Vessel Hull Fouling as a Marine Biosecurity Indicator in the Top of the South: 2014 Survey

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

The Top of the South (TOS) Marine Biosecurity Partnership was formed in 2009, and contracts a Coordination Team to promote biosecurity risk awareness and risk reduction. A key focus of the Coordination Team's effort is on management of risk pathways that could introduce or exacerbate marine pest spread in the TOS. The Management Committee that oversees the work programme recognised the need for performance measures that reflect the success or otherwise of the Coordination Team's efforts. For this purpose, monitoring of recreational vessel hull fouling status was chosen as a key indicator of potential risk reduction. Recreational vessels are themselves an important risk pathway, and also are numerous and relatively easy to monitor, making them an ideal indicator.

This report describes a survey of hull fouling on 528 recreational vessels in the TOS that was conducted in summer 2014, which repeats monitoring undertaken in summer 2013. Vessels inspected consisted of 459 in Nelson marina, and 69 on swing moorings in Nelson Harbour (19) and Waikawa Bay (50). Fouling status was assessed according to an existing Level of Fouling (LOF) scale, ranging from slime layer fouling or less (LOF ≤ 1; no visible macrofouling) to very heavy macrofouling (LOF 5). The LOF assessment was made from the surface, and then in-water using snorkel. In the case of Nelson marina, only a subset of boats was surveyed in-water. Of particular interest were the most "heavily fouled" vessels, defined as those with LOF ≥ 4 (i.e. any vessel with macrofouling covering ≥ 16% of the hull surface), as such vessels are regarded as the most high risk in terms of their potential to transport marine pests. In addition to LOF, the snorkel survey included a check for the presence of common species that indicate advanced levels of fouling, and for fouling species designated as marine pests by the Ministry for Primary Industries (MPI). However, the marine pest check was cursory only, and may under-estimate the true occurrence of such species.

The results for both surface and in-water LOF scores were similar to the 2013 survey. This finding suggests that TOS actions to date (e.g. efforts to raise boater awareness regarding the importance of keeping hulls clean and antifouled) have had no measurable biosecurity benefit in relation to recreational vessel hull fouling. For example, on swing moorings in Nelson and Waikawa, 35% and 26% (respectively) of vessels were in the heavily fouled (LOF ≥ 4) category based on their surface LOF values. Fouling was lower at Nelson marina, where vessels with surface LOF 4 or 5 made up 16% of the total. This result is the same as recorded in 2013 and comparable to earlier hull fouling studies in the TOS.

The dominant fouling organisms included well-established species with a prior pest history, such as the non-indigenous sea squirt *Ciona* spp. Two MPI-designated marine pests were also recorded. Of most interest to MPI and the Partnership was the discovery of several Mediterranean fanworms, *Sabella spallanzanii*, on the keel of a yacht moored in Waikawa Bay. This is the first recorded range extension of this species into Marlborough, although the same species was also found in Nelson marina in November 2013. As well as the fanworm, a single sea squirt, *Styela clava*, was recorded on a moored boat in Nelson. This was of no immediate concern, as the species is known to have been present in the harbour area since at least 2010 and is already widespread nationally. As was the case in 2013, the kelp *Undaria pinnatifida* was found to be common, especially on moored boats, but this species is already widespread across much of the TOS.

The results highlight the need for improved management of hull fouling in the TOS, and the report discusses some of the issues that will need to be addressed to achieve reduced biosecurity risk. Despite the absence of an improvement in the context of the monitoring study, it is evident that there have nonetheless been some marine biosecurity gains in the TOS over the 1-2 years. For example, two vessels arriving in the TOS with Mediterranean fanworms on their hulls were identified early, and remedial action taken to treat them. Similarly, the range extensions of both the fanworm (Nelson and Waikawa) and *Styela clava* (Picton) were discovered, and led to the rapid implementation of management responses. In such cases, the communication networks and systems set-up by the Coordination Team have assisted in the timely identification and response to these high risk events.

The challenge now is to achieve wider reductions in the region's marine biosecurity risk, which will be reflected in the hull fouling survey results. The 2013 and 2014 surveys, along with the previous studies, provide a baseline against which future change in hull fouling risk status can be measured. However, until more comprehensive measures are in place to address risk pathways into and within the TOS, it is unlikely that future surveys will reveal any improvement. On that basis, it is recommended that effort should be redirected from vessel monitoring to pathway risk reduction, at least for the next year. Vessel monitoring every second year would probably be sufficient, or a hybrid approach involving a full survey every two years, but continued annual assessment of surface LOF.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

The Top of the South (TOS) Marine Biosecurity Partnership (the Partnership) was formed in 2009, and consists of the three TOS councils (Tasman, Marlborough, Nelson), the Ministry for Primary Industries (MPI) and other stakeholders. The Partnership is working towards reducing marine biosecurity risk in the TOS, with its operational activities undertaken by a Coordination Team led by The Lawless Edge Ltd.

Marine biosecurity risk to the TOS arises primarily as a result of human activities that spread marine pests (and other harmful aquatic organisms) into and within the region. These include movements of vessels of all sizes, and other activities such as transfers of aquaculture stock and equipment among growing regions. A focus of the Coordination Team's work is to facilitate management of these key risk pathways, especially in relation to the domestic spread of biofouling species.

In 2013, the Partnership commissioned a project to consider performance indicators that could be monitored over time to gauge whether, and to what extent, there was a measureable change (i.e. reduction) in marine biosecurity risk in the TOS as a result of the Coordination Team's efforts. An approach was developed that measured recreational vessel hull fouling as a proxy indicator of risk reduction, to complement other more direct indicators of success (e.g. *ad hoc* records of the number of new marine pest incursions to the TOS). Accordingly, a survey of selected recreational vessels in the TOS was conducted in summer 2013. The results of that survey are described in a report by Forrest (2013), along with the rationale for focusing on recreational vessel hull fouling as a success indicator.

The present report describes a second recreational vessel hull fouling survey, and was produced by Marine Biologic Ltd under contract to The Lawless Edge Ltd. The 2014 survey repeats the work conducted in 2013, focusing mainly on recreational vessels berthed in Nelson marina, and to a lesser extent on swing moorings in Nelson and Waikawa Bay (Figure 1). The survey approach does not directly assess biosecurity risk reduction, as it targets indicators of risk, and targets stationary vessels that may not necessarily move to other locations. It nonetheless provides a means of gauging the extent to which the Coordination Team's actions are successful in reducing *potential* risk.

The emphasis on vessels in marina berths more than on swing moorings reflects that berthed vessels are relatively easy to access for sampling. Nonetheless, it was considered important to continue with limited monitoring of boats on swing moorings, as they are typically more heavily fouled than those at marina berths (Brine *et al*. 2013; Forrest 2013). Consideration was given to expanding the marina work to include Picton or Waikawa; however, this did not eventuate. The focus remained on Nelson marina, on the basis that its vessels and infrastructure (e.g. pontoons, piles) are more extensively fouled than is evident at Picton and Waikawa. Additionally, a proposed change to the Nelson marina berth agreement will require berth holders to keep their boats free of marine pests or conspicuous fouling, providing an immediate basis for future assessment of compliance and change in hull fouling status.

Figure 1. **Images of areas surveyed. Top: Nelson marina and harbour; since the top left image was taken, two new berth "fingers" have been developed to the north of those shown. Bottom: Waikawa marina and Waikawa Bay showing extensive area of vessels on swing moorings.**

2. METHODS

Vessel monitoring was undertaken in February 2014, reflecting the main boating season and the period of seasonal peak fouling for most species. Sampling was the same as in 2013, and consisted of a combination of surface observations and in-water (snorkelling) assessment of fouling, using a combination of indicators as described below.

2.1. Indicators of fouling risk

Level of fouling (LOF) scale

A simple measure of vessel hull fouling is a six-point level of fouling (LOF) scale, ranging from LOF 0 (no fouling) to LOF 5 (very heavy fouling), according to categories described by Floerl *et al.* (2005) shown in Table 1. The LOF approach was originally developed to facilitate risk-based inspection of overseas yachts arriving in New Zealand, and has subsequently been adapted and used by MPI as part of national hull fouling studies. 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 & Forrest 2010; Inglis *et al.* 2010).

Table 1. LOF categories and descriptions from 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 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

LOF is the primary indicator used for monitoring in the present study, with the main deviation from Table 1 being that the LOF score of 0 was not used; the minimum score used was LOF 1, which in this study refers to slime layer fouling or less. Slime layer fouling contains no macrofouling (i.e. no visible fouling organisms), but comprises the micro-organisms and detritus that "condition" the surface and enable macrofouling to establish (Floerl *et al*. 2005). In the present study, instances arose in which 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% 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).

Dominant fouling groups and MPI-designated pests

In addition to LOF, MPI vessel survey protocols use a range of complementary quantitative measures, recognising that the LOF scale by itself is fairly crude. It was beyond scope and budget to adopt the MPI approach (e.g. a single vessel could take 1-2 hours to sample), and as a compromise the following indicators were included:

(i) The presence of conspicuous groups of species that can be dominant at more advanced stages of vessel fouling, and which are easily recognisable on fouled vessels, hence can be rapidly surveyed on snorkel. These were:

- Solitary sea squirts: this group includes two designated marine pests (Table 2), namely *Styela clava* and *Pyura doppelgangera*, of which the former is established in Nelson Harbour and Picton. It also includes two conspicuous non-indigenous sea squirts already established in Nelson or more widely in the TOS; the vase tunicate *Ciona* spp.[1] and the light bulb ascidian *Clavelina lepadiformis*.
- Bivalves (mussels and oysters): this group includes indigenous green-lipped and blue mussels, and the non-indigenous Pacific oyster *Crassostrea gigas*.
- Large brown algae: this group includes the Japanese kelp *Undaria pinnatifida*. Although *Undaria* is strongly seasonal and more common in winter/spring, in the TOS region it can be present year-round.

(ii) The presence of five biofouling species (Table 2) out of the 11 species on the MPI marine pest list (see: New Zealand's Marine Pest Identification Guide). In this respect, the present survey complements MPI's six-monthly port surveillance programme. However, it needs to be recognised that the primary focus of the survey was on vessel LOF using a rapid snorkel-based assessment method that is not appropriate for systematic surveillance. As such, records of marine pests should be regarded as chance finds more than a reliable record of their occurrence in the survey area.

[1] Formerly the species of *Ciona* in New Zealand has been referred to as *intestinalis*. However, genetic studies indicate that another species, *Ciona savignyi,* co-occurs, and in Nelson may be more dominant than *Ciona intestinalis*. Hence, in this report *Ciona* spp. is used to indicate both species collectively.

Table 2. **Marine fouling species designated as marine pests by MPI, which were included as indicators for the vessel survey. Note that *Pyura doppelgangera* reflects a recent name change for the species *Pyura praeputialis* listed by MPI.**

Scientific name	Common name and/or group	Reported NZ distribution	Example
Eudistoma elongatum	Australian droplet tunicate/ Colonial sea squirt	Northland east coast	
Pyura doppelgangera	Solitary sea squirt	Northland west coast and Opua (Bay of Islands)	
Styela clava	Clubbed tunicate / Sea squirt	Whangarei, Tutukaka, Auckland, Tauranga, Wellington, **Nelson**, **Picton**, Lyttelton, Dunedin	
Sabella spallanzanii	Mediterranean fanworm / Tubeworm	Whangarei, Auckland, Coromandel, Tauranga, **Nelson**, Lyttelton	
Undaria pinnatifida	Japanese or Asian kelp / Large brown macroalgae	Widespread nationwide, including **Nelson** and **Marlborough Sounds**	

2.2. Sampling methods

Surface assessment

Whole vessel LOF scores were first assigned from the surface (i.e. from the marina walkways, or from a boat in the case of moored vessels), to provide a rapid screening of vessel fouling. Photographs of vessels in each LOF category are given in Figure 2. These photographs should be regarded as a rough guide, as they show only a small section of hull, whereas the LOF assessment was conducted for "whole of boat".

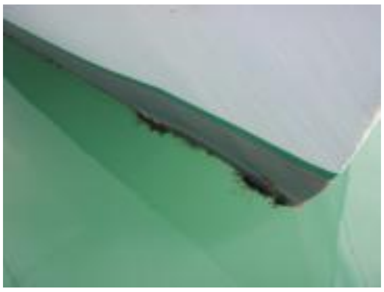
LOF	Surface	Underwater
1		
2		
3		
4		
5		

Figure 2. Examples of surface and underwater LOF categories. The photographs are close-up, hence should be considered only as a rough guide.

Surface LOF scores were assigned to all vessels present at the time of the survey, which totalled 528 boats. In Nelson these were 459 vessels berthed in the marina and 19 vessels on swing moorings in Nelson Harbour. In Waikawa Bay, surface LOF scores were assigned to 50 vessels on swing moorings, which were chosen from ca. 200 vessels in the bay, based on 5 random positions around which 10 adjacent vessels were sampled.

In addition to the LOF score, vessels were recorded as either sail or power boats, on the basis that fouling may differ because of different antifouling paint types used, or different survival patterns of fouling when such vessels are in operation. Similarly, live-aboard boats, or boats for sale were identified, assuming that such characteristics could alter fouling because of different boater maintenance behaviour. All berth numbers and mooring GPS positions were recorded, but for reasons of boater confidentiality they are not presented in this report.

In-water assessment

In-water assessment provides a “true” measure of the actual vessel LOF, given that only part of the hull is visible during surface assessment. As in 2013, in-water assessment was undertaken by snorkelling, whereas earlier surveys in the TOS (see Section 2.3 below) have used surface-operated video. However, video may not provide an overall “boat scale” impression of fouling, and is a somewhat slower method than snorkelling. Additionally, video quality in Nelson is usually very poor as a result of low water clarity.

Using snorkel, an in-water LOF score was assigned for 294 vessels in total. A score was first assigned to the whole vessel, to provide a comparison with the surface LOF assessment. In-water scores were then separately assigned to the main laminar surface of the hull and for “niche” areas. Niche areas are locations on the hull (e.g. around the stern and rudder, or on the keel of yachts) that tend to accumulate fouling more quickly than the main surfaces, often because they are not antifouled. The latter areas include the propeller and propeller shaft, trim tabs (where present), pipe outlets/intakes, and parts of the vessel (e.g. bottom of keel) on which the hull rests during maintenance. In addition to assigning LOF scores, the presence of the dominant fouling indicators and MPI-designated pests described above were assessed.

The 294 vessels surveyed using these methods consisted of all moored vessels (i.e. 69 vessels on swing moorings), but only a subset (n=225) of the 459 berthed vessels in Nelson marina. A stratified approach was taken to select these 225 berthed vessels, whereby all boats with a surface LOF of 3, 4 or 5 were sampled in-water (as these were of most interest from a biosecurity perspective), but only a random selection of those with a surface LOF of 1 and 2 were sampled. In 2013, in-water video footage was collected for vessels representative of different LOF categories. This was conducted to provide a benchmark to help ensure that surveys over time or among different assessors are as consistent as possible with each other. The video can be viewed at: http://youtu.be/LMJKZSs8Arg or via a link on the Partnership website (www.marinebiosecurity.co.nz).

2.3. Analysis and comparison with previous surveys

Most of the analyses consist of graphical presentation of mean LOF scores and the proportion of LOF scores within each of the 1-5 categories. Of particular interest were vessels with LOF scores of 4 and 5. Such vessels are generally categorised as “heavily fouled”, and it has been suggested that LOF 4 and 5 be regarded as unacceptable from a biosecurity risk perspective (e.g. Piola & Forrest 2009; Sinner *et al*. 2013).

Except where indicated, LOF scores are shown separately by location and coded as follows: Nelson marina (NM), Nelson swing moorings (NS) and Waikawa swing moorings (WS). Surface and/or in-water whole vessel LOF scores for these locations are compared to the 2013 survey. Additionally, where data are available, comparisons are made with earlier surveys conducted for the TOS (a 2011 dataset) or as part of related research (a 2010 dataset). The 2011 dataset included results for Waikawa/Picton marinas (WM, n=319) and Havelock marina (HM, n=143). The Forrest (2013) report describes the origins of these datasets.

As the 2013 and 2014 in-water surveys in Nelson marina were deliberately biased to LOF 3-5 (for reasons given above), the LOF scores are not directly compared to the random sample from the earlier surveys and other locations. To provide comparable datasets, a sub-sample of marina vessels was selected from those sampled in-water in 2013 and 2014. These vessels were randomly chosen within each LOF category, with the number of sub-samples per category chosen according to the percent occurrence of surface LOF 1-5 scores. This effectively gave a stratified random sample of in-water boats for Nelson marina in 2013 (n=107 vessels) and 2014 (n=139 vessels) that could be compared to other locations and times. However, note that there still remain differences among the various datasets in terms of sampling methods (e.g. video vs snorkel), numbers of vessels, and inspection effort per vessel (see Forrest 2013 for detail). As such, comparisons among surveys should be treated with some caution, but general comments can be made.

Additional analyses of the 2014 data alone included a comparison of: (i) surface LOF by vessel characteristics (sail vs power boat, live-aboard, for sale) for all 528 vessels; (ii) in-water LOF on main hull and niche areas for all locations (which for Nelson marina used the 139 randomly chosen vessels); (iii) the frequency of occurrence of each of the different indicator groups (i.e. solitary sea squirts, bivalves and large brown algae) in relation to each LOF category, based on all 294 vessels sampled in-water; and (iv) surface and in-water LOF scores, based on all vessels sampled in-water.

3. KEY FINDINGS

3.1. Surface LOF patterns

Levels of vessel fouling in 2014 were similar to 2013. Among all locations surveyed in 2014, 95 of the 528 vessels would be classified as heavily fouled (LOF 4 or 5), and unacceptable from a biosecurity perspective. This equates to 18% of vessels, compared with 17% in 2013. Vessels on Nelson swing moorings (NS) were the most heavily fouled in 2014, evident from their highest mean surface LOF scores (Figure 3a), and the greatest prevalence (37%) of LOF 4 and 5 scores (Figure 3b). Mean vessel fouling in 2014 on Waikawa swing mooring vessels was greater than 2013, reflecting a greater prevalence in the number of vessels with intermediate-to-heavy fouling (i.e. LOF 3 & 4).

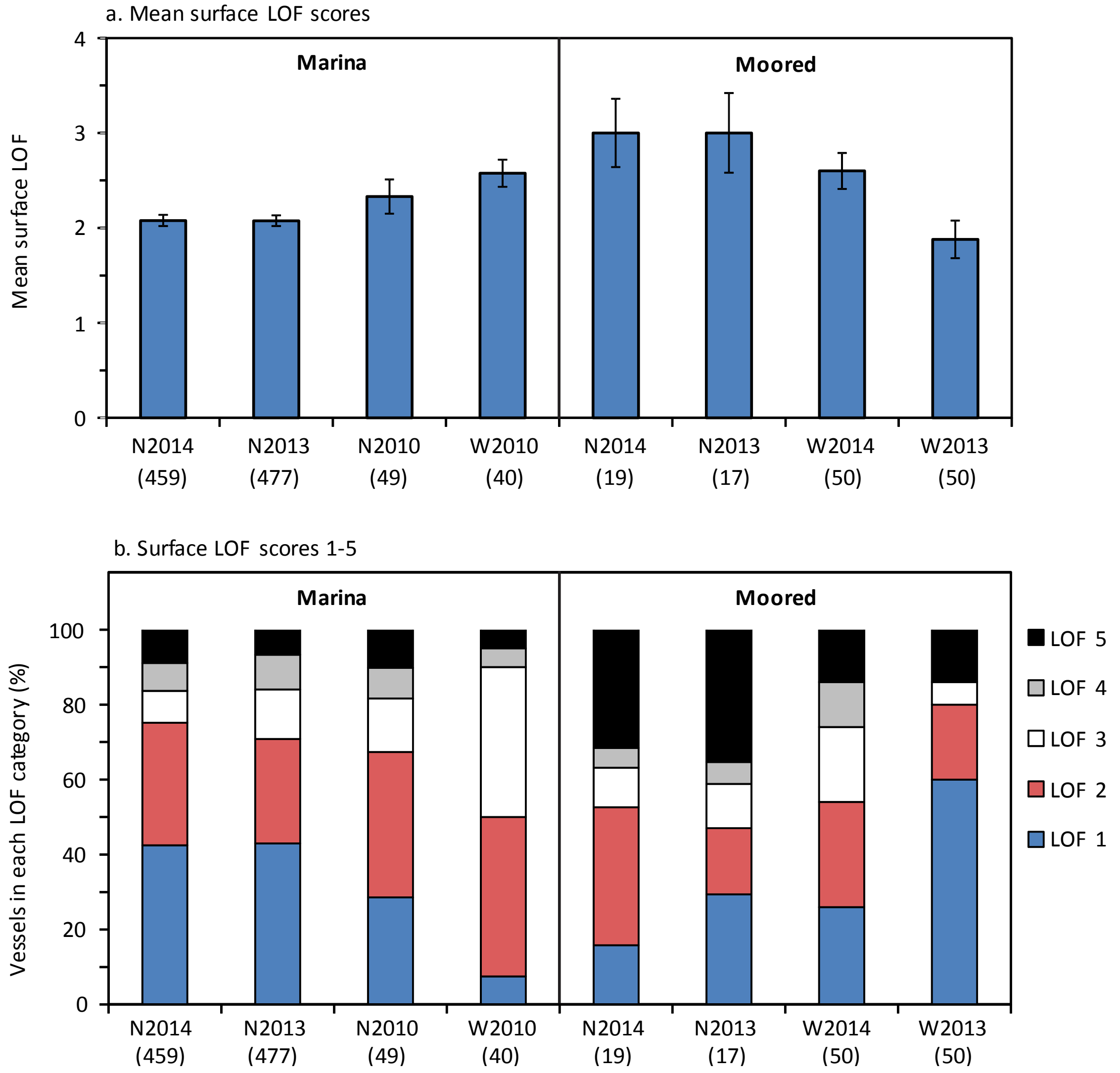


Figure 3. a) Mean (± SE) surface LOF scores; b) Proportion of surface LOF scores 1-5, among locations and survey years. Location codes: N=Nelson, W=Waikawa. Brackets after location codes indicate number of vessels.

Overall, fouling levels in 2014 were lowest in Nelson marina, but in that location were almost identical to 2013. For example, the proportion of Nelson marina vessels with surface LOF of 4 and 5 was 16% in both years. Although Waikawa marina (WM) was not surveyed in 2013 or 2014, the LOF scores from the 2010 study indicate a relatively low prevalence of LOF 4 and 5 (10%, reflecting 4 out of 40 vessels).

In terms of boat characteristics, Figure 4 shows the greatest prevalence of LOF 4 and 5 scores on the 42 live-aboard vessels. This pattern possibly reflects less interest by the boat owners in maintaining these vessels, compared to active boaters for whom excessive fouling would compromise vessel performance. Powered vessels were generally more heavily fouled than sail boats, probably indicating that some power boats are not antifouled. However, because of the relatively fast speeds that many power boats operate at, survival of fouling during voyages would likely be relatively low. Previous studies have indicated that speeds of ca. 10 knots or greater lead to low survival of hull fouling organisms (Coutts *et al*. 2010a,b).

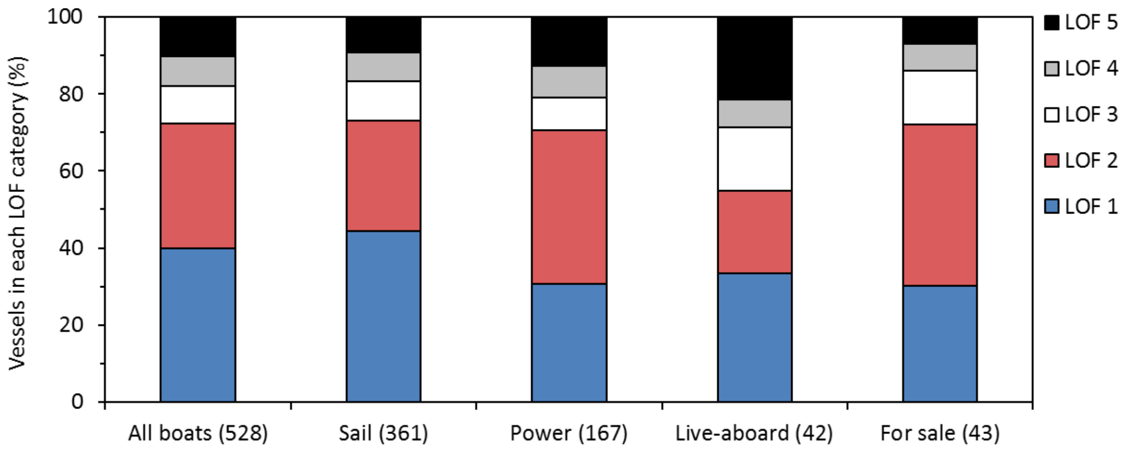


Figure 4. Proportion of surface LOF scores 1-5 in relation to some key vessel characteristics in the 2014 survey. Brackets after boat type indicate number of vessels.

3.2. In-water LOF patterns and dominant organisms

LOF patterns among locations, surveys and hull areas

In-water LOF patterns determined by snorkelling are summarised in Figures 5a and 5b. The general pattern of in-water scores among locations in 2014 is comparable to the surface LOF assessment, in that Nelson swing moorings had the greatest mean LOF and greatest proportion of LOF 4 and 5 scores (35% of vessels), while Nelson marina had the lowest values. The prevalence of in-water LOF 4 and 5 scores for Nelson marina was 12%, slightly less than the 14-16% prevalence recorded in the three earlier surveys. However, the proportion of vessels in the most heavily fouled LOF 5 category was 5% in 2014, and within the 3-6% range from earlier surveys.

As was the case for surface LOF patterns, Waikawa marina had relatively low in-water LOF scores in earlier surveys, as did Havelock in 2011. For Havelock, the maximum in-water LOF was 3. This likely reflects a strong influence of the Pelorus River, which would reduce salinities to levels that minimise fouling and restrict the range of species. For Waikawa, the maximum in-water LOF was 4 in 2011. The reasons for the relatively low fouling at Waikawa marina are unknown, but many boaters perceived it to reflect periodic freshwater influences.

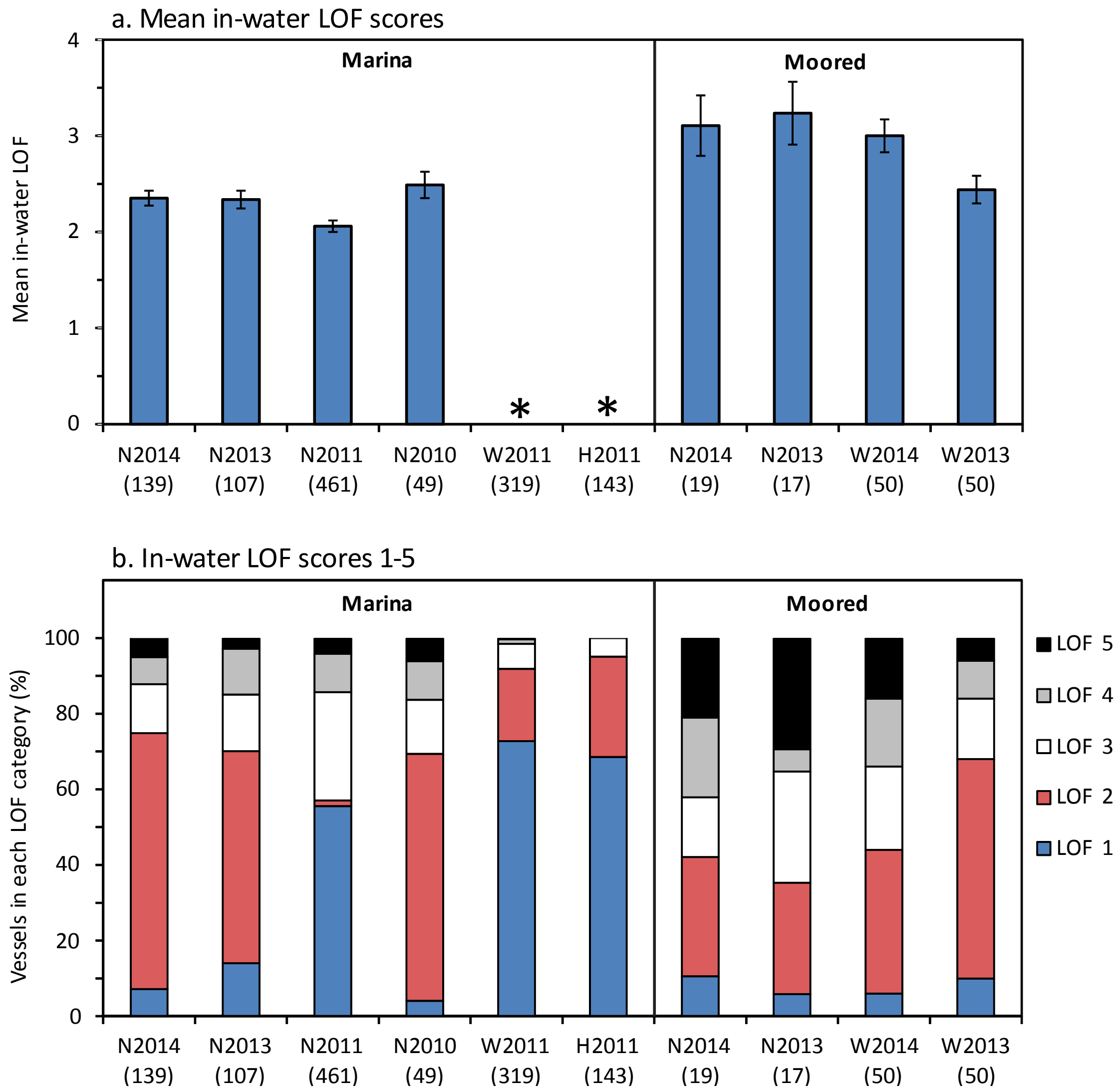


Figure 5. **a) Mean (± SE) in-water LOF scores; b) Proportion of in-water LOF scores 1-5, among locations and survey years. Location codes as for Figure 3, with addition of Havelock (H). Brackets after location codes indicate number of vessels. * = raw data unavailable for Waikawa and Havelock marinas, hence mean values could not be calculated.**

LOF differences between main hull and niche areas

Patterns of fouling among hull locations revealed a greater LOF in niche areas of all vessels, compared with the main laminar surfaces (Figure 6). Niche areas of moored vessels had particularly high fouling, with ca. 54% of boats having LOF 4 and 5. The contrast between main hull and niche areas is consistent with 2013, and with many previous studies of vessel fouling (Inglis *et al*. 2010; Lacoursière-Roussel *et al*. 2012). Such differences in part reflect the lack of antifouling coatings in many niche areas. On yachts for example, it is common to see a high cover of fouling on the bottom of the keel, even when the main hull appears clean and well-antifouled. Since yachts rest on their keel when on hardstand, this area often does not receive an antifoulant, hence can be quickly recolonised when the boat is returned to the water.

Occurrence of dominant fouling groups

Examples of the dominant (i.e. most conspicuous) foulers across the survey area are shown in Figure 7, and were the same species as in 2013. In the marina, high LOF scores reflected a dominance of non-indigenous sea squirts, especially *Ciona* spp. and the light bulb ascidian *Clavelina lepadiformis*. The non-indigenous bryozoan *Zoobotryon verticillatum* was also particularly abundant in 2014, and was noted by boaters in the inner marina area for the first time. This species forms long (e.g. 2m) spaghetti-like colonies that look like a seaweed. It is fast-growing during summer, and a number of boaters spoken to during the 2014 survey considered it to be a particular nuisance.

The dominant organisms on heavily fouled vessels on swing moorings, both in Nelson Harbour and Waikawa Bay, were bivalves; mainly green-lipped mussels. Drooping colonies of the colonial sea squirt *Didemnum vexillum* were also common on moored vessels in both locations, as was the Japanese kelp *Undaria pinnatifida*. The latter was the only large brown macroalgal species recorded on vessels during the survey.

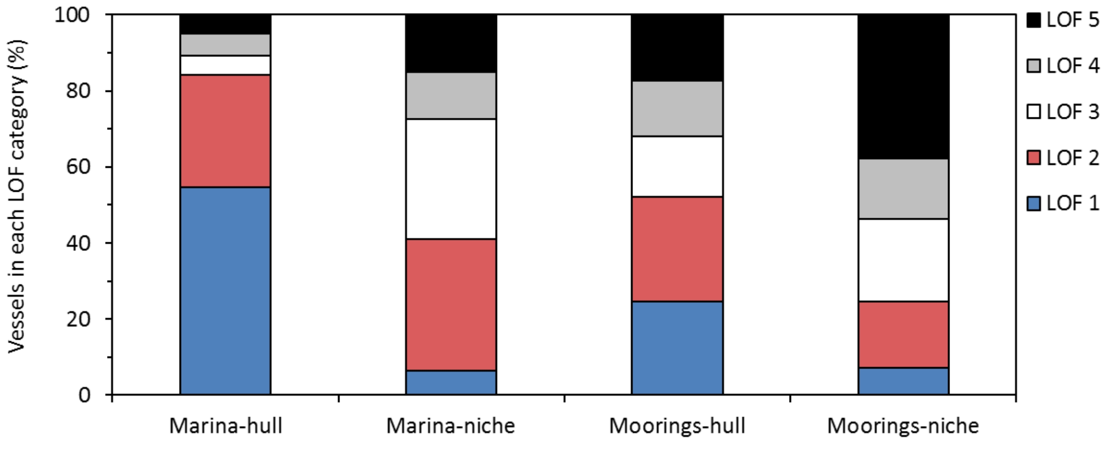


Figure 6. **Proportion of in-water LOF scores 1-5 among main hull and niche areas in the 2014 survey, comparing Nelson marina (n=139 random vessels) with data pooled across the moored vessels (n=69).**

As in 2013, the prevalence of the different dominant fouling groups or species generally increased with LOF, and was greater in niche areas than on the main hull (Table 3). However, once a vessel reached an in-water LOF of 5, hull and niche area fouling were similar. Approximately two-thirds of vessels with an in-water LOF of 5 were fouled with solitary sea squirts or bivalves, and one-third were fouled with *Undaria*. These figures are very close to that recorded in 2013. Even at low LOF levels, solitary sea squirts were common in niche areas. For example, at vessel LOF 2, solitary sea squirts were present in niche areas of 32% of vessels, which compares to 20% in 2013. The Nelson situation contrasts with the Floerl *et al.* (2005) study of international yachts arriving in New Zealand, which suggested that bivalves and solitary sea squirts had a low probability of occurrence for fouling levels up to LOF 4.

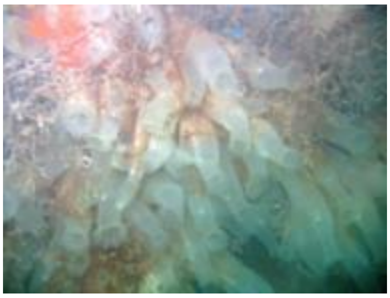
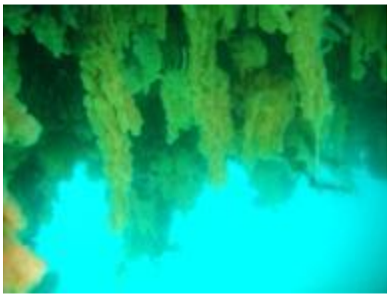
Solitary sea-squirt, *Ciona* spp.	**Solitary sea-squirt, *Clavelina lepadiformis***
	
Bryozoan, *Zoobotryon verticillatum*	**Green-lipped mussels, *Perna canaliculus***
	
Colonial sea-squirt, *Didemnum vexillum*	**Japanese kelp, *Undaria pinnatifida***
	

Figure 7. Dominant fouling organisms on vessels in the survey area. Except for native green-lipped mussels, the remainder are non-indigenous (source: Forrest 2013).

Table 3. Percentage of vessels sampled in-water in each LOF category, which had key indicator groups or species in main hull and niche areas. LOF 1 is not included as, by definition (see Table 1), it does not include any macrofouling.

In-water LOF	No. vessels	Solitary sea squirts		Bivalves		*Undaria*	
		Hull	Niche	Hull	Niche	Hull	Niche
2	133	5	32	1	7	0	2
3	60	18	60	17	43	5	17
4	46	48	61	24	46	13	24
5	39	67	64	64	67	33	33

Occurrence of designated pests

In addition to the kelp *Undaria*, two of the MPI-designated pests (see Table 2) were recorded in 2014. Of most interest to MPI and the Partnership was the discovery of several Mediterranean fanworms, *Sabella spallanzanii*, on the keel of a yacht moored in Waikawa Bay. This is the first recorded range extension of this species into Marlborough, and MDC together with MPI are currently undertaking follow up investigations. A single Mediterranean fanworm had earlier (in November 2013) been found in Nelson marina during routine MPI-funded marine pest surveillance, and 33 additional individuals (of which two were on vessels) have been removed to date during a subsequent response led by NCC. Long-term management is currently being considered.

As well as the fanworm, a single sea squirt, *Styela clava*, was recorded on a moored boat in Nelson. This was of no immediate concern to MPI, as the species is know to have been present in the harbour area since at least 2010 and is becoming widespread nationally (see Table 2). However, within the TOS, MDC are actively trying to manage a *Styela* population in Picton marina. Additionally, NCC are removing *Styela* from the marina, as part of the fanworm response programme. The occurrence of the species on a vessel in Nelson outside the marina, and its increasing prevalence on local structures and adjacent natural habitats, suggests that more boats in Nelson will probably be colonised over time. Hence, without effective management, *Styela* can be expected to slowly spread throughout the TOS.

3.3. Relationship between surface and in-water LOF patterns

It is generally accepted that surface LOF assessment may not reliably reflect fouling below the water-line (e.g. Floerl *et al*. 2005; Hopkins & Forrest 2010). Forrest (2013) evaluated this relationship for the 2013 data, as from a vessel screening and compliance perspective, it is easier to determine surface LOF than rely on remote video or diving to assess in-water LOF. The relationship between surface and in-water LOF was again assessed for the 2014 data (for the 294 vessels that were surveyed in-water), to provide a comparison with 2013.

Table 4 and Figure 8 show that at low surface LOF (1 & 2), in-water scores often exceeded surface scores; i.e. surface assessment underestimated the true in-water LOF. However, in most of these cases the in-water LOF score was only one category higher. For example, for 81% of surface LOF 1 scores, the in-water LOF was 2 (i.e. a deviance of 1 in Table 4), often because of light niche-area fouling that could not be seen from the surface. In some cases this reflected poor water clarity (especially in Nelson), and in the case of some longer vessels in Nelson marina the stern niche areas could not be seen from the marina walkway. Another factor was that some boaters clean their vessels in areas they can reach from the surface, thus giving a misleading indication of fouling deeper on the hull.

Table 4. Deviance of in-water LOF scores from surface scores for each of 294 vessels surveyed in-water in 2014. Shown is the percentage of vessels whose in-water scores differed to the extent indicated (i.e. from -3 to 3) from surface scores. Mean deviance (± SE) for each LOF is also shown.

Deviance of in-water from surface LOF	Surface LOF				
	LOF 1	LOF 2	LOF 3	LOF 4	LOF 5
3	0	0	0	0	0
2	2	3	2	0	0
1	81	27	31	18	0
0	17	69	46	32	57
-1	0	1	21	37	31
-2	0	0	0	13	6
-3	0	0	0	0	4
Mean deviance	0.86	0.31	0.15	-0.45	-0.61
SE	0.05	0.06	0.09	0.11	0.15

From a biosecurity risk and compliance perspective, it is the high LOF scores (4 & 5) that are of particular interest. Generally, the mean deviance became increasingly negative with increasing surface LOF. For LOF 4 and 5, the surface LOF on average overestimated the in-water LOF; that is, the actual extent of fouling was on average less that the surface assessment indicated (evident as a negative mean deviance in Table 4).

For vessels with surface LOF 4 in 2014, the true fouling level was LOF 3 for 37% of them and LOF 2 for 13% (Table 4). Similarly, of the vessels with surface LOF 5, true fouling was LOF 4 for 31% of boats, whereas 10% were LOF 3 or less. These general patterns are quite consistent with that evident in 2013, providing a good basis for understanding the utility of surface LOF as a monitoring tool. However, the Nelson situation contrasts to some extent with the study of Floerl *et al*. (2005) in which there was less discrepancy between surface and in-water LOF. In the present study, large differences tended to reflect situations where extensive water-line fouling was visible from the surface, but it was less extensive on the main submerged hull. From a biosecurity perspective, this situation is tolerable (i.e. surface observation is conservative in terms of reflecting potential risk), but it may alienate boat owners if they are asked to remediate apparent high levels of fouling.

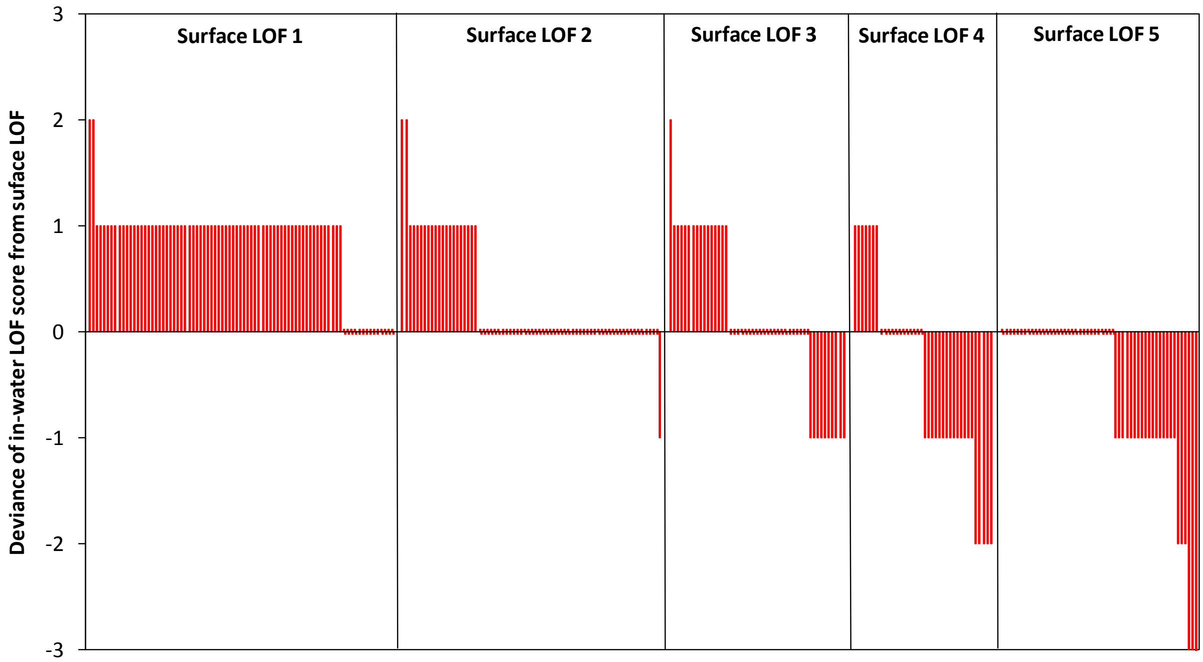


Figure 8. Deviance of in-water LOF from surface LOF for each of the 294 vessels sampled in-water in 2014, grouped by LOF. Positive red bars indicate that in-water scores exceeded surface scores, absence of bars (red line) indicates that scores were the same, and negative bars indicate that in-water scores were less than surface scores.

Data in Table 4 can also be used to highlight contrasting scenarios in which surface assessment failed to detected in-water fouling of ≥ LOF 4. This situation arose for 3% of vessels with surface LOF 2, 33% of vessels with surface LOF 3, and 18% of vessels with surface LOF 4. Clearly, therefore, the surface LOF assessment approach is not perfect, but it is a useful screening tool for identifying the majority of instances where extensive and potentially high biosecurity risk fouling may occur.

4. BIOSECURITY IMPLICATIONS AND RECOMMENDATIONS FOR FUTURE MONITORING

4.1. Biosecurity implications and pathway management issues

There have been some marine biosecurity gains in the TOS over the 1-2 years. For example, two vessels arriving in the TOS with Mediterranean fanworms on their hulls were identified early, and remedial action taken to treat them. Similarly, the range extensions of both the fanworm (Nelson and Waikawa) and *Styela clava* (Picton) were discovered, and led to the rapid implementation of management responses. In such cases, the communication networks and systems set-up by the Coordination Team have assisted in the timely identification and response to these high risk events.

Despite these positive examples, the LOF scores in the present survey suggest that wider TOS actions to date (e.g. example involving efforts to raise boater awareness regarding the importance of keeping hulls clean and antifouled) have led to no measurable biosecurity benefit in relation to recreational vessel hull fouling. Additionally, although vessels with fanworm have been intercepted, the species has nonetheless become established in the TOS. The lack of effective management of regional risks pathways means that established pests with currently confined distributions are likely to be further spread in the TOS by vessels movements, or new pests are likely to arrive from elsewhere in New Zealand.

In addition to MPI-designated pests, other species that are abundant on vessels (such as some of the species in Figure 7) also have the potential to become fouling problems in the TOS. As discussed by Forrest (2013), these include species that already have a history of impact in the region (e.g. *Ciona* spp. and *Didemnum vexillum* have historically impacted the mussel industry). However, the “boom and bust” patterns of abundance displayed by many marine pests, and considerable geographic variation in invasiveness, mean that future problems are impossible to predict with confidence. This situation highlights the merit in focusing management on the pathways by which potential marine pests are spread, irrespective of whether designated marine pests are known to be present. For this reason, MPI is considering options for management of domestic risk pathways, which complement their international border management efforts (e.g. development of a Craft Risk Management Standard for biofouling on international vessels).

Although pathway management has also been the focus of the TOS Coordination Team, the level of effort to date has clearly been insufficient to achieve a widespread risk reduction. Even though various management tools and regulatory mechanisms available for management are becoming understood, there also needs to be the willingness by stakeholders to implement effective measures. Part of the rationale for focusing on Nelson for this monitoring study was that a proposed change to the berth agreement for Nelson marina would require berth holders to keep their boats free of marine pests or conspicuous fouling, providing an immediate basis for future assessment of compliance and change in hull fouling status. However, this change has not yet been implemented.

For recreational vessels, conversations with boat owners during the 2014 survey revealed a number of additional issues that will need to be addressed to enable effective pathway management. Some of these echoed views described in the previous report (Forrest 2013). For example:

- Boaters perceive that fouling problems arise from international vessels, and fouled pontoons adjacent to boats, and that once an organism becomes established there is nothing worthwhile that can be done. This perception affects the willingness of boaters to contribute to good biosecurity practices.
- There was concern at the lack of tidal grids for boat cleaning, and at the perceived high cost of hard stand facilities. The owner of a boat with suspected *Sabella spallanzanii* on the hull, planned to sail to a cheaper hard stand in the region to conduct maintenance. Clearly, if boaters are being asked to maintain their vessels, they need the appropriate facilities.
- Many boaters clean their vessels in-water between haul out. Alternatively, boaters go for a voyage in the hope that some of the fouling will slough off. Boater education, and guidance on in-water cleaning (ideally guidance that is nationally consistent), may assist with this issue.
- While some boaters are aware of hull fouling and biosecurity issues, it appears that few recognise the range of other ways that boating activities can lead to spread of marine pests (e.g. through bilge water discharge). Again, boater education may assist in raising this broader awareness.

These are just some of the key issues for the boating sector, and no doubt some of these, as well as other issues, will be important for other marine sectors. Addressing such issues will be an important part of developing a comprehensive and effective package of pathway management measures.

4.2. Recommendations for future monitoring

The 2013 and 2014 surveys, along with the previous studies, provide a baseline against which future change in hull fouling risk status can be measured. Although the LOF method and survey approach has some limitations (discussed in the Forrest 2013 report), it nonetheless provides a useful indicator. If repeated over time using the same methods, the survey will provide a means of gauging the success of the Coordination Team’s efforts. However, until more comprehensive measures are in place to address risk pathways into and within the TOS, it is unlikely that future surveys will reveal any improvement in hull fouling status. On that basis, it may be better to redirect effort from vessel monitoring to pathway risk reduction, and perhaps consider vessel monitoring every second year. A hybrid approach would be to conduct a full survey every two years, but continue the surface LOF assessment annually (perhaps for Nelson marina only). The surface LOF assessment is relatively quick, and the last two surveys have provided a good understanding of how surface LOF relates to in-water fouling.

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