Regional Recreational Vessel Hull Fouling Survey and Boater Questionnaire

Top of the South Marine Biosecurity Partnership

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Prepared for

Top of the South Marine Biosecurity Partnership

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EXECUTIVE SUMMARY

This study found that recreational vessels pose a significant biosecurity risk to many of the locations with important values in the Top of the South (TOS). The lack of effective management of recreational vessels at present means that:

- New pests are likely to arrive in the TOS from elsewhere in New Zealand.
- Established pests with currently confined distributions are likely to be further spread in the TOS (over time-scales of a few years) by vessels movements.
- Long-established pests may ultimately be spread to most of the suitable habitats in the region.

Background

Vessel hull fouling studies and marine pest management operations in the TOS have identified high risk biofouling on recreational boats associated with key marina or mooring hubs in Nelson, Waikawa and Picton. The Coordination Team (which implements the operational activities of the TOS Marine Biosecurity Partnership) identified a need to better understand the nature and extent of the risk, which led to three studies being initiated in the summer of 2015/16, as follows:

1. A regional snorkel survey of recreational vessel biofouling was undertaken, to assess fouling levels and to check for the presence of marine pests.

2. A questionnaire survey of recreational boaters was undertaken to gauge voyage and maintenance habits. The questionnaire was delivered together with an "Is your bum clean" brochure, which contained awareness information for boaters.

3. Travel-lift operators at Nelson and Waikawa marinas were trained to assess fouling levels on vessels hauled out for maintenance, and asked boaters to complete the questionnaire at the time of haul out.

This report describes the field survey (#1), and presents an interim summary of boater habits based on questionnaire responses received to date from #2 and #3. Once #3 is complete, a more comprehensive report will be compiled based on all questionnaire returns. At that stage it is expected that there will be a dataset of sufficient size to enable a systematic evaluation of levels of fouling in relation to boater habits.

Field survey

Vessel monitoring was conducted over six days during the peak summer season, with effort focused on four sub-regions: Port Tarakohe, the Abel Tasman National Park coastline, Pelorus Sound and Queen Charlotte Sound. Biofouling was surveyed on 226 boats in total across these areas, and 135 associated moorings. Overall fouling status was assessed according to an existing Level of Fouling (LOF) scale, ranging from slime layer fouling or less (LOF $\leq$ 1; no visible macrofouling) to very heavy macrofouling (LOF 5). Additionally, boats and moorings were checked for six target marine pest species.

LOF scores in the regional survey were as follows:

- Overall, 16% of vessels were categorised as “heavily fouled” (LOF ≥ 4; fouling cover ≥ 16%), which is comparable to the levels recorded in earlier studies in Nelson and Waikawa. However, only 8% of boats classified as being in active use were heavily-fouled, reflecting that active boats tend to be better maintained than those that may otherwise be sitting idle (e.g. at moorings or marina berths).
- Sail boats (mainly yachts) were more fouled than power boats, consistent with the expectation that many fouling organisms can survive the low voyage speeds (c. 7-8 knots) at which yachts travel, whereas they become dislodged or damaged at the faster speeds travelled by power boats.

No pests were found that were new to the TOS region. However, a total of 30% of boats had at least one of the six target pest species present, with an increasing prevalence of pest occurrence with increasing LOF. Pest prevalence appeared related to the duration a given species had been established in the TOS, as follows:

- The fanworm Sabella spallanzanii (first recorded in 2013/14) was found in outer Queen Charlotte Sound on a yacht from Wellington.
- The sea squirt *Styela clava* (first recorded in 2006) was found on five yachts, three being in Tarakohe Harbour. *Styela* was also found on three Tarakohe moorings.
- The sea squirt *Didemnum vexillum* (first recorded in 2001) was detected on 10% of boats and 36% of moorings surveyed (Figure 7c,d).
- The Asian kelp *Undaria pinnatifida* (first recorded in 1991) was found on 24% of boats and 33% of moorings, despite being the “low season” for this species.

It was often the case that boats with light fouling overall (e.g. a slime layer on the main hull) had well-developed fouling in “niche” areas. Vessel keels are of particular interest in this regard, as on some boats keels provide a large surface that can develop advanced macrofouling and harbour marine pests. This situation primarily reflects that keels may be incompletely coated (or not coated) with antifouling paint during maintenance.

Boater questionnaire

The questionnaire was delivered (together with the awareness brochure) in ziplock bags that contained a pen and freepost envelope for returns. Over 1,000 questionnaires with these ziplock packs were distributed across the TOS. The analysis here in this report is based on 208 questionnaire returns received as at 17 May 2016. Data on boat maintenance and use can be summarised as follows:

- Most boaters antifouled their vessel every 12-24 months (median 18 months), with 11% of boaters antifouling at longer intervals. These figures are comparable to a recent summary of data for 906 recreational boats in New Zealand.
- A total of 7% of boats had remained idle since their last antifouling, 35% had been active for 5% or less of available days, and 57% had been active for 10% or less of available days. This low-usage profile would be expected to make the majority of boats relatively susceptible to accumulating biofouling.

- Vessel cleaning between antifouling events was reasonably common, with 35% of boaters reporting that they had cleaned their hull since last being antifouled. For this subset, cleaning locations were reported as: (i) 56% cleaned in-water; (ii) 10% cleaned on a beach or intertidal area; and (iii) 34% cleaned at a haul-out facility.

In terms of boater origin and areas of activity, key findings were as follows:

- The home port for 90% of boaters was the TOS, with 18 boats coming from elsewhere in New Zealand and two being of international origin. The New Zealand boats from outside the TOS mainly originated in Wellington marinas.
- Among the visitors from outside the TOS, only 25% reported that they always go to one of the main vessels hubs (e.g. Nelson, Picton, Waikawa) during their visit.
- Of the respondents whose vessels are domiciled in the TOS, 6% of boats had not been used since last being antifouled, 94% were active in the TOS for at least one day, 10% had travelled to locations in New Zealand outside the TOS and 2% had travelled internationally.
- Approximately 17% of boats that had visited the Marlborough Sounds since last being antifouled were from outside the TOS (mainly from Wellington). This finding was consistent with a follow-up survey of boaters in Wellington (30 respondents to date), which indicated that 60% of boaters had visited the TOS (mainly Queen Charlotte Sound) since their last antifouling.

Synthesis of risk and management implications

It is clear that recreational vessels pose a biosecurity risk to the significant values of the TOS. Many conspicuously fouled boats are active throughout the region, and many are carrying designated marine pests. Within the TOS, Tarakohe appears to be an overlooked hub for the spread of potentially problematic species (e.g. to the region's marine farms). Outside the TOS, Wellington appears to be a key source region for visiting vessels, especially those that travel to the Marlborough Sounds.

Given that some vessels visit remote parts of the region without necessarily passing through a hub, recreational vessels ideally need to leave their home ports with a "clean" hull. While some work has already started with Wellington marinas, there is clearly more that needs to be done nationally to be better ensure effective management efforts are in place. There is a need for appropriate measures (e.g. to address niche area risk), guidance (e.g. on in-water cleaning) and infrastructure (e.g. affordable hard-stand facilities) in order that hull biofouling can be reduced.

While direct management of recreational vessels (and other risk pathways) is of key importance, there is a simultaneous need for practical and affordable tools to keep marine structures (e.g. marina pontoons) free of significant fouling in general, in order to reduce source populations of all potential pests.

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1. INTRODUCTION

The Top of the South (TOS) Marine Biosecurity Partnership (the Partnership) has been focusing some of its activities on better understanding and managing biofouling risks from recreational vessel movements. There are several thousand recreational vessels at marina berths or on swing moorings in the TOS region, as well as vessels that visit from areas outside the TOS. Recreational boats are recognised as being important from a biofouling risk perspective, primarily because:

- They are prone to fouling, as they tend to spend long periods of time idle, which can reduce the efficacy of their antifouling coatings (Piola and Forrest 2009).
- Many recreational vessels travel at slow voyage speeds (< 10 knots), which enables associated fouling to survive transport from place to place (Coutts et al. 2010a; Coutts et al. 2010b).
- They often visit high-value coastal areas, providing a direct route for the spread of marine pests to such locations.

Previous recreational vessel biofouling surveys in the TOS have focused on boats in key hubs, in particular Nelson and Waikawa marinas and adjacent moorings (Lacoursière-Roussel et al. 2012; Forrest 2013; Forrest 2014). These surveys revealed “conspicuous” levels of fouling across about one third of boats present, and the presence of marine pests of some vessels. The occurrence of marine pests on recreational vessel hulls has further been highlighted during recent management efforts in the TOS for two high profile species: the clubbed tunicate *Styela clava*, and Mediterranean fanworm *Sabella spallanzanii*.

While this existing work illustrates the potential role of recreational vessel movements in marine pest spread, the Coordination Team that implements the operational activities of the Partnership identified a need to better understand: (i) the hull fouling risk profile of vessels that are in active use or are moored in the region away from the main vessel hubs; (ii) the origins and areas of travel of boats that are active in the region, and the maintenance practices of boaters; and (iii) the extent to which fouling risk relates to vessel characteristics and boater habits. Collectively such knowledge would provide a better understanding of the scale of the fouling problem that needs to be addressed, and enable management efforts to be targeted according to risk. Simultaneously, the Coordination Team identified the need to disseminate information to boaters regionally, in order to raise biosecurity awareness.

Accordingly, three separate but related projects were developed for implementation in the summer of 2015/16, as follows:

1. A regional snorkelling survey of recreational vessel biofouling was undertaken, to assess “levels of fouling” according to a predefined scale, and to check for the presence of actual or potential marine pests.

2. A questionnaire was developed to gauge the voyage and maintenance habits of boaters. The questionnaire was delivered together with an "Is your bum clean" brochure, which contained information for boaters on marine pests and the importance of having a clean hull.

3. Travel-lift operators at Nelson and Waikawa marina hard-stands were trained on how to record vessel levels of fouling, and how to recognise marine pests. Operators assess levels of fouling on vessels hauled out for maintenance, and ask boats owners (when present) to complete the questionnaire developed under #2.

Whereas components 1 and 2 have been completed, the travel-lift work is progressing only slowly, and will continue through until the summer of 2016/17. This report describes the field survey, and presents an interim summary of boater habits based on questionnaire responses received to date. Once the travel-lift surveys are complete, a more comprehensive report will be compiled based on all questionnaire returns. At that stage it is expected that there will be a dataset of sufficient size to enable a systematic evaluation of levels of fouling in relation to boater habits. As comparable studies are being undertaken in regions like Northland, these collective efforts will provide comprehensive information on vessel biofouling risk, boater practices and attitudes to management.

2. FIELD SURVEY

2.1 General approach

Recreational vessel monitoring was conducted over six days during the summer of 2015/16, across four main sub-regions in the Top of the South: Port Tarakohe in Golden Bay, the Abel Tasman National Park coastline, Pelorus Sound and Queen Charlotte Sound. Biofouling was surveyed on 226 boats in total across these areas, with the distribution of effort illustrated in Figure 1. Vessels and skippers for the survey were provided by the Tasman Harbour Master (Tarakohe and Abel Tasman), Marlborough Harbour Master (Pelorus and Queen Charlotte Sound) and the Department of Conservation (Queen Charlotte Sound).

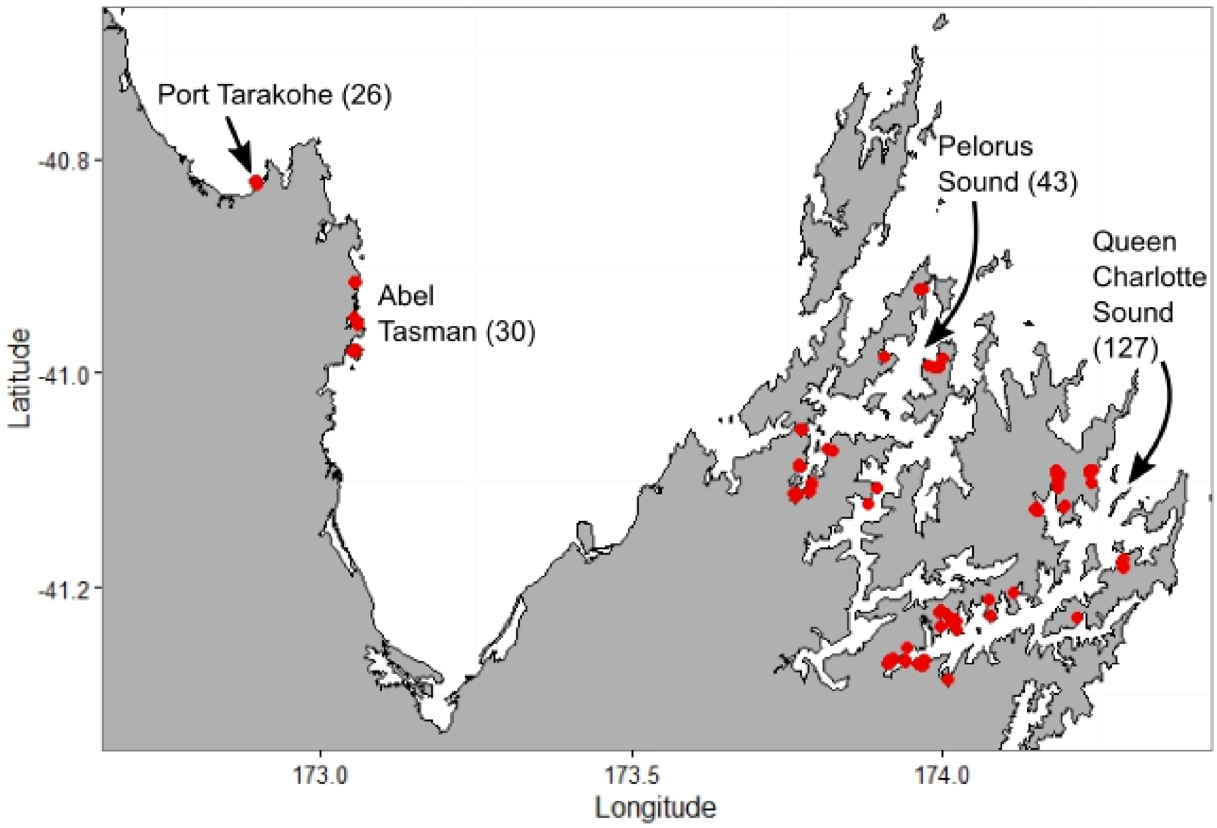

Figure 1. General localities of 226 recreational boats surveyed during summer 2015/16, with the number of boats in each of four main sub-regions indicated in brackets.

In order to maximise the likelihood of encountering vessels, the survey was undertaken during the peak holiday period from just prior to Xmas 2015 until late January 2016. Monitoring was restricted to periods of fine weather when boaters were more likely to be on the water, and targeted known high density areas for recreational vessel activity, including:

- Commonly used boat anchorages (e.g. Anchorage and Astrolabe Roadstead along the Abel Tasman coast).
- Areas with boat-club swing moorings.
- Particular hot-spots where vessels are known to aggregate during the holiday season (e.g. Endeavour Inlet in Queen Charlotte Sound).
- Localities with a high density of private swing moorings (e.g. Ngakuta Bay in Queen Charlotte Sound, Duncan Bay in Pelorus Sound, Tarakohe Harbour in Golden Bay)[1].

As 135 of the 226 vessels surveyed were on private or boat club swing moorings, each associated mooring buoy and the surface 7-8 m of rope (and mooring chain and block at shallow sites) was checked for target species as described in the next section. Although this effort will improve knowledge of the regional distribution of marine pests, it should be recognised that the mooring checks were fairly cursory. A comprehensive assessment of marine pests on swing moorings would require SCUBA diving and would need to target a representative sample of almost 3,500 moorings that are reported to exist across the Top of the South (Floerl et al. 2015).

2.2 Hull fouling assessment method

The hull of each vessel was checked in-water on snorkel, with consent first sought from the skipper/owner when present. 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, propeller shaft, pipe outlets, bow-thruster tunnels and hard-stand support areas. Each vessel was assigned an overall “level of fouling” (LOF) score based on categories described by Floerl et al. (2005) shown in Table 1. The LOF approach has been used in many hull fouling studies in New Zealand, including in the TOS (Lacoursière-Roussel et al. 2012; Forrest 2013; Forrest 2014). As a rule of thumb it can be assumed that marine pest risk, or the presence of non-indigenous species, will increase with an increasing LOF (Hopkins and Forrest 2010; Inglis et al. 2010; Forrest and Sinner 2016).

Some instances arose where the number of species groups (referred to by the term “taxa” in Table 1) did not match the descriptors for the percent cover thresholds. For example, at times LOF 2 fouling of 1-5% cover comprised several 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 taken during a survey in 2013 (Forrest 2013) can be viewed at the following link: http://youtu.be/LMJKZSs8Arg.

[1] The survey excluded the extensive area of swing moorings in Waikawa Bay adjacent to Waikawa marina, and excluded most of the Picton moorings. These areas have been surveyed as part of previous monitoring and/or marine pest control work.

Table 1. 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[2] 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

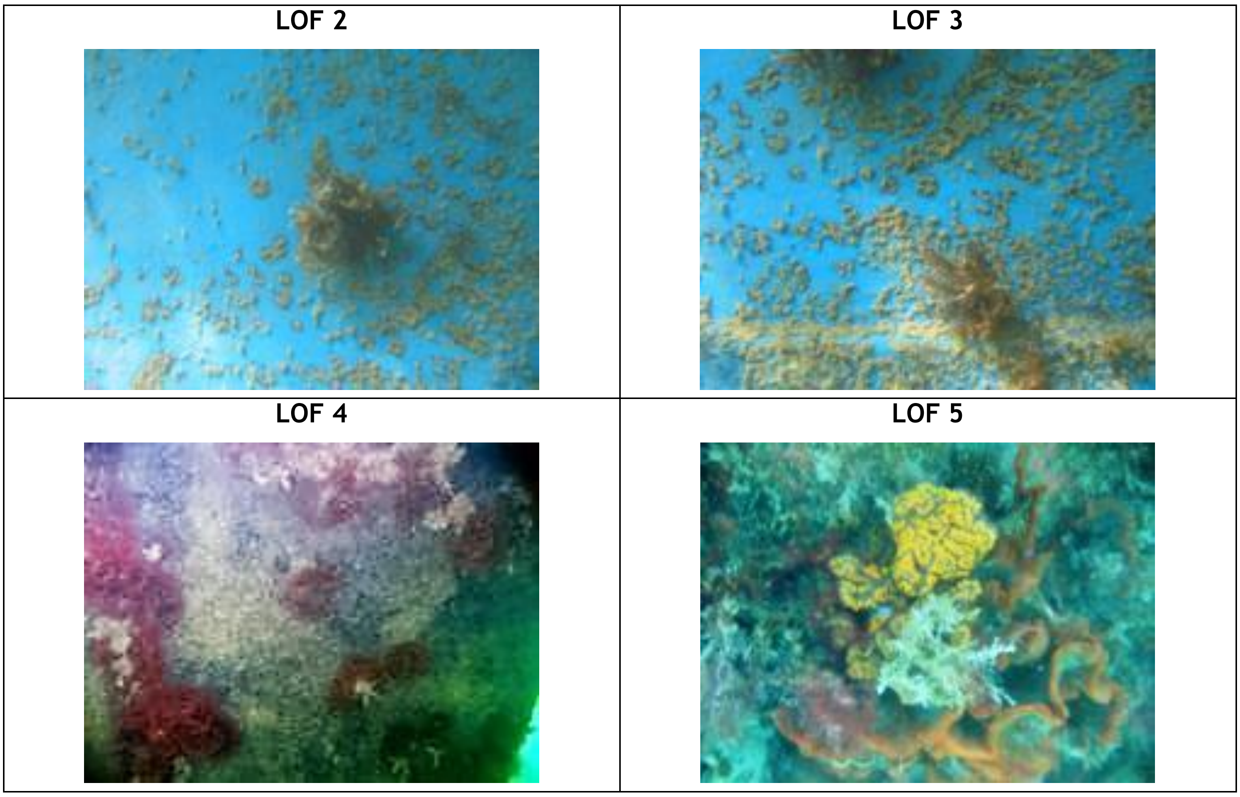

Figure 2. Level of fouling (LOF) examples. The photographs are close-up rather than depicting "whole boat" hence should be considered only as illustrative.

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

In addition to LOF scores, the presence of known marine pests was recorded, based on the target list of six species in Table 2. 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, the clubbed sea squirt *Styela clava* and the Mediterranean fanworm *Sabella spallanzanii* were of particular interest during the survey, as they have been subject to recent management efforts in Nelson, Picton and Waikawa. The two other sea squirts, *Pyura doppelgangera* and *Eudistoma elongatum*, were of interest as designated pests that have not yet been recorded in the TOS, but exist in northern New Zealand in locations connected to the TOS by vessel movements. The Asian kelp *Undaria pinnatifida* has been established in the TOS for several decades, but was nonetheless of interest give that: (i) there still remain places that are *Undaria*-free, and to which recreational vessel biofouling is the most likely means of spread; and (ii) *Undaria* is a potentially useful indicator of the future spread of new or recent biofouling incursions that are not effectively managed.

2.3 Data recording and analysis

Recording

Field data were recorded in a custom-built tablet-based reporting template developed with software available at www.fulcrumapp.com, the key elements of which are described in Appendix 1. The template was used to record the location and type of each vessel surveyed (sail or power boat), vessel LOF, and the occurrence of any of the target pests on vessels and moorings (where checked). The software automatically recorded GPS position and linked any photographs that were taken to the unique record number assigned to each vessel. The code number for each questionnaire that was simultaneously dropped off to each boat or skipper/owner (see Section 3.1) was entered into the template. This enabled field data to be linked to questionnaire responses subsequently received by post. At the end of each field day, the data were uploaded to the fulcrumapp website and exported to Excel.

Analysis

Tabulated and graphical displays of the results are presented below. All analyses and distributional maps of vessels and pests were generated using the software “R”. The LOF scores for boats surveyed were compared to the results from 2013 and 2014 surveys on vessels from Nelson and Waikawa (Forrest 2013, 2014). Given that one of the goals was to understand the fouling status of vessels in active use in the region (as opposed to sitting idle), 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.

Table 2. Marine fouling pests targeted on recreational vessels and associated moorings during the regional survey. All are MPI-designated marine pests (see MPI 2015) except for *Didemnum vexillum*, which is of interest as a potential regional pest.

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, **Nelson**, **Picton,** Lyttelton	
Styela clava	Clubbed tunicate / Solitary sea squirt	Whangarei, Tutukaka, Auckland, Tauranga, Wellington**, Nelson, Picton, Waikawa,** Lyttelton, Dunedin	
Undaria pinnatifida	Japanese or Asian kelp / Large brown seaweed	Widespread nationally, including **Nelson** and **Marlborough Sounds**	

2.4 Field survey results

Levels of fouling

LOF scores in the summer 2015/16 regional survey were comparable to that recorded in earlier studies that focused on Nelson and Waikawa (Figure 3). In summer 2015/16, 35% of vessels had an LOF of ≥ 3, reflecting a fouling cover exceeding 5%. At this level, 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 near the water-line. Vessels that can be described as "heavily fouled" are those whose LOF is ≥ 4. In the summer survey, 16% of vessels fell into this category, which was comparable to the 2013 data (17% LOF ≥ 4) but slightly less than in 2014 (20% LOF ≥ 4).

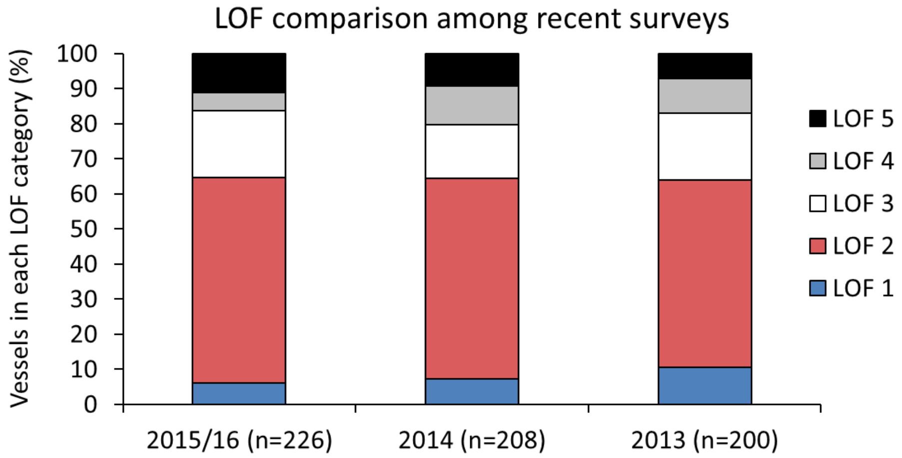

Figure 3. Proportion of vessels in each LOF category comparing the summer 2015/16 survey data with combined LOF scores from each of two Nelson and Waikawa surveys described in Forrest (2013, 2014). Bracketed numbers indicate the number of vessels sampled.

Boats that were in active use as defined above were clearly less fouled than those whose activity status was unknown (Figure 4). Approximately 8% of active boats were heavily-fouled, with LOF ≥ 4, whereas this figure was 29% for the remaining boats of unknown activity status. These data suggest that boats in active use are more well-maintained than boats that may otherwise be sitting idle (e.g. at moorings or marina berths). This finding is consistent with the expectation that many boaters clean and antifoul their vessels in the few months leading up to planned periods of summer activity (see also Section 3.3).

Boat type also appears to be important in terms of fouling status. Approximately 19% of sail boats (n=138) had LOF scores ≥ 4, compared with 13% of power boats (n=88). Previous surveys at Nelson and Waikawa marina/mooring areas have shown that fouling accumulation is as high (or higher) on power compared with sail boats. The reduced fouling on power boats in the present survey is consistent with the fact that half of the boats in the dataset were categorised as being in active use. As power boats typically travel at faster speeds (> 10-15 knots) than sail boats (typically 7-8 knots), some of the associated fouling on active boats would likely be lost due to physical dislodgement or damage. Studies by Coutts et al. (2010a, 2010b) suggest that the threshold for fouling loss by dislodgement or damage is c. 10 knots; i.e. there tends to be high survival of fouling at voyage speeds of < 10 knots, with reduced survival as speed increases above that threshold.

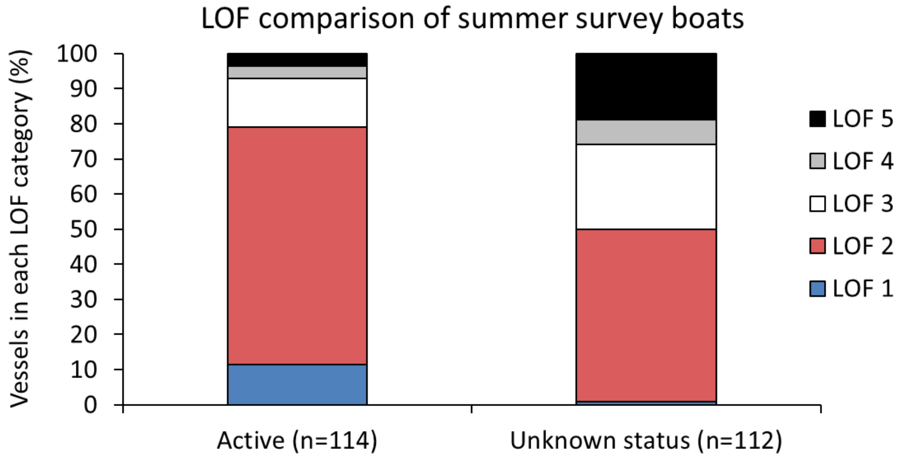

Figure 4. Proportion of vessels in each LOF category, comparing boats from the summer 2015/16 survey classified as being in active use with boats whose activity status was unknown. Bracketed numbers indicate the number of vessels in each category.

Occurrence of marine pests

Across the 226 recreational vessels and 135 moorings surveyed, no pests were found that were new to the TOS region. However, two target pests of particular interest were present on six boats across four locations (Figure 5). The fanworm *Sabella* was found in outer Queen Charlotte Sound (Endeavour Inlet), on a yacht from Wellington which had been scored LOF 3 (Figure 6). Fanworm samples that were taken were later determined to be juvenile and non-reproductive[3], and follow-up by MPI confirmed that the boat was slipped and cleaned upon return to Wellington. Also of interest were finds of the sea squirt *Styela* on five yachts, three of which were in Tarakohe Harbour on boats that were heavily fouled at LOF 4 or 5 (Figure 5). *Styela* was also found on three moorings in Tarakohe. Elsewhere in the region *Styela* was found on two boats with light fouling (LOF 2). One of these was a yacht from Nelson that was anchored at Adele Island on the Abel Tasman coast (Figure 6). The other was a yacht from Wellington that was anchored in Penzance in the mid-Pelorus Sound, which was also LOF 2.

[3] MPI were alerted to the fanworm find via their pest and disease freephone, and fanworm samples were sent to NIWA's Marine Invasives Taxonomic Service (MITS) for taxonomic verification and assessment of reproductive status.

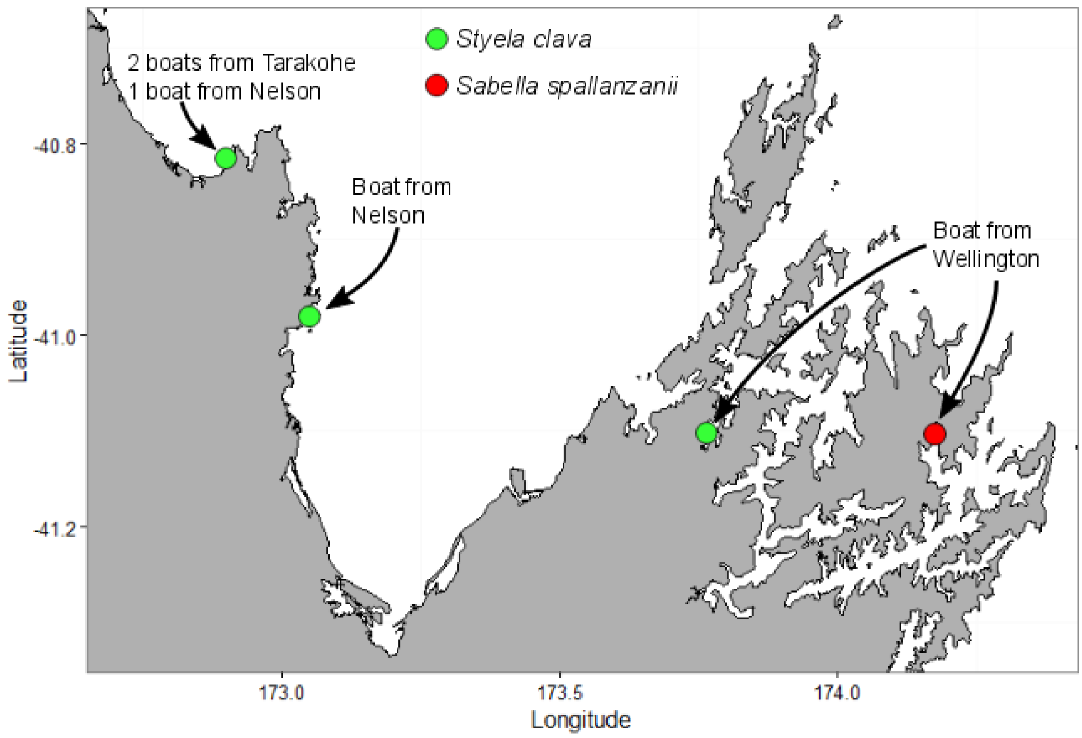

Figure 5. Occurrence and origin of the sea squirt *Styela clava* and fanworm *Sabella spallanzanii* on recreational boats surveyed.

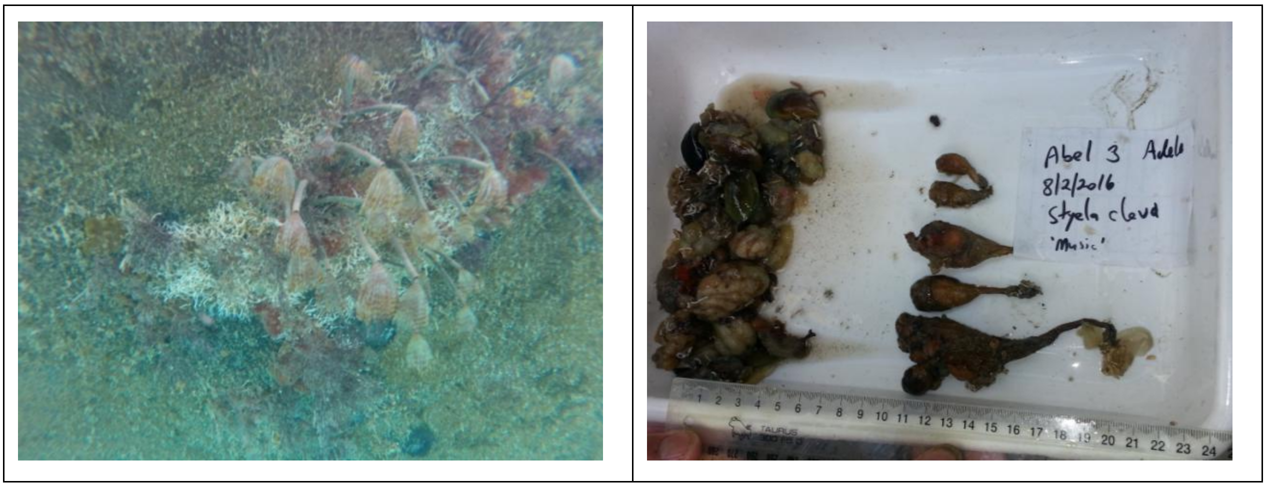

Figure 6. Fanworm *Sabella* on a yacht fouled at LOF 3 in Queen Charlotte Sound (left) and sea squirt *Styela* collected from the keel of a yacht fouled at LOF 2 in the Abel Tasman.

Compared with *Sabella* and *Styela*, longer-established marine pests were more prevalent across the region, on both vessels and moorings. The kelp *Undaria* was first recorded in the TOS in Picton in 1991 and Nelson in 1997 (Forrest et al. 2000), and has since spread regionally. It was found on 24% of boats and 33% of moorings (Figure 7a,b). These figures likely underestimate *Undaria*'s true prevalence, as the visible kelp dies back in localities with warm summer sea water temperatures (but a microscopic life-stage remains). This phenomenon is likely to explain why *Undaria* was not recorded from moorings in Pelorus Sound where the water is relatively warm in summer, even though it grows prolifically throughout the Pelorus during its seasonal peak in spring (Forrest et al. 2000).

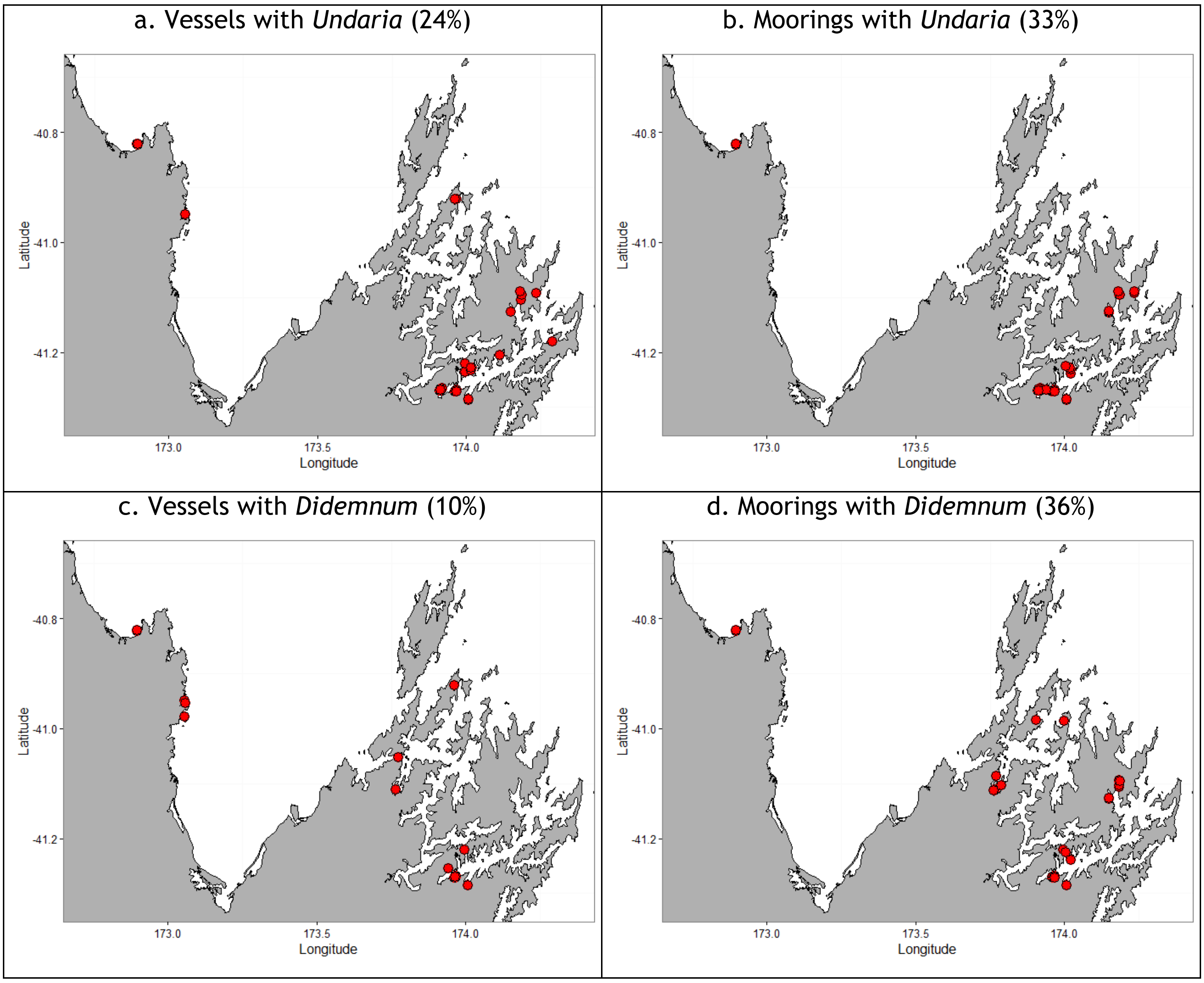

Figure 7. General locations and prevalence (% occurrence) of the kelp *Undaria* (a,b) and sea squirt *Didemnum* (c,d) on vessels (n=226) and moorings (n=135). Some red symbols overlap due to occurrences in close proximity.

The sea squirt *Didemnum* was also regionally common. After being detected in the TOS in 2001 in Shakespeare Bay (next to Picton), this species was well-established throughout the Marlborough Sounds, Nelson and Tarakohe by 2008 (Coutts and Forrest 2007; Forrest and Hopkins 2013). In the present survey, *Didemnum* was detected on 10% of boats and 36% of moorings surveyed (Figure 7c,d).

Other species of interest were the sea squirt *Ciona* spp. and calcareous fanworm *Hydroides elegans*, especially on boats originating from Nelson. Although these species have been present in New Zealand for decades, they have been reported as problem pests in New Zealand and overseas. For example, *Ciona* caused localised but severe fouling impacts on the Marlborough mussel industry in 2000/2001, and in recent years has decimated the mussel aquaculture industry in eastern Canada (Ramsay et al. 2008). *Hydroides* has also been reported to cause problematic fouling in aquaculture overseas (Antoniadou et al. 2013) and is regarded by boaters in Nelson marina as a summer fouling nuisance.

Overall, a total of 30% of boats had at least one of the pests listed in Table 2 present. Figure 8 shows an increasing prevalence in the occurrence of marine pests as LOF increases. Accordingly, patterns in pest occurrence in relation to boat activity status and type, matched the LOF patterns described above, as follows:

- In relation to boat activity status as defined above, pests were present on 14% of active boats, and on 19% of boats whose activity status was unknown. Hence, active boats with reduced fouling also tended to have a lesser prevalence of pests.
- In relation to boat type, pests were more prevalent on sail boats (34% occurrence) than power boats (23% occurrence). As above, this finding suggests that marine pests may be physically dislodged or damaged at the increased speeds at which power boats travel.

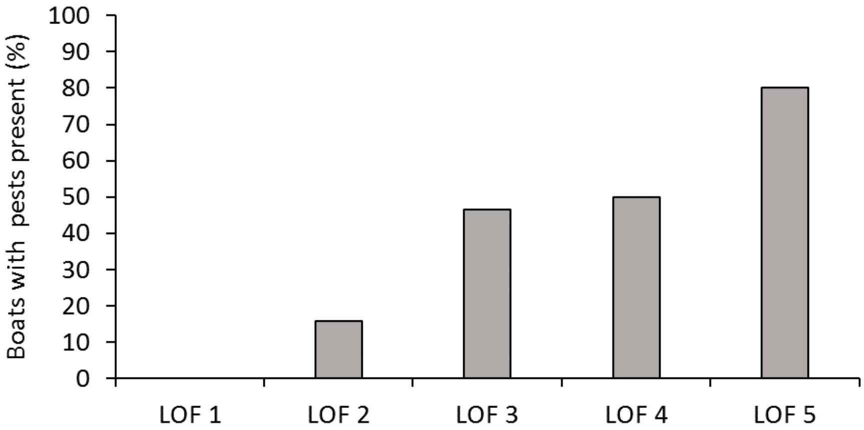

Figure 8. Percentage of recreational boats with any of the designated pests from Table 2 present within each LOF category. By definition, no visible pests can be present at LOF 1 (see Table 1).

Other fouling observations

The presence of pests on boats having light to moderate fouling is an important finding from the survey. From Figure 8, 16% of LOF 2 boats and 47% of LOF 3 boats had at least one of the target pests from Table 2. It was often the case that boats with light fouling overall (and perhaps only a slime layer on the main hull) had well-developed fouling in "niche" areas, such as described in Section 2.2 (Figure 9).

Vessel keels emerged as being of particular interest as a result of the field survey. The keel bottom often had advanced macrofouling, including designated pests. Depending on boat type, the surface area of the keel bottom can be considerable, and represent by far the most significant niche area. During maintenance, keels may be incompletely coated with antifouling paint, or not coated at all. Another consideration is that antifouling on keels can be easily damaged in shallow water when boats scrape the seabed.

From a biosecurity management perspective, it is important to recognise that niche areas can not only harbour marine pests, but that pests can be difficult to detect when advanced fouling is present.

Figure 9. Example of a yacht with a clean overall hull but pronounced niche area fouling on bottom of keel (left) and propeller area (right).

3. BOATER QUESTIONNAIRE

3.1 Questionnaire design and delivery

The design of the boater questionnaire (Appendix 2) was based on previous surveys relating to vessel biofouling in New Zealand (Floerl and Inglis 2005; Inglis et al. 2010; Lacoursière-Roussel et al. 2012), with some specific questions customised to the information needs of the TOS. The TOS questionnaire was shorter overall than that used in previous studies, being restricted to a single A4 page; it was hoped that boaters would be more willing to complete a short questionnaire. As a further incentive, boaters who wanted to go into a draw for a free haul-out and clean were invited to write their contact details on the questionnaire.

The questionnaire was delivered (together with the awareness brochure referred to in Section 1) in ziplock bags that contained a pen and freepost envelope for returns. Over 1,000 questionnaires with these ziplock packs were distributed across the TOS as follows:

- During the field survey, the questionnaire was complete by willing boaters, or it was left with them for later completion. In addition, ziplock bags were placed on unoccupied vessels throughout Queen Charlotte and Pelorus Sounds.
- The ziplock packs were dropped-off to boats in Nelson and Tasman marinas by the TOS Coordination Team, with assistance from the Tasman Harbour Master for Motueka and Tarakohe.
- In the case of Port Marlborough marinas (Waikawa, Picton, Havelock), the questionnaire and brochure were emailed to berth holders.
- A Nelson yacht owner was contracted to deliver the ziplock packs to boats around Croisilles Harbour, D'Urville Island, French Pass and outer Pelorus Sound.

3.2 Data recording and analysis

The analysis below is based on 208 questionnaire returns received as at 17 May 2016. These comprised 27 questionnaires filled out by boaters at the time of the field survey (see Section 2), 23 questionnaires returned from travel-lift operators, and the remainder returned by post. Data from the 208 returns were entered into Excel and analysed using the software R. Tabulated or graphical displays of the results are presented below. The analysis considered boater habits in terms of maintenance (i.e. antifouling and cleaning practices), boat origin and boater activity. As noted in Section 1, a more comprehensive analysis will be undertaken once the data gathering phase of the travel-lift surveys is completed. For now, the results presented below should be regarded as preliminary only. It should also be noted that despite receiving 208 returns, it was not always the case that questionnaire forms were completely filled out. As such, for each of the results presented below the sample size (n) is indicated on which the summary data are based.

3.3 Questionnaire results

Boat storage, maintenance and use

Of 205 respondents who reported on boat storage, 28% usually kept their boats on swing moorings, with the remainder at marina berths (except one at a private berth). Most boaters antifouled their vessel every 12-24 months (Figure 10). The average antifouling interval was c. 21 months (± SE 0.06, n=198), with a median interval of 18 months. A total of 67% of boaters antifoul at intervals longer than 12 months and 11% antifoul at intervals longer than 24 months. These figures are comparable to summary data from 906 recreational boats in New Zealand, which were reported in a recent publication (Floerl et al. 2016). The longest reported antifouling interval in the present study was 10 years (120 months) by a boater that used a long-life hard-wearing copper coating, which was regularly cleaned.

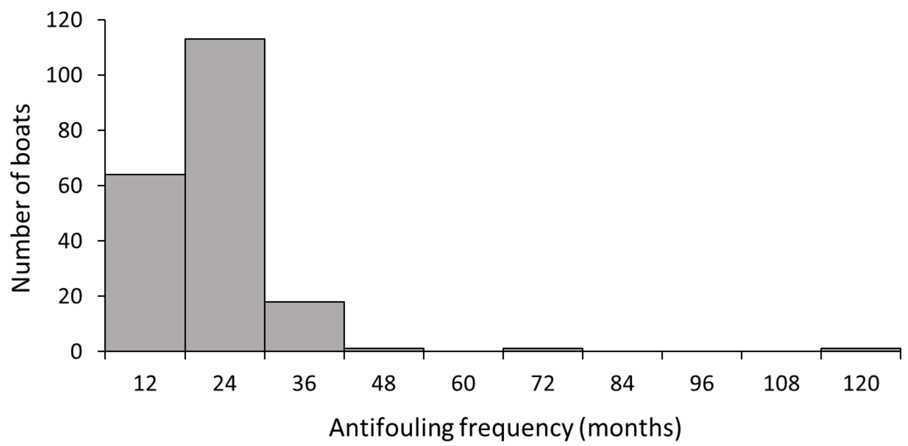

Figure 10. Frequency of antifouling in recreational boats surveyed in the TOS in summer 2015/16 (n=198). Antifouling frequency recorded as: 12 = 6-12 months, 24 = >12-24 months, etc.

The average time elapsed since last being antifouled relative to the time of the survey was reported as 394 days (± SE 1.76, n=199) which equates to c. 13 months. Not surprisingly, the peak in antifouling activity tended to occur in the months leading up to the summer holiday period, especially in November and December (Figure 11). A total of 37% of annual antifouling occurred in these two months.

A total of 196 respondents reported their boat usage, of which 187 simultaneously reported the date (usually month) of last antifouling. Accordingly, for those 187 boaters the days of active boat use since last antifouling could be determined as a percentage of the total elapsed days available. From the results, it is evident that boat usage is typically quite low (Figure 12). A total of 13 boats (7%) had remained idle since their last antifouling, 66 (35%) had been active for 5% or less of available days, and 107 boats (57%) had been active for 10% or less of available days.

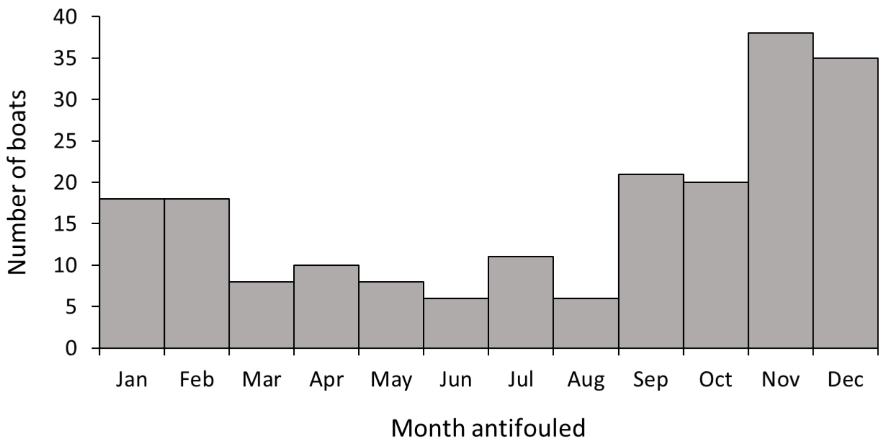

Figure 11. Pattern of recreational vessel antifouling during the year (n=199).

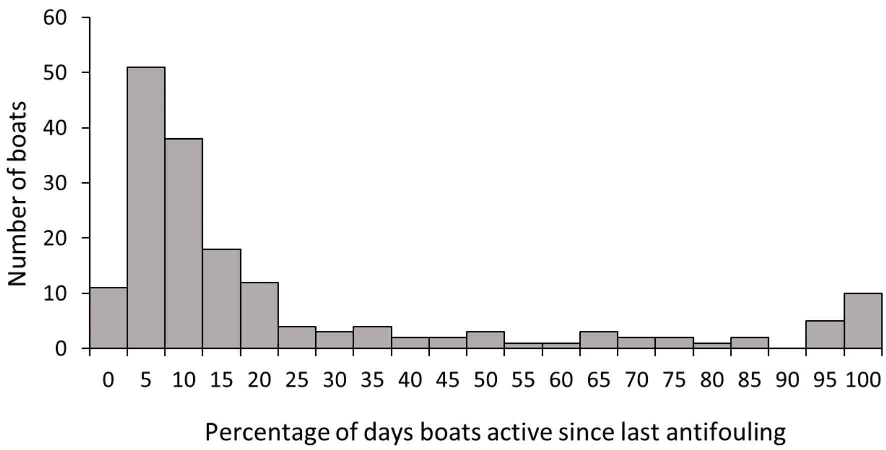

Figure 12. Percentage of days recreational boats were reported to be in active use since last antifouling, and corresponding number of boats (n=187). Percentage of days recorded as: 0 = no active days, 5 = >0-5% of days active, 10 = >5-10% of days active, etc.

This low-usage profile would be expected to make the majority of boats relatively susceptible to accumulating biofouling, despite the relatively regular antifouling evident from Figure 10. This expectation is consistent with the fouling profiles described in Section 2. Not surprisingly, therefore, vessel cleaning between antifouling events was reasonably common. Approximately 35% of boaters reported that they had cleaned their hull since last being antifouled, with cleaning locations as follows:

- 56% cleaned in-water.
- 10% cleaned on a beach or intertidal area.
- 34% cleaned at a haul-out facility.

The 35% incidence of cleaning is greater than c. 20% reported in a TOS study conducted in 2010 (Lacoursière-Roussel et al. 2012). Despite this difference, it is nonetheless suggested that the overall incidence of cleaning between one antifouling event and the next could be even higher than the 35% indicated in the present study. The phraseology in the questionnaire related to cleaning since the most recent antifouling, hence would not have captured the full extent of cleaning behaviour between antifouling intervals. The reason for this phrasing related to the ongoing third component of the study (the travel-lift surveys), which will aim to correlate vessel LOF with the time since last antifouling and cleaning, among other factors.

Boater origin and areas of activity

A total of 192 respondents provided the name of their home port. Of these, the home port for 90% of boaters was the TOS, with 18 boat coming from elsewhere in New Zealand and two being of international origin (Table 3). The New Zealand boats from outside the TOS mainly originated in Wellington marinas (13 vessels), with the remainder from Auckland (1), Northland (1), Lyttelton (2) and Akaroa (1).

Table 3. Main region of home ports of TOS questionnaire respondents (n=192).

Main region	No. of boats	% of boats
Within TOS	172	90
New Zealand	18	9
International	2	1

It was of interest that, among the visitors from outside the TOS, only 25% reported that they always go to one of the main vessels hubs (e.g. Nelson, Picton, Waikawa) as part of their visit to the region. The remaining 75% visit a hub only “rarely” (35%) or “sometimes” (40%). This finding was consistent with our impression from the field survey. For example, the boaters from Wellington that had *Styela* or *Sabella* on their hulls (see Figure 5) intended to travel only in the outer parts of the Marlborough Sounds before returning home.

Of the 172 respondents from Table 3 whose vessels are domiciled in the TOS, 164 reported their boating activity. Of these, the general activity since last being antifouled was as follows:

- 10 boats (c. 6%) remained idle.
- 154 boats (c. 94%) were active in the TOS for at least 1 day.
- 16 boats (c. 10%) had travelled to locations in New Zealand outside the TOS (e.g. Fiordland, Stewart Island, Bay of Islands).
- 4 boats (c. 2%) had travelled internationally (to Fiji).

In terms of within-TOS activity, total days of boating across all sub-regions as recorded by survey respondents is indicated in Table 4. This Table suggests that Golden Bay, Tasman Bay and Queen Charlotte Sound experience a disproportionate number of boating days relative to other sub-regions.

Table 4. Total number of boating days recorded by survey respondents since their last antifouling.

Location	Boating days
Golden Bay	2,196
Tasman Bay	2,984
D'Urville Island	526
Pelorus Sound	637
Queen Charlotte Sound	3,264
Port Underwood	48

Based on reported areas of vessel activity, the origin of boats that visit the different geographic locations in Table 4 was derived (Figure 13). Most sub-regions were characterised by a high proportion of vessels originating from the same sub-region. For example, 83% of boats visiting Tasman Bay originate from Tasman Bay (mainly from Nelson), and 60% of boats visiting Queen Charlotte Sound originate from that sub-region (mainly from Picton and Waikawa). However, of interest is the prevalence of boats (16-18%) from outside the TOS (i.e. mainly Wellington as noted above) that visit the three sub-regions of the Marlborough Sounds more than Tasman and Golden Bays.

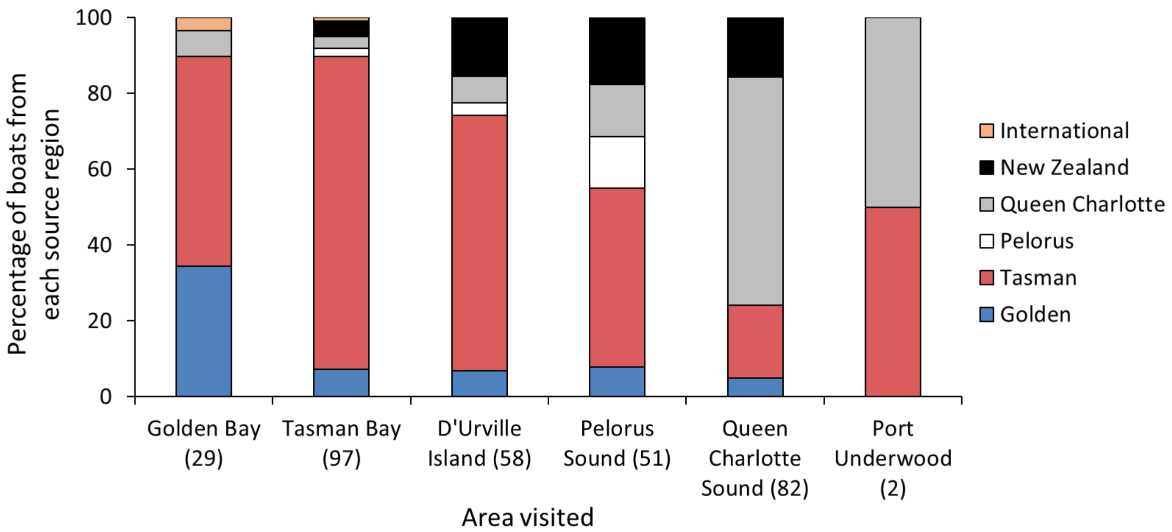

Figure 13. Origin of boats visiting different areas of the TOS. Boat origin is expressed as the percentage of boats from each of the source regions shown in the legend key. Percentages are based on numbers of boats indicated in brackets for each area visited. As such, data for places like Port Underwood (n=2 boats) may not be representative.

4. SYNTHESIS OF FINDINGS

4.1 Recreational vessel risk

When the field survey and questionnaire responses are considered collectively, it is clear that recreational vessels may pose a significant biosecurity risk to many of the locations with important values in the TOS. Some key points arising from the work to date are discussed below.

Despite the questionnaire responses indicating that boater antifouling is fairly regular (at 12-24 month intervals, median 18 months), the field survey revealed that many conspicuously fouled boats are active throughout the TOS, and many are carrying designated marine pests. The prevalence (on boats and moorings) of long-established pests like the kelp *Undaria*, and to a lesser extent the sea squirt *Didemnum*, is probably a good indication of the future prevalence of pests that have arrived more recently, in particular the sea squirt *Styela* and fanworm *Sabella*. As a rough guide, there appears to be a positive association between the length of time pests have been present in the TOS and their regional prevalence. Effective management to reduce this biofouling risk is clearly needed. In this regard, niche area fouling will be an important consideration given evidence from the field survey that vessels with light overall fouling could nonetheless have advanced fouling (and marine pests) in places such as keels.

Wellington appears to be a key source region to the TOS (especially the Marlborough Sounds), with many visiting boas travelling directly to holiday locations (e.g. Endeavour Inlet where *Sabella* was found) and not main vessel hubs. The findings of *Styela* and *Sabella* on boats originating in Wellington led the Coordination Team to liaise directly with Wellington marina managers. Mana marina was particularly proactive. The marina manager initiated a survey which revealed that *Styela* was widespread and common, and also assisted with the distribution of the information packs and questionnaire.

Although only 30 responses have been received following the distribution of questionnaire to Wellington, it is of interest that 60% of boaters reported having visited the TOS since their last antifouling. Of these, most activity was in Queen Charlotte Sound. This finding is consistent with the results in Section 3.3, and supports the Mana marina manager's belief that the Marlborough Sounds is the "playground" for Wellington boaters. As such, the findings of this report probably reflect the "tip of the iceberg" in terms of risk from Wellington boats. Interestingly, the marina manager believed that boaters were proactive in cleaning or antifouling their hull before visiting Fiordland, as they recognised the pristine nature of that region; however, they did not have the same perception in relation to the TOS.

Another point that emerges from the analysis in this report, as well as related studies, is that small ports like Tarakohe in Golden Bay should not be overlooked as potentially important reservoirs for marine pests, as well as hubs for pest spread within and beyond the TOS. A recent report prepared for the TOS by the Cawthron Institute (Floerl et al. 2015) revealed that Tarakohe has some unusual vessel activities that connect it will other parts of New Zealand outside the TOS, such as the Taranaki oil and gas fields.

Tarakohe is also a hub for regional aquaculture, hence any pest infestation there is of direct relevance to the marine farming industry. In this respect, the occurrence of *Styela* on recreational vessels and moorings (and conceivably on commercial vessels) is of considerable significance. This species decimated the mussel industry in eastern Canada for several years, until it was overtaken by *Ciona* (Davidson et al. 2005; Ramsay et al. 2008).

4.2 Management implications

In view of the Tarakohe situation, and the known impacts of *Styela*, present or recent efforts to suppress populations in Nelson, Picton and Waikawa are unlikely to be sufficient to protect the sector that appears to be most at risk from the species. More broadly, the summer survey work reiterates that effectively reducing risk to the TOS requires consideration of measures to directly address recreational vessel fouling, not only within, but also outside, the TOS. The latter appears especially important in regions like Wellington where many recreational vessels originate, and also Auckland, which has a high incidence of pests.

The incident register maintained by the Coordination Team highlights that in the last few years an increasing number of risk vessels have been intercepted and effectively managed upon arrival in the TOS. However, given that some vessels visit remote parts of the region without necessarily passing through a vessel hub, the present report highlights the essential need to address vessel risk at source; this means that recreational vessels need to leave their home ports with a “clean” hull. While some work has already started with Wellington marinas, there is clearly more that needs to be done nationally to be better ensure effective management efforts are in place.

Achieving effective management is undeniably complex. The fact that LOF scores in the present survey were comparable to earlier surveys suggests that TOS actions relating to recreational boater education and awareness have had no obvious (or measureable) biosecurity benefit. There is a pressing need for appropriate measures, guidance and infrastructure to be available to enable hull biofouling to be reduced. Various approaches to biofouling reduction have been considered to date, including “outcome-based” approaches and “standards-based” approaches. Examples of outcome-based approaches include:

- The berth agreement for Nelson marina limits the occurrence of “conspicuous” levels of fouling allowed on berthed vessels, defined in relation to LOF ≥ 4. Hence, this approach aims to deal with the most heavily-fouled vessels. However, the agreement has not yet been enforced.
- A proposed pathway management plan for Fiordland imposes a stringent measure that restricts hull fouling on all vessel types to a slime layer and goose barnacles, which matches the most strict border standard developed by MPI for vessels arriving in New Zealand (CRMS 2014).

- Auckland Council has developed permitted activity rules as part of its Unitary Plan that, among other things, aim to reduce movements of heavily-fouled recreational vessels (LOF 4 and 5).

Standards-based approaches involve specifying requirements for vessel cleaning or antifouling. For example:

- Floerl et al. (2016) suggested that biofouling risk could be reduced if the interval of recreational vessel antifouling was able to be reduced to 12 months.
- Recently, some marinas in Northland adopted/advocated a "six or one" rule, which requires visiting boaters to provide evidence that their vessel has been antifouled in the last six months or lifted and washed within one month.

The main drawback of standards-based approaches is that they don't necessarily negate risk, and don't give boaters the flexibility to reduce risk in the way that best suits them. A related issue is that there needs to be sufficient infrastructure and guidance for boaters to enable them to clean vessels to achieve a given fouling level or maintenance standard. Previous work has highlighted boater concerns regarding the lack of tidal grids for boat cleaning, and a perceived high cost of hard-stand facilities in Nelson (Forrest 2014).

There is a related need for clear guidance on allowed practices for intertidal and in-water cleaning. The questionnaire analysis revealed that these practices are common already, but there is confusion among boaters as to what is allowed. Additionally, while New Zealand has some very good guidance on in-water cleaning in relation to management of biofouling risk (ANZECC 2013), different stakeholders have differing views on the acceptability of these practices; the main concern is the associated risk of releasing antifouling contaminants (Morrisey et al. 2013). Auckland Council has addressed this issue in their Unitary Plan by specifying requirements for cleaning methods and waste capture that relate to levels of fouling. The Auckland Council approach is consistent with ANZECC in that it encourages regular in-water cleaning to ensure fouling doesn't accumulate, using gentle methods that minimise contaminant release.

The niche area issue identified during the field survey presents a considerable challenge to the goal of maintaining fouling to levels where biofouling risk is adequately reduced. Regular cleaning of niche areas could be part of the solution. However, there is also scope to improve on current antifouling practices. For example, as noted in Section 2.4, it is not uncommon for boat keels to be poorly antifouled. Similarly, effective antifouling may be absent from patches on the side of the hull where boats rest on hard-stand supports (see Figure 6). To effectively antifoul these areas is clearly not impossible, but adds another step (and time or cost) to the maintenance procedure (i.e. the vessel needs to be repositioned on keel blocks and side supports, to enable access to the untreated areas).

The lack of effective management of recreational vessels at present means that:

- New pests are likely to arrive in the TOS from elsewhere in New Zealand.
- Established pests with currently confined distributions are likely to be further spread in the TOS by vessels movements.
- Long-established pests may ultimately be spread to most of the suitable habitats in the region.

While managing the vessels themselves is critical the ongoing feedback from many boaters with marina berths relates to the futility of managing fouling on their boats when the adjacent pontoons remained fouled with marine pests. There is no easy solution to this issue. There is no doubt that control of target pests in source hubs like marinas and ports is an effective management measure (Forrest and Hopkins 2013). However, there is a need for practical and affordable tools to keep marine structures in these localities free of significant fouling in general, to reduce source populations of all potential pests.

5. ACKNOWLEDGMENTS

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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. Location	na	Multiple choice	y	y	QCS, PEL, ABEL,TORY, TARA (numbers 1,2 3 etc used to designate sub-areas)	None
2. Vessel survey	**Section**	Section	na	na	na	None
	a. Vessel surveyed	Yes/No	na	na	na	None
	b. Vessel type	Single choice	n	y	Power, Sail	None
	c. Questionnaire delivery method	Single choice	n	y	Dropped off (no one present), Dropped off (boater present), Asked all questions, No questionnaire	Vessel surveyed = yes
	d. Questionnaire code	Text	na	y	Free form	None
	e. LOF	Single choice	n	y	1, 2, 3, 4, 5	Vessel surveyed = yes
	f. Pest present on vessel	Yes/No	na	y	na	Vessel surveyed = yes
	g. Vessel pest name	Multiple choice	y	y	Didemnum, Eudistoma, Pyura, Sabella, Styela, Undaria, Unknown	Pest present on vessel = yes
	h. Vessel pest sample taken	Yes/No	na	y	na	Pest present on vessel = yes
	i. Vessel pest sample code	Text	na	y	Free form	Vessel pest sample taken = yes
	j. Vessel pest photo	Photos	na	y	na	Vessel pest sample taken = yes
3. Mooring survey	**Section**	Section	na	na	na	None
	a. Mooring surveyed	Yes/No	na	na	na	None
	b. Pest present on mooring	Yes/No	na	y	na	Mooring surveyed = yes
	c. Mooring pest name	Multiple choice	y	y	Didemnum, Eudistoma, Pyura, Sabella, Styela, Undaria, Unknown	Pest present on Mooring = yes
	d. Mooring pest sample taken	Yes/No	na	y	na	Pest present on Mooring = yes
	e. Mooring pest sample code	Text	na	y	Free form	Mooring pest sample taken = yes
	f. Mooring pest photo	Photos	na	y	na	Mooring pest sample taken = yes
4. Notes		Text	na	n	na	None

Appendix 2. Questionnaire used for boater survey.

Please hand in this survey if using the travel-lift at Waikawa or Nelson, or post in the enclosed envelope

Code:

HELP STOP MARINE PESTS SPREADING - COMPLETE AND RETURN OUR BOATER SURVEY

This survey is part of research by the Top of the South Marine Biosecurity Partnership into hull biofouling in Marlborough, Tasman Bay & Golden Bay. Survey responses will be treated as CONFIDENTIAL, but aggregated research findings will be publically available. For enquiries, contact **tosmarinebio@gmail.com**. To enter a draw for a free hull clean (valid 12 months anywhere in New Zealand), write your contact details at the bottom of the form where indicated. Thanks for helping.

QUESTIONS FOR COMPLETION BY VESSEL OWNER/SKIPPER

1. Boat type: ☐ Sail ☐ Power **2. Where is your usual home port?**____________________

3. Where is your boat usually stored? ☐ Marina berth ☐ Mooring ☐ On land

4. What is your typical voyage speed? __________ knots

5. How often do you apply antifouling paint: ____

6. When was the last anti-fouling paint applied? ______________ / _________ (month/year)

Anti-fouling paint product name: ____

7. Since the last anti-fouling application has the hull been cleaned (e.g. by scrubbing, brushing)?

☐ No ☐ Yes

If yes, was the vessel cleaned: ☐ On land/slip ☐ In-water ☐ Inter-tidal/beach

How many times has it been cleaned? _______

Geographic location(s) cleaning took place: ____

Date most recently cleaned: ______________ / ________ (month/year)

8. Since the last antifouling, approximately how many boating days have you spent in (or near) each of the following locations?

Golden Bay: _____days Tasman Bay/Abel Tasman: _____days D'Urville Island: _____days

Pelorus Sound: _____days Queen Charlotte: _____days Port Underwood: _____days

Other regions of NZ: _____ days. List regions: ______________________________________

Other countries: _____ days. List countries: ______________________________________

9. If you are a visitor from outside Marlborough, Tasman Bay or Golden Bay, do you typically travel to a regional port or marina during your visit:

☐ Always ☐ Sometimes ☐ Rarely ☐ Never

FOR OFFICIAL USE ONLY

Date: **Survey node:** ☐ Travel-lift ☐ Marina ☐ Mooring ☐ Boat at anchor

Fouling % cover (Level of fouling) ☐ Slime only (LOF1) ☐ 1 - 5% (LOF2) ☐ 6-15% (LOF3) ☐ 16-40% (LOF4) ☐ 41-100% (LOF5)

Specific location: **GPS:**

Marine pests: **Sample(s) taken?** ☐ No ☐ Yes

CONTACT DETAILS FOR FREE HULL CLEAN DRAW (OPTIONAL)

Mob: ______________________ Email:___________________________________