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FOULED YACHTS: A VECTOR FOR MARINE INVASIVE ALIEN SPECIES TO SOUTH AFRICAN SHORES?

University of Cape Town

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Thesis submitted in partial fulfilment of the requirements for the degree of
Master of Science in Conservation Biology.

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ABSTRACT

Biofouling on recreational yachts is an important vector for marine invasive alien species (MIAS) in many countries. There are various characteristics of a vessel that make it more susceptible to hull fouling. Yachts in three Western Cape marinas were surveyed to assess extent of fouling, hull maintenance patterns, travel history and yacht-owner awareness of MIAS issues. Of 548 yachts inspected from the waterline, 62% exhibited secondary fouling, as evaluated using an ordinal ranking scale. A subset of these yachts (n=60) was selected for further investigation. Yacht-owner questionnaires revealed that 50% of all yachts had had fouling control coating (FCC) re-applied in the last 12 months. In 54% of the cases, the owners painted the yachts themselves. The age of the FCC was correlated with the waterline inspection ranking scale. The majority (83%) of yacht-owners also cleaned their boats while in the water, in between FCC applications. The average fouling composition of a yacht displaying secondary fouling included ascidians (71% of fouling), crustaceans (16%), algae (6%) and other taxa (7%). Both introduced and cosmopolitan species were identified in the biota collected from local and foreign yachts. Yacht-owners seemed aware of bioinvasions, however few had considered them in a marine context, identifying terrestrial examples more readily. The majority thought that the introduction of MIAS could potentially have an economic impact on South Africa. These results have implications for biosecurity in the Western Cape. It is likely that the yachts surveyed are not using an appropriate FCC for their vessel profile (based on speed and sailing frequency). This shows that there is a definite need to increase awareness in the yachting fraternity. Mitigation of the bioinvasion risk via yacht hull fouling requires the support of biosecurity legislation. South Africa is party to several international conventions regarding invasives, but in order for these to be legally binding, there must be equivalent national legislation. The most promising existing law is the National Environmental Management Biodiversity Act 2004 (NEMBA), although this is weak on marine legislation. NEMBA is currently in the process of being revised, and will in future require strict enforcement. Several other nations have established biosecurity teams with the sole mandate of bioinvasion management. For example, Australia has developed a border control protocol for yachts plying internationally, which assesses the extent of hull fouling visible from the waterline, checks vessel documentation and, if necessary, quarantines the yacht. The incorporation of management tools, such as Risk Assessment, into such protocols is essential. The majority of yacht-owners surveyed in the Western Cape accepted the need for management actions to address the issue of MIAS.

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CHAPTER 1: LITERATURE REVIEW

The movement of non-indigenous species (NIS) is having severe and increasing impacts around the globe. An NIS is a species that spreads and becomes established outside its natural range. It is becoming increasingly common for such range expansions to result from human activities, such as trade and tourism (whether these be intentional or unintentional introductions). The rate of appearance is high, with a new marine or estuarine species establishing every 32-85 weeks on average in six ports surveyed in the United States, New Zealand and Australia (Hewitt 2003). Not all NIS introductions result in 'invasions' defined by Valery et al. (2008) as "a species' acquiring a competitive advantage following the disappearance of natural obstacles to its proliferation, which allows it to spread rapidly and to conquer novel areas within recipient ecosystems in which it becomes a dominant population". If and when an NIS becomes invasive, it can have serious economic, environmental and social impacts (Mack et al. 2000). Over a decade ago, it was estimated that invasive management programmes cost the United States $137 billion per year (Pimental et al. 2000a). On a more global scale, taking several other countries into consideration (including the costs to South Africa, the United Kingdom, Australia, India and Brazil) this figure rises to over US$336 billion (Pimental et al. 2000b) and is highly likely to have increased substantially since 2000, as the number of invasive species discovered continues to increase worldwide. Also, these figures represent market values and thus do not take into account long-term investments. It is highly likely that in addition to these figures, an 'invisible tax' exists, whereby the national economy is impacted by the reduction in available natural resources due to NIS. In Canada, this annual hidden

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cost to fisheries, agriculture and forestry has been estimated to be CDN$13.3 - 34.5 billion (Colautti et al. 2006).

These invasive alien species (IAS) are widely recognized as one of the biggest threats to global biodiversity, along with habitat degradation and climate change (Vitsouek et al. 1997). It is estimated that they cause, or contribute to, the decline of half of all threatened species in the United States (Wilcove et al. 1998). The marine environment is especially under threat, as marine invasive alien species (MIAS) often go unnoticed until it is too late, with irreversible consequences (Bax et al. 2003, Coulatti et al. 2006). Although lagging behind bioinvasion research in terrestrial and freshwater ecosystems, marine bioinvasion research is becoming more extensive and insights are accordingly being provided into their true status in the ocean and coastal ecosystems around the world (Grosholz 2002).

There are both negative and positive impacts associated with MIAS (Bax et al. 2003). The negative impacts (in addition to those on the environment) include those on human health and economic losses from marine activities, such as fisheries, aquaculture and tourism. These can result in job losses, as well as lost opportunity costs associated with the financial resources allocated to dealing with alien species in terms of personnel, scientific and technical resources. Positive impacts include increased employment in fisheries for NIS, as well as in the field of bioinvasion research and management. However, these advantages are often misunderstood, as it is initially perceived that the disadvantages outweigh them.

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South Africa has a continental Exclusive Economic Zone (EEZ) of approximately 1,065 million km^2 and over 12,900 species of marine plants and animals have been reported in its waters (Griffiths et al. 2010). Levels of endemicity are very high, with 33% of the species unique to this country (Griffiths et al. 2010). In 1992, 15 introduced marine and estuarine species were identified in South Africa, with only two of these confirmed as invasive (Griffiths et al. 1992). In 2005, Robinson et al. distinguished between introduced (10 species) and cryptogenic (22 species). A cryptogenic species by definition, cannot be assigned native or introduced status (Carlton 1996). In 2011, this was re-evaluated, with a dramatic increase to 85 introduced and 40 cryptogenic species (Mead et al. in press *a*).

Research on MIAS has attracted considerable scientific attention in the last decade. However, until fairly recently, the majority of marine bioinvasion research has focused on commercial vessels and in particular, the discharge of ballast water (Roberts & Tsamenyi 2008). Ballast water has received particular attention internationally because of known links to 'high profile' invaders (Hewitt et al. 2004). The Global Ballast Water Management (Globallast) programme, a cooperative initiative of the Global Environment Facility, United Nations Development Programme and International Maritime Organization, has conducted several surveys of commercial ports to establish baseline estimates of MIAS in developing countries. There is also ongoing research into treatment plants for ballast water discharge in New Zealand (Hewitt et al. 2004), as well as within South Africa (International Ocean Institute of Southern Africa).

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More recently, hull fouling has been recognized as a principal vector responsible for MIAS global movement. Biofouling is thought to have been occurring for hundreds of years, although it was largely undocumented before the 19th century. Using a replica 16th century vessel, Carlton & Hodder (1995) demonstrated the role of slow-moving ships (speeds of 4 - 5 knots) with long port residency times, as a global driver of change in the marine ecosystem. In South Africa, a study using historical data estimated that invasions via ship fouling have been occurring since the 1600s (Griffiths et al. 2009).

Hull fouling is now considered a significant unmanaged risk internationally (Godwin 2003), although previously ignored due to the perceived effectiveness of antifouling paints (Minchin & Gollasch 2003). Drake & Lodge (2007) estimated that it was comparable in risk to ballast water discharge when quantifying organism abundance. Gollasch (2002) found non-native species growing on 96% of ships hulls sampled in the North Sea. Hull fouling has been attributed to 28% of all MIAS in the United Kingdom (Eno 1996). This can be compared to the 48% of NIS in South Africa that are thought to be the result of ship fouling (Mead et al. in press *b*).

Although commercial vessels are undoubtedly a major vector of MIAS, recreational vessels also have a part to play (Wasson et al. 2001; Floerl & Inglis 2005a, Ashton et al. 2006a, Darbyson et al. 2009). Both commercial and recreational vessels frequent bays, inland estuaries and coastal inlets, so if they are carrying NIS these ecosystems (which are often already under pressure from pollution and overfishing) could become the most threatened on the planet (Carlton & Geller 1993). Recreational vessels are still an under-appreciated vector for marine bioinvasions in many parts of the world,

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but there have been several studies concerning their role in freshwater invasions (Padilla et al. 1996, Johnson & Carlton 1996, Johnson et al. 2001). In terms of MIAS introductions, there have been some studies, notably in Australia, New Zealand, North America and the European Union, which have focused primarily on this vector (Floerl & Inglis 2005b, Ashton et al. 2006a, Mineur et al. 2008, Darbyson et al. 2009).

There are several factors that influence the successful transfer of MIAS on ocean-going vessels. Source and destination port conditions (biotic, climatic and physical structure), vessel characteristics (size, shape, surface, paint type, usage and maintenance patterns), and characteristics of the organisms all affect the fouling assemblages which accumulate (Floerl 2005). Floerl & Inglis (2003) found that recruitment of fouling organisms (with the exception of barnacles) was greater in enclosed marinas.

There are so many variables involved in the success of invasion, that it is difficult to develop a framework to anticipate and prevent invasions. Wonham et al. (2001) recommend investigating the issue at each of the three stages – dispersal, introduction and establishment.

Marine pests appear to be sporadic in their distribution, a likely reflection of associations with human transport vectors, which suggests that management of the vector itself is the most efficient method of control (Floerl & Inglis 2005a, Forrest et al. 2009). Compared to eradication and control post-invasion, preventative biological security (biosecurity) measures have proven to be less risky, more effective and to reduce the economic impacts (Leung et al. 2002). These preventative measures can

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occur pre-border, i.e. before the MIAS enter the country, and therefore prevent the initial introduction. The completion of thorough, rigorous Risk Assessments (RA) ensures that every eventuality is considered before the MIAS can become established and is a crucial first step in managing marine bioinvasions. An RA is generally restricted to either a species or a vector and is usually specific to one location. RA ultimately aims to minimize biological invasions by identifying weak links, areas of origin, highlighting areas for future research, analysing management options through cost/benefit approaches and evaluating the probability of management failure. The alternative is the post–invasion response. Several countries (Australia, New Zealand, the United States and Canada) have developed 'rapid response' measures for those scenarios where prevention is not enough, and the invasion must be dealt with once introduced (McEnnulty et al. 2001, NISC 2003, NEANS 2006, Locke & Hanson 2009). Biological control of marine invasions is much more risky than terrestrial control, so unless a native controller can be used to target the invasive, it should be avoided (Secord 2003). Most rapid response systems ultimately aim for complete eradication, that is, the removal of all reproductive potential from the population and there are several cases of success in this (Locke & Hanson 2009).

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One often cited example of a probable yacht-fouling introduction is that of *Mytilopsis sallei*, the Black striped mussel, and a close relative of the notorious European zebra mussel, *Dreissena polymorpha*, which resulted in severe damage to the environment (Johnson & Carlton 1996) and economy (Connelly et al. 2007) of the United States. The discovery of *M. sallei* in a yachting marina in Darwin Harbour, Australia during a port survey in 1999 incited panic (Bax et al. 2002). The mussel was successfully targeted in a massive chemical eradication programme that cost in excess of AUS$

2.2 million and involved 280 personnel. The hulls of vessels inside the marina were treated, as well as their internal plumbing to remove any trace (in larval or adult form) of the mussel. However, several boats that could have been previously infected had already left the harbour when the invasion was detected. These then had to be recalled in a nationwide search, which ultimately led to the development of a vessel-tracking database, monitored by Northern Territory Police and the Australian Quarantine and Import Service (Bax et al. 2002). This system is still in place today and is used to monitor the presence of internationally cruising yachts in Australian waters in preparation of border arrivals. This will help to prevent future introductions of this (or other potentially invasive) species. The mussel introduction was dealt with extremely rapidly (within three days), despite requiring amendments to national legislation. The urgency of the situation meant that there was insufficient time to undertake a rigorous RA. However, a hazard assessment ‘Infection Modes and Effects Analysis’ (Hayes 2002a) was completed which implicated several different transport vectors, including biofouling of recreational yachts (both domestic and international) (Bax et al. 2002).

Hull fouling is an incessant problem for all ocean-going vessels. Any growth on the hull disrupts the streamlined shape of a vessel, increasing the friction and, as a result, slowing the boat down. In order to maintain a constant speed, the boat must increase fuel consumption to overcome this additional water resistance and essentially becomes less fuel-efficient (Vischer 1928). This has environmental (in terms of increased air pollution) and economic implications. Sailing boats are also affected by fouling assemblages, as their cruising speed is dramatically reduced by the additional drag. Yachts that travel internationally and carry out transoceanic crossings are

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particularly vulnerable, as they could then be in danger of running low on food and water supplies if this increase in drag causes serious time delays.

In order to mitigate the problems associated with hull fouling, the hulls of most ocean-going vessels are treated, either with fouling control coatings (FCC) or mechanically (through electrical currents or with hydrodynamic pressure/flow). FCC can be based either on a biocide release (anything that attaches is killed by toxic chemicals), or fouling release mechanism (the hull is painted with a non-stick material which prevents attachment and is self-polishing at high speeds) (URS 2007). In the 1970s, tributyltin (TBT) compounds used in FCC were shown to cause deformities in marine animals and bioaccumulation in the tissues of organisms (Alzieu 1998). As a result, the International Maritime Organization (IMO) adopted the International Convention on the Control of Harmful Anti-Fouling Systems on Ships (AFS 2001). One of the outcomes of this convention was the global ban on the use of TBT in hull paints on all ocean-going vessels. This effectively excluded commercial vessels, because of the high costs involved with increased maintenance and the financial losses while the vessel is unavailable for work (Floerl 2002). With this ban and the resulting reduced efficiency of chemical paints, TBT pollution is diminishing (Evans et al. 1995). While pollution resulting from the biocides in FCC is of huge concern, these only impact locally and will reduce with time. On the other hand, the impacts of bioinvasions will continue to increase, as populations thrive unchecked (Lewis et al. 2004). The issue of hull fouling (and thus rate of bioinvasions) is expected to worsen until a more suitable alternative is found (Minchin & Gollasch 2003, Hewitt & Campbell 2007). The biocide-containing replacements that have been proposed to date seem to be equally capable of environmental damage and their use is cautioned

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until the effects are fully realized (Evans et al. 2000, Yebra et al. 2004). Copper is another commonly used compound in FCC. It has, however, been shown that many fouling organisms have developed a tolerance to this metal, which could aid the spread of MIAS (Piola et al. 2009). The most promising non-toxic approach involves researching the bioadhesion properties of the fouling organisms to understand how they actually attach and then employing that very mechanism to inhibit attachment to the hull (Callow & Callow 2002).

The vast majority of recreational vessels today use FCC. Floerl & Inglis (2005b) demonstrated a significant correlation between the age of FCC and extent of fouling on recreational yachts. However, the owners of recreational vessels (unless they are traveling internationally) have less economic incentive than commercial ship-owners to maintain their hulls. In addition to this, they travel at slower speeds and spend longer moored in marinas, both of which are factors that can allow extensive fouling to accumulate (Hewitt et al. 2009a). As a result, these vessels are often more severely fouled than commercial vessels and hence underestimated with regards to vector strength.

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Fouling control coatings have a limited lifespan, whereby they become increasingly ineffective, with a greater diversity of fouling assemblages (Coutts 1999). The process of anti-fouling is expensive, costing approximately US$1,000 per application, including the haul-out fee, paint and labour costs (Minchin et al. 2006). In addition to this, hulls are often cleaned, between the FCC applications, in-water by divers or snorkelers (either the owner or a professional cleaning company), or a brush is used from above the waterline. The latter is a cheap and easy option, although not as effective at removing fouling, especially around the keel (Floerl 2002).

Legislation can be an effective weapon in the fight against bioinvasions. As invasive species do not pay heed to international or regional borders, this is something that requires mass co-operation at all political levels. In order to tackle the issue, international policy frameworks must be strengthened. In 2000, there were at least 50 international and regional legal instruments concerning invasive alien species (Shine et al. 2000). These are comprised of binding and non-binding laws.

In order to maximize efficacy of the legal system, each nation initially needs to look at how the existing policies can be applied to vectors and pathways in their country and determine how best they can utilize this legislation. This may be through improved enforcement, or by amending agreements. Any gaps that are identified should be covered by legislation in multi-lateral agreements (Reaser et al. 2003). Also, policies need to be adaptive to react to the feedback from scientists and managers on the ground.

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New Zealand and Australia, both countries renowned for their advanced biosecurity measures, have the most progressive legislation and detection protocols for hull fouling of commercial and recreational yachts (only those that are involved in international cruising). In South Africa, there is currently no legislation directly applicable to hull fouling, although the discharge of ballast water from commercial vessels is regulated to some degree by means of voluntary guidelines set by the IMO.

Amendment of existing legislation could result in a suitable framework to address the pathway of hull fouling (Roberts & Tsamenyi 2008).

To date there have been no studies of hull fouling on recreational yachts within South Africa. Indeed this is the first time this vector has been considered in a developing country. Although developed countries are more likely to have the means to fund invasive management programmes and higher levels of education to raise awareness, developing countries benefit (in this regard) from lower frequencies of international trade and tourism and also cheaper labour costs (Nunez & Pauchard 2009). Most of the world's biodiversity hotspots are located within developing countries (Myers et al. 2000), so in theory, this should actually be where the majority of the effort and resources are directed, if conserving biodiversity were the number one priority issue for the world today. To that end, South Africa is one of the few developing countries that have comprehensive lists of marine invasive species (although it is more than likely an underestimate) (Mead et al. in press *b*).

Thorough research is required to evaluate the true impacts (both environmental and economic) of invasive species in South Africa. Even a developed country such as the United States is struggling to get to grips with invasive control. Due to insufficient policies and budgets, the United States relies on poorly quantified risk assessments and lacks economic incentives to deal with the problem (Simberloff 2006). South Africa has many major socio-economic problems to contend with, and invasive species may appear insignificant in comparison. However, invasive species do impact on society and the economy and if allowed to spiral out of control, these issues will become even more important.

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This study aims to evaluate whether there is a need for an additional step in the South African border control, whereby recreational yachts would be subjected to a risk assessment (to assess extent of fouling) on arrival in the country. If such border control procedures were implemented, certain species might need to be targeted and quarantine could be necessary, with the costs of hull cleaning being borne by yacht owners. These procedures would mean higher costs to yacht owners, so should only be undertaken in high-risk situations with unacceptable outcomes (Forrest et al. 2009).

Too often there is a research-implementation gap (Knight et al. 2008) between scientists and managers on the ground. With this in mind, this project is designed to offer practical measures that could potentially be applied to address the issue of hull fouling on recreational yachts entering South Africa from international waters. It is essential that these recommendations are in a format which can be easily applied by managers working on the ground. Yacht-owners will be questioned as to how they feel about various regulatory scenarios currently being trialled elsewhere in the world. Their responses will give an idea of how such measures would be received by yacht-owners in this country, if they were to be imposed by the government.

Given the potential importance of recreational vessels as vectors of MIAS in the Western Cape, South Africa, this project aims to ultimately determine whether there is a risk associated with fouling of recreational yachts, especially those traveling internationally, in the Western Cape (Chapter 2). The current national and international legislation regarding MIAS introduction and spread within South Africa,

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as well as potential management options, including risk assessment procedures and the practicalities of assessing boats on arrival in the country will then be evaluated (Chapter 3).

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CHAPTER 2. HOW IMPORTANT ARE RECREATIONAL YACHTS IN THE INTRODUCTION OF MIAS TO THE WESTERN CAPE, SOUTH AFRICA?

2.1 Introduction

Recreational yachts have been linked to hull fouling in several countries (Wasson et al. 2001, Floerl & Inglis 2005a, Ashton et al. 2006a, Mineur et al. 2008, Darbyson et al. 2009). There is some evidence of yachts actually introducing MIAS through biofouling, as in the case of the Black striped mussel to Darwin Harbour, Australia in 1999 (Bax et al. 2002).

There are still many gaps in our understanding of bioinvasions. We are yet to decipher the dose-response relationship in terms of marine introductions, i.e. how many introductions actually become invasive (Ruiz 2005). However, it is generally accepted within the scientific community that the greater the propagule pressure, the more likely it is that an invasion will become established (Carlton 1996), although this is not guaranteed (Johnston et al. 2009). In the marine realm, a propagule can be an adult or larval form of an organism. Propagule pressure can be increased through a higher frequency of arrival i.e. more yachts arriving, or a higher release rate from each hull (a greater number, or larger and more mature, fouling organisms). The reason for infection can be based on several things, from ineffective hull maintenance regimes (Floerl 2002) to the design of the harbour itself (Floerl & Inglis 2003).

Floerl (2005) realised the role that vessel characteristics had to play in the introductions via hull fouling, especially hull husbandry techniques and the FCC used. Floerl et al. (2005a) found that the age of the FCC was the best single predictor of

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fouling extent, however, the number of sailing days a vessel undertook was also an important risk factor.

Floerl et al. (2005a) used an ordinal rank scale (visually assigning fouling ranks from waterline inspections) to assess the extent of hull fouling on yachts arriving in New Zealand. This was then calibrated against underwater photographs that demonstrated variety and abundance of fouling. The rank assigned from the jetty was found to be correlated with the extent of fouling based on the photographs. The authors recommended this as a risk based predictive tool for border management of MIAS. However, this concordance is likely to be site specific, depending on the clarity of the water and also the quality of images taken.

Ashton et al. (2006b) used the ordinal rank scale designed by Floerl et al. (2005a) to search ten Scottish recreational boating marinas for seven non-native species. These species were chosen based on their known presence in other marinas in the United Kingdom. It was decided to retain an open search technique (i.e. with no target species in mind) during this study, as there is currently no baseline data for marinas in the Western Cape.

The issue of recreational yachts as a vector for marine introductions has not previously been investigated in any developing country. The objective of this study was to determine the risk of MIAS arriving on yachts into the Western Cape, South Africa. This was addressed by looking at the volume of traffic (both domestic and international) arriving, assessing several factors which would make a yacht more susceptible to biofouling and collecting samples from the hulls themselves, to see

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whether they were carrying MIAS. Sampling was also undertaken at different depths in the water in order to establish whether waterline inspections gave a representative depiction of the problem.

2.2 Methods

Study site

The marinas utilised for this research were in Cape Town (within the city or on the Cape Peninsula), Western Cape, South Africa. The three target marinas were the Royal Cape Yacht Club (RCYC) in Table Bay, False Bay Yacht Club (FBYC) in Simonstown and Hout Bay Yacht Club (HBYC) in Hout Bay (Figure 2.1). The marinas vary in the number and the size of yachts they can accommodate (Table 2.1). They are also likely to vary in the types of vessels that visit, due to location.

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Yacht frequency

The yacht clubs provided data of resident boats, visiting boats (both domestic and international) for an average year, to give an estimate of visitor frequency.

Questionnaire based survey

A survey was undertaken in three marinas with 20 yachts investigated at each location. Yachts were selected at random, with the only requirement for selection being the presence of owners to answer questions. Only the owners of sail-powered yachts under 60 feet in length were questioned for purposes of this study, due to the maximum size capacity of the marinas in question.

Figure 2.1. Map of the Cape Peninsula showing the location of the three marinas (RCYC, HBYC and FBYC) where surveys were undertaken (Digital Map Studios).

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Table 2.1. Logistical details of each marina surveyed on the Cape Peninsula

Yacht club	GPS co-ordinates	Number of moorings	Maximum yacht size
RCYC	S 33˚55’14 E 18˚26’33	425	60 foot
FBYC	S 34˚11’51 E 18˚26’04	242	66 foot
HBYC	S 34˚03’07 E 18˚20’98	114	60 foot

The questionnaire was developed and then trialled on a subset of yacht-owners (n=5). Following modifications based on this initial trial, the official interviewing (n= 60) took place from 25 October - 10 December 2010. The final questionnaire had a structured format, with a mixture of closed and open questions (Appendix A). Questionnaires were completed in person, either on the yacht or in the yacht club. The aim of the questionnaire was to characterize the yachts in terms of risk factors, for example, origin, hull maintenance practices (hull cleans and application of FCC), sailing patterns (both domestic and international travel) and awareness of the issue of MIAS.

Waterline inspections and allocation of yacht fouling rank

Over a course of three days in January 2011, all sailing yachts moored to the jetty (swing moorings excluded) in the three marinas were inspected from the waterline. The length of the boat on the jetty side was inspected and then ranked according to the ordinal rank scale shown in Table 2.2.

Biota collection

All 60 boats surveyed also had four samples of fouling taken from the jetty side of the hull. Two samples were collected from just below the waterline and two from the underside of each yacht (at approximately 33% and 66% of the length of the hull). Biota were collected using 15x15cm quadrats, hard plastic scrapers and catch bags made of fine nylon mesh (0.5 mm). The samples were sorted into broad taxonomic groups and after draining external water, wet biomass of each group was measured using an electronic scale, sensitive to 0.01g.

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Table 2.2 Ordinal rank scale as used by Floerl et al. (2005a) and Ashton et al. (2006b).

Rank	Description
0	No visible fouling. Hull entirely clean, no biofilm on visible submerged parts of the hull.
1	Slime fouling only. Submerged hull areas partially or entirely covered in biofilm, but absence of any macrofouling.
2	Light fouling. Hull covered in biofilm and 1-2 very small patches of macrofouling (only one taxon). 1-5 % of visible submerged surfaces fouled.
3	Considerable fouling. Presence of biofilm, and macrofouling still patchy but clearly visible and comprised of either one single or several different taxa. 6-15 % of visible submerged surfaces fouled.
4	Extensive fouling. Presence of biofilm and abundant fouling assemblages consisting of more than one taxon. 16-40 % of visible submerged surfaces fouled.
5	Very heavy fouling. Diverse assemblages covering most of visible hull surfaces. 41-100 % of visible submerged surfaces fouled.

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Ten of the surveyed vessels that exhibited secondary biofouling (3/4/5 on the visual rank scale) were chosen for further analysis. The selection was based on the reported travel history within the last 12 months (drawn from the yacht-owners questionnaire), to include five resident (reporting only local travel) and five internationally travelling yachts. The samples collected from the hulls were sorted into taxonomic groups and then stored in 70% ethanol. These were further identified to species level (or as high a taxonomic level as possible to establish the origin (recorded in terms of indigenous, introduced, or cosmopolitan)).

All continuous data were tested for normality and analysed using Microsoft Excel and SPSS Statistics 19, Release Version 19.0.0 (SPSS, Inc., 2010, Chicago, IL, www.spss.com).

2.3 Results

The annual average number of resident and visiting (domestic and international) yachts varied depending on the marina with RCYC experiencing the highest numbers of all three categories (Table 2.3).

Table 2.3. Average number of yachts in each marina per year, separated into categories of resident, visiting (domestic) and visiting (international).

	Number of yachts belonging to each category (annual average)		
Marina	**Resident yachts**	**Domestic visitors**	**International visitors**
RCYC	315	34	51
FBYC	230	30	23
HBYC	90	40	25

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A direct approach of face-to-face interviews gave a high response rate of 95%. Of the 60 boats selected for questionnaires and biota collection, 12 were foreign visitors - five from RCYC, four from FBYC and three from HBYC.

Travel history (last 12 months)

The number of sailing days undertaken over the last 12 months reported by yacht-owners ranged from zero to 300, with a median of 20 days. Just over half of all yacht-owners (51%) did not visit any other marinas in the last 12 months. A few (9%) undertook short-range journeys (less than 100 km from the home marina) to visit other yacht clubs on the Peninsula. Long-range journeys (>100 km from the home marina) were undertaken by 40% of yacht-owners, of which 44% comprised international travel.

Hull maintenance

There was large variation between yachts (n=58) in terms of age of the current FCC, with the most recent being two weeks and the oldest being greater than ten years (Figure 2.2). Half of all yachts sampled had renewed their FCC within the last 12 months. Only 21% had FCC less than six months old. However, when asked how often they antifouled their boats, owners (n=36) tended to quote shorter time frames than their actual FCC age. Of the yachts sampled (n=59) 54% had been painted by the owner and the remaining 46% were painted by a professional company.

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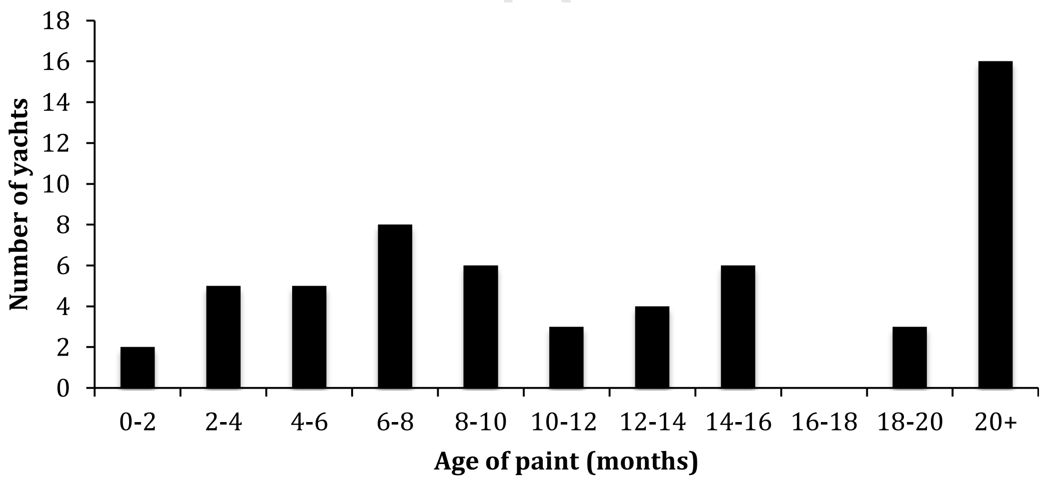

Figure 2.2. Current age of FCC stated by 58 yacht-owners.

The age of the current FCC was found not to correlate with the biomass collected from the hull (Pearson correlation coefficient r = - 0.128, $p > 0.05$) (Figure 2.3).

However, there was a relationship between the age of the current FCC and the waterline ranking (Pearson correlation coefficient $r = 0.596$, $p > 0.05$) (Figure 2.4).

The majority (83%) of yacht owners said that they manually cleaned the hull in-water in between FCC applications. Of these, 24% said that this was done infrequently. The majority (72%) had cleaned them in the water in the last six months (Figure 2.5). Few (11%) of 45 owners dry-docked their boats (in between FCC applications) as a method of hull cleaning.

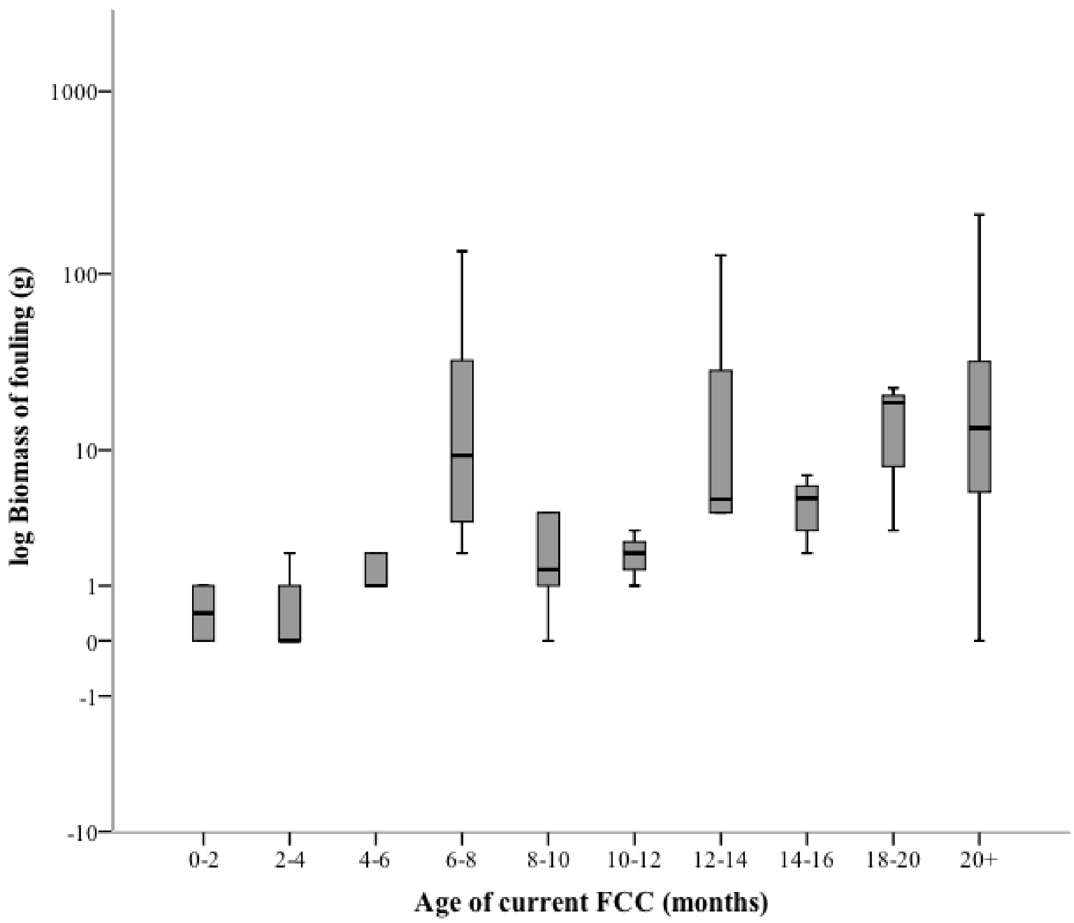

Figure 2.3. The age of the current FCC on the yachts in relation to biomass of fouling assemblages. Bars represent minimum and maximum values and boxes show the first and third quartile, with median highlighted in the box.

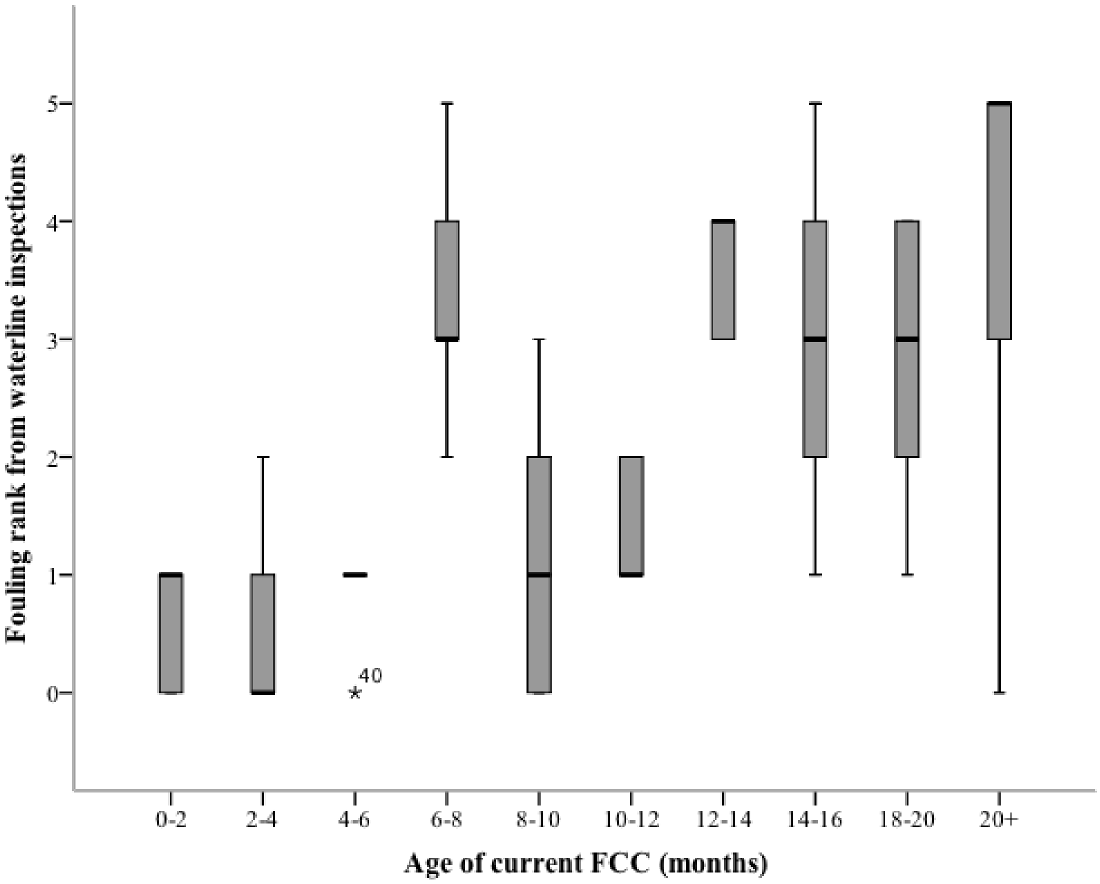

Figure 2.4. The age of the current FCC on the yacht in relation to the fouling rank assigned during waterline inspections. Bars represent minimum and maximum values and boxes show the first and third quartile, with median highlighted in the box. The outlier (labelled as 40) in the 4-6 age category was a Brazilian boat which had travelled continuously since FCC application. This could explain the extremely low fouling rank, or the anomaly could have arisen from the limited English spoken by the yacht-owners, resulting in an incorrect questionnaire answer.

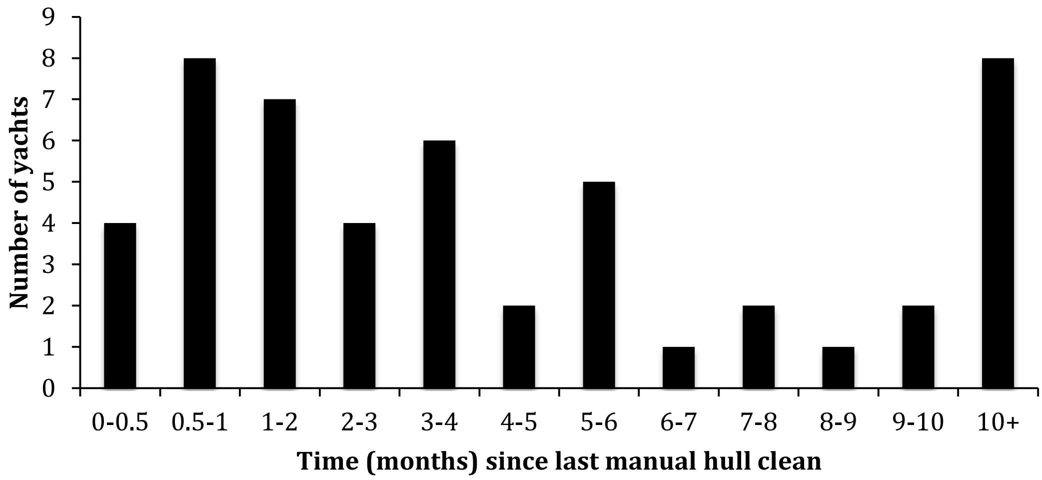

Figure 2.5. Time passed since last manual hull clean (in-water scraping, brushing)

Extent of fouling

Of a total of 548 boats ranked by waterline inspection, 38% had no visible macrofouling or primary fouling (rank 0 or 1) and 62% exhibited macrofouling or secondary fouling (level 2, 3, 4 or 5 on the rank scale) (Figure 2.6). Amongst the 60 boats which had their hulls sampled, 65% exhibited secondary fouling.

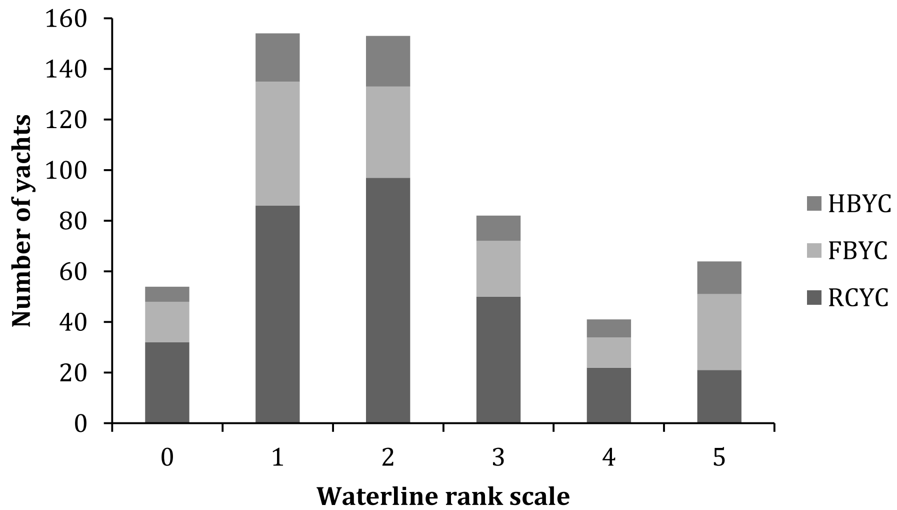

Figure 2.6. The number of yachts at each marina (HBYC, FBYC and RCYC) associated with level of fouling based on waterline ranking scale (with 0 being no visible fouling and 5 being very heavily fouled).

The yachts (n=39) noted as displaying secondary fouling from the waterline inspections were analysed for the fouling assemblage composition. On an average boat with secondary fouling, ascidians comprised the most common fouling group (71%), followed by crustaceans (16%) and algae (6%) (Figure 2.7).

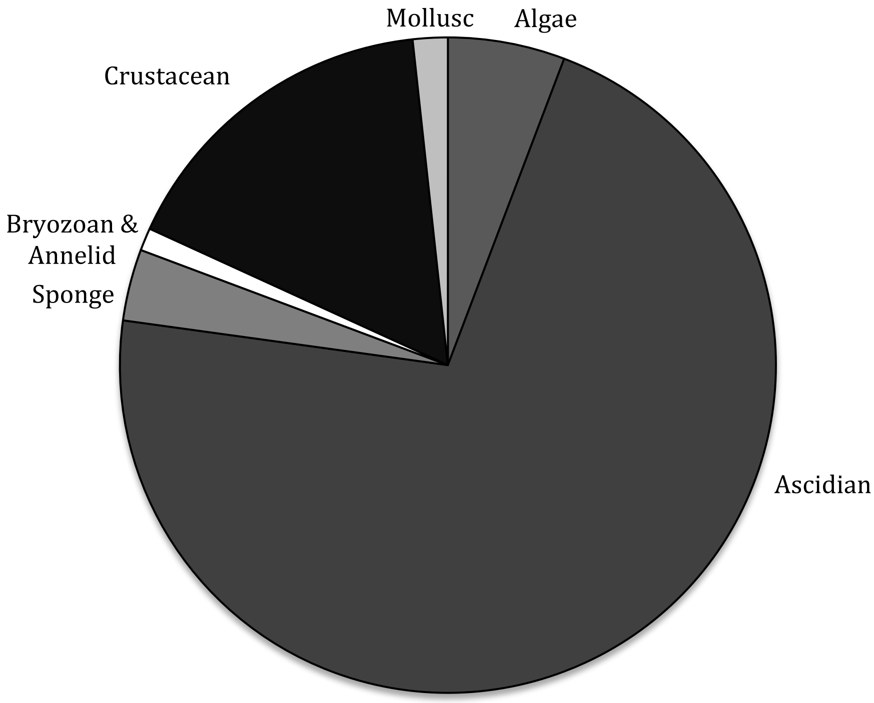

Figure 2.7. Average composition by mass of fouling assemblage on a vessel exhibiting secondary fouling.

The biota collections from foreign and local yachts contained indigenous, introduced, and cosmopolitan species (Table 2.4). All introduced species sampled have previously been recorded in South African waters (Mead et al. in press *b*). No cryptogenic species were identified from the hull samples.

Table 2.4. Specimens collected from five local yachts and five yachts that had been travelling internationally in the last 12 months (and their indigenous, cosmopolitan or introduced status) listed by investigated vessel.

Marina	Foreign/ Local	Taxonomic group	Species	Status
RCYC	Local	Amphipod	***Jassa moroni***	**Introduced**
		Barnacle	*Notomegabalanus algicola*	Cosmopolitan
			Balanus glandula	**Introduced**
RCYC	Foreign	Barnacle	*Notomegabalanus algicola*	Cosmopolitan
			Conchoderma auritum	Cosmopolitan
			Conchoderma virgatum	Indigenous
			Balanus amphitrite	Indigenous
RCYC	S.African vessel travelling internationally	Barnacle	*Conchoderma auritum*	Cosmopolitan
			Conchoderma virgatum	Indigenous
			Lepas anatifera	Cosmopolitan
			Lepas hilli	Indigenous
FBYC	Local	Amphipod	*Paramoera capensis*	Indigenous
			Caprella aquilibra	Indigenous
			Jassa spp.	**Introduced**
		Bryozoan	***Bugula neritina***	**Introduced**
FBYC	Foreign	Amphipod	***Jassa slatteryi***	**Introduced**
			Paramoera capensis	Indigenous
			Tanaid sp.	Indigenous
		Barnacle	*Conchoderma virgatum*	Cosmopolitan
			Conchoderma auritum	Cosmopolitan
		Bryozoan	***Bugula neritina***	**Introduced**
FBYC	Local	Barnacle	*Balanus trigonus*	Indigenous
			Balanus venustus	**Introduced**
FBYC	Local	Barnacle	*Austromegabalanus cylindricus*	Cosmopolitan
			Notomegabalanus algicola	Cosmopolitan

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Table 2.4 continued

HBYC	Local	Ascidian	***Clavelina lepadiformis***	**Introduced**
		Barnacle	*Balanus trigonus*	Indigenous
			Austromegabalanus cylindricus	Cosmopolitan
		Bryozoan	***Bugula neritina***	**Introduced**
HBYC	Foreign	Barnacle	*Conchoderma auritum*	Cosmopolitan
			Conchoderma virgatum	Indigenous

Five of the yachts (50% of those which had biota identified) contained introduced species, four of which were local boats that had not travelled internationally within the last 12 months. The majority (70%) contained cosmopolitan species.

MIAS awareness

When asked to name an IAS, 53 yacht-owners (88.3%) answered correctly, six (10%) were unable to do so and one person gave an incorrect answer. Of those who answered correctly, 54.7% listed a terrestrial species, 37.7% gave marine examples and 7.5% named a freshwater species. More than half of respondents (55 %) thought that marine invasions could potentially be an issue for South Africa.

The majority (80%) of respondents thought that MIAS had a negative effect on the local flora and fauna (Table 2.5). Likewise, 73% of respondents thought that the introduction of MIAS would have an economic impact on the destination country. However, there was more uncertainty about MIAS causing social and cultural impacts in South Africa, with 31 yacht-owners (52%) agreeing and 20 (33%) saying they ‘did not know’.

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When asked how important various factors were in determining hull maintenance patterns, cost, speed and preventing damage to the yacht seemed most important (Table 2.6). Preventing the spread of MIAS seemed to vary in importance, with a lot of yacht-owners admitting that they had never considered this before the interview.

Table 2.5. Responses by yacht-owners to various questions regarding the impacts of MIAS.

	Responses to questions (number of yacht-owners responding)				
Question	Strongly disagree	Disagree	Did not know	Agree	Strongly agree
Do MIAS have a positive impact on the local flora & fauna?	26	17	14	3	0
Do MIAS have a negative impact on the local flora & fauna?	0	1	11	18	30
Do MIAS have an economic impact on the destination country?	0	2	14	31	13
Do MIAS have a social & cultural impact on the destination country?	0	9	20	25	6

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Table 2.6. Responses by yacht owners to various factors in terms of how important they are and as a result how much it affects the frequency of hull maintenance.

	Importance of various factors to yacht-owners				
Factor	Very unimportant	Unimportant	Impartial	Important	Very important
Fuel efficiency	8	11	8	15	18
Cost	0	13	3	23	21
Speed	2	7	3	21	27
Aesthetics	5	11	7	27	10
Prevent damage to the hull, motor, propellers	0	11	2	17	30
Prevent spread of MIAS	4	23	5	18	10

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2.4 Discussion

Yacht frequency

Of the three clubs surveyed, RCYC receives the majority of international recreational yacht traffic arriving in the Western Cape each year. Domestic travel seems to be more evenly spread amongst the clubs. This may be because RCYC is closer to the centre of Cape Town, so international visitors have more opportunities to explore the sights. Also, many international sailing races pass through RCYC, for example the Heineken sponsored ‘Cape to Rio’ race left from RCYC in January 2011. There are six registered Ports of Entry for sailing yachts entering South Africa through the Western Cape, including RCYC, FBYC and HBYC. Therefore it might in theory, be easier to control the number of introductions, or propagule pressure, by prioritising action in these marinas.

Travel history

Just over half of all yacht-owners (51%) did not visit any other marinas in the last 12 months. Given that 41% of yacht-owners undertake long-range journeys regularly, if they were carrying MIAS, the risk of secondary spread is a cause for concern. Lodge et al. (1998) found that the domestic travel of a yacht within a country would determine the ultimate impacts (both economic and environmental). Floerl et al. (2005a) refer to boats that visit other marinas on a regular basis as demonstrating promiscuity, as opposed to fidelity, whereby only short-range journeys close to the home marina are undertaken. The authors found that in New Zealand, the majority of yachts demonstrated promiscuous travel behaviour. Busier ports (transport hubs) such as Ports of Entry were 75% more likely to be infected by bioinvasives (Floerl et al. 2009). Any domestic travel from these could potentially be high-risk. It could be that commercial ships (trading across borders) introduce MIAS, with the smaller recreational vessels moving within a country then spreading it (even though they may never have travelled internationally themselves). Stepping stone invasions have been shown to occur with species 'jumping ship' between different vessels. Apte et al. (2000) demonstrated that *Mytilus galloprovincialis* arrived on the battleship, USS Misouri, in Hawaii and was discovered three months later in ballast tanks of a submarine moored in the same harbour. MIAS have also been found in coastal regions that are not frequented by international shipping (Wasson et al. 2001). The authors identified intraregional transport of recreational boats as a potential source of MIAS introduced to an estuary in California.

Of the ten yachts which had hull samples taken, the local boats were more likely to exhibit introduced species than those which had recently traveled internationally.

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Floerl et al. (2005a) found a high similarity between biota collected on foreign and resident yachts in New Zealand. However, the introduced species identified in the current study, are already established in South Africa, so are in essence part of the flora and fauna in the Western Cape (although not native). In these ten samples, no new introduced species were recorded for South Africa (although several species were unidentifiable). Local boats containing NIS may have been colonised from populations already established (via previous yacht introductions) in the marina habitat, such as the pontoons or ropes. From there, they could have spread to adjoining vessels. Alternatively, as this study questioned owners on travel only within the last 12 months (and at least half the boats hadn't been antifouled in this time frame), these vessels may have travelled internationally over a year ago and collected fouling then, which may have still been present on the hull during sampling.

It should be noted that nearly all yacht-owners (informally) claimed that it would be foolish to undertake international travel with a heavily fouled vessel. However, a vessel does not necessarily need to be heavily fouled to contain MIAS. The concern should perhaps be directed away from quantity of fouling to quality of fouling, with an emphasis on certain problematic species, as these could be slipping through the borders unnoticed on an otherwise clean yacht hull.

Hull maintenance

Given that half of all the boats sampled had FCC that was less than 12 months old, one would expect the extent of secondary fouling to be lower than the observed 62%. However, the relationship between biomass of fouling and age of FCC was not clear. This could be due to an interplay with other factors such as, in-water cleaning,

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number and duration of voyages. Or it may be a result of the limited sample size which did not allow for significant comparisons. However, the waterline inspections did seem to be correlated with FCC age. These took the entire length of the hull into account (although the deeper portions of the hull were not visible). Floerl et al. (2005a) found that the age of the FCC was the best predictor of fouling extent. They surveyed 920 yachts in New Zealand, of which 51% had FCC applied more than nine months previously. A quarter of these had not been painted for more than 18 months. If antifouling paint age is indeed a risk factor linked to fouling intensity, it should be prioritised for action, making for more cost-effective biosecurity.

Given that the majority (just over half) of all yacht-owners questioned stated that they applied the FCC themselves, it can be assumed that this reduces the effective lifespan of the FCC as they are unlikely to follow manufacturer's guidelines as closely as professionals. A FCC can be considered effective if it meets the following three conditions (URS 2007):

1. If it is suited for the vessel use and speed;
2. If it is applied as per the manufacturers guidelines;
3. If it is well maintained for the effective lifespan set by the manufacturers.

Manual hull cleaning seemed to be a controversial maintenance decision. Many owners surveyed voiced concern that manual cleans seemed to take a layer of paint off and only succeeded in encouraging re-growth of fouling assemblages. Despite this, the present study showed that 83% of yacht-owners clean their hulls (either themselves or by employing professional diving services), with 72% having cleaned

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in the last six months. In comparison, 54% of Australian yacht-owners clean their hulls in between FCC applications (Mineur et al. 2008) and in New Zealand, 53% yacht-owners reported cleaning their hulls in the past six months (Floerl et al. 2005b). A study in New Zealand showed that hull surfaces which were manually cleaned and then returned to the water attracted up to six times more fouling than surfaces which were manually cleaned, then chemically sterilised (as would be the situation during the reapplication of antifouling) before being launched (Floerl 2002). In addition to this, the manual scraping of hulls is likely to initiate spawning of some organisms, as well as releasing live biota into the sediment below (Minchin & Gollasch 2003).

The relatively low number (11%) of yacht-owners who dry-docked their boats in order to clean the hull was similar in quantity to those found in the AQIS study (URS 2007). This is to be expected, as the costs of dry-docking are extremely high for a regular clean. However, cleaning the boat while it is dry-docked is more efficient than any in-water technique (Floerl 2005, URS 2007).

A few countries (the United States and Australia among others) have placed restrictions on in-water hull husbandry (Hopkins & Forrest 2008). This is based on the premise that biosecurity risks are increased when hulls are cleaned in the water. There is little scientific evidence behind this claim though, especially in terms of level of risk compared to leaving an un-cleaned vessel in the water.

Extent of fouling

The majority (62%) of yachts inspected from the waterline displayed some form of macrofouling, with 19% exhibiting extensive and heavy secondary fouling (ranks 4 or

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5). Many of these boats were either live-aboards (with owners using them as a home and rarely sailing them out of the marina), or in a state of disrepair (with the clubs reporting not having seen the owners for a long time). However, despite this high level of fouling, sampling took place over a very short time period and occurred at the start of the racing season, when many of the boats were being dry-docked to have their hulls re-painted and maintenance in-water is occurring more regularly. Therefore, if anything, the results from this study err on the conservative side.

During sampling it was observed that there were certain areas of the yacht, below the waterline and outside the stratified sample areas of the hull, that demonstrated high levels of secondary fouling, relative to the rest of the hull. Around the waterline, many yachts had a belt of *Enteromorpha sp.*, especially on the side that experienced the maximum sunlight hours, a well-known phenomenon on vessel hulls worldwide (Pyefinch 1950). This is known as niche fouling. It is most likely to occur on the following areas (in order of decreasing likelihood): seawater inlet/outlet ports, grills and rudder edges, anodes, keel foot and propeller shaft. This indicates the importance yacht-owners place on keeping the hull maintained for aesthetic and hydrodynamic reasons, as opposed to preventing spread of MIAS. These results are similar again to the findings of the AQIS database in Australia (URS 2007). In addition, areas on the hull itself were sometimes badly fouled. These were likely to have been the dry-docking support strips – the areas on the hull that are supported by beams when the boat is dry-docked. Coutts (1999) found that 89% of fouling taxa occurred within these areas on commercial ships, which could cover up to 20% of the submerged hull. However, the ratio is observed (although not directly measured) to be lower on recreational yachts, as they are substantially lighter in weight and thus need less

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support when dry-docked. Also other pieces of yachting equipment, such as fenders and ropes, which are semi-submerged in the water, could have the potential to harbour MIAS (Mineur et al. 2008). These would be interesting areas for further research.

Although MIAS were identified from the biota collection, the presence of NIS does not necessarily translate into a bioinvasion. There are so many factors involved in a successful invasion, not every introduction leads to establishment and subsequent invasion. In order to succeed, invaders must not only survive initial transport, but also overcome abiotic and biotic factors in their new environment. The dose-response relationship is currently unknown, and is expected to be even more complex for multiple species introductions, as is the case here (Ruiz & Carlton 2003).

MIAS awareness

Awareness is a crucial element in the fight against bioinvasions. Only 33% of respondents could give an example of a marine invasive and 45% of those interviewed did not think that marine invasives could be an issue. This demonstrates that there is a pressing need to raise awareness of these issues within the yachting fraternity. Invasives have been discussed in the media recently in the Western Cape, but with a focus on terrestrial species, one example being the conflict between fynbos and invasive alien plants all over the Peninsula, which is addressed by Working for Water (Le Maitre et al. 2002). Boshoff et al. (2008) found that following a questionnaire and interview process, the majority of visitors (who generally are more aware of conservation issues) to a South African game reserve had limited understanding of the invasive species issue.

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Often the wording of questions in questionnaires can affect the answer given (Sterngold et al. 1994), which may well have been the case here. Questioning a respondents concern or importance placed on a subject can often lead to overstated results, as the respondents feels they should be concerned with the issue.

A similar study in France and Spain showed that the majority of yacht-owners were aware of the problems associated with MIAS, in particular the species impacting their region, in this case *Caulerpa taxifolia* and *Sargassum muticium*. In New Zealand, the public has actually been enlisted to help with biosecurity matters. There have been several campaigns highlighting ‘unwanted organisms’ and a hotline has been established that the public can call to report sightings (Savarese 2005). This kind of strategy might work well in South Africa, in a similar public participation programme to the ‘Red Tide Hotline’. In addition to this, the yacht clubs have requested that the findings of this study be presented to club members in a public presentation, as well as the production of a poster highlighting the results. This demonstrates an interest in the subject and recognition of the urgency involved.

As well as tackling the yachts themselves, marina managers should be encouraged to maintain the pontoons and vertical pilings that are used to stabilise walkways more regularly. These have been found to act as reservoirs for MIAS (Arenas et al. 2006). In addition to this, there are often obsolete or neglected yachts in marinas that are very heavily fouled (personal observation). Mineur et al. (2008) recommend that marinas should offer incentives to deal with these, as they often contain MIAS.

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CHAPTER 3. MITIGATION: POLICY AND MANAGEMENT OF MIAS IN SOUTH AFRICA

3.1 Introduction

Given the importance of hull fouling as a vector for MIAS in the Western Cape (Chapter 2), action must be taken to prevent this continuing. The practicality of this requires an evaluation of the current legislation applicable to MIAS in South Africa and a review of management strategies (including risk assessment and border control protocols) used elsewhere in the world.

Legislation has proved to be useful and necessary in the management of bioinvasions, whether it be on an international or regional scale, and whether the regulations are binding or non-binding. Legislation needs to be effective in enforcing preventative and remedial action, accounting for present and potential threats. Biosecurity policies should:

1) Ensure that new introductions are prevented from taking place, by prohibiting or restricting certain activities.
2) Provide practical advice on how to control existing NIS (Bax et al. 2001).

This chapter will deal only with prevention of future introductions, as it is deemed the most effective. Only when it is unsuccessful should eradication and control be implemented (Chapter 1).

Terrestrial legislation regarding invasive species is much more developed than the marine equivalent, on both the international and domestic fronts (Hewitt et al. 2009). This chapter presents a review of the current legislation applicable in South Africa pertaining to the prevention of vessel hull fouling and thus the spread of MIAS. In addition to this, legislation enforced elsewhere in the world (specifically those laws implemented in Australia, New Zealand and the United States) will be reviewed to determine the best available practices and to assess the practicality of implementing such legislation in South Africa. These regulations will be presented to yacht-owners,

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in the form of a questionnaire, in order to establish the potential level of acceptance of the proposed regulations if they were to be applied to South African borders.

Recognition of capacity limitations and low levels of awareness warrant the need for an amenable, user-friendly approach for law enforcers and managers on the ground. To make this possible the efficacy produced by different assessment methods must be compared. In this case, waterline inspections will be compared to biota collections to show whether they can be used as a representative measure of biofouling.

An additional component of MIAS management is the crucial role of risk assessment (RA). In order to quantify all the risks involved with a vector and thus implement effective management action, an RA is essential. Risk Assessment has huge potential as a tool in preventing biofouling introductions. Some countries (for example, Australia) use them to assist border inspectors in prioritizing 'high risk' yachts, based on yacht hull husbandry, travel history and previous compliance with biosecurity measures (Hewitt & Campbell 2007). This study aims to identify the most suitable RA framework to address yacht biofouling in South Africa.

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3.2 South African legislation

Despite having some excellent environmental policies in theory, South Africa has few regulations related directly to invasive aliens. South Africa is signatory to several international treaties. However, in order for these laws to be binding on the individual citizen or corporation, they need to be reflected in domestic laws. Unfortunately, this is rarely the case and thus the international legislation is simply a recommended code of conduct and not mandatory (Richardson et al. 2003). One of the biggest issues with all South African legislation is enforcement, which is limited by resources (financial and qualified personnel) and therefore weakens policies. Responsibility and accountability for implementation and enforcement needs to belong to one agency within South Africa, so that there is limited delay before action is taken.

Generally, marine invasion legislation falls into three categories: laws with general obligations, those that aim to conserve biodiversity and those that apply to transport vectors.

General obligations

The South African Marine Living Resources Act (18 of 1998) Regulation 68 could potentially cover the introduction of MIAS on yachts, as it prohibits the release of "fish" into South Africa without a permit. Here "fish" is defined as "the marine living resources of the sea and the seashore, including any aquatic plant or animal…..and any mollusc, crustacean, coral, sponge, holothurian or echinoderm, reptile and marine animal, and includes their eggs, larva and all juvenile stages, but does not include seabirds and seals". However, this seemingly strict legislation is difficult to enforce in practice, evidence of which is in the increasing numbers of introductions found in South African waters (Richardson et al. 2003). However, the main issue with this act is in the use of the term 'release'. This implies intentional introduction, not unintentional as it would be for biofouling, so it would need to be amended if it were to be legally binding.

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Biodiversity conservation

In South Africa, the National Environmental Management Biodiversity Act (NEMBA 2004) recognises the need to address individual citizens by providing guidelines. However, NEMBA has limited relevance to unintentional introductions, such as hull fouling, and mostly deals with blacklisted species, leaving loopholes for unlisted pests to continue entering the country. These prohibitions could quite easily be amended to cover introductions via hull fouling, as the legal framework could support enforcement. A list of 575 prohibited invasive species (which have invaded other parts of the world) was produced for public feedback in 2009, however, only four of these were marine species, in particular:

- *Asterias amurensi*s (northern Pacific starfish)
- *Caulerpa taxifolia* (seaweed)

- *Eriocheir sinensis* (Chinese mitten crab)
- *Undaria pinnatifida* (Wakame seaweed)

In addition to this, a list of known invasive species already established in South Africa was produced at the same time. Only eight marine species were listed, despite there being 125 introduced and cryptogenic species currently recorded in South Africa (Mead et al. in press *b*). The list of eight was no doubt correct at the time it was drafted, but these figures are not static as the ecosystem is constantly in flux. In contrast, legislation tends to be updated with far less frequency (and ease). Ideally, this list should be reviewed every year, or whenever a publication indicates a new bioinvasion. There are many other species (known to have huge environmental and economic impacts elsewhere) that should be considered as potential invaders of South African shores. To address the likelihood of invasion by these problematic species, the biological climate of donor and recipient regions should be compared as discussed later in this chapter.

Vector legislation

In South Africa, there is currently no legislation directly regarding hull fouling. The South African Marine Pollution (Prevention Of Pollution From Ships) Act 2 of 1986 (with several later amendments) applies to any ocean-going vessel in South Africa's EEZ, or any marine vessel travelling internationally, under the flag of South Africa. Originally developed to prohibit the release of oil, it also covers harmful substances. The latter is defined as "any substance, which, if introduced into the sea, is liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea, and includes any substance subject to control by the present Convention". However, 'substances' in this case appears to refer only to "noxious liquids". Although the legislation does not actively exclude biological entities, the case would need to be made to legally include them.

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3.3 International legislation currently applicable in South Africa

General obligations

One example of an international convention which enforces general obligations is The United Nations Convention on the Law of the Sea (UNCLOS) 1982. Article 196 applies to the Exclusive Economic Zone (EEZ) of a nation and states that all participating parties must "prevent, reduce and control pollution of the marine environment resulting from …. the intentional and accidental introduction of species, alien or new, to a particular part of the marine environment, which may cause significant and harmful changes". This is currently non-binding on South African citizens (and visitors to the country) as a result of inefficient domestic legislation, although the nation is party to the convention.

Biodiversity conservation

The Convention on Biological Diversity (CBD 1982) currently addresses the conservation of biodiversity through legally binding, as well as non-binding, obligations. For many of these international agreements, a country is required to ratify before it is held accountable. There are currently 193 countries party to the CBD, but only 168 of those have signed, South Africa being one of these (ratified in 1995). The Cartagena Protocol on Biosafety was developed in 2000 and South Africa is currently in the process of accession. The following obligations of the CBD regarding NIS are binding to South Africa (paraphrased by Hewitt et al. 2009):

- **Article 3**: To ensure that activities within their jurisdiction or control do not cause damage to the environment of other States, or of areas beyond the limits of national jurisdiction.
- **Article 8(h)**: To prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species.
- **Article 14.1**: To ensure that the environmental consequences of its programmes and policies that are likely to have significant adverse impacts on biological diversity are duly taken into account.

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In 2005, the Ad Hoc Technical Expert Group on Gaps and Inconsistencies in the International Regulatory Framework in Relation to Invasive Alien Species (AHTEG) reviewed the CBD and reported that the lack of implementation of national legislation was the biggest shortfall in tackling bioinvasions (Doelle et al. 2007).

The Global Invasive Species Programme (GISP) supports Article 8(h) of the CBD. An international partnership with global strategies, it was founded by four partners, including the South African National Biodiversity Institute (SANBI). Its mission is "to conserve biodiversity and sustain livelihoods by minimising the spread and impact of invasive species". It achieves this at national and regional levels by offering support and guidance in policy, awareness raising and the sharing of information between nations. GISP provide resources in the form of toolkits, guidelines and best practices. The manual, 'Invasive Alien Species: A Toolkit for Best Prevention and Management Practices' (Wittenberg & Cock 2001) has been used extensively by managers around the globe in implementing management regimes. The GISP MIAS management training course has been applied in governments globally. More recently, the production of guidelines regarding the prevention and management of biofouling including a section on internationally plying yachts has been extremely useful (GISP 2008).

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In addition to this, the IUCN has also produced recommended Guidelines for the Prevention of Biodiversity Loss Caused by Alien Species (2000). These provide support to the CBD signatory parties and focus in particular on "strengthening the management response" by providing information on prevention, control and eradication.

Vector legislation

In terms of vector legislation, there are several non-binding international agreements which yacht-owners should be concerned with. Many of these were developed with ballast water introductions in mind, but the principles could likewise apply to international cruising.

The International Maritime Organization (IMO) has several legal instruments which are related to shipping, such as the IMO Resolution A.868 (20) of 1997: Guidelines for the Control and Management of Ships' Ballast Water to minimize the transfer of Harmful aquatic Organisms and Pathogens. From this, the International Convention on the Control and Management of Ship's Ballast Water and Sediment 2004 (BWM Convention 2004) was developed. In this, Article 1, paragraph 8 defines "harmful aquatic organisms" as: "…….aquatic organisms or pathogens which, if introduced into the sea including estuaries, or into fresh water courses, may create hazards to the environment, human health, property or resources, impairment of biological diversity or interfere with other legitimate uses of such areas.''

However, this convention has still not entered into force, as it requires a minimum of 30 states, representing a minimum of 35% of world merchant shipping tonnage to do so (Roberts &Tsamenyi 2008). As of January 2011, only 27 states, representing 25% of world tonnage, had signed the agreement (www.imo.org).

Despite all this, there is currently no international agreement that explicitly deals with biofouling (Hewitt et al. 2009). Several independent organizations (including the AHTEG in 2005) have been putting pressure on the IMO to develop a framework that would regulate this. As a result of this the IMO has formed the Biofouling Correspondence group to address the issue (DAFF 2010). They have already made a decision that pending regulations will not come as part of the BWM convention but rather a new legal instrument will be developed (IMO 2010).

3.4 Biosecurity legislation enforced in other nations

New Zealand and Australia, both countries renowned for their advanced biosecurity measures, have the most progressive legislation and detection protocols for hull

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fouling of commercial and recreational yachts (those involved in international cruising).

In order to act quickly and efficiently when required, it is essential to have strong legislation, with authority placed in one agency only, so that there are no delays in action. As awareness and impacts of bioinvasions increase, several nations have developed regulatory frameworks to address the issue. Australia, New Zealand and the United States now have official biosecurity teams that deal with the prevention of intentional and unintentional introductions of NIS.

In Australia, the majority of marine bioinvasions fall under the Quarantine Act of 1906, but the 1999 Darwin mussel outbreak led to the development of a National System for the Prevention and Management of Marine Pest Incursions (Hewitt & Campbell 2007). This assigns potential threats to vectors through RA and has detailed incursion response plans to deal with the pest as efficiently as possible (Hewitt et al. 2009). In 2005, a project was launched by the Australian Quarantine and Inspection Service (AQIS)' to trial a '*National Border Biofouling Protocol for Apprehended and International Vessels Less than 25 m in Length*' (URS 2007). This trial period during which AQIS Seaport Officers inspected boats on arrival in a Port of Entry, proved successful (Appendix B). Initially, a waterline visual inspection was undertaken to determine the presence of primary or secondary fouling. Some of these yachts were then assessed further using a pole-mounted camera to access areas and niches which were less visible from the surface, such as the bottom of the keel, the propeller, rudder and seawater inlet and outlet ports. Following the success of the phase-in period, this protocol has become mandatory (URS 2007).

New Zealand lays claim to the first legislation directly addressing bioinvasions. The Biosecurity Act of 1993 deals with pre-border and post-border management of unintentional introductions (Hewitt & Campbell 2007). In 1998, the New Zealand Ministry of Fisheries established a dedicated Marine Biosecurity team. Although

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currently there is no enforced legislation regarding hull fouling in New Zealand, there are voluntary guidelines for vessels visiting areas of high biodiversity.

The US Aquatic Nuisance Species Task Force was created to address the Aquatic Nuisance Prevention and Control Act of 1990. This is done through the Risk Analysis Review Process that involves both risk assessment and risk management (Orr 2003). Although there are no direct references to recreational vessels in the Act it could have this application.

3.5 South African legislation of the future

In order to maximize efficacy of the legal system, South Africa now needs to look at how the existing policies can be applied to vectors and pathways within the country and determine how best this legislation can be utilized. This may be through improved enforcement, or by amending agreements. Any gaps that are identified should be covered by new domestic legislation and supported by multi-lateral agreements (Reaser et al. 2003). Regional or national legislation is advantageous, in that it can be written to suit the circumstance. Also, decisions regarding policy changes can be made more quickly, without the need for international agreement (Doelle et al. 2007). Above all, legislation must be adaptive to react to the feedback from scientists and managers on the ground, with regular evaluation of the current regulations.

South Africa would benefit hugely from a designated biosecurity team. There is a need within South Africa to develop prioritisation frameworks and design research projects to address policy issues. This project has taken a step in that direction, but is focussed on only one piece of the picture when it comes to MIAS. South Africa has been very involved in mitigating ballast water issues through an inter-ministerial committee, the development of draft policies (within Department of Environmental Affairs and Tourism as well as Department of Transport) and ratification of an international convention. Given the success of this co-operation and the acceptance by government, the groundwork has been laid for further involvement in other MIAS vectors such as hull fouling.

3.6 Management Strategies - Risk Assessment

The aim of a risk assessment is to fulfill three goals: 1) identify the hazard, 2) quantify the risks involved, and 3) propose a management strategy (which is transparent and consistent) to deal with the risk (Hayes 2003). The management strategy should include pre-border, border and post-border management (Hewitt et al. 2004).

Identifying the hazard

The risk analyst must choose between an inductive (model-based) or deductive (experience based) approach. Deductive approaches are more commonly used in biosecurity RA, as they are simple, based on historical records and rely on expert opinion. However, they can lead to a false sense of security, as the analyst thinks all the hazards have been identified. Inductive approaches, on the other hand, rely on rigorous models that are more complicated to run, but less biased and can be used to identify risks unidentified by the deductive method (Hayes 2003). An example of this is the fault tree analysis used in Australia's Quarantine and Inspection Services (AQIS) ballast water risk assessments (Hayes 2003). Fault tree analysis can identify all the hazards associated with an event by varying the combination and sequence of different events leading to the final event (in this case, establishment). The limited number of studies into the role of recreational yachts in MIAS transfer have focused only on hull fouling, whereas boats in freshwater ecosystems have been analysed more thoroughly (Johnson et al. 2001). If the comprehensive approach suggested by the authors were applied to ocean-going yachts, there would be five different vessel components to consider, namely the hull, deck, internal spaces, anchor and fishing gear. However, there are also limitations of the fault tree analysis. It is reliant on expert opinion and also does not take into account temporal aspects of invasions. As a result, it could be used as an initial framework on which to base quantitative RA in the future, highlighting the current gaps in knowledge (Acosta & Forrest 2009). In

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essence, it seems a good starting point to address the issue of yacht biofouling in South Africa.

When conducting an RA for hull fouling (which could potentially transport multiple species at any one time), it is important to identify which NIS are most likely to be transported. However, this is dependent on good biological data for the species (as well as information on the pathway and destination). General risks involved with the species can be addressed by basing the RA on attributes of similar species or the functional group. However this introduces more uncertainty into the analysis and, as a result, a rigorous quantitative assessment becomes less feasible (Hayes 2003). Often a combination of quantitative and qualitative techniques are chosen, in order to reduce significant uncertainty, while keeping the analysis relatively simple, as demonstrated by the Globallast programme. However, by targeting certain species, a gap is left open for non-target species to enter unnoticed. A hierarchical RA (as in the AQIS ballast water approach) addresses the issue of data uncertainty by remaining conservative when data are scarce, as per the 'precautionary principle' (Fairbrother & Bennet 1999) and only allowing progression to higher tiers as the information becomes available.

Uniform application of an RA (where all vessels go through the same RA process) is simpler in terms of administration and does not require expert training. It also reduces the chance of unanticipated MIAS entering the country. Alternatively, voyage specific risk assessments (chosen based on the source bioregion) reduces the number of vessels which require assessment by selecting only those from high-risk regions. In Africa, where capacity is low, both voyage specific and uniform RA should be undertaken to help reduce data uncertainty (Awad et al. 2004).

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Quantifying the risk

Policies can be strengthened by focusing on pathways, in particular identifying species associated with a pathway and then calculating risks for each (Andow 2003, Orr 2003).

An initial decision should be made as to whether the RA will be quantitative, qualitative or a combination of the two. Qualitative risk assessment is often subjective (Hayes 2003, Awad et al. 2004). It is, however, the simplest form of risk assessment, allocating low-, medium- and high-risk classification and this explains why it is so often used in management as the more practical option. Semi-quantitative ranking of risk is based on quantitative data with a ranking of results. However, the best approach (in term of quality of output, if all input is certain) is a Quantitative Risk Assessment, which provides a comprehensive analysis, but is reliant on thorough research and advanced technology to compute the overall risk. Quantification of the risk and consequences of an undesired event is essential. Inferences are made based on probability, but quantitative techniques are much less subjective than deductive techniques and as a result withstand scientific scrutiny (especially important when the risk is influenced by politics) (Hayes 2003). Despite this, few studies actually quantify the risk. One exception to the rule is the study by Drake & Lodge (2007) where 74 distinct taxa (comprised of 100-200 species) were identified fouling one transoceanic bulk carrier ship.

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However, despite all this, Simberloff (2006) believes that it is impossible to quantify fully the risks involved with non-intentional introductions, and that one can only identify the pathways that were risky in the past. He states that “quantified risk assessments are an illusion”, based as they are on ad hoc algorithms. This makes them seem weak under scrutiny. With intentional introductions under trade agreements, quantified RAs are an accepted necessity. Unintentional introductions are equally controversial, so in order to be guaranteed urgent action, the risks would have to be clearly backed by science.

What is the appropriate RA for this situation?

Predictive tools are needed to allow managers/yacht clubs to recognise (and quantify the risk associated with) high-risk vessels. The AQIS ballast-water risk-assessment framework (Figure 3.1) could be modified accordingly and trialed on South African marinas. The approach could be further developed by considering variations on the environmental parameters in terms of "higher", "lower" etc, as demonstrated in the Hazard and Operability (HAZOP) analysis (Kletz 1986). This allows for a more creative outlook, which is not as limited as a fault-tree analysis (Hayes 2003). A more technical approach involves the use of fuzzy expert models (Acosta et al. 2010) that could be incorporated into risk analysis and assessment to strengthen policies.

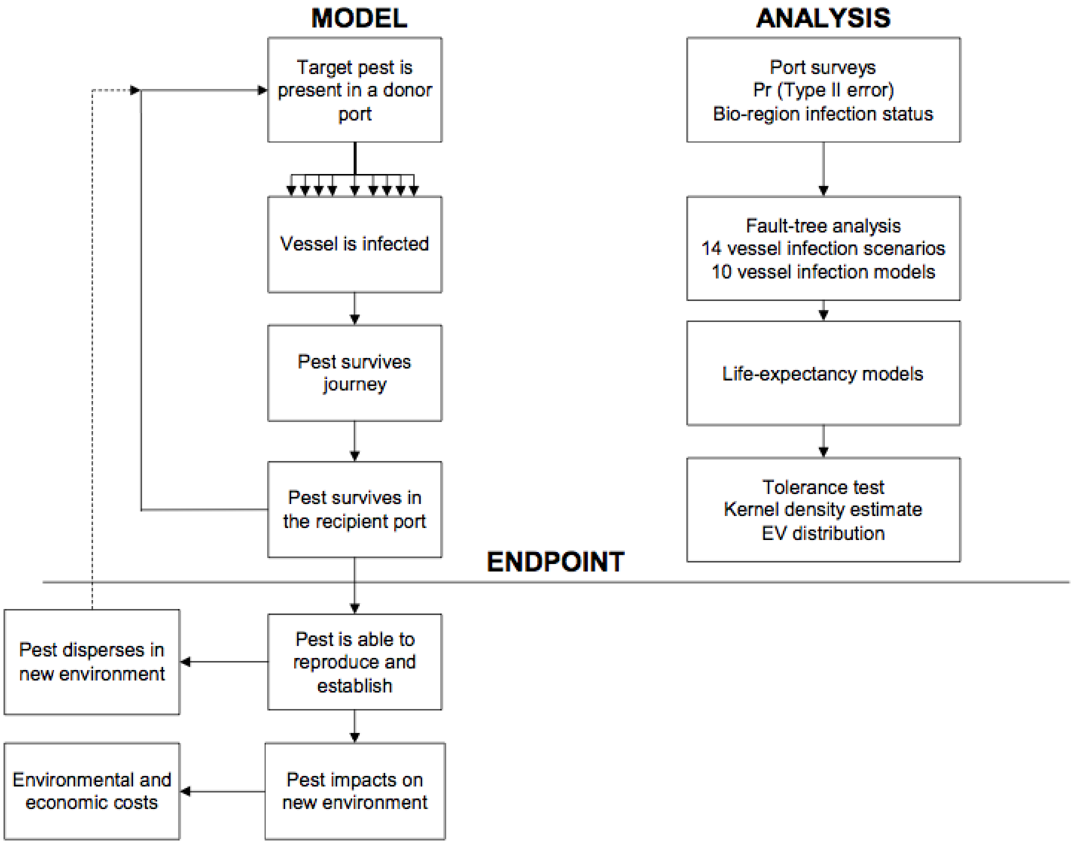

Figure 3.1. Summary of the AQIS ballast-water risk-assessment framework, showing the analyses at each step of the bio-invasion event chain (Hayes 2003).

Risk assessments proved an extremely useful component of the Globallast programme in identifying those vessels that had travelled via high or low risk routes. This format will also be useful in allowing border control personnel to identify high risk vessels based on information provided by the yacht-owners (Hewitt & Campbell 2007). One of the indirect advantages of the Globallast programme was the training and development of a South African team highly skilled at completing Ballast Water Risk Assessment and a framework to work for similar surveys elsewhere in Africa (Awad et al. 2004). With limited additional training, this team of experts would be well poised to assess the high-risk travel routes of yachts and identify the source bioregions which must be prioritized by officials assessing arriving yachts.

Risk assessment procedures need a clear endpoint to minimize misinterpretation by the managers who put the theory in to practice (Andersen et al. 2004). This will help to address the Research-Implementation gap, a long-standing phenomenon in science (Knight et al. 2008). Despite this, it is important for managers to recognize that although the aim of an RA is to stop the introduction of MIAS, it is highly unlikely that bioinvasions will be eliminated entirely. No matter how good the RA, there will always be MIAS arriving on South Africa shores. Reducing the strength of the pathway is still an acceptable outcome, although less desirable (Sharov 2004). An important part of the evaluation managers should undertake is to record which species (against all odds) succeed in invading and how they achieve this (Morley 1993). The more detailed records of these successful introductions or invasions, the easier it will become to manage bioinvasions in the future.

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3.7 Management Strategies - Border Control

Hull assessment

If hulls are not inspected on arrival, MIAS will keep entering the country unnoticed. This seems to conflict with the importance and funding allocated to regulating and treating ballast Water (Globallast 2010) So inspection of arriving yachts is an essential first step. Black lists are used especially in the import industry, to prevent intentional introduction of a potentially invasive species (Simberloff 2006). However, they do also have their use in unintentional introductions. Black lists could be developed to detail and help identify known MIAS for training of quarantine and border control staff, as well as to educate yacht-owners on which are the most damaging fouling organisms. Caution is advised with species that do not feature on this list, as they are not by default guaranteed to be ‘safe’ (IUCN 2000).

Waterline inspections have potential in border control assessments of arriving vessels. There was a correlation between the ordinal rank scale determined from waterline inspections and the biomass of the biota collected (Spearman rank coefficient: $\rho=0.832$, $P<0.001$) (Figure 3.2).

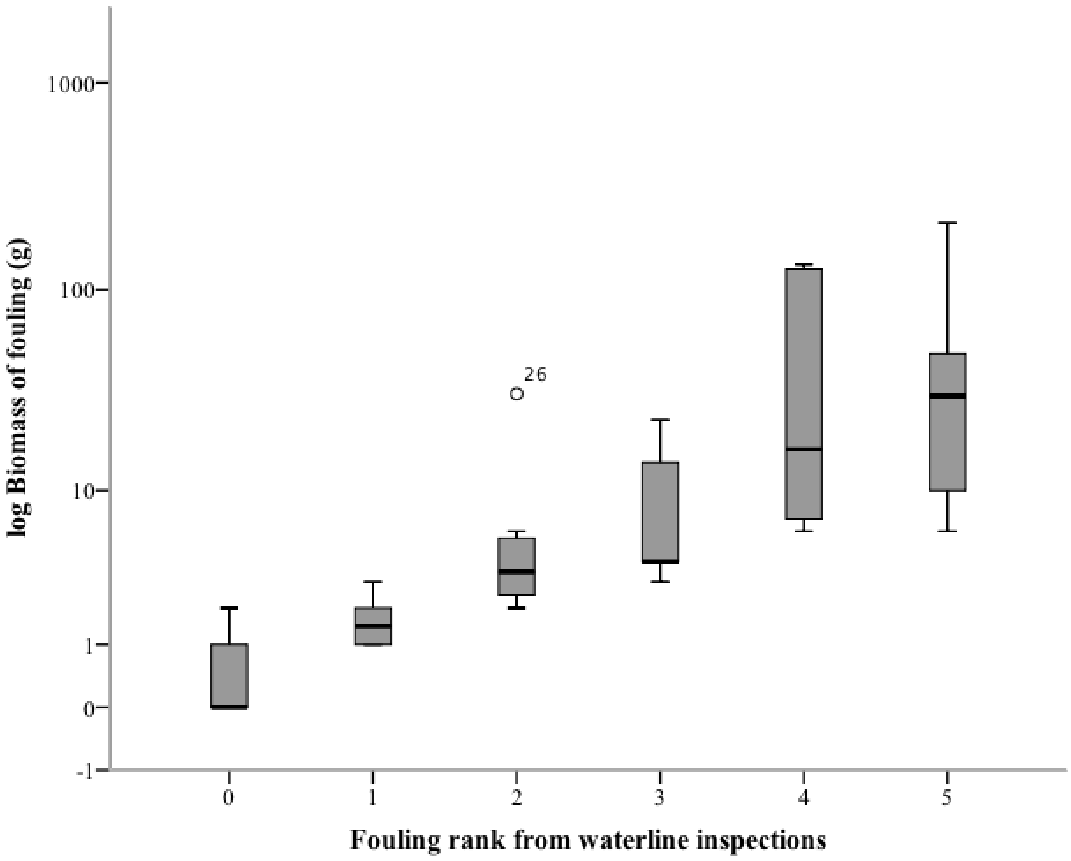

Figure 3.2. Relationship between the total biomass of fouling organisms collected from each hull (using 15x15cm quadrats) and the fouling rank assigned from the waterline inspections. Bars represent minimum and maximum values and boxes show the first and third quartile, with median highlighted in the box. The outlier (labelled as 26) with a high biomass for a fouling rank of 2 exhibited higher fouling at the sample points than was visible from the surface.

Such inspections provide a quick and easy assessment technique (especially regarding checking effectiveness of FCC). However, waterline assessments have their limitations and this may be the cause of the similarity in mean fouling biomass of yachts ranked at level two and three. Sometimes the water visibility is too poor, while in some marinas, visual access to the hull is limited by the design of the wharf, or by the design of the yacht itself. However, where no secondary fouling is detected, confirmation (either by camera or by diver inspection) is essential (URS 2007). A random subset should be tested to evaluate the technique and ensure inspectors are following the same standards. In addition, in order to increase effectiveness, officials checking boats need to be provided with sufficient training (in classroom and field) and equipment (binoculars, field guide, polarized glasses).

Hulls are often cleaned half-heartedly from the deck or jetty using a brush (personal observation). However, this only really targets the waterline and often areas lower on the hull are untouched, so in this case waterline inspections would not be representative of the overall fouling. False negatives (Type II error) are more likely to occur (20-40% of the time) with waterline inspections, where the inspector notes that there is no secondary fouling, when actually there is (URS 2007). Adopting the precautionary principle would minimize this kind of error and reduce the likelihood of bias (Fairbrother & Bennett 1999).

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There are many different methods for measuring the extent of fouling on an ocean-going vessel. Many commercial ships have their hulls checked (for structural integrity, as well as biofouling) with hull cameras (Coutts & Taylor 2004; Cordell & Sosik 2009; Lee & Chown 2009). In Australia and New Zealand, similar technologies are now being employed for recreational yachts (Floerl et al. 2003, Bridgwood 2010). However, this equipment is expensive to purchase and maintain, and even more so if it is required at all ports of entry to the country. It is thus unlikely to be adopted as a standard for border control in South Africa in the near future. With this in mind, simpler and less expensive alternative measures of fouling extent (for example, waterside inspections or diver-collected biota sampling) might be more appropriate.

Divers could be employed on a part-time basis (by marinas) to inspect boats immediately on arrival. Many divers are currently employed on a freelance schedule by marina managers to maintain the underwater surfaces of pontoons as well as by yacht-owners to clean vessel hulls, so the structure for such implementation is already established. The cost of this inspection could then be charged to the owner (with costs ranging from ZAR 500-1000 per hour). The length of inspection (and thus the associated costs) would be dependent on several factors such as accessibility, vessel size and shape and the extent of fouling.

When boats are found to be carrying secondary fouling (which could contain MIAS), there are three management options, all of which have limitations. The vessel can be refused entry to the port, cleaned in water, or containment can be undertaken.

Avoiding draconian management actions, such as a standard haul-out for all arriving yachts, will minimise complaints. This is especially crucial at busy times of year, with haul-out facilities only able to service a few yachts at a time. This is where the voyage-specific RA can be applied to prioritise those yachts arriving from high-risk bioregions. Also, tolerance of certain cosmopolitan species, which are already established and do not therefore represent a further risk, will help yacht-owners comply with regulations. For example, *Enteromorpha* beards and goose barnacles (which are normally considered secondary fouling) have now been designated as acceptable fouling by AQIS (URS 2007). Strict inspection regimes (which often fail and result in haul-outs), may also lead to higher propagule introduction as yacht-owners realise it is more cost- and time-effective to simply arrive with a fouled hull and clean it once in country. The temptation simply to fake the documentation may also be too great for some cruisers who are living on a tight budget. However, there are logistical advantages involved in treating all macrofouling as unacceptable. It removes the need for taxonomically trained border control officials and limits the confusion surrounding discrimination between species in the pre-border identification materials presented to yacht-owners.

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Dry-docking immediately on arrival in the country could be the most suitable mitigation measure to reduce propagule pressure. However, removing boats from the water may not be the biosecurity panacea that everyone has been led to believe. Not only are the costs high (and usually at the owner's expense), but it has also been shown that mobile MIAS are often induced to release from the hull surface on removal from the water. The effect is greater on vessels with extensive fouling. Boats exhibiting secondary fouling lose up to 20% of total organisms. The majority of mobile species are released into the recipient environment within 30 seconds of being hauled out of the water (Coutts et al. 2010). This highlights the urgent need for improved retention and treatment facilities at haul-out locations (Woods et al. 2007).

While turning boats away seems the simplest biosecurity solution, it does not address the problem and simply transfers it to another port. One low-cost solution could be the removal of the vessel to a freshwater location, such as a nearby river. Brock et al. (1999) found this to be extremely effective at removing fouling assemblages, with 90% removal after nine days of exposure to freshwater. Alternatively, in-water encapsulation has proven to work well, whereby the vessel is wrapped in tarpaulin and some chemical e.g. chlorine is added (Coutts & Forrest 2007, Hopkins & Forrest 2008, Coutts et al. 2010). The liquid containing MIAS must then be removed through filters without leaking into the surrounding environment. These techniques require further research, particularly as several nations (backed by the IMO) have proposed the implementation of mandatory regulations that would mitigate the introduction of MIAS by 2012 (Takata et al. 2006; Roberts & Tsamenyi 2008).

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Another alternative would be to limit the port residency time for heavily fouled vessels. The AQIS protocol originally allowed a period of seven days before action would be taken on a vessel (either quarantined or removed from port). However, this has been revised and changed to 24-36 hours for vessels that are carrying molluscs or other bivalves deemed to be a threat to local waters (URS 2007). This short time frame is dependent on the availability of a crane to haul out the yacht (a potential problem at busy times of the year). If this is impossible, all effort should be made to limit the impacts, for example, sealing over seawater ports or alternatively, moving the vessel to a low-risk area until such time as it can be removed from the water (URS 2007).

Documentation

Voluntary reporting of maintenance practices should be encouraged, as is now mandatory in the State of California (Takata et al. 2006). In particular, a vessel log (backed wherever necessary with receipts) should be provided with details of:

- Last FCC application, including what type of FCC was used, where it was applied and whether it was done by the owner or a professional company
- Travel history over the last 12 months (or if FCC is older than 12 months, all travel since the application) including ports of call, dates and duration of stay
- Hull maintenance practices since last FCC application

3.8 Acceptance by yacht-owners of potential management strategies

Method

Using the questionnaire methodology detailed in Chapter 2, 60 yacht-owners were asked to give their opinion on the following three potential management options, in terms of whether this should be considered for South Africa.

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1. **International yachts should be checked by customs officials on arrival in the country and if necessary, cleaned in containment.** This is currently practised in Australia as part of the 'National Border Biofouling Protocol for Apprehended and International Vessels Less than 25 m in Length' (URS 2007).

2. **Yachts departing internationally should be cleaned in-water before leaving South Africa, receiving a 'Clean bill of health' certificate.** If the country of departure could guarantee that the vessel was clean when it

departed, the destination country could be assured that any growth detected on arrival was picked up en route.

3. **Anti-fouling paints should be re-applied annually as a component of the Certificate of Fitness.** Yacht owners must comply with the South African Maritime Safety Authority (SAMSA) Certificate of Fitness, a mandatory checklist for yachts planning to leave the mooring and move into coastal waters (with different requirements depending whether this involves international or domestic travel). This annual certificate currently checks equipment on board to ensure the safety of crew and passengers in an emergency but could also provide a suitable framework to monitor MIAS.

Results

The majority (67%) of respondents agreed that yachts arriving from international waters should be checked by customs officials on arrival at the South African Port of Entry and, if deemed to have a high level of fouling, the vessel should be removed from the water and cleaned at the owner's expense (Figure 3.3).

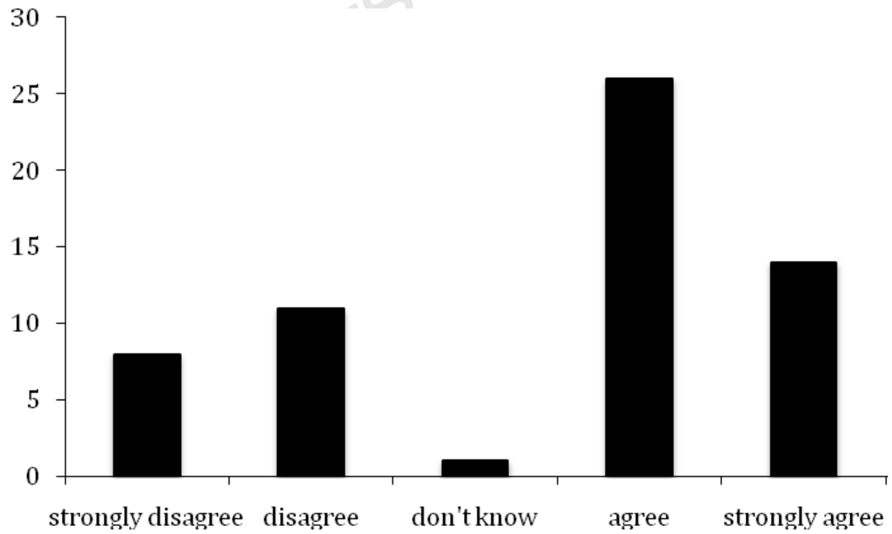

Figure 3.3. Response by yacht-owners to the question "Should international yachts be cleaned on arrival if heavily fouled?"

The ‘clean bill of health on departure’ scenario received the most support from respondents (Figure 3.4) with 70% (n=42) agreeing, of which 64% strongly agreed. However, some yacht-owners felt that international departures are always frantic, and that there is already too much existing paperwork to complete. Also, departure dates are often postponed at short notice, and concerns were expressed as to how this could be successfully accommodated into the system.

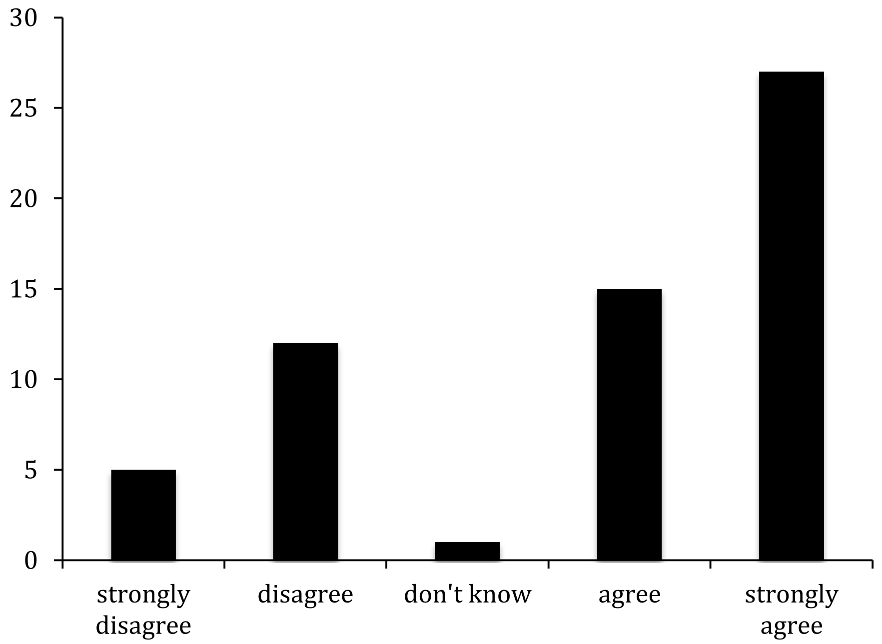

Figure 3.4. Response by yacht-owners to the question “Should yachts leaving SA for international waters be cleaned in water, to obtain a clean bill of health?”

Regarding the final proposal, 62% agreed with having the FCC checked on an annual basis as part of the SAMSA Certificate of Fitness (Figure 3.5).

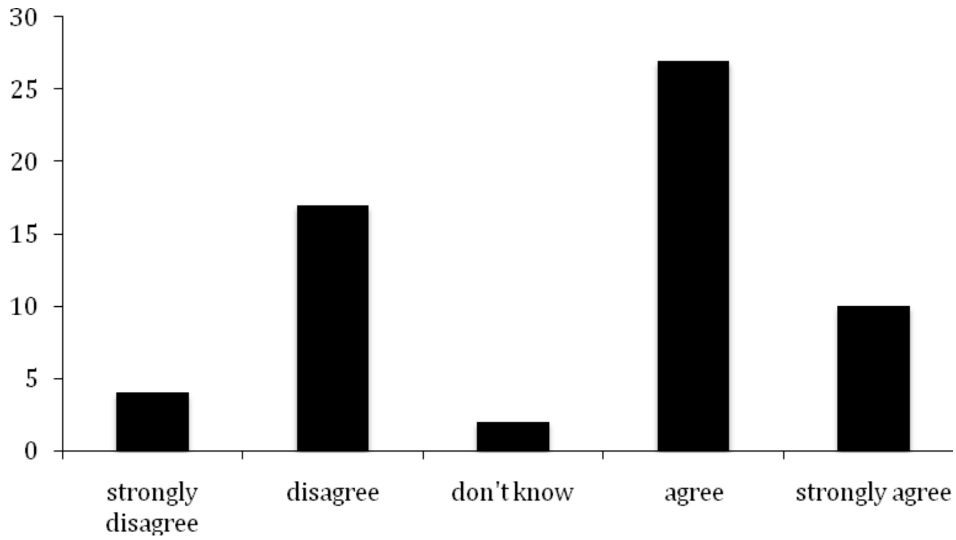

Figure 3.5. Response by yacht-owners to the question "Should FCC be applied regularly (or as when needed) as part of the Certificate of Fitness?"

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Discussion

Although the first scenario received majority support from yacht-owners, it may be unacceptably expensive for some international cruisers. As bioinvasions are essentially a form of biological pollution, "the polluter pays" principle should be applied (Fairbrother & Bennet 1998). This provides an incentive for yacht-owners to maintain their boats and take responsibility for their actions, or in this case, inaction. The liability fine needs to be high enough to motivate the individual to mitigate the risk of MIAS introduction (Doelle et al. 2007).

The 'clean bill of health on departure' concept has a lot of potential, but would require international co-operation (from all potential source countries) to be successful. Defining a standard of cleanliness that is acceptable globally will prove challenging, but is not impossible, having been achieved for ballast water discharge (Roberts & Tsamenyi 2008). Cleaning the hull in-water would be a cheaper alternative than dry-docking to clean or re-paint. Research vessels returning from the Antarctic considered in-water cleaning procedures prior to departure to the high-risk localities as the most cost-effective mitigation measure (Lee & Chown 2009). Also, if a yacht were travelling through multiple countries on a rapid schedule, it would be impractical (and extremely costly) for the yacht to be slipped at every departure port.

Although the SAMSA Certificate of Fitness currently regulates safety items only, it could be argued that biosecurity is indeed a safety concern. This certificate provides the basic framework for an additional item to be added regarding FCC condition. However, the Certificate of Fitness has already received mixed reactions, as many people believe that it is simply a moneymaking scheme, with untrained inspectors who insist on unrealistically high standards (personal observation). Associating marine biosecurity with such a controversial regulation may not be particularly wise, especially when considering how important this issue is, and the urgency of compliance. However, SAMSA is the regulatory body that carries out all IMO related inspections for the South African Department of Transport, and therefore as IMO is most likely to be regulating biofouling, it will fall within their mandate eventually.

Several additional comments were made by respondents during the interview process. Many raised concerns about heavy-metal pollution. They recognised the need to paint their yachts with FCC regularly, but did not know how to balance this with the toxicity of the available paints. Support for further research and development of antifouling paints that are less toxic to the environment should be encouraged, along with investigation into the import of technology for in-water cleaning.

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Many respondents believed that commercial ships presented the biggest cause for concern (personal observation), as they represented a larger surface area and seemed to be free of the regulations applicable to recreational vessels. Some felt that the same standard should be applied to both commercial and recreational vessels, while others felt that the regulations for recreational vessels are already unnecessarily stringent.

3.9 Communication strategy

An outreach and education programme should be implemented to raise awareness both within the yachting community (specifically regarding MIAS) and in the general public, especially amongst the younger generation. This could be undertaken through the presentation of a poster or a talk explaining the issue with emphasis on relevance to the stakeholders. In addition the construction of a website (such as the American site www.protectyourwaters.net) would encourage public participation with regular updates on confirmed sightings and a blog for members of the public to ask questions and post pictures of discoveries.

Ultimately, the awareness raising should aim to demonstrate that the best solutions for mitigating introductions are also the best for the yacht-owners. With regular hull maintenance, the yacht will sail more efficiently, cost less in terms of upkeep (especially the long term costs), damage to the boat will be prevented and thus the resale value will also be higher. In addition to these direct benefits, there are also indirect benefits to the community as a result of improved ecosystem health.

General hull maintenance

With reference to the results of Chapter 2, yacht-owners should be presented with a recommended code of conduct. For example, the efficacy of different cleaning methods could be highlighted (Appendix C). In addition, owners should be encouraged to purchase the most suitable FCC for their sailing profile, taking into account speed, location and frequency of use, rather than basing their choice on cost alone. FCC should be applied as per the manufacturers guidelines, or even better, a professional vessel painting company should be employed for the job. The effectiveness of FCC can only be guaranteed for six months when owner-applied, in comparison to 12 months for professional application (URS 2007).

In-water cleaning

Yacht-owners should be encouraged to clean their boats in-water always in the departure port and never in the destination port itself, or in the vicinity of the port (URS 2007). Special attention should be paid to areas of the yacht which are susceptible to secondary fouling, Figure 3.6.

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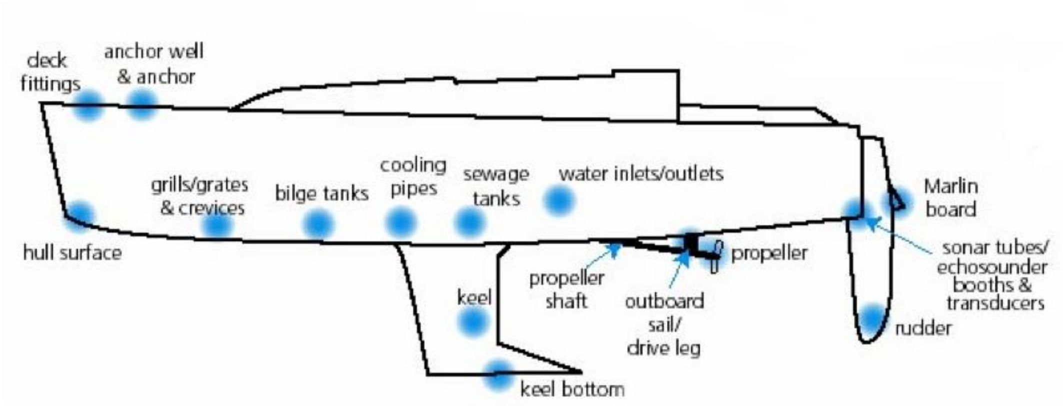

Figure 3.6. Areas of the yacht susceptible to secondary fouling in addition to the hull surface itself, which should be targeted by yacht-owners for cleaning prior to departure for international waters (DAFF 2010).

In-water cleaning ranges from the small (manual cleaning) to large scale. Most commonly on recreational vessels, the owner or a member of crew dives (with scuba or snorkel) under the vessel with sponge/scraper/brush/scourer. Floerl et al (2008) found that 80% of yachts that had been manually cleaned in the three weeks prior to surveying contained fouling organisms. On commercial vessels, diver-operated rotating brush cleaning systems are the norm. The efficacy of a Submersible Cleaning and Maintenance Platform (SCAMP) was tested on an extensively fouled obsolete commercial vessel in the USA. The results showed that although fouling was reduced following cleaning, there was still a substantial and diverse sample of organisms left on the ship (Davidson et al. 2008).

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In-water cleaning also raises concerns regarding the collection of paint waste and biofouling material. In 1997, the Australian and New Zealand Environment and Conservation Council (ANZECC) developed a code of practice to “prevent the release of toxic chemicals and biofouling organisms into the marine environment”. This is not an enforced standard across all jurisdictions however, and varies in applicability to recreational vessels. The majority of in-water cleaning techniques result in viable material being dropped to the sediment below or transported by currents (Hopkins & Forrest 2008). Even those systems that claim to retain biota are not completely effective. Diver-operated cleaning systems that retain fouling allow up to 12% of fouling to drop to the sea floor (containing viable organisms), and become less efficient on vessels that are heavily fouled. In addition, there is a risk of divers accidentally removing fouling with their fins or ropes (Hopkins & Forrest 2008).

Shore-based cleaning

Although shore-based cleaning (via haul-out facilities) is generally a more expensive option (DAFF 2010), it should be encouraged, but only if it can be guaranteed that fouling organisms will be retained during removal from the water. Owners should be aware of what happens to the waste (fouling assemblages and paint remains) cleaned from the hull before re-application of the new coat. By asking questions about waste disposal, a demand for more environmentally friendly practices in the boat maintenance industry is created.

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CHAPTER 4. SYNTHESIS & FUTURE RESEARCH

4.1 Synthesis

In conclusion, this study has shown that recreational yachts can act as vectors for MIAS found in the Western Cape. Based on waterline inspections in three marinas, 62% of yachts exhibit secondary fouling, with the majority of biomass comprised of ascidians. The specimens identified (from both local South African and international vessels) contained MIAS, although none of these were new records for South Africa. There is a chance that these fouling organisms could add to the reservoirs in the marinas (on pontoons, piling and resident yacht hulls), or they could be transported across the country via local yachting excursions. Age of the FCC was correlated with biomass of fouling assemblages. This indicates that there are opportunities for yacht-owners to assist in mitigation of the issue. However, awareness of MIAS was generally low within the yachting fraternity.

Legislation regarding marine bioinvasions in South Africa is still in its infancy. Although no legislation exists globally to address hull fouling directly, there are several existing policies in South Africa that could be amended to control the introduction (and spread) of MIAS. South Africa is also party to several international conventions and treaties. For example, the current legal instruments of the IMO are in the process of being modified to address hull fouling which may be accepted by 2012. However, without reflection in national legislation, these international laws are not legally binding.

Australia and New Zealand are world leaders in biosecurity. The Australian 'National Border Biofouling Protocol for Apprehended and International Vessels Less than 25m in Length' is an exemplar protocol. South African yacht-owners should be encouraged to adopt 'best practices' in terms of hull husbandry, undertaking the most effective in-water cleaning techniques wherever possible. These techniques would also have maximum return in terms of the interests of the owners as assessed in the

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questionnaire. It is impractical to suggest that owners haul-out their boats in order to clean them manually, as these costs are too high to be incurred regularly.

4.2 Future research

Due to time constraints, the sample size for this study was limited. As the questionnaire included questions that varied in complexity, it seemed sensible to undertake face-to-face interviews, so that further explanation could be given if required. Also, as many people felt strongly about some of the issues raised, the facilitation and resulting completion of the survey was ensured by undertaking interviews in person. However, this limited the number of questionnaires that could be completed. Given more time, I would have liked to increase the sample size and to have included all major ports of entry to South Africa. This would allow for more comparisons between local and foreign vessels, for example, how the risk profile differs between international, domestic and local yachts.

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It would be very interesting to follow a yacht travelling internationally, and to collect samples from the hull at regular periods as it traverses bioregions. To characterise fully the risks involved in MIAS introduction via hull fouling, ‘high-risk’ bioregions (Spalding et al. 2007) should be identified, in terms of route preference demonstrated by yacht-owners. Alternatively, a similar study could be undertaken along the coast of South Africa, which has nine different marine bioregions (Lombard 2004). This would give an idea as to the extent and need for action to deal with secondary spread of MIAS within South Africa.

The study was also limited by taxonomic expertise. The species identified from biota collections were biased towards the specialities of taxonomists available at the time of identification. As a result, many specimens could not be identified within the time frame allocated.

Chemical levels in the marina should be tested, along with an investigation into the efficacy of containment and drainage facilities at the marinas. Water quality parameters could be used as a means of controlling MIAS. Minchin and Gollasch (2003) argued that if water quality were improved in areas that had high TBT burden previously, this could potentially allow MIAS to spread further.

All of the yacht clubs surveyed have recently been approached by the City of Cape Town with regards to obtaining a certain standard of sanitation. It is being considered as an element of the ‘Blue Flag Marina’ global programme, requiring environmental education and management, water quality and various services. Awareness raising campaigns are urgently required, but should be followed by an evaluation study to test whether the desired results have been reached.

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APPENDIX A. YACHT-OWNERS QUESTIONNAIRE

This questionnaire is part of a student project being undertaken at the University of Cape Town, South Africa. My research aims to analyse the traffic patterns of recreational yachts (Domestic and International) into and within South Africa. Maintenance of hulls will be investigated to assess extent of biofouling, as a potential vector for the introduction of marine invasive alien species (MIAS).

Where several options are given, please circle the appropriate answer.

Date: ________________________

Yacht club & yacht name: __________________________

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General information and vessel maintenance

a. Where is the home marina/port/country of the yacht? _______________________

b. Age of current anti-fouling paint (months)?

none	0-2 m	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	>20

c. Who applied the paint?

yourself	a member of the crew	a professional company

d. How is it applied?

roller	brush	spray painted

e. Do you manually clean (by scraping/brushing) the hull in between antifoul applications?

Yes	No	Sometimes

f. What do you use for this?

sponge	scraper	brush	high-pressure hose	abrasive scourer	Other

g. Where do you manually clean your yacht?

In the water	Dry dock / on the slip

h. How long has it been since the last manual hull clean (months)?

never	0-0.5	0.5-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10

Travel history (past 12 months)

a. What is the purpose of your yachting?

Cruising	Racing	Business	Other

b. Location of other marinas visited (other than home) (rank in order with i. being the most recent). Please also indicate time spent moored in each marina (days) and how long ago this was.

	Location	**Duration**	**Approx. date**
i.	______________________________	_____________	____________
ii.	______________________________	_____________	____________
iii.	______________________________	_____________	____________
iv.	______________________________	_____________	____________
v.	______________________________	_____________	____________
vi.	______________________________	_____________	____________
vii.	______________________________	_____________	____________
viii.	______________________________	_____________	____________
ix.	______________________________	_____________	____________
x.	______________________________	_____________	____________

c. Number of days spent sailing over last year? __________________ (/365)

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__Future travel plans (for the following 12 months)__

Proposed future ports of call (please rank in chronological order with i. being the closest in time). Please also indicate approx. duration of stay planned in each port (days).

	Location	**Duration**
i.	______________________________	__________
ii.	______________________________	__________
iii.	______________________________	__________
iv.	______________________________	__________
v.	______________________________	__________
vi.	______________________________	__________
vii.	______________________________	__________
viii.	______________________________	__________
ix.	______________________________	__________
x.	______________________________	__________

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Value of hull maintenance and IAS

An Invasive Alien Species (IAS) is one which is introduced from one country to another and then becomes established in the destination country.

a. Can you give me an example of an IAS which has been transported outside of its natural range anywhere in the world? ____________________________

b. Do you think that the introduction of marine IAS is an issue in South Africa?

Yes	No	Unsure

c. How do you feel about the following statements?

The introduction of marine IAS has a positive effect on local flora and fauna.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

The introduction of marine IAS has a negative effect on local flora and fauna.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

Introduction of marine IAS has economic impacts on the destination country.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

Introduction of marine IAS has social and cultural impacts on the destination county.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

d. In terms of frequency of hull maintenance, please rank the following factors in order of importance to you:

Fuel efficiency

Very unimportant	Unimportant	Impartial	Important	Very important

Cost

Very unimportant	Unimportant	Impartial	Important	Very important

Speed

Very unimportant	Unimportant	Impartial	Important	Very important

Aesthetics

Very unimportant	Unimportant	Impartial	Important	Very important

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Preventing damage to the hull, motor and propellers

Very unimportant	Unimportant	Impartial	Important	Very important

Preventing introduction of marine AIS

Very unimportant	Unimportant	Impartial	Important	Very important

Other (please specify) ____

Very unimportant	Unimportant	Impartial	Important	Very important

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i. How do you feel about the following <u>hypothetical</u> mitigation measures, which could <u>potentially</u> alleviate the problems with marine IAS introduced by recreational yachts?

International yachts should be checked by customs officials on arrival in the country and if necessary, cleaned in containment.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

Yachts departing internationally should be cleaned in water before leaving South Africa, receiving a ‘Clean bill of health’.

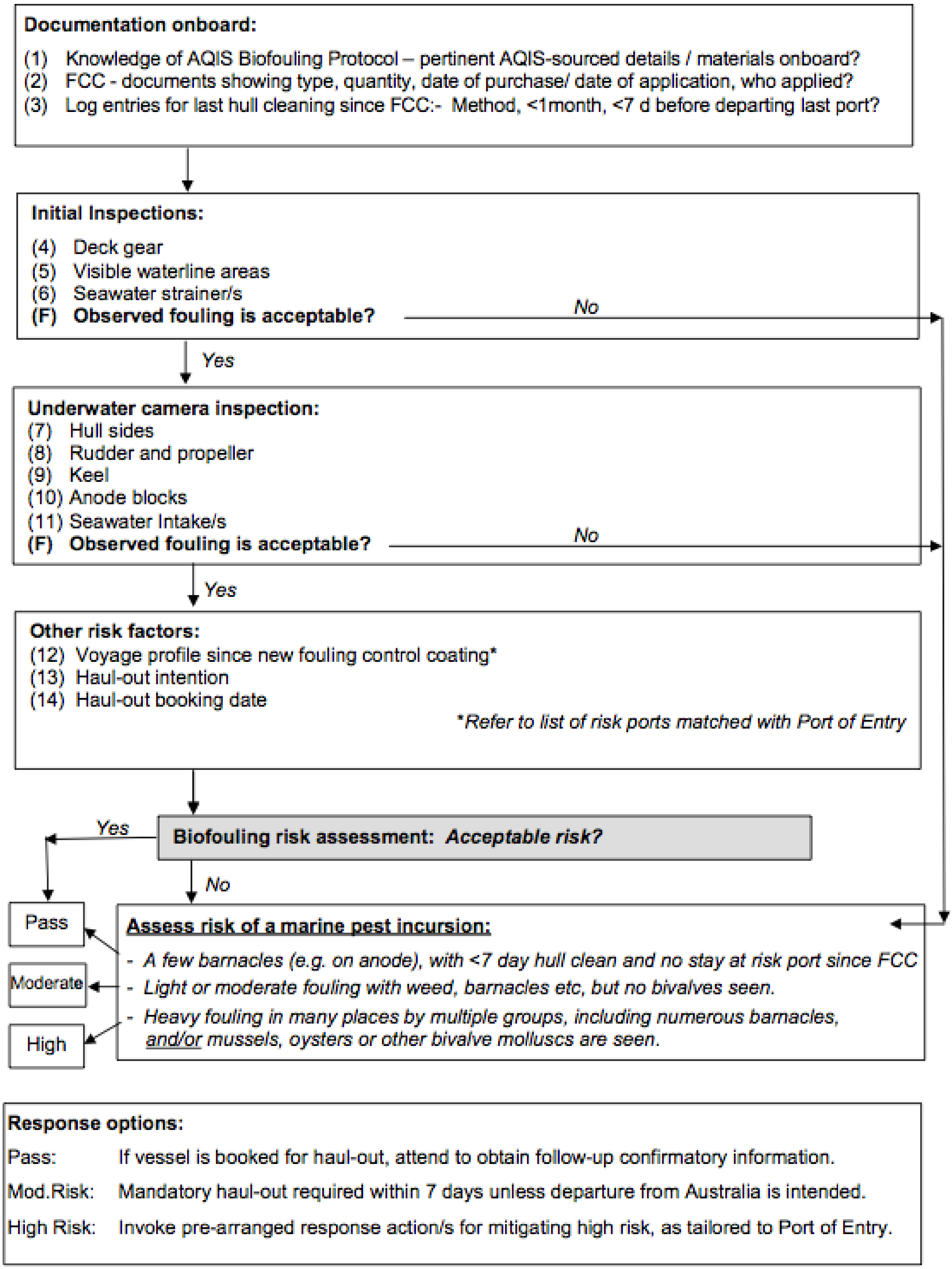
Strongly disagree	Disagree	Don't know	Agree	Strongly agree

Anti-fouling paints should be re-applied annually as a component of the Certificate of Fitness.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

APPENDIX B.

AQIS checklist for arriving international and apprehended vessels <25m (URS 2007). A similar inspection could be used in South Africa to assess the risk associated with recreational yachts.



APPENDIX C.

Recommended hull maintenance practices (URS 2007) beginning with the most efficient in terms of reducing MIAS introductions.

Cleaning by Haul-Out:

(i) Haul-out, cleaning and FCC application, with appropriate type and number of coatings applied to fast-wearing surfaces and niches (waterline/boot topping, rudder, behind anodes, seawater ports, propeller, shaft, keel foot);

(ii) Haul-out, cleaning and FCC application without specific attention to fouling-prone areas;

(iii) Haul-out and cleaning by power-assisted methods (for hard or semi-hard burnishable FCCs or self-polishing copolymer FCCs with adequate remaining lifespan).

(iv) Haul-out and cleaning by wiping/rubbing (for fouling release and semi-hard non-burnishing coatings).

In-Water Cleaning:

(v) Using SCUBA for in-water wiping/rubbing/scrubbing (according to FCC type) with particular attention and scrapers applied to uncoated fittings and other niches.

(vi) Using snorkeling for the above (likely to be less effective for deep-drafted yachts with niches below 2 m and keel below 3 m, depending on snorkeling skill and gear).

(vii) As above (vi, vii) but with no particular attention paid to finding or cleaning niches.

(viii) Waterline and hull side rubbing or scrubbing from a dinghy using long handled brushes.

(ix) Deck-based use of long handled brushes to clean boot toppings and upper hull sides.

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