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Options for Managing Biosecurity Risks from Recreational Vessel Hubs

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Options for Managing Biosecurity Risks from Recreational Vessel Hubs

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EXECUTIVE SUMMARY AND RECOMMENDATIONS

Traditionally, scientists and environmental managers have focused on marine biosecurity risks from commercial vessel traffic; however, recreational vessels are increasingly being linked with the introduction and spread of some high profile pest species. Due to concerns around this issue, Cawthron Institute was commissioned by Nelson City Council under the Foundation for Research, Science and Technology's Envirolink medium advice grant scheme to conduct a desktop assessment and evaluation of management options for the mitigation of marine biosecurity risks associated with recreational vessels at Nelson marina. Currently, 24 non-indigenous marine species are known to occur within Nelson marina and the wider Port of Nelson, several of which are classified as 'unwanted' under the Biosecurity Act 1993. The two approaches for managing biosecurity risks associated with recreational vessels involve: (1) direct management of vessels to reduce the risk that pest species will be transported with vector movements; and (2) control of the source population of a pest(s) within the marina environment itself. While we consider vector management to be the most realistic and achievable, it should be noted, that these two approaches are not mutually exclusive.

Based on the findings of this report, we recommend the following management options for the mitigation of biosecurity risks associated with Nelson marina (following a period of consultation with all relevant parties before implementation):

1. Ensure all recreational vessels comply with a regular antifouling regime, at intervals of 12 months. Longer time intervals between applications may be considered on a case-by-case basis, based on a range of criteria including the antifouling formulation in question, its correct use and application, the vessel in question and its mode of use, and an assessment of the antifouling coating integrity following inspection by appropriately qualified personnel. As part of this, evaluate the feasibility of implementing a Warrant of Fitness 'sticker' or displayable document indicating compliance.
2. Implement a regime of regular vessel inspections to identify high risk vessels, based on a combination of: (1) surface identification of target pests; and (2) in-water inspections (*e.g.* by diver or surface-operated camera).
3. Ensure appropriate resources (*e.g.* facilities, expertise) are available for mitigation of biosecurity risks related to high risk vessels using land-based cleaning, in-water wrapping, or similar approaches in which the release of viable fouling (and chemical contaminants) to the marine environment is minimised. In addition, consider developing guidelines to allow in-water cleaning by mechanical methods in an approved area(s) as an alternative to other approaches.
4. Consider implementation of a biosecurity levy to fund measures under Recommendations 1 – 3. This would involve investigating the legal and practical feasibility of imposing and recovering costs of enforced mitigation measures (*e.g.* haul-out to land, in-water wrapping) for high risk vessels where owners are unable or unwilling to comply. Part of this approach should be to consider whether provisions to allow mitigation can be included in the standard berth licensing agreement. Where possible, the agreement and voluntary compliance of owners in the timely mitigation of high vessel risks is preferred.

In addition to the above recommendations, consideration should be given to:

- Ongoing public communication and awareness programmes of marine biosecurity risk from fouled vessels (and other sources of vessel risk), in conjunction with MAF BNZ and as part of the Top-of-the-South (ToS) marine biosecurity partnership.
- Management options for swing moorings in the Nelson region (which may be more feasible than in other regions given their relatively confined distribution). Evaluation of the merits of this would need to at least consider the various legal and practical issues identified in this report.
- Ensuring all operators in Nelson are working to achieve improved biosecurity in the region through coordinated and/or complementary management strategies. Such outcomes would logically be progressed as part of the ToS partnership.

Ideally, management approaches implemented for Nelson would be complemented by comparable approaches at a regional and/or national scale, since the transport of pests by recreational vessels from other source regions (within and outside the greater Nelson area) is likely to undermine any management measures applied in Nelson marina alone. Accordingly, as part of the preparation of this report we sought opinion from a number of organisations on the wider applicability of the management measures. While feedback was generally positive, marina operators in other regions had significant reservations about some of the measures, in particular the concepts of a Warrant of Fitness scheme and the introduction of a biosecurity levy system. Rather, it was suggested that many of the biosecurity mitigation approaches proposed in this report may be enforceable through amendments to existing marina berthage agreements, thereby placing the onus (and cost) of maintaining a clean vessel back on the individual vessel owners. Hence, we stress that the recommendations for Nelson should not be seen as a 'template' that is directly transferable to other marinas in New Zealand.

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1. INTRODUCTION

1.1. Background

Cawthron Institute (Cawthron) was commissioned by Nelson City Council (NCC) under the Foundation for Research, Science and Technology's Envirolink medium advice grant scheme (Envirolink Contract 607-NLCC27) to investigate management options for the mitigation of marine biosecurity risks associated with recreational vessels in Nelson marina. Marine non-indigenous species (NIS) and pest organisms are recognised as a significant biosecurity threat to New Zealand's marine environment. Effective management of such species is a major challenge facing government agencies, industries and other stakeholders throughout New Zealand. Many of New Zealand's high profile marine pests (*e.g.* the Asian kelp *Undaria pinnatifida*) have a limited ability for natural dispersal, to the extent that their regional and national spread is attributable primarily to vectors such as aquaculture activities and vessel movements. Recreational vessels moored in-water are a particular biosecurity concern because they:

- Remain idle for long periods (Hewitt *et al.* 2009) and can become heavily infected by pest species, especially fouling organisms (Figure 1).
- Are often slow moving, meaning associated fouling assemblages tend to survive vessel passage rather than being dislodged or otherwise affected by shear forces (Coutts *et al.* in review).
- Are numerous, for example there are greater than 10,000 marina berths in New Zealand (Dodgshun *et al.* 2007).
- Often make direct visits to high value areas such as marine reserves and aquaculture sites (Stuart 2002a; Stuart & McClary 2008).
- Are presently largely unmanaged for biosecurity risk. In contrast, in New Zealand there has already been work on the development of biosecurity tools for aquaculture vectors (*e.g.* NZMIC 2001; Forrest & Blakemore 2006; Forrest *et al.* 2007; Denny & Hopkins 2007), and for some vessel types (*e.g.* hull fouling management code of practice for fishing vessels operating around the sub-Antarctic Islands, deed of agreement for Cruise Ships in Southland).

As a result of the above risk factors, movements of recreational vessels are often implicated in the national and regional spread of marine pests (*e.g.* Hay 1990; Dodgshun *et al.* 2007). Without effective management of recreational vessel risks, any efforts to manage other vectors in isolation are likely to be compromised. A focus on recreational vessel risks and management is, therefore necessary and timely, and consistent with an increasing general emphasis by MAF Biosecurity New Zealand (MAF BNZ) on the management of vector pathways around the New Zealand coastline. Experience in New Zealand highlights that established marine pests are difficult to eradicate, and ongoing control requires the long-term commitment of significant funds (Coutts & Forrest 2007; Hunt *et al.* 2009). Consequently, vector management to contain the spread of pest organisms is regarded as preferable to the alternative of dealing with established pest populations.

Figure 1. Examples of recreational vessel fouling in the Top-of-the-South, from vessels at marina berths and on swing moorings. a. the sea squirt *Ciona intestinalis* and other fouling in Nelson; b. *Undaria* and the sea squirt *Didemnum vexillum* in Nelson.

1.2. Purpose and scope of this report

This report describes the results of a desktop assessment of management options for recreational vessels in Nelson marina in Port Nelson. Port Nelson is one of New Zealand's busiest shipping ports and a potential hot-spot for the arrival of pest species, as recognised by its inclusion in national marine pest baseline survey and surveillance programmes (Inglis *et al.* 2006; Morrisey 2008). Any inadvertent introduction of a marine pest to the Port area would increase the likelihood that moored vessels (especially those within the marina) will act as vectors for the further spread of the pest to high value areas within the Nelson region, and more widely around the top of the South Island. These high value areas within the region include four marine reserves, New Zealand's most significant and intensive area for aquaculture, the coastline of Abel Tasman National Park, and the Marlborough Sounds.

The incursion of several high risk pests into the Port of Nelson (and Nelson marina) over the last decade (especially the kelp *Undaria pinnatifida* and sea squirt *Didemnum vexillum*) have led to a high level of biosecurity awareness in the Nelson region, and the development of a MAF BNZ-coordinated Top-of-the-South marine biosecurity partnership. An understanding of the options for managing biosecurity risks from recreational vessel marinas in this region will contribute to the goals the partnership seeks to achieve. Nelson also provides a novel opportunity to consider freshwater diversion from the adjacent Maitai River as a marine pest management tool.

The scope of the work described in this report is as follows:

1. Review literature and assess recreational vessels risks, current management approaches, and their efficacy for mitigation of biosecurity concerns, with particular reference to Nelson marina.
2. Present and discuss a range of management options for recreational vessels and marina facilities in Nelson. Broadly, these fall into two categories: (1) source control of pest

populations to prevent vector infection; and (2) direct management of vectors. Note that we address separately the issue of recreational vessels associated with swing moorings.

3. Evaluate and rank the management options in relation to the following criteria:
   - Technical feasibility.
   - The estimated cost of each option and a qualitative assessment of benefits in terms of efficacy of risk reduction.
   - Likely acceptability to stakeholders.
   - Regulatory constraints.

A project of this scope has not previously been undertaken, despite long-standing recognition of issues surrounding management of recreational vessel biosecurity risks. Auckland Regional Council has considered options for managing vessel cleaning risks, and in-water cleaning regulations are also being considered by MAF BNZ. However, neither of these agencies has considered in any detail the options for management of recreational vessel hubs to reduce the human-mediated spread of pests, nor considered the risk of cleaning by in-water methods (generally perceived as high risk) in the context of a full range of management alternatives.

It is important to note that marina facilities are not the sole source of biosecurity risk associated with recreational vessels, and indeed in many regions may not be as high risk as recreational craft on swing moorings (as discussed in Section 5.1). Nonetheless, recreational vessels frequenting marinas do still pose a significant biosecurity threat. In Nelson marina, this is evident in the occurrence of pest species such as *Undaria pinnatifida* on berthed vessels. *Undaria* has also been widely observed on vessels in marinas throughout New Zealand (Hay 1990; Morrisey & Miller 2007; B. Forrest, pers. obs.). Similarly, the clubbed tunicate (sea squirt) *Styela clava* has been observed in marinas or on berthed vessels in Magazine Bay marina (Lyttelton), the Viaduct basin (Auckland) and Tutukaka marina (Coutts & Forrest 2005; Gust *et al.* 2005; Gust *et al.* 2007; B. Forrest, pers. obs.)

Given the management practices and infrastructure already associated with Nelson marina, it is a logical starting point to address the often overlooked issue of recreational vessel biosecurity mitigation. Furthermore, following the effective implementation of biosecurity management strategies in the marina, we may then begin to address the more difficult biosecurity risks associated with swing moorings. Successful management of recreational vessels to reduce biosecurity risks in Nelson will lead to significant long-term and sustainable benefits by protecting the region's significant marine values from the adverse effects of pests.

Ideally, management approaches implemented for Nelson would be complemented by comparable approaches at a national scale. Accordingly, as part of the preparation of this report we sought opinion from a number of organisations (see Acknowledgements) on the wider applicability of the management measures we recommend for Nelson. While feedback was generally positive, marina operators in other regions had significant reservations about some of the measures, as we highlight in various places throughout this report. Hence, we stress from the outset that the recommendations for Nelson should not be seen as a 'template' that is directly transferable to other marinas in New Zealand.

2. BIOSECURITY RISKS AND EXISTING PESTS IN NELSON

2.1. Biosecurity risks from recreational vessels and marinas

2.1.1. Recreational vessels

Traditionally, scientists and environmental managers have focused on biosecurity risks from commercial vessel traffic more so than recreational vessels and leisure craft (*e.g.* Carlton 1985; Coutts & Taylor 2004). Increasingly however, recreational vessels are being linked with the introduction and spread of some high profile pest species. For example, the incursion of the black striped mussel, *Mytilopsis sallei* into a marina in Darwin, Australia, was almost certainly attributable to an infected recreational vessel (Bax 1999). Similarly, spread of *Undaria pinnatifida* (Hay 1990; Mineur *et al.* 2008) and several tunicate species such as *Styela clava* (Darbyson *et al.* 2009) and forms of *Didemnum* (Auker & Oviatt 2008) have been closely linked with recreational boating. The appearance of non-indigenous species (NIS) in areas that receive little to no commercial shipping traffic has often been attributed to recreational vessel transfers, particularly in high value marine habitats such as world heritage areas and marine parks (Wyatt *et al.* 2005; Piola & Johnston 2008a).

The mechanisms associated with recreational vessels that may lead to the transport of NIS include: (1) the hull of the vessel; (2) 'niche' areas of the vessel, such as rudders, keels, water intake/outtake systems, thrusters; (3) infected gear and equipment (*e.g.* ropes, anchors); (4) bilge water sumps; and in certain instances (5) trailers (Hayes 2002; Acosta & Forrest 2009; Darbyson *et al.* 2009; Hewitt *et al.* 2009). None of these mechanisms are species-specific, with most having the capacity to transfer suites of organisms. In general, sessile fouling species (*i.e.* sedentary organisms growing on submerged surfaces such as hulls) are the primary organisms transported via recreational vessels, though pelagic organisms or adult life-stages may be entrained by mechanisms such as bilge water, keel centre cases, or associated equipment (Dodgshun *et al.* 2007; Darbyson *et al.* 2009).

Maintenance practices and the often sporadic patterns of use of recreational vessels make them arguably a greater biosecurity risk than commercial vessels. The commercial shipping industry now recognises that even minimal amounts of biofouling on a vessel's hull can have dramatic impacts on fuel usage, running efficiency and speed (Gollasch 2002). For this reason, major efforts have been made to ensure the adoption of stringent hull fouling maintenance practices and effective antifouling strategies (Hewitt *et al.* 2009). Unfortunately, many slow-moving recreational craft and yachts do not have such strong economic incentives to maintain their hulls free from fouling. Furthermore, recreational vessels often remain idle in the water for extended periods of time between use, which can markedly reduce the effectiveness of even relatively new antifouling paints (Hilliard *et al.* 2006) and result in the accumulation of extensive fouling cover on hulls. Floerl *et al.* (2001) found that in tropical Australian waters the cover of fouling organisms on recreational vessels increased by approximately 10% for every five months spent moored and uncleaned. This means that within two years of being painted, more than half the submerged area of a vessel may be covered by marine organisms. The majority of international recreational yachts arriving in

New Zealand come from the tropical South Pacific (*e.g.* Fiji and Tonga; C. Denny pers. comm.), hence the biosecurity risk associated with these vessels has the potential to be significant.

Another factor contributing to the biosecurity risk associated with many recreational craft (especially yachts) is their relatively slow operating speed (5 – 10 knots) compared to commercial vessels (≥15 knots). Cawthron research on a range of fast- versus slow-moving vessel types indicates that speed is a key contributor to NIS transport (Coutts *et al.* in review; R. Piola, unpub. data). Most fast-moving vessels in regular use (*e.g.* merchant vessels exceeding ≥15 knots) tend to have relatively low levels of hull fouling, with that present being confined to protected 'niche' areas of the hull (Coutts & Taylor 2004). In contrast, slow-moving vessels (*e.g.* ≤5 knots) can support substantial fouling communities across large areas of the hull (Coutts 2002). A recent experimental study by Coutts *et al.* (in review), which specifically examined the effect of vessel speed on fouling assemblages, found that speeds of up to 10 knots had little effect in reducing the composition and cover of hull fouling assemblages.

2.1.2. Recreational vessel marinas

Marinas tend to be the first port of call for international and domestic recreational vessels arriving to a new region. As such, along with commercial ports, they are one of the major locations (or 'transport hubs') for the introduction, establishment and spread of NIS (Carlton 1996; Floerl *et al.* 2009). Given that marinas contain an abundance of artificial surfaces (which are generally considered to be preferentially colonised by NIS; Glasby *et al.* 2007), in addition to an often high density of tightly-spaced vessels, the risk of NIS establishing within such an environment is high. Once established, the proliferation of a pest species within or adjacent to a marina environment creates a constant source of planktonic propagules (*e.g.* seaweed spores or invertebrate larvae) for the infection of resident vessels. Hence, marinas and berths are important contributors to the biosecurity risks associated with recreational vessels.

Research has shown that marina and boat harbour design may actually exacerbate the proliferation of NIS. Many marinas are designed with solid breakwalls that protect vessels from high currents, winds and wave action. Floerl & Inglis (2003) found that water movements within such enclosed marinas can create retention areas (*e.g.* eddies) that entrain the water-mass (and propagules of fouling organisms) for longer periods of time than non-enclosed marinas. Hence, recruitment rates of resident fouling species within enclosed marinas can be considerably greater than those in non-enclosed facilities (Floerl & Inglis 2003) and has the potential to dramatically increase a resident vessel's risk of infection by an unwanted fouling species.

It is unclear whether the situation described by Floerl & Inglis (2003) is common; in fact our observations of marinas in Nelson and Marlborough suggest the opposite could also be true, *i.e.* the most protected and poorly flushed sections of local marinas have relatively little fouling. However, irrespective of the level of fouling, it has been documented that resident fouling communities among different marinas may differ quite markedly over small sailing distances (Floerl & Inglis 2005), a fact also evident in Nelson and Marlborough marinas. Clearly therefore, recreational vessels have the capacity to transport and spread NIS among closely located marinas that may otherwise avoid infection. This is of particular significance in the case of high risk pest species which are unable to spread among marina hubs by natural mechanisms; for example, because they are limited by barriers to their dispersal or establishment (Forrest *et al.* 2009).

A combination of tolerance by fouling organisms to antifouling biocides and poor water quality in marina environments, may further facilitate the establishment and spread of NIS. The majority of recreational craft use copper-based antifouling coatings to inhibit the growth of fouling organisms on submerged surfaces. Despite this, studies have shown that some well-recognised non-indigenous hull fouling species, such as the bryozoan *Watersipora subtorquata*, remain able to settle and grow directly onto newly antifouled surfaces, facilitating their transport and spread (Wisely 1958; Floerl *et al.* 2004). In fact, numerous taxa associated with vessel hull fouling have shown significant tolerance to copper, including calcareous tubeworms (Johnston & Keough 2003; Dafforn *et al.* 2008), barnacles (Weiss 1947), hydroids (Stebbing 2002), bryozoans (Floerl *et al.* 2004; Piola & Johnston 2006), bivalves and algae (Jelic-Mrcelic *et al.* 2006).

Tolerance to antifouling biocides like copper not only facilitates the transport of NIS, but may also aid in their establishment into polluted recipient locations. Copper is one of the major metal pollutants discharged into urban marine environments, from sources such as antifouling paints (Warnken *et al.* 2004), industrial waste (Hall Jr. *et al.* 1998), urban runoff (Pitt 2002), sewage discharge (Scanes 1996) and treated timber pilings (Weis & Weis 2002). Copper contamination can lead to fundamental changes in the structural composition of fouling communities (Weis & Weis 1996; Johnston *et al.* 2002), decreasing the diversity and dominance of native assemblages while promoting establishment and community dominance by NIS (Piola & Johnston 2008b). It is not difficult to imagine therefore, that the very same copper-tolerance traits that allow some NIS to be transported to a new environment (via hull fouling for example), also serve to aid in their establishment within copper-polluted habitats.

Hence, enclosed bodies of water such as those found in marinas may accumulate significant levels of pollutants, in turn providing an ideal environment for the establishment of copper-tolerant NIS. In support of this, a recent study by Dafforn *et al.* (in review) found that boating areas with a history of use by recreational vessels using copper-based antifoulants had higher levels of copper contamination in the water column than other sites frequented by vessels using non-copper-based antifoulants. Additionally, recruitment of NIS to settlement surfaces treated with copper antifouling paints was generally greater in the recreational boating harbours than in areas with lower recreational vessel numbers. Despite such findings, antifouling nonetheless remains an important strategy for fouling management on vessels, as we discuss in Section 4.2.

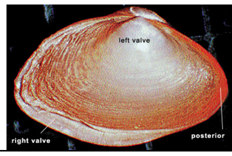
2.2. Non-indigenous and/or pest species in Nelson

There are currently 24 non-indigenous marine species known to occur within Nelson marina and the wider Port of Nelson (Inglis *et al.* 2006; Morrisey & Miller 2007; Piola *et al.* 2009). These include species from six taxonomic groups, comprising annelid worms (2 species), bryozoans (12 species), cnidarians (4 species), molluscs (2 species), algae (1 species) and tunicates (also referred to as sea squirts or ascidians; 4 species). Table 1 shows species that are considered by MAF BNZ to be of concern to New Zealand. Most have been declared as 'unwanted' based on a high likelihood of arrival, their potential for significant spread and their history of invasiveness overseas.

Five of the species in Table 1, the sea star *Asterias amurensis*, crabs *Carcinus maenas* and *Eriocheir sinensis*, the green alga *Caulerpa taxifolia*, and bivalve *Potamocorbula amurensis* have not yet been recorded in New Zealand. The fanworm *Sabella spalanzanii* has been recorded only from Lyttelton Harbour and is currently the subject of an eradication attempt there, while the tunicates *Styela clava* and *Didemnum vexillum* have restricted distributions. Whereas *Styela* is not known to have established in Nelson (although was removed from a vessel there), *Didemnum* is already widespread throughout the Port (but less so in the marina). This species is currently classified as 'cryptogenic' in New Zealand (Table 1; Inglis *et al.* 2006), meaning that its status as native versus non-indigenous is unclear. However, recent evidence from taxonomic and genetic studies suggests a likely origin for *Didemnum vexillum* in the Northwest Pacific/Japan (Lambert 2009; Stefaniak *et al.* 2009). Such evidence, together with assessment against other criteria (Coutts & Forrest 2007), suggests that a revaluation of this species status would likely see it reassigned as non-indigenous.

It should be noted that even for the high risk pests in Table 1 there are very few studies that describe actual impacts. Furthermore, for the species already established in New Zealand, the little information available on impacts in a New Zealand context is equivocal, such as the findings of a study of *Undaria*'s ecological effects in Lyttelton Harbour (Forrest & Taylor 2002). Similarly, for *Didemnum*, anecdotal evidence suggests the potential for significant impacts on aquaculture, but rigourous studies to assess this possibility have only recently begun (Cawthron, unpub.). Hence, the assumption on which New Zealand's marine biosecurity system operates, and on which this report is based, is that species with demonstrated 'pestiness' (either in New Zealand or overseas) have the potential to cause harm to New Zealand's core values (*i.e.* environmental, economic, social or cultural values).

Table 1. Unwanted or recognised marine pests to New Zealand, and their recorded distribution. Of these, only *Undaria* and *Didemnum* are known to have established in Port Nelson.

Scientific name	Common name	NZ distribution	Example
Declared unwanted species			
Asterias amurensis	Northern Pacific seastar	Not present	
Carcinus maenas	European shore crab/green crab	Not present	
Caulerpa taxifolia	Green aquarium weed	Not present	
Eriocheir sinensis	Chinese mitten crab	Not present	
Potamocorbula amurensis	Asian clam	Not present	
Sabella spallanzanii	Mediterranean fanworm	Lyttelton	
Styela clava	Clubbed tunicate (also known as a sea squirt or ascidian)	Whangarei, Tutukaka, Lyttelton, Otago (found on vessels in Nelson and removed)	
Undaria pinnatifida	Asian kelp	Widespread in harbours between Stewart Island and Hauraki Gulf, including Nelson	
Other pest species			
Didemnum vexillum	Colonial sea squirt	Whangamata, Tauranga, Wellington, Marlborough, Nelson, Lyttelton, Otago and Bluff	

3. MANAGEMENT BASED ON SOURCE CONTROL

3.1. Introduction

There are two broad ways in which the biosecurity risk from vessels and other vectors can be reduced or negated. One is direct management of vectors to reduce the risk that pest species will be transported with vector movements, for example by implementing measures to ensure that the transport mechanism is pest free. The alternative approach that we discuss in this section is control of the source population of the pest. Control approaches that reduce pest density will theoretically reduce the likelihood that the vector will become infected in the first instance; obviously if there was no source population of a pest there would be no reservoir of propagules for vector infection. For reasons outlined below, we consider the first approach to be the most realistic and achievable, and discuss a range of potential vector management options in Section 4. It should be noted however, that these broad management approaches are not mutually exclusive; in fact the most comprehensive strategy would be to employ both direct vector management and source population control simultaneously (Gust *et al.* 2007). Appendix 1 presents a comparison of source control and vector management options to mitigate the biosecurity risks associated with recreation vessels and transport hubs, including the feasibility, acceptability, legal and practical considerations, benefits, negatives and estimated costs of each approach.

3.2. Evidence for efficacy of source control

Current Cawthron work for MAF BNZ suggests that source-population control that achieves near-zero pest density can be highly effective in reducing the risk of vector infection (Sinner *et al.* 2009). This work analysed data generated during a management programme for *Undaria* in southern New Zealand over 1997-2004, based on information reported in Stuart (2002a) and Hunt *et al.* (2009). It indicates that a reduction in the *Undaria* population to very low densities (*e.g.* 1% of infestation densities) in Bluff Harbour and Big Glory Bay (Stewart Island) in combination with direct vessel management, reduced the incidence of infection by *Undaria* to ~1% of vessels in those two locations. In contrast, a vessel infection level of 34% was evident in ports with unmanaged populations of *Undaria*. Similarly, in January 2009 the incidence of *Undaria* infection on vessels in Bluff was 43% despite recent (although unsuccessful) efforts to once again reduce the population of the seaweed (*Undaria* re-infested Bluff Harbour following cessation of the southern New Zealand management programme in 2004). The recent Bluff experience was comparable to the attempts made to control *Undaria* in the Nelson Port and marina area in the late 1990s; despite initial efforts, in the absence of a regular and sustained long-term commitment the kelp quickly re-established a widespread and substantial population on Port structures and adjacent natural habitats.

The apparent need for source control to achieve a very low population density of the target pest in order for vector infection to be minimised, is supported by findings from a recent New Zealand study by Floerl *et al.* (in review). Modelling simulations described in that study suggest that pest species attaining a large population size (defined as occupying 10% of local habitat) before initial detection/management are likely to already have been spread to other locations by recreational yachts. Conversely, if detection and management occur while a population is small (occupying 0.1% of local habitat), the transportation frequency of a pest species to new locations may be reduced by 77-99%, and the number of new infected locations reduced by 74-78%.

One of the issues in effective source control is the definition of the control zone. If significant pest populations within the dispersal range of resident vessels remain unmanaged, they will act as an ongoing reservoir for vessel infection; this was the key downfall of the recent attempts at *Undaria* source control in Bluff Harbour. In Nelson therefore, sustained population control of pests within the marina may be of little benefit in the absence of control across the wider port area; although the efficacy of highly localised control would depend on local hydrodynamic conditions and the dispersal characteristics of target species.

Overall, we recognise that source control can be a highly effective means of reducing vector infection and hence risk. However, when multiple pests species are considered, and recognising that many established pests in Nelson marina have source populations in the wider port (and in fact outside the Nelson region), we suggest that widespread source control with present management tools is unrealistic. Nonetheless, in the discussion below we highlight some of the tools that have been developed as a result of regional pest management attempts in New Zealand, many of which were described in a recent review by Piola *et al.* (in press). We also highlight areas of current research or possible directions for novel source control methods. To this end, we discuss in the context of Nelson marina possibilities for source control based on enhancing the freshwater influence of the Maitai River.

3.3. Source control tools

3.3.1. Wrapping

Encapsulation of marine structures such as marina pontoons, wharf piles and moorings (see Figure 2 and Figure 3) in impermeable plastic (a technique widely referred to as 'wrapping') has proven to be an effective strategy for controlling pest organisms associated with these habitats. Wrapping was originally developed for eliminating the sea squirt *Didemnum* from wharf piles in Shakespeare Bay near Picton (Coutts & Forrest 2007), and then modified for application to marina pontoons in trials against *Styela clava* in the Viaduct Basin, Auckland (Coutts & Forrest 2005). Subsequently, these methods were widely used and further developed as part of the Top-of-the-South *Didemnum* management programme (Pannell & Coutts 2007). In that programme the wrapping method was also widely applied to vessels and their moorings (see Section 4).

Plastic wrapping that is correctly applied to prevent exchange of the encapsulated water can be 100% effective in eliminating fouling (Pannell & Coutts 2007). Essentially the wrap encloses a relatively small volume of water, which becomes anoxic (oxygen-depleted) within a matter of days (to weeks) dependent on the level and types fouling on the treated area.

Figure 2. Plastic wrapping methods used to treat marina pontoons infected with the sea squirt *Didemnum vexillum* (Source: Pannell & Coutts 2007).

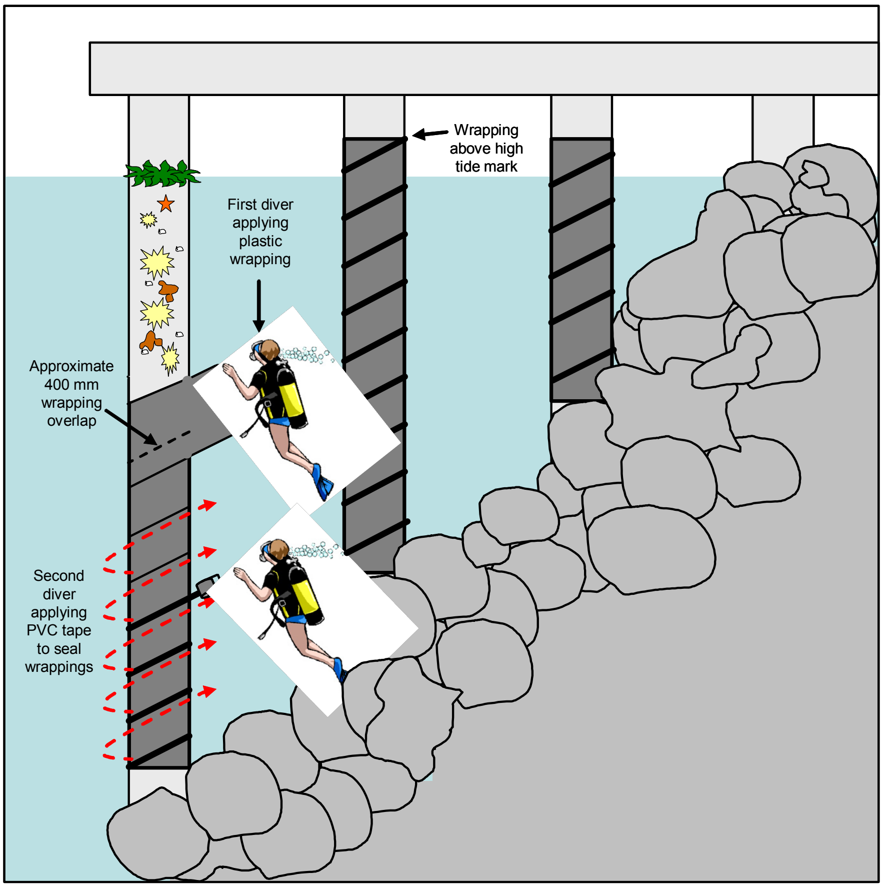


Figure 3. Schematic of the plastic wrapping method used to treat wharf piles infected with the sea squirt *Didemnum vexillum* in the Marlborough Sounds, and recently applied in similar form to piles in Bluff Harbour (source: Coutts & Forrest 2007).

For wrapping to be totally effective however, it is important to ensure that the integrity of the wrap remains intact for the duration of its application period (*i.e.* no external water is allowed to mix with the encapsulated water via holes or tears in the wrap). In areas where wharves and pontoons are in high demand and require rapid treatment, chemicals such as acetic acid and bleach (chlorine) can be added to the encapsulated water within the wrapping to accelerate mortality (Forrest *et al.* 2007). For example, the addition of acetic acid within wrapped pontoons resulted in 100% mortality of *Styela* within 10 minutes in experiments done in the Viaduct Basin (Coutts & Forrest 2005). Similarly, wharf piles infected with *Undaria* have been successfully sterilised using bromine compounds applied inside PVC sleeves (Stuart 2002b). On natural substrata, plastic sheeting or geotextile fabric has also been used to smother *Didemnum* (Coutts & Forrest 2007; Pannell & Coutts 2007), and *Undaria* (Lines 2007). Overseas, comparable methods have been used to eliminate small populations of the alga *Caulerpa taxifolia* (Zuljevic & Antolic 1999; Meinesz *et al.* 2001; Creese *et al.* 2004).

While wrapping is probably not a cost-effective strategy for long-term management of biofouling within Nelson marina, it may be a useful tool for reducing fouling during key seasonal periods, for example during spring and summer months when the abundance of many fouling species (*e.g. Undaria*, *Didemnum*) can reach high densities. Alternatively, wrapping may be used as a response tool to manage specific unwanted species or troublesome areas of the marina environment (*e.g.* high risk berths or moorings). Since the technique of wrapping artificial structures was developed in 2003, the knowledge and expertise to implement this method has advanced significantly. Today, wrapping a structure is generally a straight-forward process, and in some situations can be a successful and cost-effective biosecurity management tool (provided rigorous quality control and ongoing maintenance practices are implemented).

3.3.2. Freshwater input

Under some circumstances, the natural surroundings of a marina may offer solutions for reducing biosecurity risks. For example, the Nelson marina is located adjacent to the mouth of the Maitai River. This situation raises the possibility of diverting freshwater from the River into the enclosed waters of the marina, altering physico-chemical properties (especially salinity) in such a way as to deter or reduce the levels of fouling present on marina pontoons, piles and vessels. At present, there exist two 600 mm diameter pipes connecting the lower Matai river (~100 m north of the Queen Elizabeth II Drive bridge) and the head of the Nelson marina basin (Figure 4).

The extent and rate of freshwater intrusion into the marina basin was recently characterised by NCC over the course of half a tidal cycle on a spring tide (0.4m low tide to 4.2m high tide). Salinity measurements in the Maitai River upstream of the pipes (Site 7, Figure 4) revealed values of 11.2 ppt (Table A1.1, Appendix 1). Salinity values recorded in the marina basin approximately 50 m from the discharge point of the pipe (Site 6, Figure 4) were ~35.6 ppt at depths of 0 - 1.5 m, which is similar to undiluted seawater. Additional salinity measurements along the length of the marina (Sites 1-5, Figure 4) recorded similarly high salinity readings (~35.5 ppt). These results indicate that the present inflow of freshwater from the Maitai River into the Nelson marina basin (estimated at 0.062 $m^3.s^{-1}$; Table A1.2, Appendix 1) is insufficient to cause any measurable reduction in salinity levels.

Based on preliminary calculations, we estimate that a freshwater flow of 3.5 $m^3.s^{-1}$ would be required into the head of the marina to cause a drop in salinity to 25 ppt across the depth range 0-1 m (Appendix 2). This level of salinity change sustained over a period of days would likely be sufficient to eliminate most of the fouling species in Table 1. Given that typical dry weather flows for the Maitai River are generally under 1 $m^3.s^{-1}$, it appears unlikely that sufficient freshwater flow would be available to meet this requirement without altering the current marina design (*e.g.* freshwater reservoir system; tidal gates to periodically isolate the marina from oceanic waters). Appendix 2 provides a broader discussion on this issue, including an outline of the effort required to make more robust predictions and additional considerations regarding changes to marina design. It should also be noted that, while a decrease in salinity may eradicate some unwanted species, it may also result in conditions which favour the proliferation of other pests species, including organisms not listed in Table 1.

Related research carried out in Nelson marina and the wider Top-of-the-South region has demonstrated that natural predation plays a significant role in reducing the abundance of newly introduced organisms to the seabed environment, and helps explain why artificial structures are often heavily fouled in areas where the seabed is quite barren (Cawthron, unpub. data). If predation pressure were enhanced, or focused more effectively toward fouling on fixed and floating structures (*e.g.* piles, pontoons), there may be opportunities to achieve a natural reduction in fouling biomass and greatly decreased population densities of target pests. Cawthron is at the initial stages of further developing this concept as part of a Foundation for Research, Science and Technology programme.

3.3.3. Marina design and use of fouling-deterrent materials

Traditionally, biofouling on marina structures has been largely unmanaged, and managed with toxic paints or polymers in the case of vessels. However, there is ongoing research into the development and use of novel materials and surfaces that may inhibit the establishment of fouling assemblages. For example, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia is currently developing a range of alternative fouling resistant materials that could one day be applied to marina structures (Poole 2008). These include: nano fibre ‘armour’ that prevents settlement and growth of unwanted organisms, environmentally safe photoactive materials that release reactive forms of oxygen to kill or repel settling organisms, micro-structured surfaces with unique topographies that prevent organisms from attaching, and specialty fibres and fabrics with specific surface properties (*e.g.* specific surface chemistries). Knowledge that marina design may also play a role in the development of biofouling (see Section 2.1.2) may also lead to fruitful avenues for research. Some related concepts regarding biosecurity-compliant marina design and construction are presently being developed by Cawthron as part of a project funded by the Foundation for Research, Science and Technology.

Figure 4. Map indicating the location of pipes joining the lower Maitai River and the head of the Nelson marina basin. Also indicated are the sampling locations (1 – 7) where salinity measurements were recorded within the marina basin and the Maitai River (source: Paul Sheldon, NCC).

3.3.4. Biological control of fouling

An approach with the potential to control fouling on marina structures is the use of biological control. *Classical* biocontrol involves the deliberate introduction of a non-indigenous species to a new environment, and is generally discouraged in marine systems given that it could exacerbate rather than mitigate biosecurity risk (Secord 2003). In contrast, *augmentative* biocontrol relies on enhancement of naturally occurring predators, parasites or pathogens to regulate target species numbers. This may include such strategies as deliberately increasing the density of predators (*e.g.* sea stars, crabs) present on fouled structures, or providing amenable conditions for the enhanced natural colonisation of predator species.

4. MANAGEMENT OPTIONS BASED ON VECTOR CONTROL

4.1. Introduction

Vector management to date in New Zealand has primarily relied on the voluntary implementation of different management approaches by different maritime sectors. For example, in the case of *Didemnum* management in the Marlborough Sounds, MAF BNZ and the Didemnum Working Group aimed to address long-term risks from recreational vessel fouling through a programme of education and awareness among vessel users, and by encouraging self-management. However, at the inception of the management programme, vessels (especially recreational vessels on swing moorings in Shakespeare Bay) were actively treated to eliminate *Didemnum*. Treatment consisted of either haul-out and land-based cleaning, or the application of in-water wrapping-based methods (see Sections 3.3.1 & 4.3), which were completely effective against targeted vessels (Coutts & Forrest 2007).

However, while direct and active vessel management is effective, it is also expensive on a large scale, which is why voluntary self-management is often defaulted to as an easy option. We are unaware of the success of education and self-management approaches, but recognise that the participation of stakeholders generally in marine biosecurity management is enhanced in situations where efforts are made to increase awareness of the issues. In fact, we acknowledge that many (if not the majority of) recreational vessel owners maintain their vessel in a state where hull fouling is generally low. As such, these vessels may pose a relatively low biosecurity risk except where 'niche area fouling' occurs (see below).

The primary considerations for management of recreational vessels in Nelson marina, therefore, are: (1) how to improve on the present situation to address the 'rogue' vessels that operate at times with high levels of fouling on their hull; and (2) to detect and mitigate risks from vessels with below-water niche area fouling by pest species that may not be readily apparent from the surface. The approaches, in order of priority, that we describe below are based around: (i) a regime of regular antifouling coating application to reduce biosecurity risk; and (ii) ways to identify and mitigate biosecurity risk through more active monitoring and intervention. A summary of these approaches, and rationale and explanation for their use is detailed below in Sections 4.2 and 4.3. In Section 4.4 we discuss the concepts of a biosecurity levy and targeted cost recovery to fund the application of these approaches. Note that none of the measures we propose are 'silver bullets' for recreational vessel fouling in Nelson; rather they are all aimed at risk reduction as the most practical way forward. Swing moorings, for example, remain a difficult-to-manage source of vessel risk that we consider separately in Section 5.1.

Note also that the focus on hull fouling in the text below recognises this mechanism as the primary source of risk, but in the context of promoting awareness among vessel operators it is important to remember that there may be other important mechanisms (*e.g.* infected equipment, bilge water) associated with recreational vessels (see Section 2.1.1). Cawthron is presently working on a biosecurity strategy for Fiordland with MAF BNZ, which seeks to develop (and assess stakeholder compliance with) an operational plan that will address this broader spectrum of vessel risks (Sinner *et al.* 2009).

4.2. Prevention of fouling

4.2.1. Prevention based on regular antifouling

When considering options for managing biosecurity risks associated with recreational vessels, prevention is clearly preferable to cure. The single most effective way of preventing or restricting vessel infection by fouling organisms is the regular application and maintenance of hull antifouling. Risk analysis studies have determined that the age of antifouling paint on recreational vessels such as yachts can be a key factor determining the presence of hull fouling organisms (Floerl *et al.* 2005a).

Recreational boat owners have good reasons (largely unrelated to biosecurity concerns) for wanting a well-antifouled clean vessel hull. These include improved speed and manoeuvrability in the water, and greater fuel efficiency. There is currently little published information on recreational vessel antifouling maintenance regimes in New Zealand, but recent survey data collected by the Australian Quarantine and Inspection Service indicates that ~70% of international recreational vessels that were inspected prior to entering Australian waters between October 2005 and June 2006 had been antifouled within the previous 12 months (Hilliard *et al.* 2006). There are however, always likely to be a percentage of boats and vessel owners that do not conform to a regular antifouling maintenance regime (*e.g.* indifferent owners, absentee owners, live-aboard vessels, infrequently used vessels). The actual effectiveness of any antifouling coating is dependent on a range of factors, including:

- The appropriateness of the paint type (*i.e.* self-polishing copolymer, ablative, hard non-ablative, foul-release) to the vessel type and mode of operation.
- Quality assurance to ensure the coating has been applied to the manufacturer's specifications.
- Effectiveness of the paint type across a variety of different areas on a vessel hull (*e.g.* smooth hull surfaces versus niche areas).

Antifouling paint manufacturers acknowledge that coatings vary in effectiveness and lifespan across different areas of a vessel or modes of vessel use. It is therefore possible that even a regularly maintained vessel may experience a certain degree of fouling during the stated lifespan of its antifouling paint. Typically the niche areas become more readily fouled than other parts of the hull and this can occur within a 12 month period. Nonetheless, a review of the Australian biofouling protocol for small vessels (<25 m) concluded that it may be acceptable to assume that an antifouling coating up to 12 months old is likely to pose little biosecurity risk, assuming the coating has been properly applied and is the correct type for the vessel operating profile (Hilliard *et al.* 2006). As such, we suggest as a guideline for recreational vessels that professional antifouling at intervals of 12 months be promoted as a management option. We note however, that advancements in the research, formulation and manufacture of modern antifouling coatings have resulted in antifouling coatings that *may* remain effective under low-flow marina conditions for 18-24 months between applications (W. Sowman, Foreshore Painting, pers. comm.). Therefore, exceptions to the recommended 12 month time interval between antifouling application may be considered on a case-by-case basis, depending on factors such as: the type of antifouling formulation being used (*e.g.* emergence of new and improved products), the appropriate use of any given antifouling formulation, and following an assessment of the integrity of an existing antifouling coating by suitably qualified personnel.

4.2.2. Antifouling 'Warrant of Fitness'

During talks with NCC and the Nelson marina manager, it was suggested that one method for ensuring adequate antifouling (*i.e.* ≤12 months) among recreational vessels could be the introduction of a 'Warrant of Fitness' (WoF) system for all vessels using and/or visiting the marina. Such a system may function in a similar manner to the WoF regime for motor vehicles, whereby at the time of antifouling maintenance carried out on a vessel, a qualified assessor provides documentation or authorisation that:

1. The vessel's antifouling has been appropriately applied (preferably by a professional).
2. The correct paint type has been used for the type of vessel and its operational profile.

Given compliance with these conditions, one option would be to allow for a reassessment of the vessel after 12 months to recommend whether the fouling control coating requires reapplication, or whether it is adequate to remain as is for a further period of time. However, it may be more straightforward to simply stipulate a requirement for professional application of antifouling every 12 months. Obviously an important consideration would be the availability of resources to implement this type of system. For example, the availability and adequacy of vessel maintenance (*e.g.* antifouling) facilities would need to be considered given that many boat owners may historically have opted to undertake vessel antifouling maintenance themselves.

If feasible, however, the above antifouling requirement could be included as part of the standard agreement between the marina operator and berth holder. As part of such a requirement, a vessel could receive a WoF 'sticker' or displayable document that would be recognised by all marinas in the country, acknowledging that the vessel poses a low biosecurity risk based on a regime of ongoing antifouling maintenance. Determination of compliance with such a requirement could be incorporated into routine vessel inspection procedures already conducted by the marina operator (*e.g.* checks for electrical WoFs). If feasible, visiting and/or international vessels could be required to receive an inspection within a specified time of arriving at the marina, with an adequate standard of fouling control on vessels being a condition of stay under the Nelson marina berthing agreements.

It must be noted that some marina operators expressed major concerns regarding the issue of a WoF-style system for ensuring vessel antifouling maintenance (J. Paul, Port Marlborough, pers. comm.). While there was overall agreement that regular antifouling was crucial for maintaining clean vessel hulls, some managers believed a WoF scheme for policing antifouling compliance was an expensive and difficult-to-manage solution. Rather, it was suggested that compliance may be better managed through the implementation and enforcement of specific vessel maintenance requirements in individual marina berthing agreements. Using this approach, failure of vessel owners to comply with marina guidelines around vessel maintenance would result in a forfeit of their berthage rights, and possible eviction from the marina. One downside with this approach is the fact that non-compliant vessel owners may simply "move on" to other marinas or locations where antifouling guidelines are less stringent – potentially contributing to the spread unwanted species.

4.3. Identification and mitigation of biosecurity risks

Full compliance with a regime of 12-monthly antifouling would go a long way towards reducing biosecurity risks from recreational vessels. However, we note above that risks may still arise in some circumstances, for example through fouling of niche areas of the hull. Similarly, there are likely to be vessel owners/operators who do not comply with the antifouling measure. Both situations highlight the need for a process to:

1. Identify vessels that pose a biosecurity risk despite a requirement for 12 monthly antifouling.
2. Mitigate any remaining biosecurity risk through treatment of vessels classed as high risk.

To mitigate ongoing risk, land-based vessel cleaning methods are generally preferred, given the minimal likelihood of viable organisms or propagules being released into the marine environment. However, under certain circumstances; for example, where haul-out and cleaning is not possible or not timely, in-water treatment options are also available. In Section 4.1 we noted that both land-based and in-water treatments were applied to recreational vessels in Shakespeare Bay to eliminate *Didemnum*. We are also aware that marina operators in the Top-of-the-South have on occasions requested owners of heavily fouled vessels to have them hauled out and cleaned. Hence the process that we are suggesting is already used to some extent, but in an *ad hoc* or reactive manner. In essence, what we are proposing below is a more systematic means of identifying high biosecurity risks and a formal process for mitigative action.

4.3.1. Identification of high risk vessels

A systematic process to identify high risk vessels requires a number of facets to be considered:

1. **Clarity around what is 'high risk':** We suggest that high risk could be deemed to occur if: (i) any of the target species in Table 1 (or other species of regional concern) were visible on a vessel hull; or (ii) hull fouling exceeded a threshold 'level of fouling' (LoF) chosen from the categories specified in MAF BNZ / NIWA vessel sampling guidelines. We suggest that a LoF score of 4 would be appropriate for this purpose, as it corresponds

with relatively conspicuous fouling, and can suggest an increased likelihood that NIS will be present (*e.g.* Hopkins & Forrest 2009).

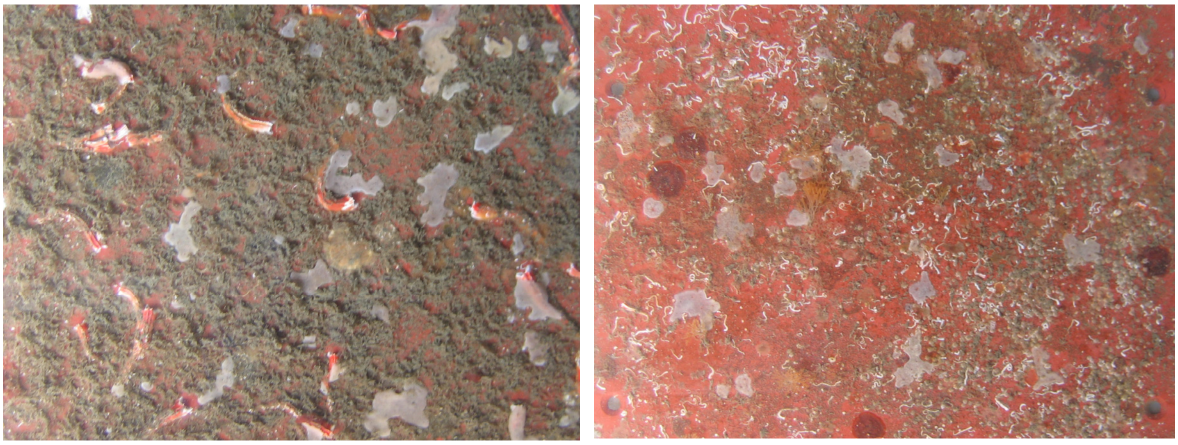


Figure 5. Examples of Level of Fouling category 4 (source: G. Hopkins, Cawthron).

2. **A procedure to identify high risk vessels:** There are two approaches to achieve this aim:
   i. The simplest approach is to assess fouling risk based on surface-inspection. This will assist identification of the most heavily fouled vessels (the classic 'rogue' vessels). However, a vessel that appears clean from surface inspection may be fouled in niche areas; this can be because many boat owners clean visible surface fouling from their vessels (essentially the fouling they can see and easily clean from the surface).
   ii. The issue raised in (i) indicates that a comprehensive inspection regime would require an under water inspection. Traditionally divers have been used for this purpose, but surface-operated remote cameras are increasingly being used. MAF BNZ is currently trialling the use of cameras to assist in the inspection of biofouling on international recreational vessels entering New Zealand (C. Denny, MAF BNZ, pers. comm.). These cameras are relatively inexpensive (~$4000) and require minimal training to operate. More importantly they provide a convenient method for quickly determining the actual levels of fouling across an entire vessel, in particular hard-to-see niche areas. Similar cameras are used by the Australian Quarantine and Inspection Service (AQIS) for assessing the biosecurity risk of vessels entering Australian waters (Hilliard *et al.* 2006).
3. **Appropriately trained personnel:** It is crucial that inspection personnel be provided with adequate training on procedures to identify high risk vessels. In addition to the option of training marina staff, an alternative would be to use appropriately qualified third-party personnel such as staff from government agencies (*e.g.* MAF BNZ) or qualified contractors.

4. **A systematic inspection regime:** A regime of monthly inspection would be ideal. The simplest approach described above in 2(i) could be implemented as a 'tick box' exercise as part of routine vessel inspections conducted for other purposes (*e.g.* electrical WoF). Obviously the need for underwater inspection described in 2(ii) is more time consuming and expensive to the extent that it may be unrealistic to undertake routine monthly inspections. However, it may be possible to stagger inspections so that all vessels are inspected at least once every 6-12 months. There is also the option to use underwater inspections on an 'as required' basis (*e.g.* to inspect visiting vessels arriving at the marina, or to look for target pests on vessels with an LoF of ≥4). Alternatively it may be decided that the 2(ii) option is unrealistic and 2(i) is chosen as a compromise.

4.3.2. Mitigation

Removal to land

Once a vessel has been determined to be of high biosecurity risk, as stated above, the preferred treatment option is to remove the vessel from the water and clean it on land. In such a situation, the best-case scenario would be that the owner of the vessel promptly complied with the marina manager's request to haul-out and clean their vessel. In reality however, there may be many instances where a vessel owner is unable or unwilling to comply with a haul-out request, such as in the case of an uncooperative or absentee owner. In these circumstances, the marina manager may benefit from having the power and resources to forcibly haul-out and clean offending vessels. Already, some marinas (*e.g.* Picton, Waikawa and Havelock) include stipulations in their marina berthage agreements that state a vessel must be removed from the water and cleaned should they exceed an acceptable level of fouling (J. Paul, Port Marlborough, pers. comm.). Obviously, the availability of space and infra-structure (*e.g.* hard-stand space) to manage high risk vessels would be an important consideration. Currently, Nelson marina has the facilities to cope with the estimated 25 vessels per year that are regarded as high risk (C. Hawkes, pers. comm.).

In situations where haul-out and cleaning of a vessel is not possible (*e.g.* insufficient resources), or timely (*e.g.* a new pest species is discovered on a vessel and must be removed urgently), in-water treatment is a feasible alternative. Sometimes this can be as simple as hand removal of a target pest, as was the case for the sea squirt *Styela clava* when discovered on vessels in Nelson in 2006 (Morrisey & Miller 2007) and is typically the case for *Undaria* (Stuart 2002b). However, such approaches do not account for the subsequent development of such pests from cryptic or microscopic life-stages. Hence, some alternatives are described below.

In-water 'wrapping' as an alternative to land treatment

The plastic wrapping method described in Section 3.3.1 is a proven in-water method for managing the biosecurity risks associated with vessel fouling (Figure 6). Freshwater, or eco-friendly chemicals such as acetic acid and bleach may be added to the encapsulated water within the wrap to accelerate mortality of target pests. This wrapping approach, with or without freshwater/chemicals has the advantage of completely sterilising a vessel's hull.

Hence, wrapping offers an effective, affordable and rapidly deployable tool for marina managers to quarantine a vessel that is deemed to be a high biosecurity risk. Currently, the cost of wrapping a vessel is comparable to the cost of hauling-out and cleaning (~$500 for an average 12 m vessel) and may be a viable alternative if quick action is required and access to haul-out facilities is problematic or subject to delays. Wrapping can also be used by vessel owners as a preventative measure against the establishment of fouling on their vessels. At least one vessel owner in Nelson has already adopted the practice of routinely encapsulating the hull of their vessel and adding freshwater to the wrap every time they are stationed at their marina berth for an extended period of time. This preventative approach is also routinely used by commercial fishing vessel operators in the port of Bluff (Paul Young, Young Fishing Co. Ltd, pers. comm.). In this way, some owners are adopting a pro-active and cost effective approach for successfully preventing the establishment of fouling organisms during the period when a vessel is most susceptible to colonisation (*i.e.* when stationary in a marina environment).

Commercial 'wrapping' or enclosure systems are also becoming available for recreational vessel owners. For example, the Sea Pen (www.seapen.com.au) is a dry-docking unit that allows vessels in marina berths to be encapsulated and isolated from the surrounding water within a water-proof membrane. Unlike conventional wrapping approaches however, the Sea Pen removes any residual water from within the wrap, exposing the hull to air and thus inhibiting the establishment of fouling. This system is presently designed to allow retrofit into existing marina berths. At many marinas overseas it is routine for recreational vessels to be lifted from the water (but within their berth space) in the periods between their use. Ultimately, it may be appropriate or possible to adopt similar approaches at marinas in New Zealand, or to include such considerations as part of the design for new or expanded marina developments.

Figure 6. Plastic wrapping methods used to treat moored recreational vessels in the Marlborough Sounds infected with the sea squirt *Didemnum vexillum* (source: Pannell & Coutts 2007).

In-water cleaning

In-water cleaning is another treatment method for mitigating high risk vessels, and generally involves divers manually removing fouling on a vessel hull, either by the use of hand- (*e.g.* scrapers, brushes) or powered-tools (*e.g.* rotating brushes). Most commonly, in-water cleaning is conducted on larger commercial vessels to remove light fouling (*e.g.* algal slime layers) and re-activate antifouling coatings. Less common is the practice of in-water cleaning to remove heavy amounts of fouling (*e.g.* macro-organisms) from vessel hulls. Ideally, an acceptable underwater cleaning method should have the means by which to capture and retain any organic (*e.g.* organisms) or inorganic (*e.g.* paint particles) defouled material dislodged as part of the cleaning process.

While there are currently no firm national guidelines prohibiting the practice of in-water cleaning for recreational vessels, some regional councils have rules governing its use in Regional Plans, which in turn are based on regulations stipulated in the Resource Management (Marine Pollution) Regulations (1998) and the Australian and New Zealand Environment and Conservation Council (ANZECC) water quality guidelines. For example, NCC stipulates that the dumping of organic material of natural origin (*e.g.* defouled material) is a discretionary activity, requiring prior council consent. Such restrictions are not necessarily in place for biosecurity reasons, but rather to address concerns around water quality (*e.g.* paint and contaminant discharges). Despite this, the practice of in-water cleaning is one that undoubtedly continues to occur within Nelson marina on a regular basis. For example, it remains a common practice for many recreational boat owners to use brooms, brushes or cloths to remove surface-visible fouling from their boat hulls in between antifouling treatments (R. Piola, pers. obs.).

At the time of writing, the Australian Department of Agriculture, Forestry and Fisheries (DAFF) is commissioning a review of the current ANZECC code of practice for antifouling and in-water hull cleaning and maintenance; in part to determine whether in-water cleaning should be employed as part of a more comprehensive strategy to minimise the presence of fouling on vessels. Hence, it is possible that guidelines governing the use of in-water cleaning will be relaxed, in particular as a tool to minimise the transfer of organisms from one region to another. For example, there is likely to be little biosecurity risk associated with in-water cleaning of a vessel that has accumulated fouling (even of target pests) from within the marina where it is berthed. If there was a ban on in-water cleaning within the marina, however, the vessel skipper may chose to in-water clean elsewhere (*e.g.* out of sight and possibly in a high value area), hence potentially transferring or exacerbating the problem.

If in-water cleaning was ultimately adopted as a biosecurity risk-reduction tool, it would be advisable to formulate best-practice guidelines, and set aside an area of the marina and/or port specifically for this purpose. For example, specific cleaning tools (such as rotating brush systems with material capture capabilities) should be used to reduce the overall amount of biological material released into the environment. One New Zealand study indicates that these systems retain ~90% of defouled material (Hopkins & Forrest 2008). Additionally, the in-water cleaning site may be located in an area, or designed in such a way, so as to minimise the impact of this activity. This may include: surface-to-seabed drop curtains employed to contain the majority of defouled material prior to settlement on the seafloor, location of the in-water cleaning station in a well flushed area of the marina to reduce water quality concerns and minimise build up of organic material, and the provision of adequate access to the in-water cleaning area in order to make it amenable to regular clean-up and maintenance (*e.g.* by dredging). Finally, existing marina guidelines may also need to be considered; for example, some marinas prohibit all diving activities in and around vessel berths on the basis of health and safety concerns (B. Colby, NZ Marina Operators Assoc., pers. comm.). Again, the designation of a dedicated in-water cleaning area may mitigate some of these issues.

Despite the technical feasibility of in-water cleaning, it cannot be considered a 100% effective means of reducing the biosecurity risk of a vessel. Not all fouling may be removed from a vessel using a system such as rotating brushes, in particular hard calcareous organisms may be difficult to remove and fouling may remain in 'nook and cranny' areas of the hull. As was the case for hand removal of target pests, mechanical in-water cleaning methods may also be ineffective against small or microscopic life-stages (Hopkins & Forrest 2008). Furthermore, research has shown that even trace amounts of organic material left behind after manual cleaning may act as an attractant and actually enhance the recruitment of new organisms to a recently cleaned surface (Floerl *et al.* 2005b). Finally, fragments of organisms (in particular colonial species) may remain viable and drift away to establish in other areas, or the physical disturbance of the cleaning may induce fouling species to release planktonic propagules (Hopkins & Forrest 2008).

4.4. Funding and cost recovery for biosecurity measures

Following discussions with the manager of Nelson marina, a proposed option for funding a biosecurity management system within Nelson marina is to introduce a biosecurity levy as follows:

1. A relatively small levy imposed on all vessels using or visiting the marina to cover costs associated with implementation of a biosecurity risk management programme, including costs of a regular vessel inspection regime (*e.g.* antifouling WoF check and evaluation of vessel risk status) and associated administration.
2. A larger fee imposed on owners of vessels identified as high risk to cover costs associated with vessel haul-out, cleaning, and storage, where owners are unable or unwilling to do this. In the case of unwillingness, an infringement notice (*i.e.* fine) system, or even eviction from the marina are possible additional options.

While such approaches were supported in principle by ToS marine biosecurity partners attending a meeting on 3 April 2009, it must be noted that the NZ Marina Operators Association (NZMOA) and some individual marina managers contacted, had strong reservations regarding the implementation of such measures. Objections were primarily based around concerns that a marina-wide levy penalises the majority of vessel owners who already practice good 'hull hygiene' and unfairly targets marina-based vessels as the major source of biosecurity risk, when in fact recreational vessels outside marinas, such as those on swing moorings, potentially posed a greater biosecurity risk (see Section 5.1). As stated previously, some marina managers consulted believe that all the authoritative powers necessary to demand the haul-out and cleaning of a fouled vessel can successfully be incorporated into existing marina berthage agreements, thereby placing the onus (and cost) of maintaining a clean vessel back on the individual vessel owner and negating the need for a marina-wide charge. Should NCC seriously consider implementation of a biosecurity levy scheme, we strongly advise a prior period of extensive consultation and communication with all relevant parties, including the marina manager, NCC regulatory departments, marina vessel user groups and NZMOA.

If Nelson marina were to consider implementing a biosecurity levy scheme, it would be important to keep the levy relatively small (~$25 per vessel per annum) so that it may be more widely accepted. Furthermore, it should be made clear that money from such a levy would be used to establish a biosecurity fund to pay the costs associated with administering a biosecurity management programme, and its associated vessel inspection regime. The funds could also be used to slip and clean high risk vessels within the marina in situations where owners were absent or unwilling to comply, but this would be on a cost-recovery basis; whereby such vessels were stored on hardstand until the owner had repaid all fees incurred.

Currently, the most streamlined implementation of a biosecurity levy at Nelson marina would likely be through its incorporation into the existing marina berth licensing fees. Given that the current payment structure of marina berthing fees caters to resident/long-stay vessels, temporary-stay vessels, and visiting vessels, this would ensure that all marina users were covered. Importantly, such a system would allow for the biosecurity management of international recreational vessels, which are arguably one of the most significant risk vectors for the introduction of new non-indigenous and unwanted marine species (Hewitt *et al.* 2009).

Box 1 outlines an example of how a biosecurity levy might be incorporated as a component of the current Nelson marina berthing pricing structure. Based on an annual levy of $25 per resident vessel, and $50 per temporary and visiting vessel (reflecting the greater likelihood of new unwanted marine species occurring on visiting craft), a biosecurity fund implemented at Nelson marina could net approximately $16,365 per annum (Box 1). Additional direct costs associated with haul-out, cleaning and hard-stand could be initially taken from this fund with later cost-recovery from vessel owners as noted above. If we estimate that approximately 5% of vessels in Nelson marina likely pose a biosecurity threat in any year (equating to approximately 25 vessels per year; C. Hawkes pers. comm.), and that at the time of writing the cost of slipping and cleaning an average 12 m vessel is approximately $500, this fund appears sufficient for Nelson marinas needs. In reality, we assume that many vessel owners would be willing to have their vessels cleaned when requested, hence use of the biosecurity fund to initially cover costs of active intervention would be unnecessary.

In addition to cost recovery from owners, an additional concept is to also introduce an infringement notice (*i.e.* fine) system. Such a strategy may be particularly useful for repeat offenders, or owners who see direct cost recovery as an easy way of having their vessels cleaned and removed to land (*i.e.* they ignore their biosecurity obligations because the cost of doing so is no greater than if they organised their own haul-out and cleaning). An infringement notice system could perhaps be incorporated into lease agreements between the marina operator and berth holders, but we are unsure about the legal issues associated with such an approach. It is possible that an infringement system could be based on a similar approach to that currently used by MAF BNZ border control, which has the power to impose fines on people attempting to import undeclared quarantined goods into New Zealand. However, such a scheme would ideally require implementation nationally, centralised governance, and the necessity for appropriately trained and authorised field officers/personnel for the inspection of vessels and issuing of infringement notices.

Obviously the infringement notice approach adds complexity, but even before the simpler levy-based and cost-recovery system was introduced, consideration would need to be given to:

- The amount of the levy. Obviously it needs to be sufficient to cover costs associated with an effective programme, but small enough to be accepted and supported by marina users.
- Clarification of the legal rights of the marina operator to haul-out and clean vessels (and recover costs), or fine owners of vessels considered a biosecurity risk, when owners are unable or unwilling to do so. We assume that the Nelson marina operators could include such provisions as part of berth lease agreements and marina code of conduct guidelines. Note: operators of Nelson marina (controlled by NCC) already have the power to haul-out vessels that have fallen behind on payment of berthing fees.
- Boater education and awareness. Vessels owners are likely to be critical of a marina that imposes a biosecurity levy on users while the berth structures remain heavily fouled.
- How a biosecurity levy system would be administered. NCC currently administers all fees and payment schedules associated with daily operation of Nelson marina; hence, it may be relatively easy to also handle the implementation of biosecurity charges.
- Extensive consultation and communication with all relevant parties, including the marina manager, council regulatory departments, marina vessel user groups and NZMOA

Box 1: Theoretical biosecurity levy structure based on current berthage licensing fees for Nelson marina.

Annual Marina Berth Licence: Marina Berth
Current cost: $192 + GST per metre of vessel, or berth size, whichever is greater
Proposed Biosecurity Levy: $25 per annum fixed amount
Example of revised costs: $194.50 + GST per metre for 10 m vessel (Total: $1556 + GST per annum)

Annual Marina Berth Licence: Pile Mooring
Current cost: $100 + GST per metre of vessel, or berth size, whichever is greater
Proposed biosecurity levy: $25 per annum fixed amount
Example of revised costs: $102.50 + GST per metre for 10 m vessel (Total: $820 + GST per annum)

Temporary Berth
Current cost: $0.76 + GST per metre of vessel per day
Proposed biosecurity levy: $50* per annum fixed amount
Example of revised costs: $0.774 + GST per metre of vessel per day for 10 m vessel

This represents approx. $0.14 per day per temporary berth toward Biosecurity Fund

Visitor Berth Rates
Current cost: $21 per day for vessels < 18 m
$35 per day for vessels 18 - 20 m
$3.50 per metre per vessel > 20 m
Proposed biosecurity levy: $50* per annum fixed amount
Examples of revised costs:

- $21.14 for a vessels < 18 m
- $35.14 for a vessels 18 - 20 m
- $77.14 for a 22 m vessel

This represents approx. $0.14 per day per temporary berth toward a biosecurity fund

* Higher biosecurity levy reflects the potentially greater biosecurity risk posed by temporary and visiting vessels

Between January 2008 and January 2009, Nelson marina operated approximately 515 resident vessel marina berths, 44 resident pole berths and 82 temporary berths. The marina also received approx 876 visiting vessels which stayed for a cumulative total of 16,984 days[a]. Based on these figures and the biosecurity levy structure outline above, the Nelson marina would have accrued a biosecurity fund of approximately $16,365[b] during the period Jan 2008 – January 2009.

[a] Vessel and berthage data provided by C. Hawkes, Nelson marina manager
[b] Final total assumes all visiting vessels are less than 18 m

5. RELATED ISSUES

5.1. Swing moorings

5.1.1. The issues

During discussions with marina operators and managers, it has been highlighted that recreational vessels associated with swing moorings may pose a greater biosecurity risk than vessels at marina berths. This is due to several factors, including:

- Cheaper costs associated with moorings relative to marina berths tend to result in some moorings being frequented by poorly maintained vessels.
- The relative isolation of many swing moorings results in an 'out of sight out of mind' mentality to inspection and maintenance.
- A lack of funding to adequately police moorings, and a prevalence of unauthorised moorings that do not appear on any administrative records or databases.

For example, cheaper costs may: attract absentee owners who are unavailable to clean and maintain their vessels, owners who use their vessels very infrequently, or users who have inherited a vessel and mooring with little interest in boating. As discussed previously (in Sections 3.3.1 and 4.1), the 2001 infestation of the pest ascidian *Didemnum vexillum* in Shakespeare Bay provides an excellent example of this situation (Coutts & Forrest 2007). In the 1-2 years following the initial incursion, recreational vessels on swing moorings situated in the Shakespeare Bay became extensively infected with *Didemnum* (often in addition to extensive other fouling), indicating a lack of regular maintenance and use by the vessel owners in question. Interestingly, one mooring maintenance contractor has commented on a trend toward increased mooring occupation over the last several years, where moorings that were previously unoccupied for the majority of the year are now almost permanently in use (J. Johnson, Johnson Barge Services, pers. comm.). This may in part be a reflection of rising marina berth fees and a desire for vessel owners to seek cheaper alternatives for housing their boats.

5.1.2. Current and future management of moorings

NCC currently has no formal control procedures governing swing moorings, but is in the process of implementing similar regulations to those in Marlborough, whereby all swing moorings in the region (~50) will require approval via resource consent application, and a regular inspection and cleaning of the mooring structure and gear. Marlborough Regional Council currently requires that all swing moorings located in the Marlborough Sounds are inspected, repaired and cleaned every two years, at a cost to mooring holders of ~$200-300 dollars (excluding any materials required). While these approaches may have some benefits in reducing the biosecurity risks associated with the swing mooring structures, some maintenance practices may, in fact, exacerbate risk. Maintenance generally involves lifting a mooring onto the deck of a barge, and scraping all growth from the ropes, chains and the mooring block (J. Johnson, pers. comm.). This growth is then deposited back onto the seabed at the mooring location. If an unwanted organism were to be present on the mooring structure prior to maintenance, it may inadvertently be spread via removal/fragmentation and dispersal by currents, or via infection of the maintenance vessel itself (*e.g.* via reuse of infected maintenance equipment, and dispersal of fragments remaining on the vessel deck).

Given the small numbers of swing moorings present in the Port of Nelson (<50) and their relatively confined geographic distribution (within the Nelson Haven and in proximity of Haulashore Island), NCC has an opportunity to managing the biosecurity risks associated with these structures more effectively than many other councils. For example, Marlborough Regional Council is responsible for managing approximately 3,000 moorings throughout the Queen Charlotte and Pelorus Sounds.

5.1.3. *Options for vessels*

Putting aside whether maintenance of moorings may actually reduce or increase biosecurity risks associated with these structures, there remains the concern that the primary transport vector associated with swing moorings (*i.e.* the moored vessel occupying the structure) remains unmanaged under current regulations. While Nelson marina managers may be able to stipulate biosecurity measures via the marina berth licensing agreement (as proposed above), no such agreements are required for vessels occupying swing moorings.

Ideally, resource consents would stipulate biosecurity conditions comparable to marina berthing agreements, and undergo a similar regime of inspection and active intervention. However, the resource consent for a mooring is for the mooring structure, and we are unclear as to whether it is possible to impose conditions on vessels that use the structure. Moreover, even if it was possible legally, common sense would suggest that determining compliance would not be practical. Key reasons include the fact that vessels may be absent from moorings at the time of compliance inspections, and any one mooring may have multiple users both known and unknown to the consent holder.

Based on such considerations, we suggest that effective management of vessel risks from swing moorings will require a national system that imposes biosecurity requirements similar to those discussed for marina berth holders (*e.g.* annual antifouling) on all vessels. In the meantime, communication and education of swing mooring consent holders regarding biosecurity issues may promote some measure of self-governance. Groups such as the Swing Mooring Holders Association in Nelson, may be important avenues for increasing awareness and may encourage some degree of self-policing among mooring users. For Nelson, management of swing moorings may be more feasible than other regions given their relatively confined distribution. Evaluation of the merits of these management options is beyond the scope of this report, but would need to at least consider legal and practical issues.

5.2. Tidal grids

Many marinas throughout New Zealand provide tidal grids for the out-of-water maintenance and repair of vessels. Grids are intertidal facilities that allow for a vessel to be suspended independently of the surrounding water, such that when the tide recedes the vessel hull is exposed. In addition to maintenance and repairs, grids have traditionally been used as a means of easily accessing vessel hulls for the purpose of defouling and cleaning. Although hull cleaning at grids occurs out-of-water, unless defouled material is adequately captured and contained following removal, it is ultimately released into the surrounding waters within a single tidal cycle (*i.e.* when the tide rises and re-submerges the grid). As such, the biosecurity issues and considerations associated with this form of cleaning are in essence the same as those for in-water cleaning (*e.g.* effective capture of all viable defouled material; dispersal of larval stages and fragments released during the mechanical removal process). Currently, many New Zealand marinas (including Nelson marina) limit the hull-cleaning activities at grids to hand scrubbing/water blasting removal of slime layers (*i.e.* no significant fouling); though this stance is primarily due to concerns around the release of toxic chemical and pollutants associated with antifouling paint removal rather than concerns with marine biosecurity.

Some managerial measures that may be implemented to reduce biosecurity risks associated with use of tidal grids include:

- Ensuring that any vessel using a tidal grid has not been overseas or out of the local area for an extensive period of time (*e.g.* >3 months) between grid visits.
- Any hull cleaning conducted on grids is limited solely to the removal of slime layer by hand scrubbing or low pressure water blasting (≤1400 psi).
- Implementation of a grid user registration system to ensure that all vessel owners using grids adhere to prescribed conditions of use. For example, users may be required to complete and sign a grid user agreement form prior to access to the grid, which outlines allowed and prohibited grid activities (including hull cleaning).
- Appointment of a grid manager whose responsibilities would include: processing and approval of all grid users (through the grid user registration system); monitoring (*i.e.* visual inspection) of grid(s) to evaluate user compliance with grid use guidelines; regular review of grid use guidelines; maintenance of grid facilities.

In addition to the biosecurity risks associated with vessel hull cleaning on tidal grids, it is important to acknowledge that other environmental risks may be associated with such activities, including: the release of toxic biocides associated with antifouling coating as a result of scrubbing and/or water blasting and the release of other toxic or hazardous substances associated with cleaning

5.3. Multiple ownership and responsibilities

Multiple ownership issues in some marina locations introduce a layer of complexity around biosecurity management, and indicate the need for effective consultation among organisations. In Nelson, the marina basin is immediately adjacent to the commercial fishing vessel berths in the harbour, and located within the greater Port of Nelson. While NCC is responsible for administering the day-to-day operation of the marina, some areas of the marina are the responsibility of Port Nelson. The ideal biosecurity management scenario in a situation like this would be a coordinated approach across all organisations present in the region or location. In reality however, this is not always achievable. If the preferred biosecurity management approach were one of source control of pest populations, this shortcoming could have a major impact on the success or any biosecurity program (*i.e.* there may be little point in the marina manager trying to stop the establishment of an unwanted organism if the adjacent port authorities do nothing and vice versa). However, if the preferred biosecurity management option was one of vector management (as proposed in this report), then non-participation by one organisation would not necessarily mean the likelihood of failure as a whole.

6. SUMMARY AND RECOMMENDATIONS

Summary

Recreational boating traffic poses a significant and often overlooked biosecurity risk to the New Zealand coastal environment through the introduction of marine non-indigenous species and pest organisms. There are two broad ways in which the biosecurity risk from recreational vessels can be reduced or negated. One is to control the source populations of target pests, as this will theoretically reduce the likelihood that vessels will become infected in the first instance. Our analysis shows that intensive source control that targets a single pest species can be a highly effective means of reducing vessel infection and hence risk. However, when multiple pests species are considered, and recognising that many established pests in Nelson marina have source populations in the wider Port (and in fact outside the Nelson region), we suggest that widespread source control with present management tools is unrealistic. The alternative and preferable approach to source control, is to directly manage vessels to reduce the risk that pest species will be transported. We describe management measures for vessels based on: (i) a regime of regular antifouling to reduce biosecurity risk; and (ii) ways to identify and mitigate biosecurity risk through more active monitoring and intervention.

From the discussion in this report, the management measures we recommend for Nelson marina are given below. However, given the transport of pests by recreational vessels from other source regions (both within and outside the greater Nelson area) is likely to undermine any management measures applied in Nelson marina alone, we encourage other marina operators to consider the adoption of similar measures. We also suggest that similar national level approaches to managing vessels are needed to address recreational vessels on swing moorings, and other vessel types. We note that the recommendations below target hull fouling as the primary source of biosecurity risk. However, in the context of promoting awareness among vessel operators it is important to remember that there may be other important mechanisms (*e.g.* infected equipment, bilge water) associated with recreational vessels that need to be considered.

Recommendations for Nelson Marina

1. *Regular antifouling:*
   a. Change berth licensing agreement to require all resident and visiting vessels to comply with a code of conduct that stipulates:
      i. An antifouling coating is applied by a suitably qualified professional at intervals of every 12 months. Longer time intervals between applications may be considered on a case-by-case basis, based on the antifouling formulation in question, its correct use and application (see Item (ii) below), the vessel in question and its mode of use, and an assessment of the antifouling coating integrity following inspection by appropriately qualified personnel.
      ii. The correct antifouling formulation has been used to suit the vessel type and its operational profile (*e.g.* regular versus intermittent use).
   b. As part of 1(a), evaluate the feasibility of implementing a WoF 'sticker' or displayable document indicating compliance with (i) and (ii) above, along with the 'expiry date' of the antifouling coating.
2. *Inspection of high risk vessels*
   a. Implement inspections at intervals of 1-2 months to identify high risk vessels. Determination of vessels as high risk should be on the basis of surface identification of target pests (Table 1 of this report) on the hull. This is likely to underestimate vessel risk but will allow for identification of the most obvious problems. In the event that target pests are not present, but fouling exceeds a Level of Fouling Category 4, an in-water inspection for target pests is desirable.
   b. Consideration should also be given to implementing systematic in-water inspections (*e.g.* by diver or surface-operated camera) of all vessels in the period 6-12 months after last antifouling. This approach would facilitate identification of vessels that remain high risk despite compliance with 1a (or because of non-compliance).
3. *Mitigation of high risk*
   a. Ensure resources (*e.g.* facilities, expertise) are available for mitigation of high risk vessels using land-based cleaning, in-water wrapping, or similar approaches in which the release of viable fouling (and chemical contaminants) to the marine environment is minimised.
   b. Consider developing guidelines to allow in-water cleaning by mechanical methods in an approved area(s) as an alternative to (a).
4. *Biosecurity levy*
   a. To fund measures under Recommendations 1 - 3, amend the Nelson marina berth charges to include a biosecurity levy. The nominal figure in this report was $25

per year; however, the amount of this levy should be calculated according to a more accurate estimate of costs.

b. Investigate the legal and practical feasibility of imposing and recovering costs of enforced mitigation measures (*e.g.* haul-out to land, in-water wrapping) for high risk vessels where owners are unable or unwilling to comply. Part of this approach should be to consider whether provisions to allow mitigation can be included in the standard berth licensing agreement. Where possible, the agreement and voluntary compliance of owners in the timely mitigation of high vessel risks is preferred.

In addition to the above recommendations, consideration should be given to:

- Ongoing public communication and awareness programmes of marine biosecurity risk from fouled vessels (and other sources of vessel risk), in conjunction with MAF BNZ and as part of the ToS partnership.
- Management options for swing moorings in the Nelson region (which may be more feasible than other regions given their relatively confined distribution). Evaluation of the merits of this would need to at least consider the legal and practical issues outlined in this report.
- Ensuring all operators in Nelson are working to achieve improved biosecurity in the region through coordinated and/or complementary management strategies. Such outcomes would logically be progressed as part of the ToS partnership.

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9. APPENDICES

Appendix 1. Summary of source control and vector management options to mitigate the biosecurity risks associated with recreation vessels and transport hubs

Table A1.1. Comparison of source control and vector management options to mitigate the biosecurity risks associated with recreation vessels and transport hubs, including the feasibility, acceptability, legal and practical considerations, benefits, negatives and estimated costs.

Management option **(VM=Vector management)** **(VS=Source management)**	**Type of approach**	**Feasibility at time of writing**	**Stakeholder acceptability and chance of success**	**Legal issues**	**Application issues / considerations**	**Benefits**	**Negatives**	**Estimated costs**
Wrapping (VM / SM)	Mechanical treatment	v. High	Acceptability: High Success: High	- Resource consent may needed for application and removal - OSH certified commercial divers required	- Specialised equipment and expertise required - Relatively simple to deploy and can be 'set-n-forget' - Slow acting (*i.e.* days/weeks) - May inconvenience port operations	- 100% effective if applied correctly - Cost-effective - Structures/habitats can be treated *in situ* - Can remain on for long periods and may act as a secondary treatment	- Unselective - May emit offensive odours - Disposal issues (plastic and collected biota) - Specialised equipment and expertise required - Diver safety issues	- Wharf piles ($11 to treat & $3.20 to remove per lineal m) - Jetty/pontoon ($611) - Vessel mooring ($176) - Vessel ($560) - Seabed >50m ($600/m)
Freshwater input (SM)	Physio-chemical approach	Low-Medium	Acceptability: High Success: Medium	- No immediate legal issues apparent	- Requires adequate freshwater source near to marina to achieve adequate volume and flow - Freshwater flows may vary over time resulting in variability in effectiveness	- Relatively cost effective once in place - Requires little management intervention - Once underway, largely "set and forget"	- Require steady source of freshwater - Initial setup costs (*e.g.* design, engineering) may be high	- Unknown at time of writing
Biological control (SM)	Biological approach	Low (research required)	Acceptability: Medium-High Success: Medium-Low	- Any new pest control organisms introduced to a new area may inadvertently impact HVA (fisheries, aquaculture), requiring compensation (this is	- Do appropriate pest-control species occur natively in area of interest? - Are such species amenable to manipulation? - Will new non-indigenous species	- Requires little management intervention - Once underway, largely "set and forget"	- Depending on the approach adopted, may introduce new harmful organisms to a new region	- Unknown at time of writing

Management option **(VM=Vector management) (VS=Source management)**	Type of approach	Feasibility at time of writing	Stakeholder acceptability and chance of success	Legal issues	Application issues / considerations	Benefits	Negatives	Estimated costs
				depending on the approach adopted)	need to be introduced to a new area? - Any new pest control organisms introduced to a new area may inadvertently impact HVAs (depending on the approach adopted)			
Marina design (SM)	Physical approach	Low (research required)	Acceptability: High Success: Medium-Low	- No immediate legal issues apparent	- Requires an "all or nothing" approach to be truly effective	- Effective control of organisms at the marina would mean less money spent on vector management	- Many novel materials remain untested under real-world scenarios - Likely to be more expensive than existing materials and designs	- Unknown at time of writing
Improved water quality (SM)	Physio-chemical approach	Medium	Acceptability: High Success: Medium-Low	- Requires means to punish person who breach clean-water guidelines (measures likely already in place)	- This approach not only requires clean-up of current pollution, but likely remediation of areas with history of contamination - Low levels of pollution must be maintained - May be problematic in many marinas given the protected their protective design and poor water flushing regimes	- Provides aesthetic improvements in additional to managerial benefits - Relies on native assemblages to reduce the introduction of new organisms	- Likely requires extensive remediation of areas with a history of long-term degradation and impact - Will not completely eliminate fouling - Unwanted species may still establish and spread	- Unknown at time of writing
Regular anti-fouling regime (VM)	Preventative treatment	v. High	Acceptability: High Success: High	- Resource consent may be required - Issues related to waste products of the application process (*e.g.* issues with paint residues, heavy metal and biocide	- Antifouling should be applied strictly to the manufacturers guidelines for the product - Correct antifouling product must be chosen for the vessel	- Ensures that vessel remain relatively risk-free irrespective of whether source regions (*e.g.* marinas) or nearby rogue vessels are infected with pest	- Active biocides in some antifouling treatments can contribute to environmental pollution (*e.g.* leaching of heavy metals)	- Approx. $1200-1400 for an average 12m recreational vessel (excluding slipping costs)

Management option (VM=Vector management) (VS=Source management)	Type of approach	Feasibility at time of writing	Stakeholder acceptability and chance of success	Legal issues	Application issues / considerations	Benefits	Negatives	Estimated costs
				run-off)	in question - Effective service-life of any antifouling product may differ depending upon type of paint, manufacturer, environmental conditions, vessel type and mode of vessel use - Application by private vessel owners may need to be carried out in an approved area (*e.g.* boat yards)	species - Cost effective - Improves vessel handling and fuel economy	- Environmental pollution may also result from vessel maintenance facilities with inadequate control measures or poor operating practices	
Identification of high risk vessels (VM)	Preventative treatment	High	Acceptability: High Success: High	- OSH certified commercial divers may be required	- Requires that inspectors be adequately trained to identify and categorise varying degrees of vessel fouling (both from the surface and underwater) - May require specialised equipment (underwater cameras) - Some marinas may prohibit diving in and around vessel berths	- Can identify and mitigate the risks from vessels that appear clean from the surface but may harbour unwanted species	- May be time-consuming the adequately inspect all vessels in a large marina facility (especially in the case of underwater inspection)	- Dependant upon the approach taken (*e.g.* train existing marina personnel; employ dedicated inspection staff; use third-party contractors or agencies) - Optional use of underwater pole cameras ($4000 each + training)
Removal of vessel to land for defouling (VM)	Mechanical treatment	v. High	Acceptability: High Success: High	- Resource consent may be required - Issues related to the disposal of removed fouling material	- Maintenance facilities must have adequate containment facilities to capture all organic (*e.g.* fouling) and inorganic (*e.g.* paint run-off) waste produced	- Cost effective - Can be quickly applied - Can be done in combination with antifouling (further reducing cost and effectiveness)	- A lack of sufficient resources or facilities may affect the speed with which a vessel can be removed and cleaned - May fragment and distribute organisms if adequate	- Approx. $500 for an average 12m recreational vessel

Management option (VM=Vector management) (VS=Source management)	Type of approach	Feasibility at time of writing	Stakeholder acceptability and chance of success	Legal issues	Application issues / considerations	Benefits	Negatives	Estimated costs
							containment measures are not in place, or if conducted in a non-suitable location	
In-water cleaning (VM)	Mechanical treatment	v. High	Acceptability: High Success: High	- Resource discharge consent may be required - OSH certified commercial divers required	- Special equipment may be required (*e.g.* rotating brushes, pumps, collection bags) - Not all fouling may be removed - Not all areas of the vessel may be accessible (*e.g.* niche areas)	- Well established methodology and expertise - Quick - Can be done *in situ* - Given the right methodology, most (~90%) defouled material can be captured	- Inevitable discharge of some defouled material into the environment - Many result in viable fragments or organisms recolonising other areas - May induce some organisms to release propagules or spawn - Diver safety issues	

Appendix 2. Characterisation of freshwater input from the Maitai River into Nelson marina

On 11 March 2009, sampling was undertaken by Nelson City Council to characterise the nature and extent of freshwater input form the Maitai River into Nelson marina. Freshwater enters the Nelson marina via two 600 mm diameter pipes located at the head of the marina. Sampling commenced at approximately 1500 (NZST), at the start of an incoming tidal cycle (low tide of 0.4 m occurred at 1547), and finished at approximately 1900 (NZST). During this time period, salinity, temperature, and dissolved oxygen (DO) measurements were recorded at six sites throughout the marina and one site in the Maitai River at the entrance of the pipes (Table A1.1). The rate of freshwater flowing into the marina was also recorded by placing a Greyline Stringray flow meter into one of the conduit pipes (Table A1.2).

Table A2.1. Measurements of salinity, temperature and dissolved oxygen (DO) recorded at depths of 0 – 1.5 m at sites in Nelson marina (1 – 6) and the Matai River (7). Measurements were recorded on 11 March 2009 during an incoming tidal cycle.

Site Number	Site Location	Depth (m)	Salinity	Temp (°C)	DO ($mg.l^{-1}$)	Time (NZST)
1	Finger A between berths 14-16	0	35.5	18.3	12.7	1345
		0.5	35.6	18.3	12.86	
		1	35.6	18.3	12.98	
		1.5	35.6	18.3	12.98	
2	Talleys Wharf	0	35.5	18.2	12.58	1350
		0.5	35.5	18.2	12.75	
		1	35.5	18.2	12.87	
		1.5	35.5	18.1	12.87	
3	Finger E between berths 16-18	0	35.6	18.4	11.84	1405
		0.5	35.5	18.3	11.9	
		1	35.5	18.3	12.08	
		1.5	35.5	18.1	12.2	
4	Finger H between berths 16-18	0	35.6	18.1	11.85	1410
		0.5	35.5	18	12.03	
		1	35.5	18	12.15	
		1.5	35.5	18	12.18	
5	Finger I between berths 16	0	36	18.7	11.15	1420
		0.5	35.6	18.6	11.26	
		1	35.7	18.4	11.31	
		1.5	35.6	18.1	11.38	
6	Finger N between berths 15-17	0	35.6	18.5	11.45	1427
		0.5	35.5	18.4	11.3	
		1	35.6	18.2	11.3	
		1.5	35.7	18	11.4	
7	Maitai River below QEII Drive Bridge	0	11.2	17.8	17.95	1439
		0.5	11.2	17.7	18.2	

Table A2.2. Freshwater flow rates from the Maitai River into the head of Nelson marina via 600 mm diameter connecting pipes. Flow rates presented are for one of the two existing pipes, recorded during an incoming tidal cycle.

Date	Time (NZST)	Water flow ($m^3.s^{-1}$)
11/03/2009	15:29:30	0.039
11/03/2009	15:39:30	0.034
11/03/2009	15:49:30	0.041
11/03/2009	15:59:30	0.031
11/03/2009	16:09:30	0.033
11/03/2009	16:19:30	0.038
11/03/2009	16:29:30	0.035
11/03/2009	16:39:30	0.034
11/03/2009	16:59:30	0.031
11/03/2009	17:19:30	0.022
11/03/2009	17:29:30	0.029
11/03/2009	17:39:30	0.03
11/03/2009	17:49:30	0.028
11/03/2009	17:59:30	0.026
11/03/2009	18:09:30	0.027
11/03/2009	18:19:30	0.03
11/03/2009	18:29:30	0.029
11/03/2009	18:39:30	0.031
11/03/2009	18:49:30	0.022
	Average flow:	**0.031**

Appendix 3. Salinity treatment feasibility in Nelson marina

It has been proposed that lowering the salinity in Nelson Marina by diverting fresh water from the Maitai River may offer a cost effective method for reducing the amount of fouling in the marina possibly reducing the potential for invasive species to establish in the area. The proposal suggests that if the surface metre of water could be reduced to a salinity of approximately 25 psu (a reduction of ~30%) that floating structures (*i.e.* boats and pontoons) will be subject to a reduced salinity. This would prevent subtidal marine organisms from establishing on these structures allowing the benefits proposed above. The purpose of this short report is to discuss the feasibility of this proposal using a "quick approximations" to determine if this proposal represents a realistic possibility.

Currently, pipes are located under Akersten Street which allows some fresh water from the Matai River to enter the marina. Measurements in the area proximate to the pipe show little deviation in salinity from marine salinities under "average" river flow conditions. Given this information, it seems likely that modifications to current structures would be needed to allow significant flow to enter the marina. Nevertheless, if sufficient flow could be diverted (and exists in the river) the question then becomes what quantity of water could and would be required to meet the requirement of at least a 30% reduction in the surface metre?

If the marina was able to be separated from the sea via a lock system, this would be a simple calculation, as the time for the marina to fill would simply be the volume of fresh water required (V_M)to meet the requirements of the proposal divided by the freshwater entering the marina (Q_R). In the case of the marina this is calculated at:

$$
\begin{aligned}
V_M/Q_R &= 52935/2.1 \\
&= 25207 \text{ sec} \\
&\approx 7 \text{ hours}
\end{aligned}
$$

Where V_M is calculated from the surface area (176,449 m^2) multiplied by the depth (1m) multiplied by the dilution required (30%) and Q_R assumes that all of the mean annual flow from the Maitai River (estimated at 2.1 m^3/s based on WRENZ[1] estimate) could be pumped to the marina. Assuming the large volumes of water assumed in this calculation could be diverted, and that the diverted water was pure freshwater (0% salinity) and very little mixing occurred, then this proposal seems possible.

However:

- the marina is not separated from the sea and will therefore experiences tides
- mixing of fresh water with underlying salt water will occur within the marina

Without requiring the building of a complex numerical model in order to account for these factors, calculations can be reworked using a tidal prism method to calculate the average salinity in the marina for given freshwater input flows. This method assumes that tidal

[1] NIWA Water Resource Explorer Tool (WRENZ) - http://wrenz.niwa.co.nz

replenishment of oceanic water mixes completely with any freshwater entering the marina to derive an average salinity for a tidal cycle.

Given the assumption that a diurnal 2 metre tide exists in the marina, the average flow over 12 hours required to lower the average salinity in the marina is about 3 to 3.5 $m^3.s^{-1}$.

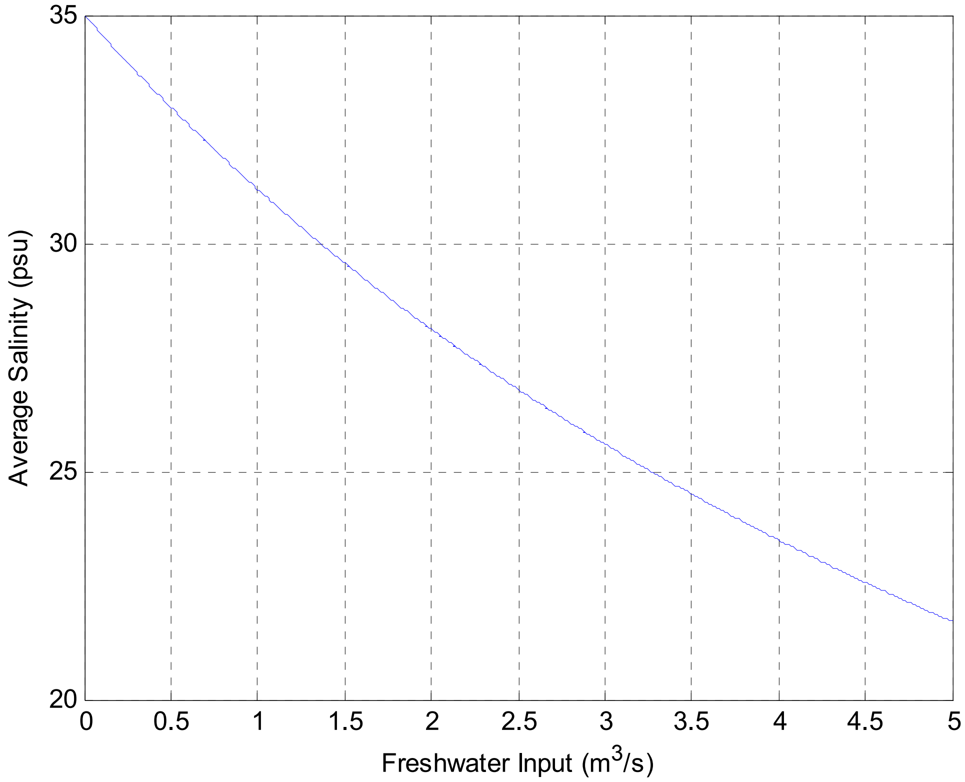

Figure A3.1. Average salinity in the marina for given freshwater flows, assuming an average tide of two metres.

Given this information, it seems unlikely that sufficient flow would be available to meet this requirement from the river without some storage mechanism, given that typical dry weather flows from the Maitai River are generally less than 1 $m^3.s^{-1}$. However, as discussed previously, if a lock mechanism to isolate the marina from oceanic water was developed it may be possible to lower salinity levels by the required 30% for extended periods of time. Without such a system, it seems extremely unlikely that a flow-through diversion of freshwater from the Maitai River would have a significant impact on salinities in the marina unless the entire flow was diverted through it.