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Regional recreational vessel fouling and marine pest surveys: synthesis of data 2016-2019

Prepared for
Top of the South Marine Biosecurity Partnership
June 2019

Salt Ecology
Report 017

RECOMMENDED CITATION

Forrest BM 2019. Regional recreational vessel fouling and marine pest surveys: synthesis of data 2016-2019. Salt Ecology Report 017, prepared for Top of the South Marine Biosecurity Partnership. 27p.

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June 2019

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ACKNOWLEDGEMENTS

This work could not have been undertaken without the generous support of the Tasman, Nelson and Marlborough Harbourmasters, and Department of Conservation.

Dan Cairney (Harbour Master, Tasman) and Jimmy MacKay (Deputy Harbour Master, Tasman) provided boat support for the Abel Tasman surveys.

Amanda Kerr (Deputy Harbour Master, Nelson) provided boat support for Nelson Harbour.

Luke Grogan (Harbour Master, Marlborough) and Jan Everleens (Deputy Harbour Master, Marlborough) provided boat support for Pelorus and Queen Charlotte Sounds, along with MDC skippers including Alex Moore and Rob Carpenter.

Leanne Flynn (DOC, Picton) coordinated DOC skippers (Richard Andrell, Dan Palmer) for work in Queen Charlotte Sound.

Finally, I thank Thomas Scott-Simmonds (Salt Ecology) and Peter Lawless (TOS Coordination Team) for field assistance, Leigh Stevens (Salt Ecology) and Peter Lawless for review of a draft report, and Charmayne King (TOS Coordination Team) for report compilation.

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EXECUTIVE SUMMARY

BACKGROUND

This report provides an overview of a summer survey of biofouling and marine pests on recreational vessels, coastal structures and seabed locations, which was conducted across the Top of the South (TOS) region in 2018/19. In addition, the report provides a synthesis of the latest data together with that collected from three earlier surveys conducted from summer 2015/16 through to summer 2017/18. For simplicity, survey years are referred to as '2016' for the 2015/16 survey through to '2019' for the 2018/19 survey.

The surveys involve checks of biofouling on boats 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 and areas of seabed are simultaneously checked for the presence of six target marine pest species, in particular the Mediterranean fanworm *Sabella spallanzanii*. When boaters are present, they are given information on marine biosecurity and asked questions about their home port and vessel maintenance habits.

A particular focus of the present report was to break down the survey effort and results by two main regions of the TOS; Marlborough and Nelson-Tasman. Nelson and Tasman were aggregated on the basis that they are highly connected by vessel movements, and because the data set for Nelson was insufficient for a standalone analysis. The results from the four surveys are assessed in relation to regional rules and other requirements that have been put in place to control vessel biofouling in Marlborough. Furthermore, given a key goal of understanding risk from boats that are moving throughout the TOS, compared with those that are assumed to be idle, a focus of much of the vessel data analysis is on vessels classified as 'active' according to criteria defined in the report.

KEY FINDINGS AND IMPLICATIONS

In the 2019 survey checks were made of 521 vessels, 401 structures and 47 seabed sites, with a total effort over the four surveys of 2,683 records, comprising 1,478 vessels and 1,158 structures, as well as the 47 seabed sites surveyed in 2019. Key results across four surveys were as follows:

- No pests were found that are new to the TOS region.
- The Mediterranean fanworm was recorded only once outside the know infected vessel hubs. This was in 2016, when juvenile specimens were found on a vessel (originally from Auckland) that was holidaying in Queen Charlotte Sound.

Other than the single vessel record, the absence of fanworm beyond the known infected areas (i.e. in Picton, Waikawa, Nelson, Tarakohe) likely reflects that populations in those areas are being periodically removed by divers as part of a SCUBA-based control programme, thereby reducing the reproductive reservoir for infection of vessels. By contrast with the fanworm, the sea squirt *Styela clava* has become regionally common in certain areas, although the longest-established pests (the Asian kelp *Undaria pinnatifida* and sea squirt *Didemum vexillum*) are by far the most widespread, especially on artificial structures. For all established species, the disjointed distribution is consistent with human-mediated spread rather than natural dispersal, highlighting the importance of managing spread by hull fouling.

The fouling (LOF) status of boats in 2019 was largely similar to previous surveys, except for those originating from Nelson-Tasman on which the incidence of heavy fouling appears to have increased. Overall, hull fouling was the greatest on vessels from Nelson, less on vessels from Marlborough, and least on vessels visiting from outside the TOS region. Out-of-region visiting boats made up 23% of total records, but their occurrence was disproportionate across the two TOS regions, with visitors comprising ~30% and 12% of boats active in Marlborough and Nelson-Tasman, respectively. In the case of Marlborough, most of the out-of-region boats were from Wellington, especially Mana marina on the Kapiti coast. Very few boats come from other parts of New Zealand, and it is uncommon to encounter vessels from overseas. Wellington marinas are not currently thought to have the fanworm or other pests of significance to the TOS, but if such pests established, those locations would clearly become significant sources for new introductions.

Findings were assessed in relation to compliance with hull biofouling rules developed by Marlborough District Council and Port Marlborough marinas, revealing that non-compliance is likely for a relatively high percentage of visiting boaters. The results reinforce the importance of direct management of vessel fouling as an integral part of effective biosecurity. A significant challenge 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 macrofouling organisms.

A related challenge, and a 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 that many boaters clean their fouled hulls while they are moored or anchored in high-value areas. Arguably, it is futile to be advocating or regulating improved hull hygiene without infrastructure and systems in place to support best practice.

FURTHER CONSIDERATIONS AND RECOMMENDATIONS

In the 2018 survey report a range of options and approaches were discussed for improving on the current situation, by systematically implementing management intervention at key points in the chain of events that lead to risk to the TOS. Among the key needs identified were approaches to ensure that visiting vessels:

- Are detected before or upon arrival through an improved intelligence system.
- Arrive in the TOS with a 'clean' hull where this can be achieved.
- Are subjected to a risk-profiling procedure with in-built decision support that links the level of response (e.g. pass, fail/clean, inspect) to the level of assessed risk.

With respect to ongoing summer surveys and related Coordination Team efforts, a number of recommendations for improvement were made in the 2018 report, and many of these were adopted in the 2019 survey. For regional surveillance next summer, it is recommended that survey questions are included relating to hull cleaning practices and locations, and reasons for current behaviours, as this knowledge will better inform the nature of the risk and the types of solutions that might be developed.

Finally, given the high frequency of encounters with visiting boats from Wellington, it would be worthwhile putting in a greater effort to work with marina operators and boaters from that region, as well as with the Greater Wellington Regional Council, to try and further reduce hull fouling risk. Simultaneously, efforts to integrate other stakeholders (e.g. marine farmers) into the surveillance programme should be continued. With all such elements in place, the programme has the best chance of managing the ongoing threat from fanworm and other existing or potential pests to the TOS region's values.

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 (fig. 1), with recreational boats being of particular significance (see Box 1).

As part of engagement activities, four regional field surveys have been undertaken by the Coordination Team during the summers of 2015/16 to 2018/19 (for simplicity, survey years are referred to hereafter as '2016' for the 2015/16 survey through to '2019' for the 2018/19 survey). The purpose was to: (i) collect data on the fouling status of recreational boats; (ii) check for the presence of key marine pests, in particular the Mediterranean fanworm *Sabella spallanzanii* (Table 1), on vessels, moorings, and in other potential habitats; and (iii) engage with boaters regarding marine biosecurity risks, and the need for improved hull antifouling and cleaning practices. Whereas the first two surveys were relatively limited in terms of regional coverage and effort, the latter two have been reasonably comprehensive. This situation reflects an increase in regional surveillance efforts for the Mediterranean fanworm, which is being conducted as part of a broader programme that aims to prevent the establishment of this species beyond its known distribution in four TOS vessel hubs (Picton, Waikawa and Nelson marinas, Port Tarakohe).

To date, reports have been produced for the three surveys up to and including the summer of 2018 (Forrest 2016; Forrest 2017a; Forrest 2018). Together with data collected from regional haul-out facilities (Forrest 2017b), these surveys have revealed a gradual spread of established marine pests in the region, and confirmed the significant risk presented by recreational boats. The present report summarises the findings of the 2019 survey and considers trends in marine pest prevalence and boater maintenance practices across the four survey years. Of particular interest to the TOS council were the trends in their respective regions; hence, a focus of the report is to draw out regional differences between Marlborough and Nelson-Tasman. The latter two subregions were pooled on the basis that they are highly connected,

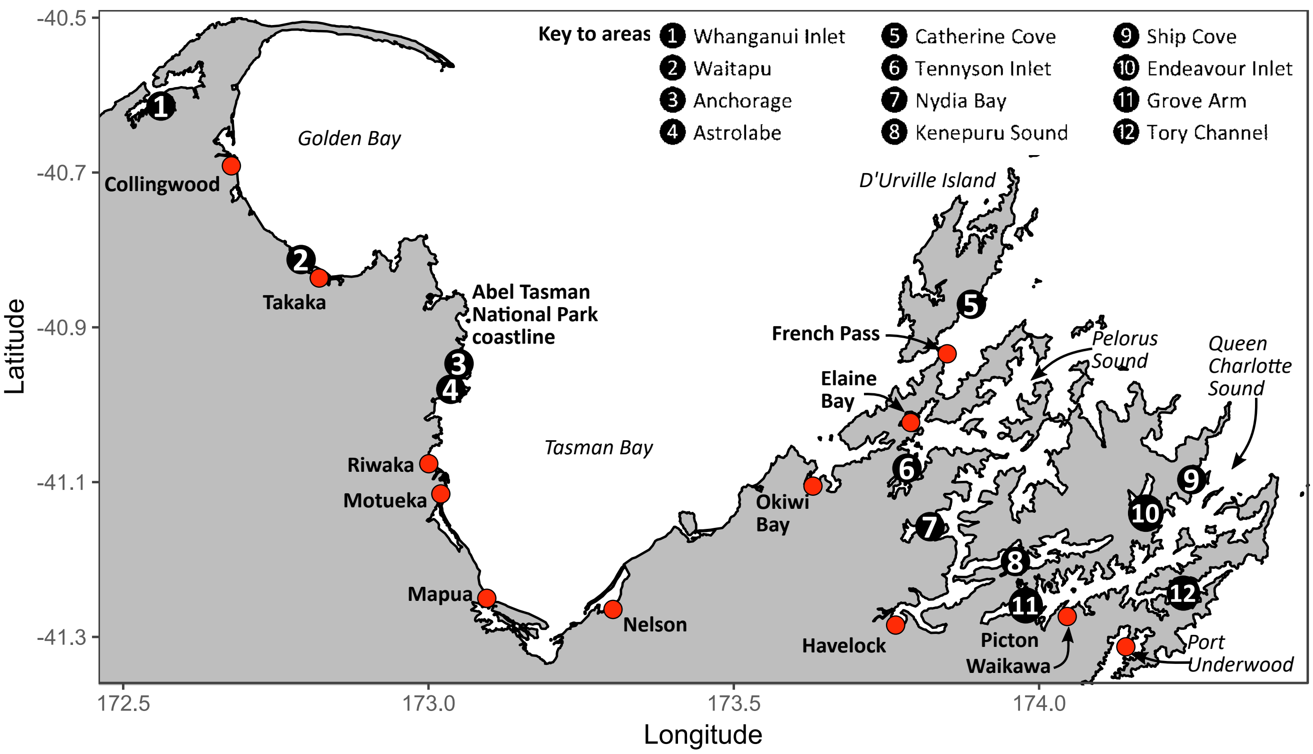


Fig. 1. General region covered during the summer biofouling and marine pest surveys over 2015-2019. The main place names mentioned in the text are shown.

and given that the dataset for Nelson was insufficient for a standalone analysis.

Note that the Coordination Team's surveys have a focus on active vessels (especially visitors from outside the TOS) and marine habitats outside the main marinas and high-density mooring areas. These busier vessel hubs are targeted using intensive SCUBA-based surveys whose primary focus is fanworm detection and removal. The SCUBA surveys are concentrated within the four fanworm-infected hubs, areas adjacent to these hubs (e.g. Shakespeare Bay near Picton), and more remote areas that have not already been comprehensively checked or are considered at potential risk due to vessel activity (e.g. Endeavour Inlet, Elaine Bay). The surveys by the Coordination Team attempt to 'fill the gaps' outside of these intensively-surveyed areas. The main areas of Coordination Team focus, relative to the SCUBA surveys, are shown on Fig. 1.

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 (~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.

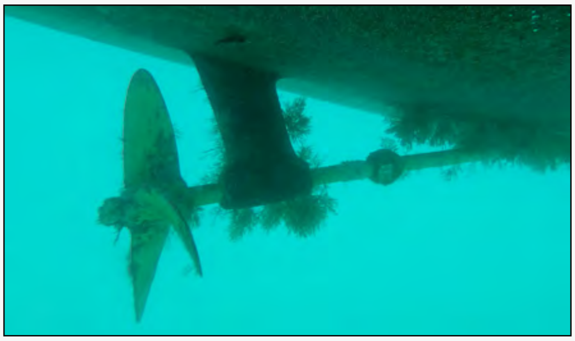
The first reason is that recreational vessels are numerous, and widely scattered across the region. For example, there are almost 2,000 vessels in marina berths in the TOS alone, and around 3,500 consented swing moorings, most of which (c. 3,100) are in Marlborough (Floerl et al. 2015). A second key 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 2017b).
- 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 2017b).

Recreational boats often get heavily fouled.



Some boats have a hull that appears clean, but can be fouled in 'niche' areas below the water-line.

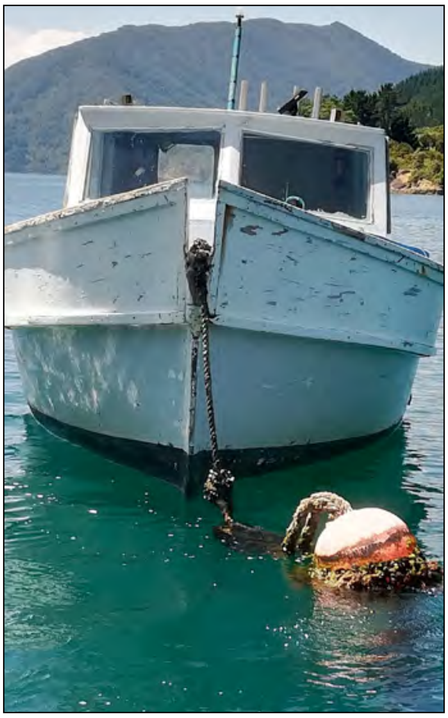
Table 1. Marine fouling pests targeted during regional field surveys. All are MPI-designated marine pests (see MPI 2015) except for *Didemnum vexillum*, which is of regional interest. Specific management programmes in the TOS are currently in place for Mediterranean fanworm.

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, Waikawa,** Lyttelton	
Styela clava	Clubbed tunicate/ Solitary sea squirt	Whangarei, Tutukaka, Auckland, Tauranga, Wellington, **Tarakohe, Nelson, Picton, Waikawa**, parts of **Pelorus Sound, Okiwi Bay**, Lyttelton, Dunedin	
Undaria pinnatifida	Japanee or Asian kelp/ Large brown seaweed	Widespread nationally, including parts of **Tasman, Nelson** and **Marlborough Sounds**	

2. FIELD SURVEY METHODS

2.1 GENERAL APPROACH

The 2019 regional summer survey programme had a similar focus to the comprehensive survey in 2018, in that it encompassed: (i) recreational boats in active use in the TOS region (including vessels visiting from elsewhere in New Zealand); (ii) recreational boats 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). Compared with previous surveys, in 2019 greater emphasis was also placed on checking seabed areas in the vicinity of a selection of the structures.



Swing moorings were checked to depths up to 8m

The survey was conducted over 16 days between 9 December 2018 and 5 February 2019, 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 (including French Pass and Catherine Cove on D'Urville Island), and Queen Charlotte Sound (see Fig. 1). The locations surveyed were coordinated with the SCUBA-based fanworm control programme described above, in order to avoid duplicated effort.

In the regional survey described here, biofouling and/or pest checks were made on recreational vessels and associated structures by free-diving 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.

Vessels and skippers for the summer 2019 survey were provided by the Tasman Harbour Master (Abel Tasman coastline), the Nelson Harbour Master (Nelson Harbour swing moorings), 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.

Boat support was provided by TOS Harbour Masters and the Department of Conservation.

All checks of boats, structures and seabed area involved snorkel diving.

2.2 PRIORITISATION OF SURVEY LOCATIONS

The general snorkel survey locations shown in Fig. 1 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:

- High density mooring areas outside the main hubs (e.g. Grove arm of Queen Charlotte Sound, Tennyson Inlet in 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).
- Remote locations through which out-of-region boats transit (e.g. French Pass).

Random checks were also made of occasional vessels or structures in areas perceived as being lower use, in order to increase geographic coverage.

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.

Unless consent was denied by the boater (when present), the hull of each vessel was checked in-water, with particular attention given to 'niche' areas where fouling tends to accumulate. Depending on vessel type, such areas may include the keel, rudder, trim tabs (power boats only), propeller shaft, pipe outlets, bow-thruster tunnels, and hard-stand support strips.

2.3.2 In-water level of fouling assessment

Each vessel surveyed in-water was assigned an overall 'level of fouling' (LOF) score based on categories described by Floerl et al. (2005) and shown in Table 2 and Fig. 2. The LOF approach has been used in hull fouling studies in the TOS as well as elsewhere in New Zealand (e.g. Lacoursière-Roussel et al. 2012; Brine et al. 2013; Forrest 2016, 2017a, 2018). It is evident from such studies that the likelihood of marine pests being present amongst vessel biofouling increases with increasing LOF.

In some instances, the number of species groups (referred to by the term 'taxa' in Table 2) 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 2 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 Fig. 2. Video examples of LOF categories can be viewed at the following link: http://youtu.be/LMJKZSs8Arg.

Fig. 2. Vessel level of fouling (LOF). Examples of LOF 3 and LOF 5.
For a better impression see video at: http://youtu.be/LMJKZSs8Arg.

Table 2. Vessel 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 (may be only one species)	1 – 5
3	**Considerable fouling**. Presence of biofilm, and macrofouling still patchy but clearly visible and often one or several different species	6 – 15
4	**Extensive fouling**. Presence of biofilm, and abundant fouling assemblages usually consisting of many species	16 – 40
5	**Very heavy fouling**. Diverse fouling 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.

Typical biofouling visible on a jetty at low tide.

Example of pontoon and pile jetty.

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 noted. 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 although not regionally widespread it is becoming common in certain areas outside of 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 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. For the 2019 survey, the template was standardised with that used for the fanworm SCUBA searches, although for present purposes extra fields were added for recording of information from boater interviews. 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 and the software R 3.4.0 (R Core Team 2019) for quality assurance checks, data analysis, and cloud 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 inactive/unknown, which included some boats that appeared relatively derelict (i.e. they were clearly not in use), and others assumed inactive; however, some of these were on private moorings adjacent to dwellings and may have been in active 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 R software. The LOF scores for boats surveyed are compared to the results from the previous summer surveys 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. The results are assessed in relation to regional rules and other requirements that have been put in place to control vessel biofouling. Given the goal of understanding risk from boats that are moving throughout the TOS, compared with those that are assumed to be idle, a focus of much of the vessel data analysis is on vessels classified as 'active' according to the criteria above.

3. KEY FINDINGS

3.1 SURVEY EFFORT

The regional distribution of vessels and search habitats surveyed over the four surveys is shown in Fig. 3, with Fig. 3a showing vessels according to their activity status and Fig. 3b showing the different structure and seabed search habitat categories. A breakdown of survey effort by vessels and search habitats is provided in Table 3. In total, the data set contains 2,683 records collected across the four surveys, comprising 1,478 vessels and 1,158 structures, as well as 47 seabed sites (Table 3). The total effort in 2019 was similar to the comprehensive regional survey in the prior summer, and consisted of searches of 521 vessels, 401 structures and 47 seabed sites. The high vessel numbers achieved in the latest survey reflected that fine weather during the holiday season meant a lot of boaters were on the water.

Table 3 highlights that the majority (~90%) of structure checks are swing moorings. The distribution of effort across the TOS region is weighted to Marlborough, which represents 74% of total vessel checks and 89% of structure checks. This disproportionate effort reflects the far greater boater activity in Marlborough (especially Queen Charlotte Sound), and the substantially greater number (by at least 10-fold) of regionally-dispersed moorings and other coastal structures. In turn, this situation reflects that the Marlborough Sounds covers a vast area (~4,000km^2) and has 1,500km of coastline, which represents about 10% of New Zealand's total.

3.2 ORIGIN OF BOATS ACTIVE ACROSS THE TOS

Home port information was obtained for 656 active boats over the four surveys. The breakdown in Table 4 indicates the home port of origin of active boats for each of the two main regions. Within each region, most of the boats encountered originated from a within-region location. For boaters surveyed in Marlborough, the home region was within Marlborough for ~65% of boaters, who were mainly from Waikawa and Picton. For boaters surveyed in Nelson-Tasman it was even higher, with ~79% originating from within that region. The Nelson-Tasman data mainly reflects boats surveyed along the Abel Tasman coastline, of which about two-thirds originate from Nelson marina.

Of interest is that the data suggest limited movement among regions, with 5% of boats in Marlborough coming from Nelson-Tasman, and ~9% in the opposite direction. The balance reflects out-of-region visiting boaters, which made up 23% of total records for data pooled across four surveys. However, encounters with visiting boaters were disproportionate across the two regions, with visitors comprising ~30% and 12% of boats active in Marlborough and Nelson-Tasman, respectively. In the case of Marlborough, most of the out-of-region boats were from Wellington, especially Mana marina on the Kapiti coast. Very few boats come from other parts of New Zealand, and it is uncommon to encounter vessels from overseas. The bar chart and map in

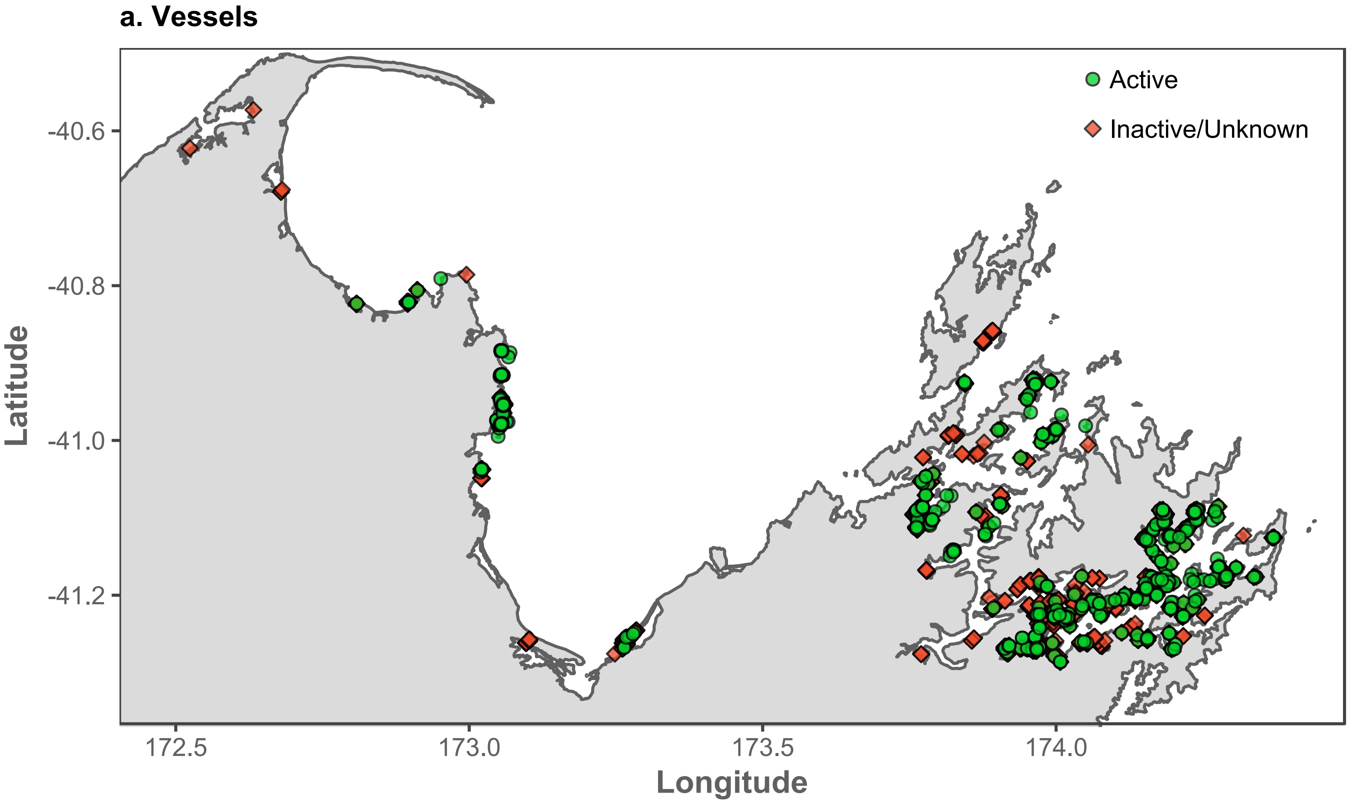
Fig. 4 show the main origin of the boats encountered in each region across each of the four surveys, highlighting both the increased incidence of active boats surveyed over the last two summers (due to efforts to specifically target such boats), and the greater numbers of out-of-region boats active in Marlborough (Fig. 4a,b).

3.3 LEVELS OF FOULING

Fig. 5a shows LOF scores over regions and surveys, comparing active boats with those whose activity status was classified as inactive/unknown, with Fig. 5b illustrating the regional distribution of active boats with respect to each of the five LOF categories.

The summer survey targets vessels scattered across the TOS. Except for Ngakuta Bay seen here, and the head of the Grove arm of Queen Charlotte Sound, surveys of high density mooring areas involve intensive SCUBA-based searches.

The largest vessel encountered was the Aqua Joe, an overseas super yacht that was seen in Queen Charlotte Sound and later inspected in Nelson.



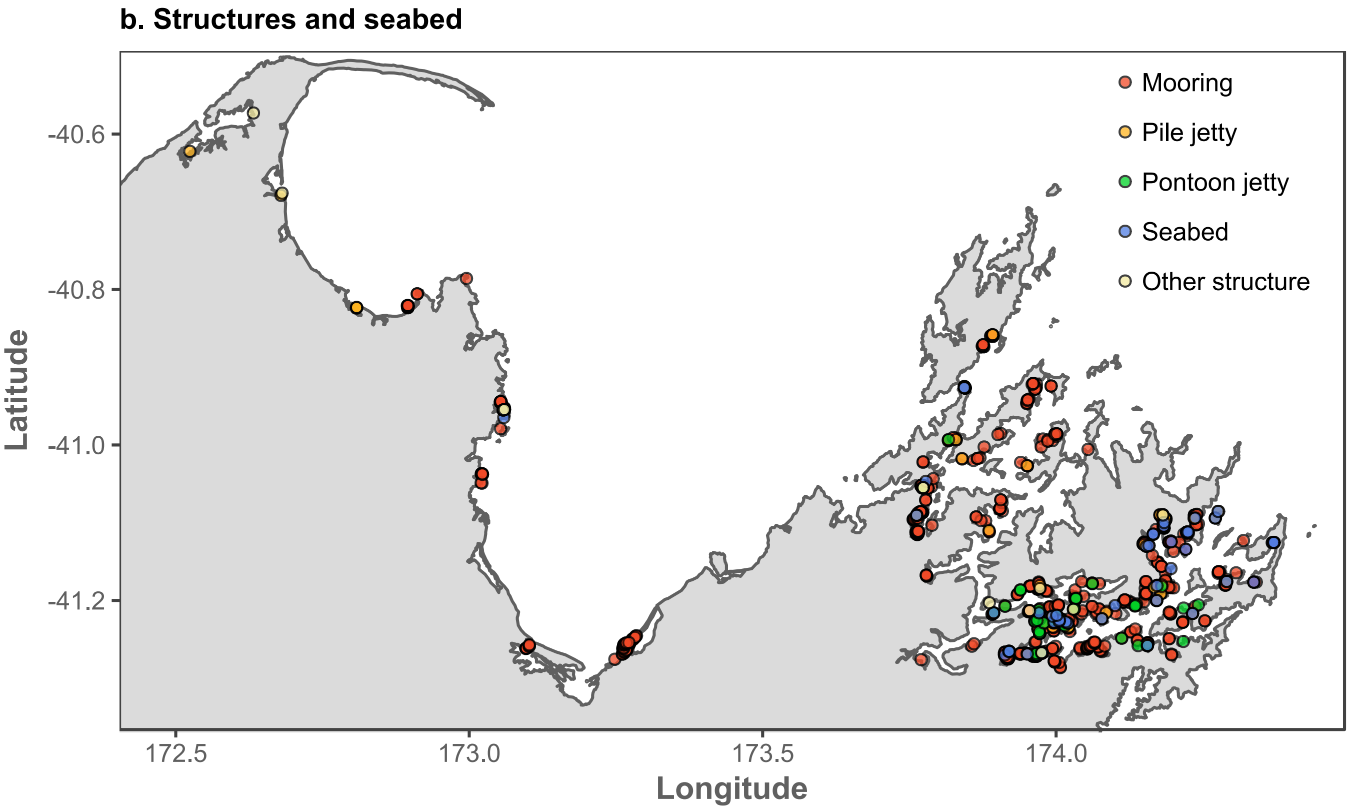


Fig. 3. General localities of: a) 1,478 vessels, showing activity status (as active [n=693] vs inactive/ unknown [n=785]), and b) 1,205 search habitats colour coded by structure type or seabed. These were surveyed for biofouling and marine pests over four summers. Symbols overlap or are obscured due to survey points close to each other.

Table 3. Breakdown of vessels, structures and areas of seabed checked over the four surveys, from a total 2,683 survey records.

Subregion	Survey year	Total vessels	Moorings	Pile jettys	Pontoon jettys	Other structures	Seabed
Marlborough	2016	170	122	-	-	-	-
Marlborough	2017	113	69	3	-	-	-
Marlborough	2018	412	410	39	29	5	-
Marlborough	2019	399	325	14	17	3	45
Marlborough subtotal		***1094***	***926***	***56***	***46***	***8***	***45***
Nelson-Tasman	2016	56	13	-	-	-	-
Nelson-Tasman	2017	74	4	-	-	-	-
Nelson-Tasman	2018	132	54	5	1	3	-
Nelson-Tasman	2019	122	41	-	-	1	2
Nelson-Tasman subtotal		***384***	***112***	***5***	***1***	***4***	***2***
TOTAL		**1478**	**1038**	**61**	**47**	**12**	**47**

As expected, active boats tended to be less fouled, but nonetheless active 'heavily fouled' (LOF ≥4) vessels have been encountered across all parts of the TOS region. The incidence of heavily fouled vessels over the four surveys has ranged from 6-10% on active boats, but is considerably greater on vessels classified as inactive (range 28-31%). This finding is consistent with the expectation based on related research that fouling can be physically dislodged or damaged on active vessels (Coutts et al. 2010a; Coutts et al. 2010b), and that many boaters active in summer will clean or antifoul their vessel hull in the few weeks or months prior to departure from their home port (Forrest 2017b).

Interestingly, the greatest incidence of heavily fouled vessels, both active and otherwise, was recorded in the most recent survey. Similarly, the proportion of active boats in 2019 that had 'conspicuous' fouling on their hull (defined here as LOF of ≥ 3, fouling cover exceeding 5%), was greatest in the latest survey (~28%). 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, therefore, despite progress being made within the TOS Partnership, the overall fouling status of vessels is either not appreciably changing or is in fact getting worse. However, the relatively small year-to-year changes may simply reflect sampling variation (i.e. due to the subjective nature of the LOF assessment) or temporal variation in fouling extent due to natural factors. In Section 3.6 we consider the extent to which changes in hull maintenance practices may also be a contributing factor.

When hull fouling is considered in relation to the main region where vessels were sampled (Fig. 6), it is evident that Nelson-Tasman has a greater incidence of heavily-fouled boats that are active in the region (range 3-16%) than does Marlborough (range 6-7%). Further, while the incidence of heavily-fouled boats has remained fairly constant in Marlborough, in Nelson-Tasman it has become steadily worse, with 16% of active vessels classified as heavily-fouled in 2019.

Out-of-region boats are often found on club moorings in idyllic bays.

Remote outer locations like French Pass attract vessels in transit.

Table 4. Detail of home port information obtained from active boaters, pooled over four consecutive summer surveys. Data shown separately for the two main regions: a. Marlborough, b. Nelson-Tasman.

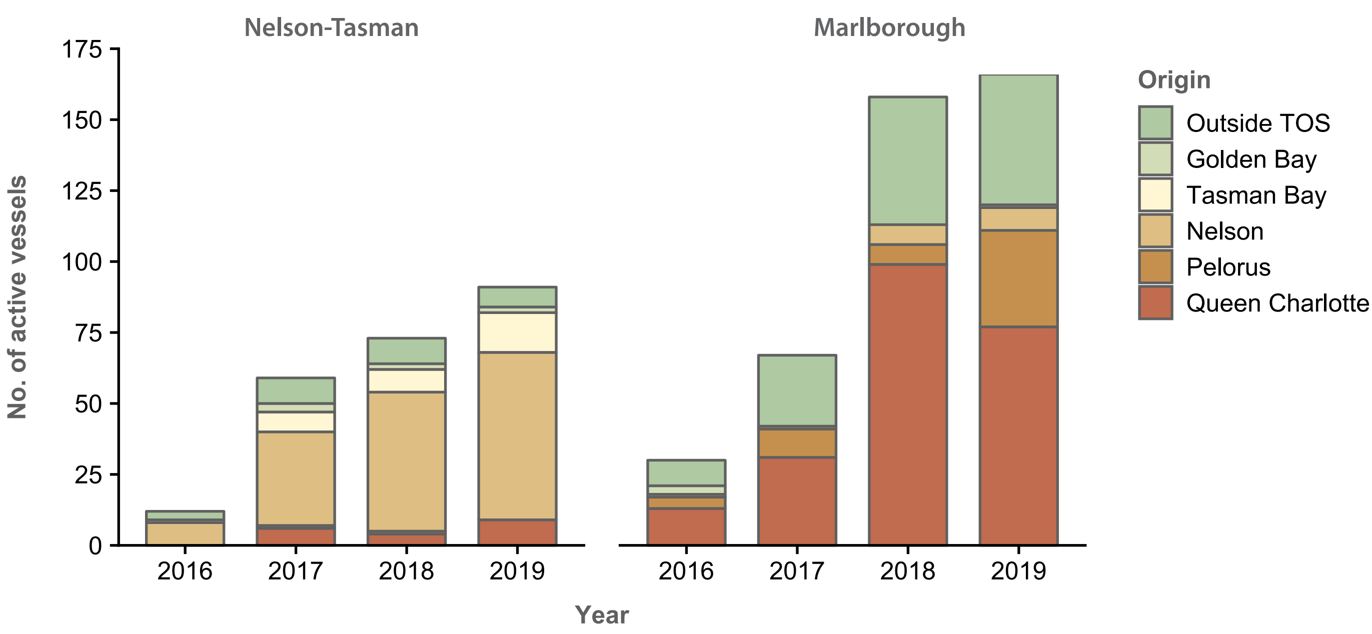
a. Boaters surveyed in Marlborough

Home port of origin	n	% total
Nelson-Tasman		
Golden Bay	1	0.2
Mapua	0	0.0
Motueka	1	0.2
Nelson	17	4.0
Tarakohe	2	0.5
Nelson-Tasman subtotal	***21***	***5.0***
Marlborough		
Havelock	30	7.1
Pelorus Sound	9	2.1
Picton	69	16.4
Queen Charlotte Sound	26	6.2
Waikawa	125	29.7
Marlborough (other)	16	3.8
Marlborough subtotal	***275***	***65.3***
Outside TOS		
Auckland	5	1.2
Lyttelton	9	2.1
Northland	3	0.7
Otago	3	0.7
BOP	1	0.2
Wellington (Chaffers)	15	3.6
Wellington (Clyde Quay)	0	0.0
Wellington (Evans Bay)	3	0.7
Wellington (Mana)	44	10.5
Wellington (other)	19	4.5
Wellington (Seaview)	20	4.8
International	3	0.7
Outside TOS subtotal	***125***	***29.7***
TOTAL	**421**	

b. Boaters surveyed in Nelson-Tasman

Home port of origin	n	% total
Nelson-Tasman		
Golden Bay	1	0.4
Mapua	2	0.9
Motueka	28	11.9
Nelson	149	63.4
Tarakohe	6	2.6
Nelson-Tasman subtotal	***186***	***79.1***
Marlborough		
Havelock	1	0.4
Pelorus Sound	1	0.4
Picton	6	2.6
Queen Charlotte Sound	1	0.4
Waikawa	12	5.1
Marlborough (other)	0	0.0
Marlborough subtotal	***21***	***8.9***
Outside TOS		
Auckland	6	2.6
Lyttelton	2	0.9
Northland	1	0.4
Otago	0	0.0
BOP	0	0.0
Wellington (Chaffers)	1	0.4
Wellington (Clyde Quay)	2	0.9
Wellington (Evans Bay)	1	0.4
Wellington (Mana)	4	1.7
Wellington (other)	7	3.0
Wellington (Seaview)	2	0.9
International	2	0.9
Outside TOS subtotal	***28***	***11.9***
TOTAL	**235**	

a. Numbers of active vessels by main home region



b. Regional distribution of active vessels by main home region

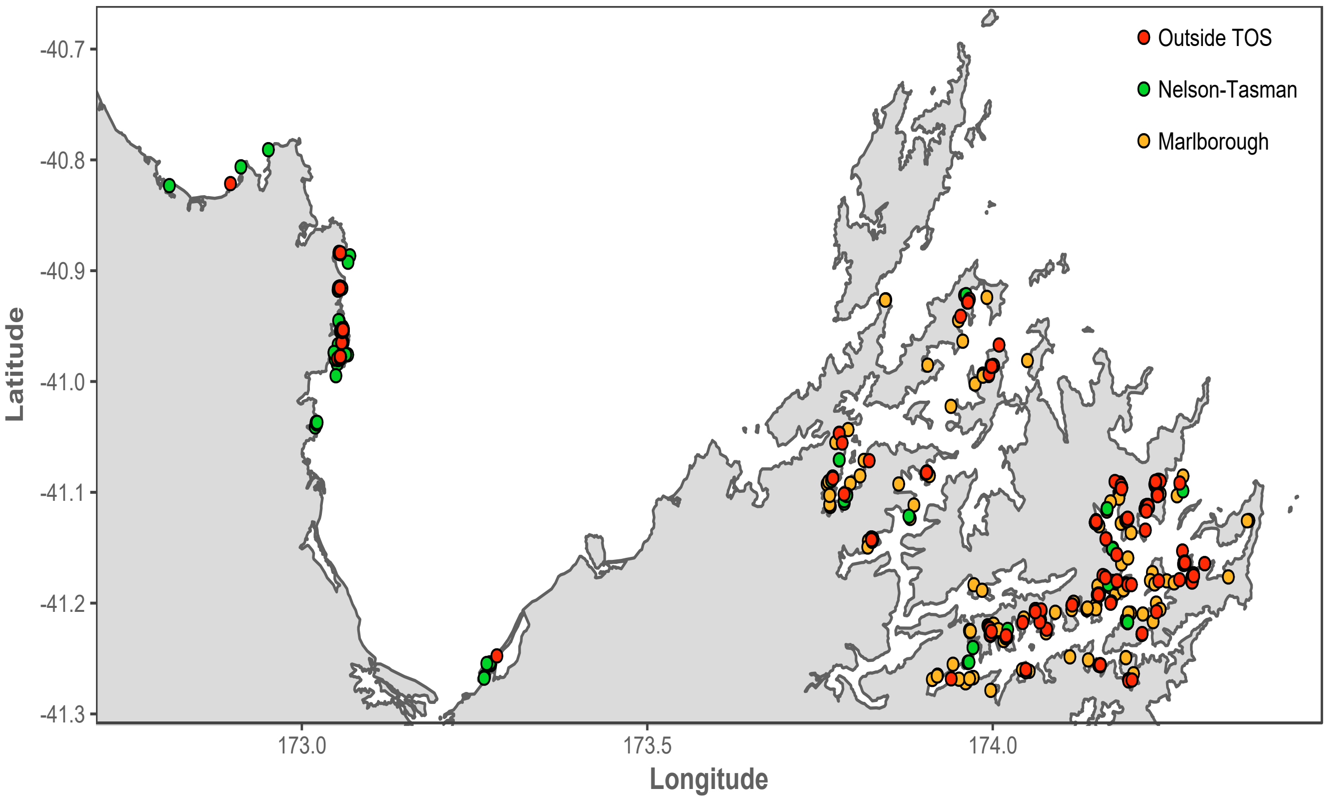
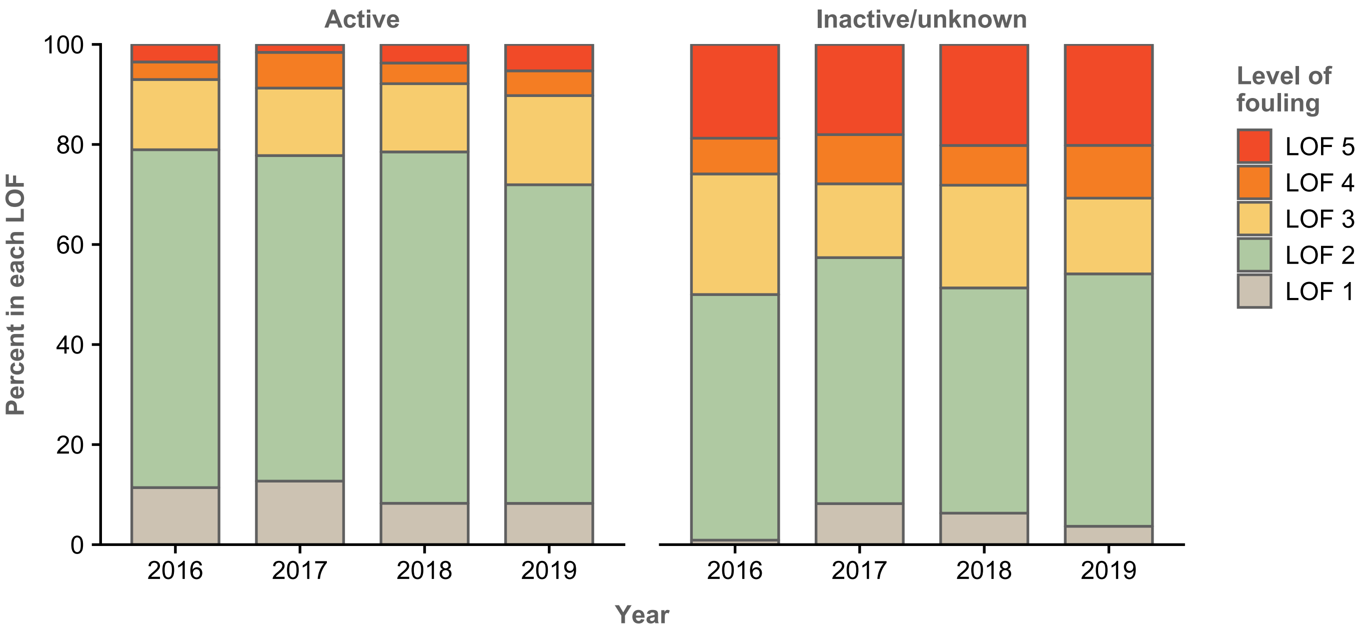


Fig. 4. Patterns in the main origin of active vessels within the two TOS regions over the four surveys. a) Number of active vessels by home region (n = 12 to 166), b) Home region of active vessels in relation to location where surveyed.

b. LOF by vessel activity status



b. Regional distribution of LOF on active vessels

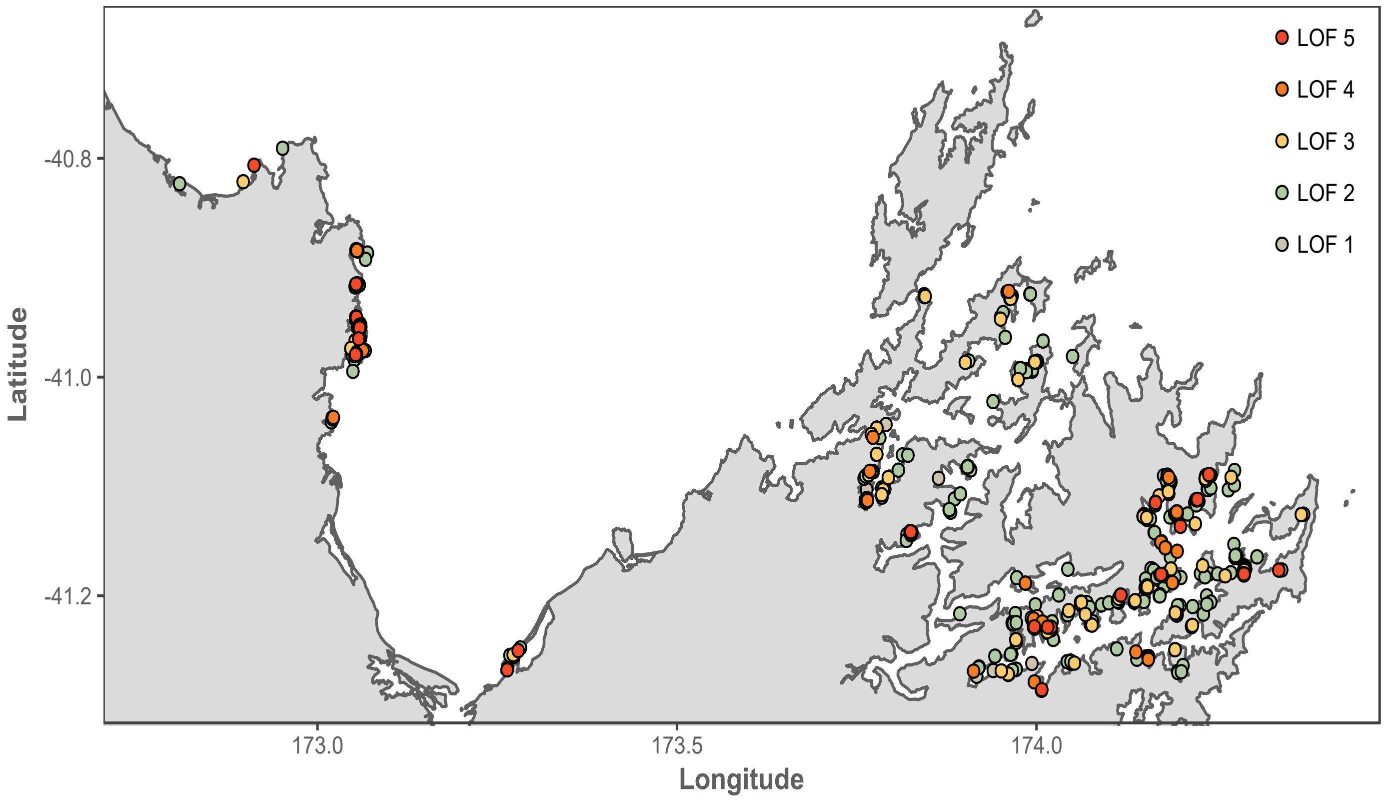


Fig. 5. Regional patterns in vessel LOF. a) Proportion of vessels in each LOF category comparing boats classified as being in active use vs inactive/unknown (n = 61 to 303), and b) Regional distribution of active boats for each of the LOF scoring categories.

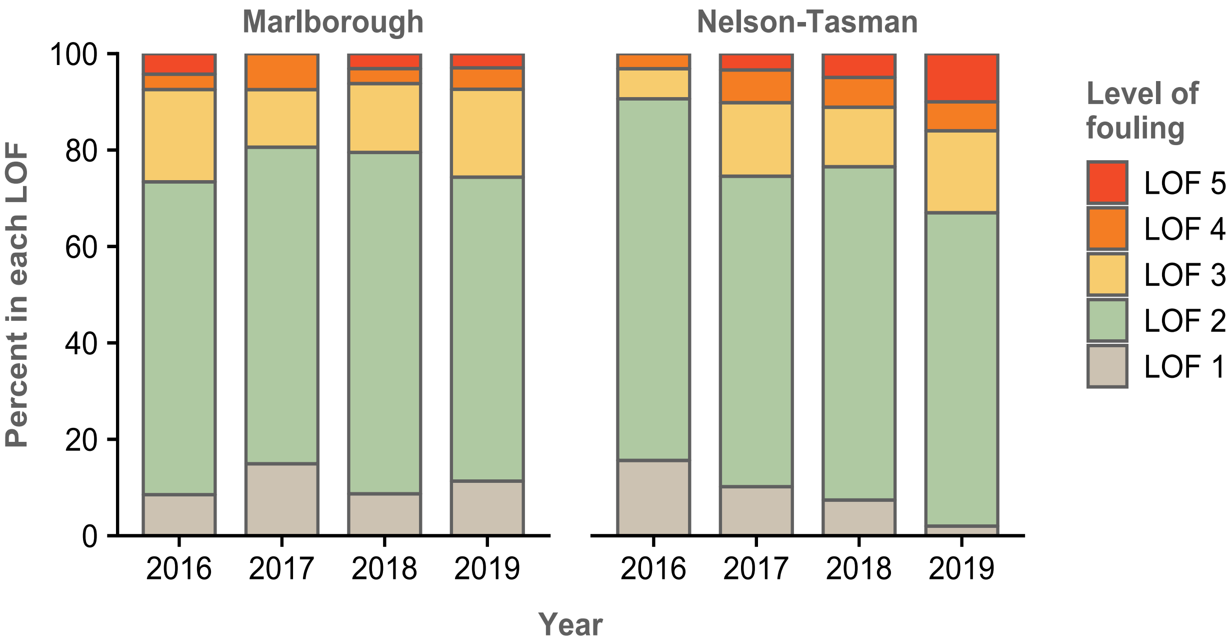


Fig. 6. Proportion of active vessels in each LOF category that were recorded in the two main regions over the four survey years (n = 30-203).

This result is consistent with other contributing factors. One is that boats originating in Nelson-Tasman (whose home port is mainly Nelson marina) are more heavily fouled than boats originating from Marlborough or from outside the TOS (Fig. 7). Combined with the data from Table 4 showing that ~79% of Nelson-Tasman boats originate from within that region, it is not surprising that relatively high fouling based on port of origin translates into high within-region fouling on active boats.

These findings are almost undoubtedly a partial reflection of problems that have emerged in recent years with lack of availability of boat maintenance facilities in Nelson marina (Forrest & Lawless 2018). Over the last two surveys, in particular, we have become increasingly aware of boaters along the Abel Tasman coastline leaving Nelson marina knowing they have significant hull fouling, but unable to obtain hard-stand space to rectify the problem in advance of their departure. It is not uncommon for such boaters to then clean their vessels in-water while moored or at anchor.

Despite the Nelson situation being an ongoing and unresolved situation of regional significance, on the positive side is that boats visiting from outside the TOS are much cleaner than within-region boats (Fig. 7). Only three of 153 boats visiting the TOS over four surveys have been heavily-fouled (~2%), of which all were recorded in Marlborough. These vessels were one each from Opua (where the fanworm is managed), Mana marina (Wellington) and Otago Harbour. Most Wellington boats are on short-duration visits and arrive reasonably well-maintained. Over the four surveys, 118 outside boats encountered have originated in Wellington, of which 105 (89%) had light fouling or less (i.e. LOF 1 or 2). Boaters from this region are reasonably aware of marine biosecurity issues, as the TOS Coordination Team has been working with Wellington marina managers to encourage vessel maintenance before departure for the TOS. Understanding the regional LOF profile of external vessels is of particular relevance to Marlborough, as both MDC and Port Marlborough (marinas) have recently developed rules relating to biofouling. What can be learned from the current data with respect to compliance with these rules is considered separately in Section 4.

3.4 OCCURRENCE OF MARINE PESTS

Key results across four surveys are as follows:

- No pests were found that are new to the TOS region.
- The Mediterranean fanworm was recorded only once outside the know infected vessel hubs. This was in 2016, when juvenile specimens were found on a vessel (originally from Auckland) that was holidaying in Endeavour Inlet (Queen Charlotte Sound).

Other than the single vessel record, the absence of fanworm beyond the known infected areas (i.e. in Picton, Waikawa, Nelson, Tarakohe) conceivably

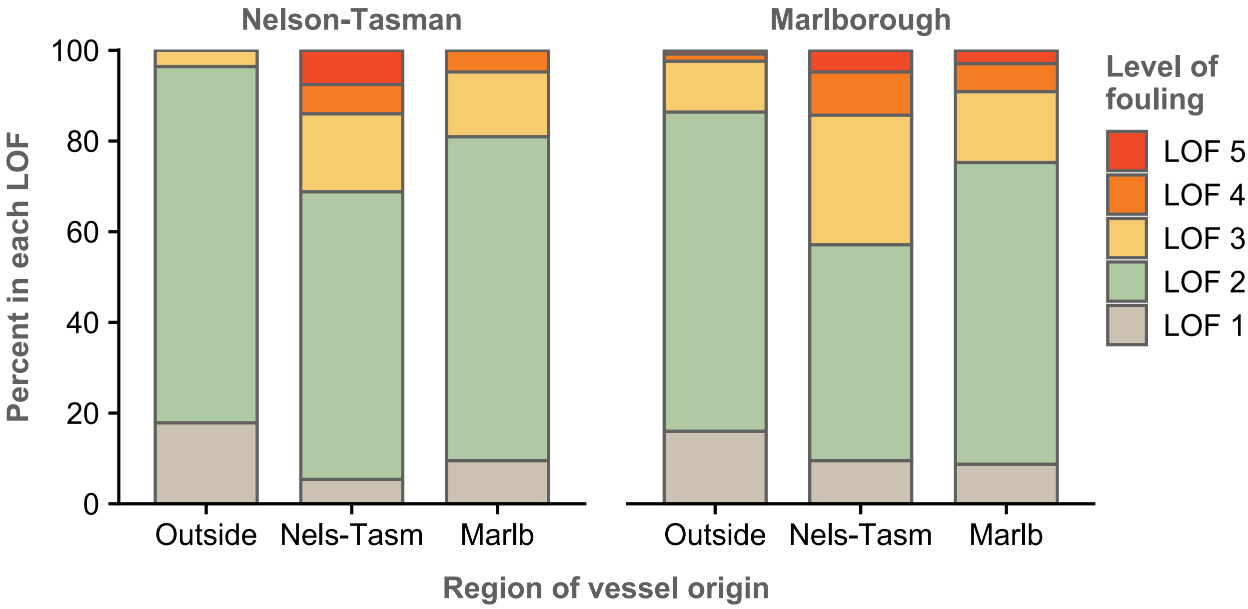


Fig. 7. Proportion of active vessels in each LOF category comparing boats whose home port was from either Marlborough, Nelson/Tasman or outside the TOS, partitioned according to the TOS region in which the vessels were active. Data pooled across four survey years. Sample sizes as per Table 4.

reflects that populations in those areas 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 (Forrest & Hopkins 2013).

Despite these encouraging results, established marine pests are nonetheless widespread across the TOS. Over the four survey years, a total of 13% of active boats, 31% of 'inactive' boats and 47% of structure/seabed locations have had at least one of the target pests listed in Table 1 present. An annual breakdown by region is provided in Table 5, with mean values in Fig. 8. The general pattern is for structures to have a greater incidence of pests than vessels, with mean pest prevalence similar across the two regions. A small proportion of the structure and seabed records reflect six instances of the kelp *Undaria* being present in seabed locations, plus one instance of Didemnum attached to seaweed. Pests were otherwise confined to artificial structures. The variability in pest numbers over surveys for structures in Nelson-Tasman reflects in part the distribution of survey effort over time; in 2017 no pests were detected on structures, as the only structures checked were moorings along the Abel Tasman coastline and these remain uninfected. Other years include records from Nelson Harbour or Tarakohe, which among the target pests has the sea squirts *Styela* and *Didemnum*, and the kelp *Undaria*.

Regional distribution plots for *Styela, Undaria* and *Didemnum* are shown in Fig. 9 for active vessels, and

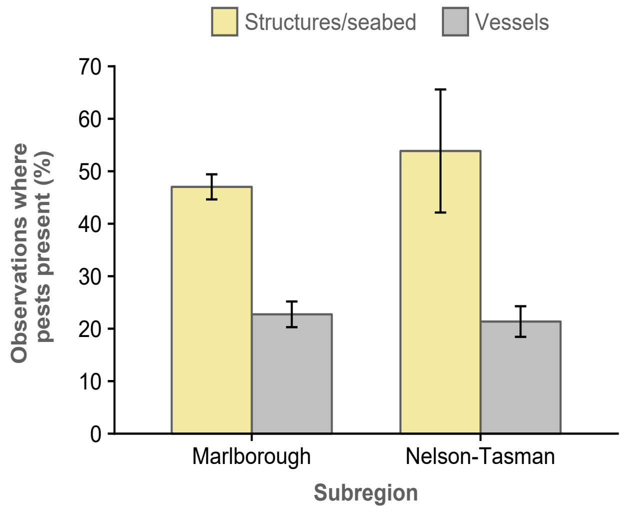


Fig. 8. Prevalence of designated or regionally significant marine pests for vessels and structures or seabed areas in each main region, based on data aggregated across four surveys. Data represent percentages of the total survey records for each subregion and habitat type, and are based on any one of the designated pests from Table 1 being present (in some instances more than one pest was present). Sample sizes as per Table 3.

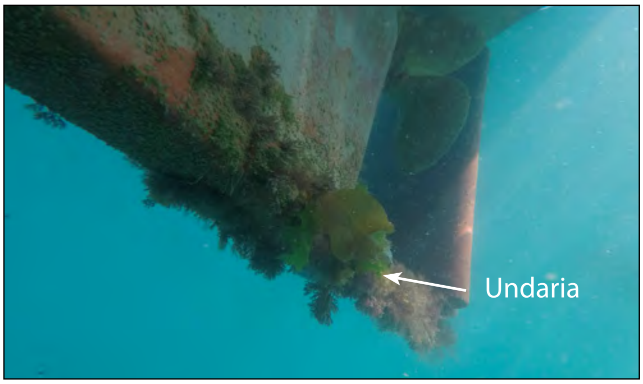
Table 5. Prevalence of designated or regionally significant marine pests (see Table 1) over time, based on results of four surveys. The 2016 survey year included Port Tarakohe, and the 2018 and 2019 surveys included vessels and swing moorings in Nelson Harbour.

Subregion	Survey year	Vessels		Structures and seabed	
		n	Pest prevalence (%)	n	Pest prevalence (%)
Marlborough	2016	170	30	122	52
Marlborough	2017	113	21	72	42
Marlborough	2018	412	20	483	45
Marlborough	2019	399	20	404	49
Nelson-Tasman	2016	56	27	13	77
Nelson-Tasman	2017	74	15	4	0
Nelson-Tasman	2018	132	26	63	46
Nelson-Tasman	2019	122	18	44	39

in Fig. 10 for structures and seabed. By contrast with the fanworm, *Styela* has become more widespread regionally over the last four years (Fig. 9a, Fig. 10a). At the time the surveys began the recorded distribution of this sea squirt was largely confined to the main vessel hubs. In the latest survey, *Styela* was found to be even more widely established in Kenepuru Sound than evident one year earlier, where it occurs mainly on mooring lines. *Styela* has also been noted on mussel farms in the Kenepuru and other parts of Pelorus Sound. Of interest is that *Styela* was found on the swimming raft at Anchorage (Abel Tasman coastline), which undoubtedly reflects a vessel-mediated introduction.

Despite its increasing regional distribution, Styela was recorded on only 22 active vessels over the four surveys. All of these were yachts, with the sea squirt in most cases on the bottom of the keel. Hence, as highlighted by previous TOS surveys, and supported by overseas studies (Clarke Murray et al. 2013), there is a need for better maintenance practices for this key niche area. Nelson is a clear source hub for *Styela*, reflecting that the species has been established in the marina and wider Harbour for more than 10 years, and the population has never been extensively controlled (due to practical constraints). Only a small amount of *Styela* removal work has been undertaken, confined to Nelson marina and conducted as part of fanworm searches.

The four surveys have highlighted the widespread occurrence of the two longest-established pests – the kelp *Undaria* and sea squirt *Didemnum* (Fig. 9b,c; Fig. 10b,c). As was the case for *Styela*, the base of the keel was also an important niche area for these two



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

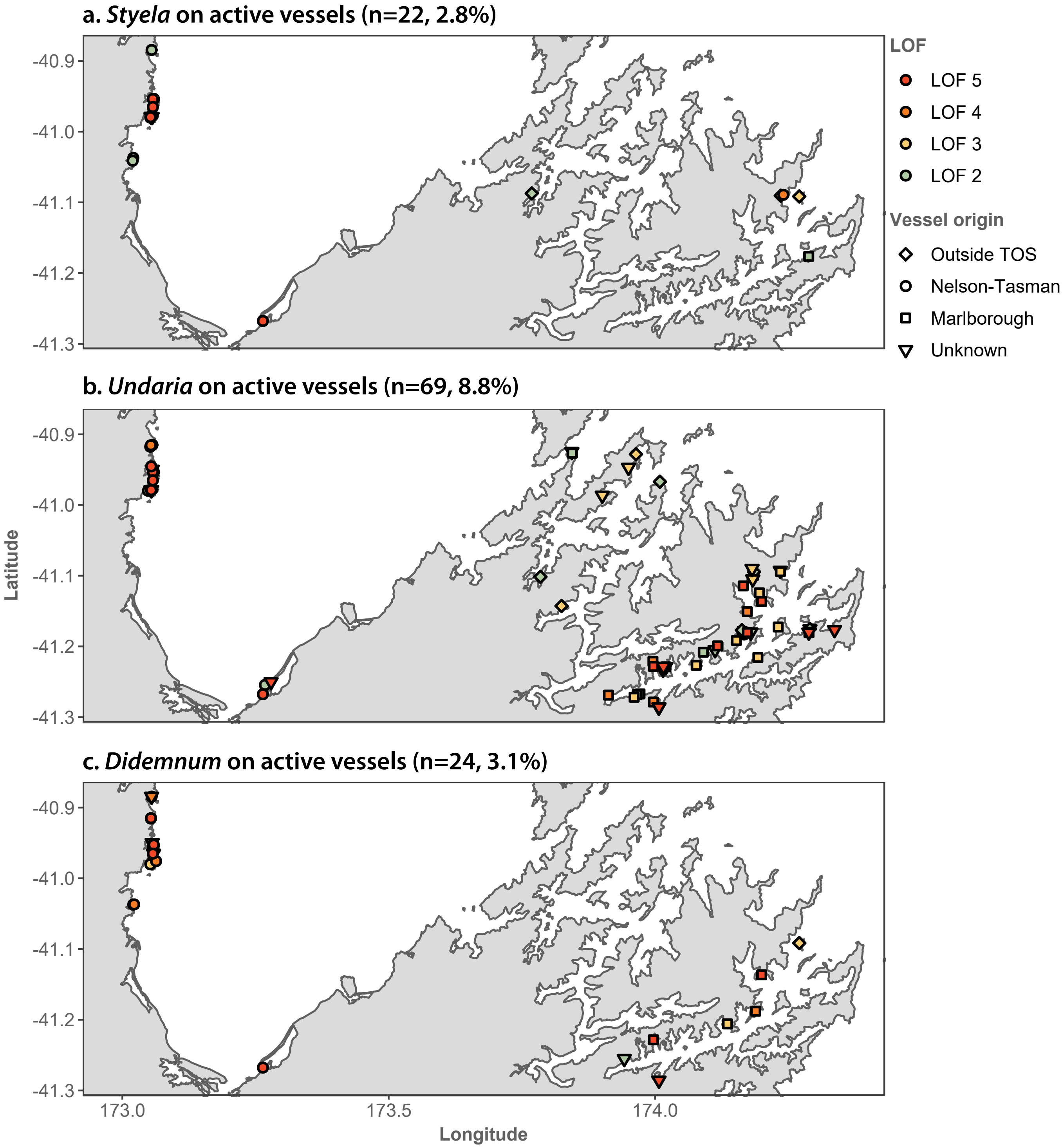


Fig. 9. Locations of active vessels surveyed over four summers that were fouled by: a. *Styela*, b. *Undaria* or c. *Didemnum*. Vessel LOF is shown by colour coding, and symbols used to represent vessel origin. Bracketed numbers indicate the number of vessels infected by each species over four surveys, and the percentage of total active boats. Some symbols overlap due to survey points close to each other.

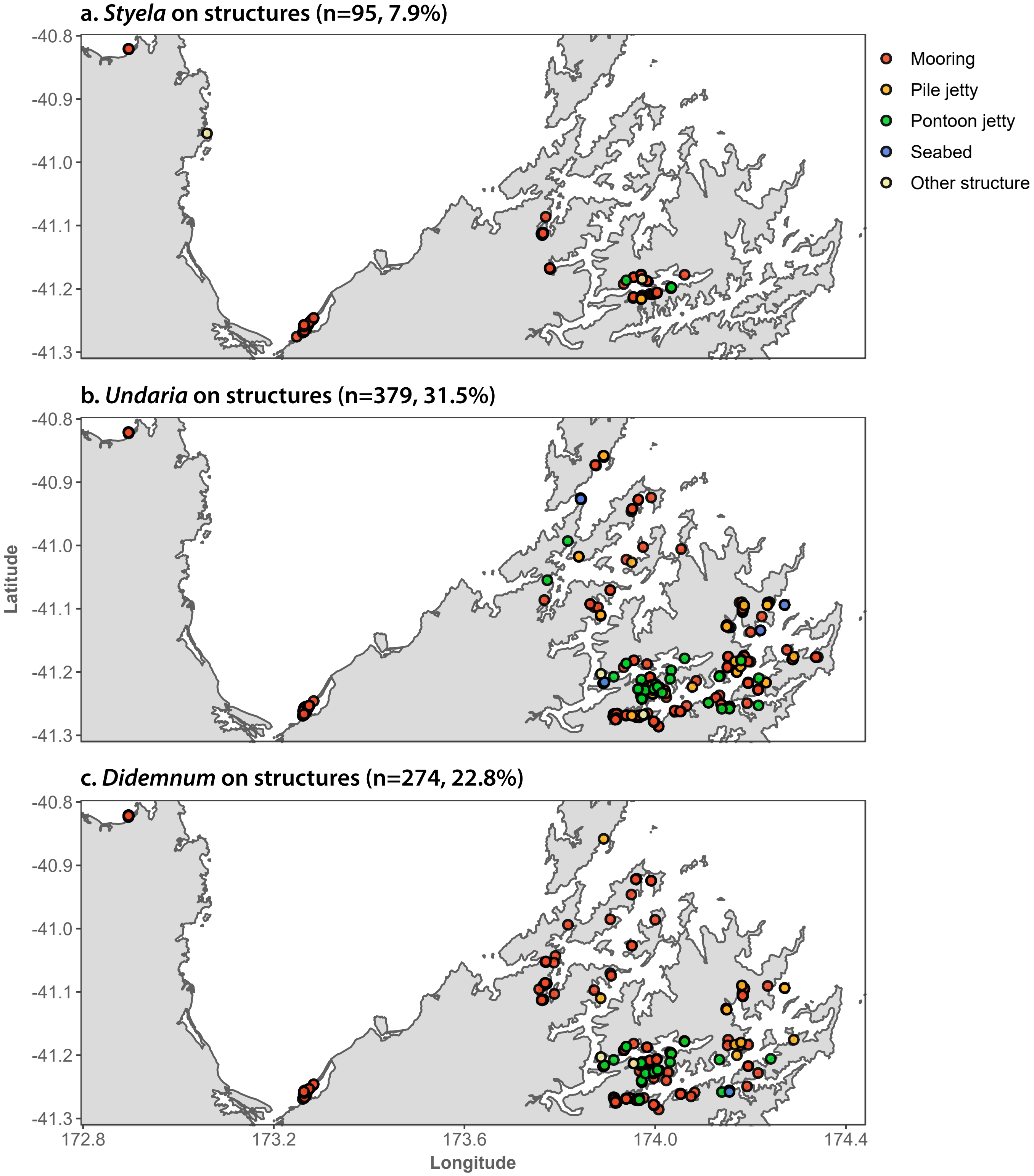


Fig. 10. Locations of structures or seabed areas where three established pests were recorded: a. *Styela*, b. *Undaria* or c. *Didemnum*. Bracketed figures indicate the number of structures or seabed areas infected by each species over four surveys, and the percentage of total records. Some symbols overlap due to survey points close to each other.

species. Both *Undaria* and *Didemnum* illustrate that, without effective vector management, marine pests can become well-entrenched regionally, relatively quickly. *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 boats are a potentially significant vector for the spread of *Undaria* to such areas. *Didemnum* is a more recent arrival than *Undaria*, being first detected in the TOS in 2001 in Shakespeare Bay (Coutts & 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 & Hopkins 2013).

3.5 OCCURRENCE OF MARINE PESTS IN RELATION TO LEVELS OF FOULING

When considered in relation to vessel activity and LOF, Fig. 11 highlights that as LOF increases, so does the proportion of vessels carrying marine pests, with active vessels having a lower prevalence of pests across all LOF categories. As well as activity itself contributing to reduced pest survival (irrespective of vessel type), the timing of maintenance relative to boat use is an explanatory factor, as described in the next section (Section 3.6).

Of relevance from Fig. 11 is that even vessels with 'light' fouling (LOF 2) can harbour marine pests. In all cases this reflects niche area fouling by pests, usually on the bottom of the keel as noted above. Furthermore, although only 8% of active LOF 2 vessels had pests compared with 64% of active LOF 5 vessels, in terms of total numbers, there were 38 LOF 2 vessels with pests present, compared with 20 LOF 5 vessels.

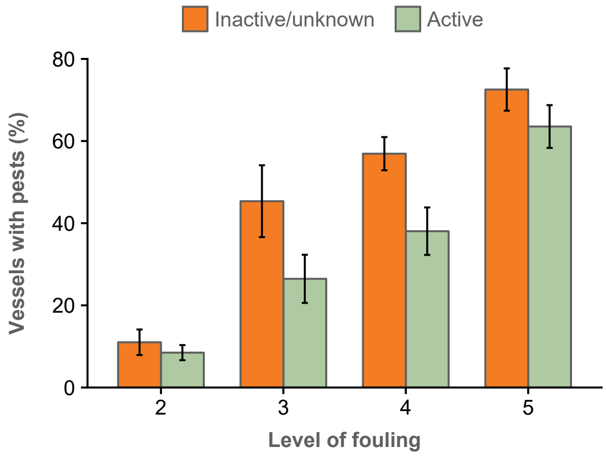


Fig. 11. Mean percentage (±SE, n=4 surveys) of recreational boats with any one of the designated pests from Table 2 present in each LOF category, with vessels categorised as being in active use or inactive/unknown in terms of their activity status. By definition, no visible pests can be present at LOF 1 (i.e. no macrofouling is present at LOF 1, see Table 1). Samples sizes for calculating of means ranged from 31 to 102 observations.

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

3.6 BOATER ANTIFOULING AND CLEANING HABITS

Across the four surveys, 627 active boaters knew the antifouling history of their vessel. Based on their responses, Fig. 12 shows a boxplot by year of the months since vessels had been last antifouled (i.e. antifouling paint age) at the time of the survey, revealing that the median and interquartile range in months since last antifouling have remained similar over the four surveys. A frequency histogram of the data pooled across surveys shows that the median time since last antifouling is 7.4 months (Fig. 13). However, a subset of the boater population tend to antifoul in the few months leading up to Xmas, just prior to the summer period when they use their boat; this pattern is expected given the increased demand placed on regional hard-stand facilities over the same period (e.g. Forrest & Lawless 2018).

Of active boaters who knew the cleaning history of their vessel, 179 (27%) had cleaned their hull at least once since last being antifouled, which 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). Over the survey years, cleaning patterns have been reasonably consistent, although in the most recent survey the time since last cleaning was marginally longer than in the two previous years (Fig. 14). For aggregated data, the median time since last cleaning was 1 month (Fig. 15), a portion of which reflects boaters who had cleaned in-water while on their summer holiday (typically in the few days prior to our hull inspection). Overall, 72% of boaters had cleaned within three months of being surveyed, and 91% within six months.

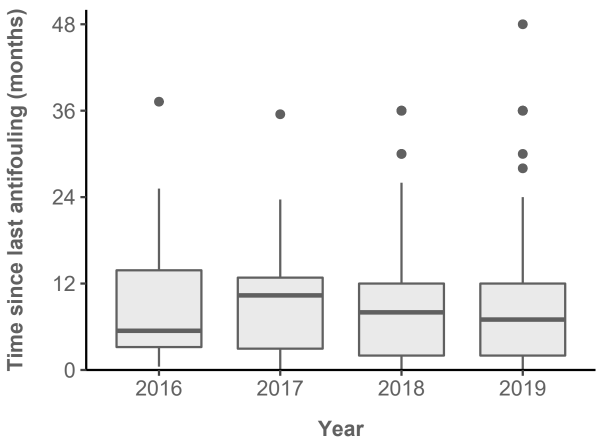


Fig. 12. Boxplots of time (months) since last antifouling (i.e. antifouling paint age) for each survey year. Horizontal bars in the boxes represent medians, the top and bottom ends the upper (75th) and lower (25th) quartiles, respectively, with the extending lines (and dots) being the extremes. Sample sizes: 2016 (n=42), 2017 (n=120), 2018, (n=221), 2019 (n=244).

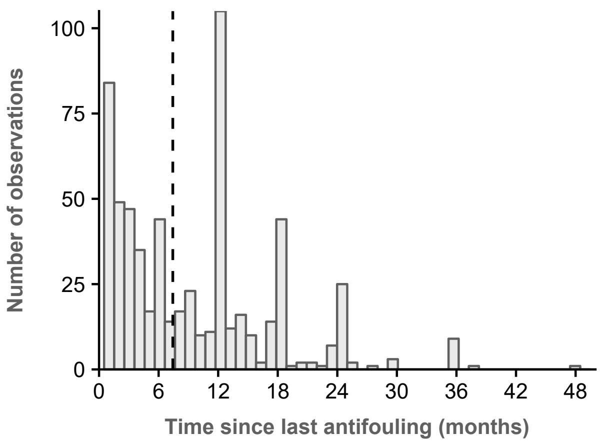


Fig. 13. Frequency histogram of time since last antifouling (i.e. antifouling paint age) reported by boaters, based on data pooled across four surveys (n=627 observations). The dotted vertical line represents the median antifouling age.

The bottom of vessel keels is difficult to anti-foul, and is a problem area for pests.

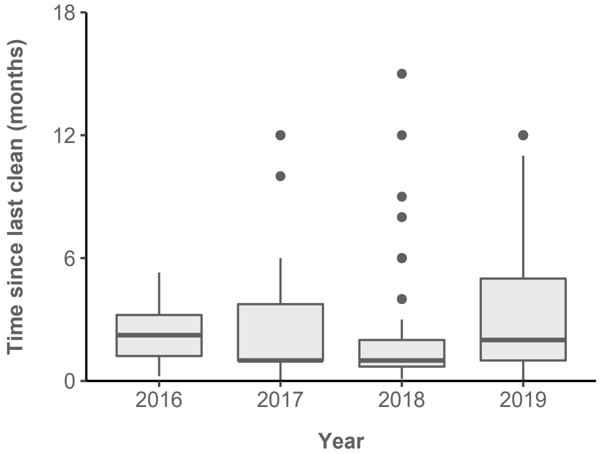


Fig. 14. Boxplots of time (months) since last hull clean reported by boaters for each survey year. Horizontal bars in the boxes represent medians, the top and bottom ends the upper (75th) and lower (25th) quartiles, respectively, with the extending lines (and dots) being the extremes. Sample sizes: 2016 (n=15), 2017 (n=42), 2018, (n=57), 2019 (n=65).

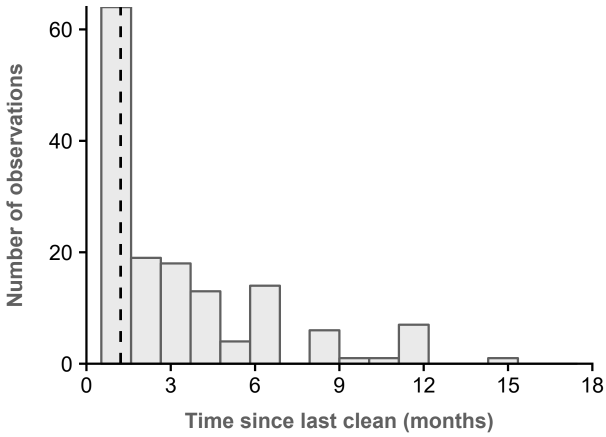


Fig. 15. Frequency histogram of time since last hull clean reported by boaters, based on data pooled across four surveys (n=181 observations of boats that had been cleaned). The dotted vertical line represents the median time since last cleaning.

Although only a minority of boaters had cleaned their hull, many of those that had would be expected to have reduced their likelihood of transporting marine pests. However, in practice this does not appear to be the outcome. Fig. 16. reveals that cleaned boats have a similar or higher incidence of pests present across most LOF categories compared with boats not cleaned. A similar finding has been reported from previous analyses of TOS data, whereby LOF is greater overall on boats that have been cleaned compared with those that have not (Forrest 2018). A possible explanation for this counterintuitive pattern is that the process of cleaning damages the antifouling coating, thus exacerbating fouling. This reflects than many boaters clean 'soft' (ablative) coatings (which are used by ~83% of TOS recreational boaters) with methods that are too abrasive (e.g. brooms, scrubbing brushes) and likely lead to coating damage.

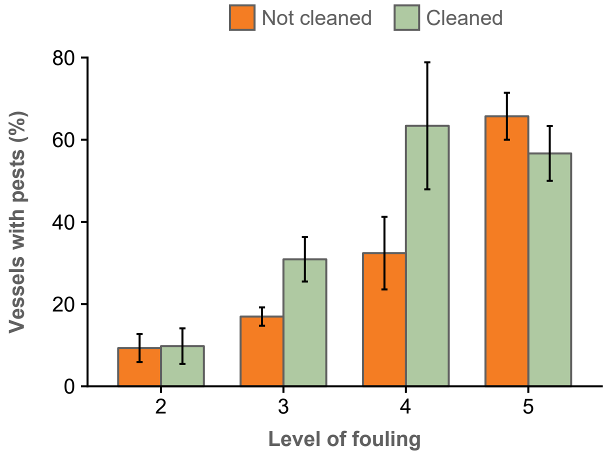


Fig. 16. Mean percentage (±SE, n=4 surveys) of recreational boats with any one of the designated pests from Table 2 present in each LOF category, for vessels categorised as being cleaned or not cleaning. By definition, no visible pests can be present at LOF 1 (i.e. no macrofouling is present at LOF 1, see Table 1). Samples sizes for calculating means ranged from 12 to 326 observations.

The type of cleaning method is particularly relevant to the consideration of cleaning efficacy. Whereas high-pressure water blasting on a hard-stand is likely to remove all visible fouling, including the slime layer, in-water cleaning by scrubbing is far less effective, in particular when fouling is at an advanced stage. The latter situation reflects a combination of difficulty removed advanced fouling in-water (e.g. due to hard calcareous organisms being present) and the rapid regrowth that can occur (itself reflecting that advanced fouling occurs when the antifouling coating is no longer effective).

Although from the summer surveys we know that a certain proportion of boaters clean in-water at their holiday destination, since 2017 we have not formally collected data on cleaning method used. TOS data from two previous surveys (one field-based, the other at haul-out facilities) reveal that 53-56% of boaters that clean their hull between antifouling, undertake the cleaning in-water, of which perhaps as many as two thirds do so away from their home port (Forrest 2016, Forrest 2017b). It would be worthwhile introducing the question of cleaning practice and location back into the summer survey, as it is relevant for understanding and improving some of the undesirable current practices. Addressing the proportion of boaters cleaning in-water away from the main vessel hubs is a particular need, as this practice has the potential to spread pests to new locations. Related research highlights that physical disturbance from cleaning may induce the release of reproductive propagules (e.g. spores and larvae) or dislodge pests to the seabed where they could establish new populations (Hopkins & Forrest 2008; Hopkins et al. 2011).

4. IMPLICATIONS IN TERMS OF REGIONAL BIOFOULING MANAGEMENT RULES

4.1 BACKGROUND

This section focuses on rules that have been developed for biofouling management on vessels in the TOS. These are as follows:

- MDC has developed a rule in its 2018 Regional Pest Management Plan (Rule 5.18.2.1) stating that *"The owner or person in charge of a craft entering Marlborough must ensure that the fouling on the hull and niche areas of the craft does not exceed 'light fouling'…".* Light fouling is defined as: small patches (up to 100 millimetres in diameter) of visible fouling, totalling less than 5% of the hull and niche areas"; hence, is roughly equivalent to LOF 2, meaning that vessels entering Marlborough with LOF >2 (i.e. LOF 3, 4 or 5) would be non-compliant. This is a similar standard to that adopted by Northland Regional Council.
- Port Marlborough marinas are considering adopting a 'six or one' rule developed by Northland marinas, whereby obtaining a berth is conditional on provision of evidence that either of the following has been met: (a) the boat has been antifouled in the last six months; (b) the boat has been lifted and washed within one month.
- Note that Nelson and Tasman do not currently have any regional standards, although Nelson marina has an LOF-based standard for berthed vessels, for which compliance cannot be assessed with the present dataset.

The Marlborough rules reflect two approaches. The MDC rule is trying to manage risk to achieve an LOF-based outcome. This approach essentially leaves it to boaters to determine how such an outcome is best met, but to work there needs to be an effective inspection and enforcement regime.

The Port Marlborough approach is rules-based; it imposes minimum maintenance practices on boaters, on the assumption that such practices will lead to the outcome of reduced fouling. Inspection and enforcement are relatively straightforward (i.e. can be conducted on vessel arrival, if not prior). However, such an approach penalises boaters that only have light hull fouling (and may be low risk) despite not meeting the rules. Moreover, no one appears to have considered, at least in a quantitative sense, how these rules relate to fouling outcomes.

The analysis below considers the extent to which boaters comply with the above types of rules, and what that might meet in terms of risk reduction. Even though the rules are not relevant to Nelson-Tasman, we present data for that region for comparative purposes. In relation to the MDC rule, we also present comparative data for an LOF > 3 threshold, as these represent the subset of active boats that are heavily fouled.

4.2 MDC REGIONAL PEST MANAGEMENT PLAN RULE 5.18.2.1

In terms of MDC's outcome-based LOF rule, Table 6 summarises the number and percentage of vessels that exceed LOF 2 and 3 thresholds, for each main region according to region of origin. For Marlborough, the summer survey dataset has 146 records of vessels visiting from outside the region (21 Nelson-Tasman, 125 outside TOS). Of these, 26 did not meet the recently developed LOF >2 rule, representing ~18% of arrivals overall, and six of those were classified as heavily fouled (LOF >3).

For boats visiting from outside the TOS (the greatest risk in terms of the introduction of new pests to the Marlborough region), 14% of arrivals would have been non-compliant if the rule had been in place over the last four years. It is also relevant that 25% of Marlborough boats had an LOF >2. Even though the rule doesn't apply to within-region boats, when this percentage is considered in the context of Fig. 11, it means that Marlborough boats active within that region present a considerable risk of transporting and possibly spreading established marine pests. The same is true for Nelson-Tasman vessels, where 31% of within-region boats exceed LOF 2 (Table 6).

It is important to keep in mind that the survey dataset represents only the boats that are encountered in remote parts of the region during the summer

Table 6. Number and percentage of active vessels in each region that exceed LOF 2 (the RPMP threshold put in place by MDC), or LOF 3 (the Nelson marina berth licence condition put in place by NCC). For completeness and comparative purposes, both thresholds are shown for both regions.

Vessel origin	No. vessels	LOF >2 (#)	LOF >2 (%)	LOF >3 (#)	LOF >3 (%)
a. Boaters surveyed in Marlborough					
Marlborough	275	68	25	25	9
Nelson-Tasman	21	9	43	3	14
Outside TOS	125	17	14	3	2
b. Boaters surveyed in Nelson-Tasman					
Marlborough	21	4	19	1	5
Nelson-Tasman	186	58	31	26	14
Outside TOS	28	1	4	-	-

period. There will be many more regional visitors, as well as arrivals into vessel hubs, which are not represented in these data, but which likely represent a biosecurity risk. As yet there is no effective system to identify these arrivals (in advance or on arrival) and subject them to a risk screening process. However, a recent incursion of the fanworm in Waikawa was attributed to an infected Auckland boat that had not been identified, and highlights the need for an improved systems. Potential risk profiling methods for such a system were outlined in a recent report to NCC (Forrest and Lawless 2018).

4.3 PORT MARLBOROUGH MARINAS SIX OR ONE RULE

Table 7 presents a summary of the number and percentage of active vessels in each region that comply with the 'six or one' rule put in place by Port Marlborough, and the extent to which compliance with the rule mitigates higher levels of fouling. Although most relevant to Marlborough, both TOS regions are shown, with three scenarios (A-C) considered, relating to whether vessels meet marina rules according to:

A. Their antifouling is ≤6 months old

B. Their antifouling is > 6 months old, but they have been cleaned within 1 month of arrival; and

C. They comply with both the antifouling and cleaning rules.

From Table 7 it is apparent that:

- Roughly half of boats surveyed would have complied with antifouling rule scenario A. Many of the boats meeting the antifouling rules had no more than light fouling (LOF ≤2). The main exception was boats from Nelson-Tasman visiting Marlborough, for which fouling levels on 25% of boats that complied with the antifouling rule exceeded the light fouling threshold.
- An even lower percentage of boats would have complied with cleaning scenario B, although compliance differed greatly depending in location. Furthermore, it should be noted that the rule requires a lift and clean, whereas based on the discussion in Section 3.6 it seems likely that many of the surveyed boats represented in Table 7 may have been cleaned in-water. As noted above, in-water cleaning will general be less effective in terms of biofouling removal.
- In terms of scenario C, very few boaters undertook antifouling and cleaning in a way that simultaneously met both rules.

The findings in Table 7 should be regarded as only a rough indicated of compliance and its implications in terms of LOF. As noted, the cleaning data may underestimate the efficacy of the rule, due to many of the boats having been in-water cleaned rather than lifted and washed. Moreover, it should be kept in mind that the analysis is somewhat contrived; for example, the boats we surveyed were not necessarily going to a marina, and if they been planning such a visit (at least to Marlborough) they may have maintained their hull to comply (assuming they knew about the rule).

Table 7. The number and percentage of active vessels in each region that comply with the 'six or one' rule put in place by Port Marlborough, and the extent to which compliance with the rule mitigates higher levels of fouling. Although most relevant to Marlborough, both TOS regions are shown. Three compliance scenarios (a-c) are considered. Note that the reduced number of total vessels by comparison with Table 6 reflects that not all boaters knew the maintenance history of their vessels (e.g. charters).

a. Antifouled in previous 6 months

Region	Origin	No. boats	Boats complying (#)	Boats complying (%)	Complying boats LOF >2 (#)	Complying boats LOF >2 (%)
Marlborough	Marlborough	253	121	48	11	9
	Nelson-Tasman	20	8	40	2	25
	Outside TOS	115	63	55	1	2
Nelson-Tasman	Marlborough	19	6	32	0	0
	Nelson-Tasman	176	77	44	6	8
	Outside TOS	24	14	58	0	0
TOS total	Within TOS	468	212	45	19	9
	Outside TOS	139	77	55	1	1

b. Non-compliant with antifouling rule but cleaned in previous month

Region	Origin	No. boats	Boats complying (#)	Boats complying (%)	Complying boats LOF >2 (#)	Complying boats LOF >2 (%)
Marlborough	Marlborough	132	17	13	5	29
	Nelson-Tasman	12	2	17	2	100
	Outside TOS	52	15	29	4	27
Nelson-Tasman	Marlborough	13	2	15	1	50
	Nelson-Tasman	99	28	28	14	50
	Outside TOS	10	7	70	0	0
TOS total	Within TOS	256	49	19	22	45
	Outside TOS	62	22	35	4	18

c. Compliant with both antifouling and cleaning rules

Region	Origin	No. boats	Boats complying (#)	Boats complying (%)	Complying boats LOF >2 (#)	Complying boats LOF >2 (%)
Marlborough	Marlborough	253	3	1	1	33
Marlborough	Nelson-Tasman	20	0	na	na	na
Marlborough	Outside TOS	115	6	5	0	0
Nelson-Tasman	Marlborough	19	0	na	na	na
Nelson-Tasman	Nelson-Tasman	176	8	5	1	12
Nelson-Tasman	Outside TOS	24	0	na	na	na
TOS total	Within TOS	468	11	2	2	18
	Outside TOS	139	6	4	0	0

Note: % boats complying with cleaning rule based on total respondents, not just the minority of boaters that had cleaned

5. SYNTHESIS OF FINDINGS AND FURTHER CONSIDERATIONS FOR REGIONAL SURVEILLANCE

5.1 KEY FINDINGS AND IMPLICATIONS

The 2019 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 has been detected on only one visiting vessel, the fouling status of boats remains similar to previous surveys, and in the case of Nelson-Tasman boats appears to have become worse. 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, and the sea squirt *Styela clava* has spread from its original confines within vessel hubs, to become firmly established in a few sub-regions and bays across the TOS. The disjointed distributional pattern of these three 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 suggest 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 until a further vessel-mediated introduction to Waikawa in 2019. 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 marinas would become significant sources for 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. It also requires recognition that even light fouling can harbour pest species, especially in niche areas such as the bottom of the keel. Effectively recognising and addressing these types of risks is far from straightforward.

If they could be enforced, the recent rules developed to manage fouling on boats entering Marlborough or Marlborough marinas would go some way towards risk reduction. However, across the TOS, any such rules but need to be accompanied by a better system for identifying arriving vessels (especially those from outside the region), profiling their biofouling risk, and responding appropriately. Any regime that require a greater need for cleaning or antifouling of vessels will increase demand for appropriate maintenance facilities. While Marlborough appears to be generally well catered, the same cannot be said about Nelson and Tasman. For Nelson in particular, the absence of sufficient facilities is almost undoubtedly a significant contributing factor to regional biosecurity risk. One of the outcomes is that boaters are transferring potential risks to new locations, by cleaning their vessels in-water away from the main hubs, usually while they are moored or anchored in high-value areas. Simultaneously, many boaters are cleaning using methods that damage their antifouling coating, and make it even less effective as a biofouling barrier. Arguably, it is futile to be advocating or regulating improved hull hygiene without systems in place to support best practice. To address this issue for Nelson, the report by Forrest and Lawless (2018) recommended developing improved facilities that enabled boaters to clean their hull out of water (e.g. water blasting) before leaving the marina, at a low enough price that cost was not seen as a barrier.

5.2 FURTHER CONSIDERATIONS AND RECOMMENDATIONS

In the 2018 survey report a range of options and approaches were discussed for improving on the current situation, by systematically implementing management intervention at key points in the chain of events that lead to risk to the TOS. Among the key needs identified were approaches to ensure that visiting vessels:

- Are detected before or upon arrival through an improved intelligence system.
- Arrive in the TOS with a 'clean' hull where this can be achieved.
- Are subjected to a risk-profiling procedure with in-built decision support that links the level of response (e.g. pass, fail/clean, inspect) to the level of assessed risk.

With respect to ongoing summer surveys and related Coordination Team efforts, a number of recommendations for improvement were made in the 2018 report, and many of these were adopted in the 2019 survey. For regional surveillance next summer, it is recommended that survey questions are included relating to hull cleaning practices and locations, and reasons for current behaviours, as this knowledge will better inform the nature of the risk and the types of solutions that might be developed.

Finally, given the high frequency of encounters with visiting boats from Wellington, it would be worthwhile putting in a greater effort to work with marina operators and boaters from that region, as well as with the Greater Wellington Regional Council, to try and further reduce hull fouling risk. Simultaneously, efforts to integrate other stakeholders (e.g. marine farmers) into the surveillance programme should be continued. With all such elements in place, the programme has the best chance of managing the ongoing threat from fanworm and other existing or potential pests to the TOS region's values.

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