hubs such as Elaine Bay, which is important for the aquaculture industry. In 2017/18, only a limited check was made on the vessels and some of the structures in Elaine Bay (floating pontoons, pilings and parts of the rock wall).

- **Enhancing stakeholder surveillance:** The Coordination Team has been working with the aquaculture industry and mooring service providers, to try and enhance regional surveillance for the fanworm. As well as informal and formal training sessions in fanworm identification and reporting, this approach involves encouraging addition of a fanworm check-box (or similar) to data sheets that these stakeholders used to record operational information. It is hoped that this approach will keep the fanworm front-of-mind for stakeholders who are on the water daily, hence enhance the likelihood of detection.

5 ACKNOWLEDGMENTS

This work could not have been undertaken without the generous support of the Tasman and Marlborough Harbourmasters, and Department of Conservation. Dan Cairney (Harbour Master, Tasman) and Jimmy MacKay (Deputy Harbourmaster) provided boat and support for Golden Bay and the Abel Tasman surveys. Luke Grogan (Harbour Master, Marlborough) and Jan Everleens (Deputy Harbour Master) provided or arranged boat support and skippers (Clive Whitlock, Alex Moore, Paul Smith, Mark Randall, Rob Carpenter) for Pelorus and Queen Charlotte Sounds. Leanne Flynn (DOC, Picton) coordinated DOC skippers (Joe Healey, Dan Palmer, Phil Clerke) for work in Queen Charlotte Sound. James Brodie (Marlborough Diving Services) provide boat support for Pelorus Sound. Finally, I thank Peter Lawless and Charmayne King (TOS Coordination Team) for field assistance, report review and formatting.

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Appendix 1. Design elements of tablet-based reporting template developed with software available at: www.fulcrumapp.com

Main field	Main field and sub-field	Type of field	Allow other	Required	Field choices	Conditional rule for field display
1. Survey location	**Section**	Single choice	y	y	Abel, Gbay, Mapua, Mot, Nel, Qcs, Pel, Pundy, Riwaka, Tory	None
2. Vessel survey	**a. Vessel surveyed**	Yes/No	na	na	y, n	None
	b. Vessel type	Single choice	n	y	Power, sail	Vessel surveyed = yes
	c. Boater present	Yes/No	na	y	y, n	Vessel surveyed = yes
	d. Home port	Multiple choice	y	y	Auckland, Havelock, Lyttelton, Motueka, Nelson, Picton, Portunderwood, Riwaka, Tarakohe, Waikawa, Wgtn_Chaff, Wgtn_Clyde, Wgtn_Evans, Wgtn_Mana, Wgtn_Seaview, Wgtn_Other, Na	Vessel surveyed = yes
	e. Months since last AF	Decimal	n	y	Free form	Vessel surveyed = yes
	f. Boat cleaned?	Single choice	n	y	y, n, na	Vessel surveyed = yes
	g. Months since last clean	Decimal	n	y	Free form	Boat cleaned = yes
	h. LOF	Single choice	n	y	1, 2, 3, 4, 5	Vessel surveyed = yes
	i. Pest present on vessel	Yes/No	na	y	y, n	Vessel surveyed = yes
	j. Vessel pest name	Multiple choice	y	y	Didemnum, Eudistoma, Pyura, Sabella, Styela, Undaria, Unknown	Pest present on vessel = yes
	k. Vessel pest sample taken	Yes/No	na	y	y, n	Pest present on vessel = yes
	l. Vessel pest sample code	Text	na	y	Free form	Vessel pest sample taken = yes
	m. Vessel pest photo	Photos	na	y	na	Vessel pest sample taken = yes
3. Mooring survey	**a. Structure surveyed**	Yes/No	na	na	y, n	None
	b. Structure type	Single choice	y	y	Mooring, pile jetty, pontoon jetty, rockwall, other	Structure surveyed = yes
	c. Pest present on structure	Yes/No	na	y	y, n	Structure surveyed = yes
	d. Structure pest name	Multiple choice	y	y	Didemnum, Eudistoma, Pyura, Sabella, Styela, Undaria, Unknown	Pest present on structure = yes
	e. Structure pest sample taken	Yes/No	na	y	y, n	Pest present on structure = yes
	f. Structure pest sample code	Text	na	y	Free form	Structure pest sample taken = yes
	g. Structure pest photo	Photos	na	y	na	Structure pest sample taken = yes
4. Notes	**Section**	Text	na	n	Free form	None