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Research Article

Perceptions of ecological risk associated with introduced marine species in marine protected areas

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Abstract

The perception of ecological risks (impact and acceptability) associated with introduced marine species (IMS), what demographic variables influence those perceptions, respondent's knowledge of IMS, and people's support for controlling introduced marine species impacts on the marine environment was explored at three locations in Western Australia: Ningaloo Reef Marine Park, Rottnest Island Marine Reserve, and Hamelin Bay. Recognition that introduced marine species are an issue at state, national and international levels exists; yet often marine protected area management plans do not reflect this recognition. Therefore, we hypothesise that there is a lack of translation of concern regarding introduced marine species as a risk into tactical objectives within marine protected area management plans. This may be due to low stakeholder perceptions of the risk posed by introduced marine species. Survey respondents had a high level (89%) of self-rated awareness of introduced marine species and they also indicated (93%) a willingness to support management interventions to prevent, or control the spread of introduced marine species in Western Australia.

Our results also indicate that gender (males) and age (18–45 age group) influenced respondents' perception of risk (impact) of IMS, yet no examined demographic variables influenced respondents acceptability of risk. Furthermore, knowledge of introduced marine species, education level, and income variables did not influence respondents' perception of risk (impact or acceptability). Understanding demographic characteristics that influence participants perceptions related to introduced marine species can be useful for targeted, educational initiatives to reduce the likelihood of IMS incursions. This begins to smooth the way for management to proactively develop and implement policies that are necessary to more fully protect the Western Australian marine environment.

Key words: non-indigenous species; opinions; demographic risk factors; marine reserves; environmental management

Introduction

There is an increasing awareness of the need to manage and reduce human impacts on coastal ecosystems due to human population increases and dwindling resources within these regions (Jennings 2009; Miller and Cuff 1986). To aid this initiative, the number of Marine Protected Areas (MPAs) is steadily increasing (Wells et al. 2007), with MPAs becoming a global business (Lubchenco et al. 1991) that aims to conserve the marine environment and its associated resources (Boersma and Parrish 1999; McNeill 1994). One aspect of MPAs that makes them successful is community engagement and the ability to react to community perceptions (e.g., Pollnac et al. 2001). The ability to understand, anticipate and respond to people's perceptions of hazards is a useful management tool (Slovic 1987, 2000) that is only recently being used within MPAs (e.g., Fatimah et al. 2012; Stoffle and Minnis 2008; Trenouth et al. 2012) and aquatic biosecurity contexts (see Campbell 2008; Cliff and Campbell 2012; Kuhar et al. 2009). Yet, the use of perceptions has not been fully harnessed to effectively and pro-actively address the issue of introduced marine species (IMS) within MPAs.

Despite an increase in the number of MPAs (Wells et al. 2007), human-mediated impacts, such as IMS, continue to have deleterious effects on these protected environments (Allison et al. 1998; Byers 2005; Hewitt et al. 2005; Hewitt and Campbell 2007; Klinger et al. 2006; Wyatt et al. 2005). The impacts of IMS are diverse (Bax et al. 2003; Campbell 2008; Carlton 1996; Godwin et al. 2006; Gribben et al. 2009; Hallegraeff 1998; Jorgensen and Primicerio 2007; Ludyanskiy et al. 1993; Torchin et al. 2001) and are potentially compounded when an IMS incursion occurs in an MPA. A potential avenue to improve the management of IMS within MPAs is to explore the public's perception of IMS (perceived impact and acceptability) and to develop pro-active management strategies that target these perceptions. This is particularly useful if the perceptions of the public link to behaviours that can mitigate or escalate risk (e.g., Cliff and Campbell 2012). The effect of such strategies would be to improve people's awareness and understanding of IMS, in general, and IMS within MPAs, and to change behaviours that may escalate IMS risk and to promote behaviours that mitigate IMS risk.

Determining public opinion and gauging their perceptions (including concerns) can be achieved through a variety of tools including extensive public consultation, small group meetings, or surveys (Carey et al. 2007; Cliff and Campbell 2012; McDaniels et al. 1999; Slavin et al. 2012; Trenouth et al. 2012). The information gained via consultation can then be used to gauge the public perception of risk, associated with specific hazards (e.g., Campbell 2008; McDaniels et al. 1995, 1997; McFarlane 2005; McFarlane and Witson 2008; Miceli et al. 2008). For example, survey tools (questionnaires) have been used to collect information about fishermen's perceptions on increasing number of MPAs in Tasmania, with the aim to understand whether the fishermen supported or were opposed to the new MPAs (Stump and Kriwoken, 2006). Similarly, Cliff and Campbell (2012) interviewed travellers into Tasmania, hikers, fishers, and kayakers to determine the likelihood they had been exposed to *Didymosphenia geminata* (Lyngbye) M. Schmidt (an introduced freshwater diatom) in their travels and their level of concern and behavioural intent when potentially confronted with this introduced species in their recreational areas. Based on these analyses hikers were exposed as a major risk group and management could address this recreational user group.

Within a marine biosecurity context surveys, interviews, and focus groups have been used to examine trends related to the vectoring of species, impacts on tourism, and informing management decisions after an incursion event occurs (except see Acosta and Forrest 2009; Campbell 2008; Dahlstrom et al. 2012; Kuhar et al. 2009). Yet few studies have focussed on risk perceptions as a mechanism to develop effective management strategies. Gauging perceptions and opinions is particularly useful to management when the focus is to understand the differences in how individuals perceive risk and therefore how to create effective risk communication strategies (e.g., Cliff and Campbell 2012), as opposed to classical risk perception theory that seeks to explain differences in how risks are perceived (e.g., Slovic 2000). In some marine biosecurity contexts (such as the intentional movement of a species or species complex) it is people's actions and behaviours that ramify risk and it is those variables that influence this ramification that managers need to be aware of and understand.

In general, the public judge risk using intuitive estimates of risk (Slovic 1987) that rely on cognitive psychology (e.g., 'Psychometric risk' - Slovic 1997, 2000). This is influenced by social contexts that effect their beliefs and behaviours (e.g., 'Cultural Theory' - Dake and Wildavsky 1991; Douglas 1992; Douglas and Wildavsky 1982; Sjoberg 2000; Wildavsky and Dake 1990). There are numerous variables that influence people's judgements, with a number of the more commonly discussed variables within the literature summarised in Table 1. These variables often overlap. Variables can act synergistically to amplify risk, or through careful education and awareness raising programs can be employed to mitigate risks.

IMS are rarely studied within MPAs (but see Byers 2005; Hewitt et al. 2005; Klinger et al. 2006; Wyatt et al. 2005), even though these locations often have artificial substrates that introduced species can preferentially colonise (e.g., Glasby et al. 2007; Sheehy and Vik 2010; Tyrrell and Byers 2007), and boating vectors (e.g., Dodgshun et al. 2007; Milazzo et al. 2005). Similarly, perceptions and behaviours of stakeholders of these marine environments and how these perceptions and behaviours affect policies and management plans to deal with perceived risk are rarely examined (but see Cliff and Campbell 2012; Petrosillo et al. 2009; Trenouth et al. 2012). Thus, this paper aims to explore the level of awareness of IMS held by stakeholders of the Western Australia marine

Table 1. Examples of variables that influence a person's perception of risk(s) or hazards.

Variable	Theory/Concept/Comments	Example references
Psychometric model		
New versus old (unfamiliar)	Unfamiliar things are seen as confronting as people do not yet understand them.	Renn (1998) Sjoberg (2000)
Dread (fear)	Fear of loss or injury results in negative emotions.	Renn (1998) Sjoberg (2000)
Number of individuals exposed	The more widespread a hazard is the more confronting it may be.	Sjoberg (2000)
Morality	Tends to focus on 'bad' actions/intentions or decisions: e.g., immorality of a hazard, outrage and social stigma.	Sjoberg (2000) Sjoberg and Torell (1993) Sjoberg and Winroth (1986) Stern et al. (1985)
Controllability	A sense of control often reduces a perception of risk.	Ajzen (1991) Kollmuss and Agyeman (2010) Renn (1998)
Value-Belief-Norm (VBN) theory		
Personal values	The standards we set for ourselves to live by.	Leiserowitz (2005) Stern (2000) Stern et al. (1995, 1999)
Personal norms and beliefs	Rules that we create for ourselves that are outside of social norms.	Ajzen (1991) Stern (2000) Stern et al. (1995, 1999)
Awareness of consequences	Dependent upon personal experience, observation, knowledge, spatial proximity.	Leiserowitz (2005) Stern (2000) Stern et al. (1999)
Ascription of responsibility	Behaviours may be modified if a person becomes aware of an impact and they feel that they have a moral obligation to prevent that impact from occurring. If they feel that the responsibility lies elsewhere (i.e., with management, or government) then they may not change their behaviours to prevent the impact from occurring	Kollmuss and Agyeman (2010) Slimak and Dietz (2006) Stern and Dietz (1994)
New Ecological Paradigm (NEP)		
Personal attitudes (influenced by demographics)	Builds upon VBN and recognises the fragility of earth. It uses the metaphor that the earth is a spaceship, which is delicate and has limited resources.	Ajzen (1991) Dunlap and Van Liere (1978) Kollmuss and Agyeman (2010) Stern et al. (1995b)
Spirituality	NEP, with the addition of spirituality. Linked to concepts about stewardship, which is promulgated within a number of religions and indigenous/traditional owners.	Schaefer (2006) Slimak and Dietz (2006) Truelove and Joireman (2009)
Other variables		
Acceptance if benefit outweighs the consequence	Balance between costs and benefits.	Renn (1998) Sjoberg and Winroth (1986)
Gender	Differences are socially produced and related to power relations.	Finucane et al. (2000) Flynn et al. (1994) Gustafson (1998)
Ethnicity	Differences may be due to prior experiences, exposure to hazards and dissimilar beliefs.	Boholm (1998) Finucane et al. (2000) Vaughan and Nordenstam (1999)
Imagery (vividness)	Vivid images evoke a more lasting effect on people, they create mental models that are more easily remembered, and they are more easily retrieved from our memories.	Leiserowitz (2005) Schwartz and Heiser (2006) Slovic et al. (1991) Wahlberg and Sjoberg (2000)
Trust	Relates to power, responsibility, and the creation of distrust.	Leiserowitz (2005) Slovic (1993, 1997, 2000) Slovic et al. (1991)
Worldview	Worldview group peoples behaviours into categories such as egalitarians, individualists, hierarchists and fatalists.	Leiserowitz (2005) Palmer (1996) Wildavsky and Dake (1990)
Emotion	Emotion affects our ability to form memories, to sustain our attention, and to aid with processing of information. Emotion can cloud judgement.	Bohm (2003) Leiserowitz (2005) Slovic (1997, 2000)
Ethics	Considers whether the risk or hazard violate any ethical principles.	Bohm (2003)

environment and to focus on stakeholder perceptions of the potential impacts of IMS on each study location. This new knowledge will be used to explore what demographic variables affect perceptions, with the aim to develop management recommendations. We have focussed on demographic variables, instead of the myriad of other variables, as they are tractable and because these have not been examined within the context of IMS and MPA management previously. Thus, we feel that these variables may offer the best strategies to mitigate risk via awareness raising and education.

We're interested in perceptions of risk related to MPAs, because we feel that stakeholders often have an influence on MPA management (e.g., Agardy et al. 2003; Kelleher 1999; Pollnac et al. 2001). Thus, if IMS are perceived as a low risk by stakeholders, then potentially management may be ignoring a hazard that has proven impacts on the marine environment (e.g., de Villele and Verlaque 1995; Finenko et al. 2006; Hewitt et al. 2004; Piazzi and Ceccherelli 2006). We hypothesise that this lack of concern transference may be due to low stakeholder perceptions of the risk posed by IMS, with recognition of the issue of IMS at national and state levels, but a lack of translation of this concern into tactical objectives within MPA management plans. Therefore, to explore this hypothesis, we have four aims to determine: 1) the level of knowledge MPA stakeholders have about IMS; 2) how people perceived the risk of IMS in terms of the potential impact of IMS and the acceptability of these impacts at three study sites (Ningaloo, Rottnest, and Hamelin Bay); 3) how these perceptions were influenced by demographic characteristics; and 4) the level of support for controlling and preventing the spread of IMS in Western Australia.

Western Australia was selected as the focus of this research because it represents a region where introduced marine species are recorded (e.g., Campbell 2003a, 2003b; Hewitt et al. 1997a, 1997b, 1999, 2000; Wells et al. 2009), including within MPAs (Hewitt et al. 2000) and a World Heritage Property (Wyatt et al. 2005). Although Western Australia is the focus of this paper, the issues discussed have a global relevance as all MPAs are potentially vulnerable to introduced marine species (e.g., Bax et al. 2003; Byers 2005; Klinger et al. 2006) due to increased visitation rates once a place is declared and gazetted as an MPA.

Methods

Study sites

This exploratory study examined people's perception of risk associated with introduced marine species at three sites in Western Australia (WA): 1) Ningaloo Reef Marine Park; 2) Rottnest Island Marine Reserve; and 3) Hamelin Bay (Figure 1). These sites represent a fully protected area (Ningaloo: Commonwealth waters IUCN II category and State waters IUCN IV category and after this study was subsequently listed as a UNESCO World Heritage Property), a multi-use protected area (Rottnest), and an iconic area that is not protected (Hamelin Bay). Sites were chosen to allow sampling of respondents from within different regions of WA with data collected on site via face-to-face interviews using a survey instrument (questionnaire). Visitation to these sites is generally high (200,000 – 500,000 visitors per annum).

Ningaloo Reef Marine Park (herein referred to as Ningaloo), was surveyed from Exmouth (14.15°E, 22.15°S) in the north, to Coral Bay (113.83°E, 23.11°S) in the south. Surveys occurred on beaches within the Maud sanctuary zone and the Lighthouse Bay sanctuary zone, as well as nearby caravan parks, backpacker accommodation, and local shopping centres (malls). Ningaloo is iconic, has worldwide recognition and has high levels of protection from both State and Commonwealth agencies. Ningaloo is the largest fringing barrier reef in Australia and is unique in that it exists in an overlap between the temperate and tropical bioregions of Western Australia. Ningaloo protects various habitats including oceanic seabeds, near and offshore coral reefs, intertidal and lagoonal systems and the high diversity these environments support (CALM 2005). It forms part of the biodiversity hotspot for coral reefs, ranking seventh highest in the world due to this high diversity of species (Roberts et al. 2002). Some well-known species supported by Ningaloo include the whale shark (*Rhincodon typus* Smith, 1828) and humpback whales (*Megaptera novaeangliae* (Borowski, 1781)) (CALM 2005), both of which are popular with nature based tourism ventures.

To our knowledge there has been no formal, extensive survey of IMS within Ningaloo although some of the developed ports further north of Ningaloo (e.g., Port Headland; Hewitt et

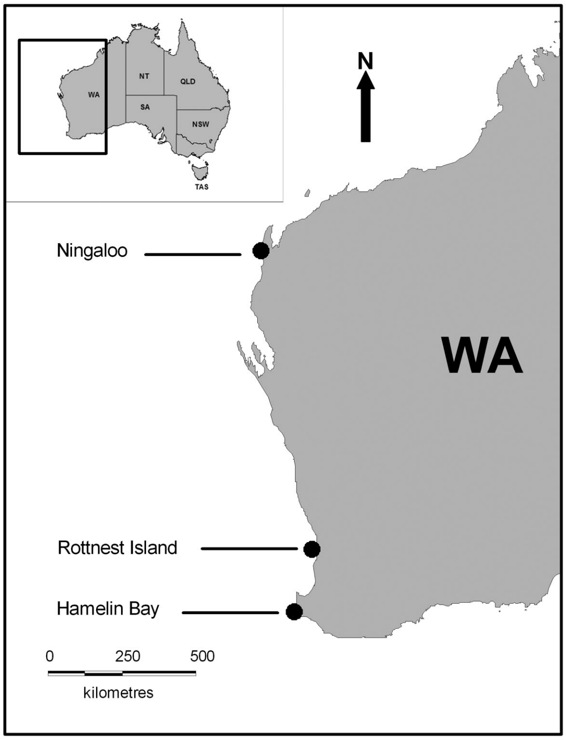

Figure 1. Study locations in Western Australia (Ningaloo representing the Ningaloo Reef Marine Park, Rottnest Island, representing the Rottnest Island Marine Reserve and Hamelin Bay).

al. 1999) have identified numerous IMS present. This is unsurprising considering the WA Department of Fisheries recognises six species of tropical IMS and a further 17 IMS with tropical and temperate distributions currently found along the coastline of WA (Wells et al. 2009). In addition, a variety of voracious, potential IMS including the black striped mussel (*Mytilopsis sallei* (Recluz, 1849)) and the Asian green mussel (*Perna viridis* (Linnaeus, 1758)) have also been identified (Wells et al. 2009) but not become established.

Surveys at the second site, Rottnest Island Marine Reserve (herein referred to as Rottnest), were conducted at locations within the Perth metropolitan area, focusing efforts at beaches in Fremantle (32.04°S, 115.44°E), shopping centres, the Rottnest Island ferry terminals (in Fremantle and Sorrento), and on Rottnest Island (115.54°E, 31.99°S). The marine environments surrounding Rottnest Island are diverse, ranging from sheltered bays to heavy surf beaches, with this locality being the most southerly point along the WA coastline for the occurrence of tropical coral species (Rottnest Island Authority 2009). Biodiversity is high with over 420 fish species recorded, 20% of which are endemic to the region (Rottnest Island Authority 2009). This MPA is heavily utilised by approximately 500,000 visitors annually (in 2004; Rottnest Island Authority 2009), more than double the number that visited Ningaloo for the same period (CALM 2005). This high visitation rate is most likely due to its close proximity to the WA capital, Perth, and the international Port of Fremantle. Forty six species of IMS have been identified within the Port of Fremantle (Hewitt et al. 2000; Wells et al. 2009) which, combined with high commercial and recreational boat traffic between the Fremantle and Rottnest Island, highlights the potential (and past) risk for IMS incursions.

Hamelin Bay, the third study site, was surveyed from Cape Naturaliste *(*115.00°E, 33.32°S) in the north to Cape Leeuwin (115. 08°E, 33.22°S) in the south. Surveys were conducted at beaches in Hamelin Bay, the light-houses at Cape Naturaliste, and Cape Leeuwin, as well as shopping centres and caravan parks between Margaret River and Augusta. Hamelin Bay is iconic and a popular spot for marine recreation with increasing nature tourism and activities such as interacting with the abundant stingrays (Newsome et al. 2004). This area also contains abundant kelp forests of high macroalgal diversity (Wernberg et al. 2003), but it is not a formally protected area. The temperate region of WA is under pressure from IMS with at least 37 known temperate IMS present, with a further 17 IMS that have a wider geographic tolerance range that are found the length of the WA coast (Hewitt et al. 2000, 1997a, 1997b; Wells et al. 2009). To date no information on introduced species is available for Hamelin Bay.

Data collection – respondents

Surveys occurred in June-July 2009 during the tropical dry season. Data was collected via face to face interviews of people over the age of 18.We used face-to-face interviews employing a skip-interval combined with a sample point sampling strategy. This involved approaching every third person that walked past our geographical sampling points to participate in the survey. Geographical sampling points (described above) were chosen to ensure people utilising the beach area associated with the MPAs and locals were captured in the sampling (our sampling frame was MPA users). This sampling method did under-represent environmental managers. Surveys were conducted on weekdays and weekends at each of the three study sites. When respondents were too busy to take part in the face-to-face surveys, but still wished to participate in the study, they were provided a copy of the survey instrument and information sheet with relevant instructions and asked to post their responses back to the investigator. Fewer than 10% of survey responses were collected using the postal method (n = 14).

Data collection - surveys

The survey took approximately 10 minutes to conduct and consisted of 43 questions. Only a portion of the survey questions and results are presented here due to the scope of this paper (a copy of the survey questions is available upon request). This paper focuses on questions that delineated factors that may have influenced respondent responses, such as demographics (gender, age, average income, education level and status, whether a respondent was a local, a visitor, or an environmental manager) and respondents self-rated level of IMS knowledge. Respondents were also asked their opinion about management and control of IMS. Questions to assess perception of risk of IMS were fixed response style questions using a 5-point Likert scale. These questions asked respondents to rate how much impact they believed IMS could have and how acceptable these impacts were on the ecosystem and to humans. The same survey was undertaken at each of the three study sites, primarily asking respondents to consider the MPA that they were visiting, but also asking the respondents to answer the same set of questions within the survey relating to the other two study sites, if the respondent knew of the other sites. Hence, all participants were asked to consider all three study locations, irrespective of the region the respondent was in, and to respond to the questions accordingly.

Statistical analyses

Descriptive statistics were used to determine respondents' level of knowledge of IMS and to examine respondents support for controlling and preventing the spread of IMS. Perception of ecological risk (questions that explored respondents' opinions about IMS impacts and the acceptability of these impacts) was examined using a data matrix with mean responses. The 5-point Likert scales were collapsed into 3-point scales due to the smaller sample size and to prevent violation of the assumptions of chi-square (χ^2) tests of independence conducted at the 5% level of significance (α = 0.05). Statistical analyses were undertaken using the SigmaStat 3.5 software (Systat Software 2005).

Results

Descriptive results

A total of 175 individuals were approached to participate in the study, resulting in 143 usable responses (82% response rate). This was represented by 65 from Ningaloo, 36 from Rottnest Island, and 42 from Hamelin Bay. Fifty percent of respondents were younger than 35 years of age and 58% of the respondents were female. The majority of respondents (79%) had an average income level below AUD$80,000. Status (local, visitor, or manager) was not representative across all categories, with only 3% of respondents being marine or coastal environmental managers (Supplementary material Appendix 1).

The respondents were able to rate their knowledge of IMS across four levels of understanding, with 89% of respondents being aware of IMS. Of these, the majority (47%) indicated that they had heard of IMS but had little knowledge. Similarly, 36% of participants responded that they had some knowledge of IMS (i.e., fair knowledge), and 6% indicated that they had a high level of IMS knowledge. Eleven percent of respondents had no knowledge of IMS. Regardless of their levels of knowledge of IMS, respondents were supportive of controlling and preventing the spread of IMS. On a scale of 1 (strongly disagree) to 5 (strongly agree), respondents with little or no knowledge of IMS were supportive of controlling and preventing the spread of IMS (M = 4.61, SD = 0.53) as were respondents with fair or high levels of knowledge of IMS (M = 4.23, SD = 0.69).

In general, respondents perceived IMS as posing a high risk of impact to the WA marine environment (Table 2). More specifically, respondents indicated that IMS pose a high risk of impact, with this impact being unacceptable (Table 2). In contrast, respondents perceived the IMS impacts to them (via human enjoyment) as low and felt that the impacts of introduced marine species on the WA marine environment

Table 2. Summary response data illustrating the descriptions of the survey questions, the perception of risk scale endpoints and the response mean (M), standard deviation (SD) and standard error (SE).

Descriptions	Possible Response Levels	M	SD	SE
Risk to The Environment				
Please rate the extent to which you think Introduced Marine Species can have an impact on the Western Australian marine environment	1 = very low 3 = midpoint 5 = very high	3.88	0.88	0.048
Please state whether you agree or disagree that Introduced Marine Species impacts on the Western Australian marine environment are acceptable	1 = strongly disagree 3 = neutral 5 = strongly agree	2.00	0.88	0.042
Risk to Humans				
Please rate how much you think Introduced Marine Species will impact on visitor enjoyment of the Western Australian marine environment	1 = very low 3 = midpoint 5 = very high	1.96	0.91	0.050
The impacts of Introduced Marine Species on Western Australian marine environment are acceptable to you personally	1 = strongly disagree 3 = neutral 5 = strongly agree	3.63	1.12	0.064

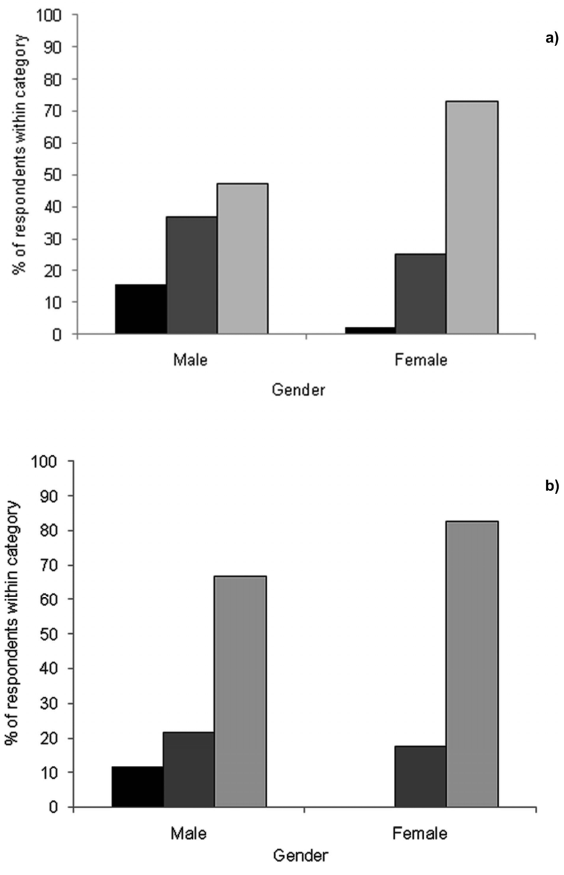

Figure 2. Differences in gender perception of the level of impact caused by introduced marine species at two sites in Western Australia: a) at Rottnest Island Marine Reserve; b) Hamelin Bay. Level of impact is denoted by black bars (low), dark grey bars (medium), and light grey bars (high).

were acceptable to them personally (Table 2). Thus, there was a dichotomy between perceived impacts and acceptance to the marine environment versus the individual's enjoyment and their personal acceptance.

Perception of risk of IMS to the marine environment

To explore trends found at each site, the respondents' perceptions of risk to the marine environment were assessed against their demographic characteristics. At Ningaloo there was no relationship between demographic characteristics and respondent perception of risk to the marine environment from IMS (Supplementary material Appendix 2). Yet at both Rottnest and Hamelin Bay some patterns were apparent.

There were no statistically significant trends between the demographic variables of income, status, knowledge and education and the perception of risk from IMS to the marine environment at Rottnest (Supplementary material Appendix 2). However, there was a statistically significant relationship between gender and the level of perceived impact of IMS ($\chi^2_{[2]} = 7.83$, $p = 0.020$; Supplementary material Appendix 2) at this site. This trend was also evident at Hamelin Bay ($\chi^2_{[2]} = 6.49$, $p = 0.039$) (Supplementary materials Appendix 2). At Rottnest the level of perceived risk varied between males and females with males rating the perceived risk lower than

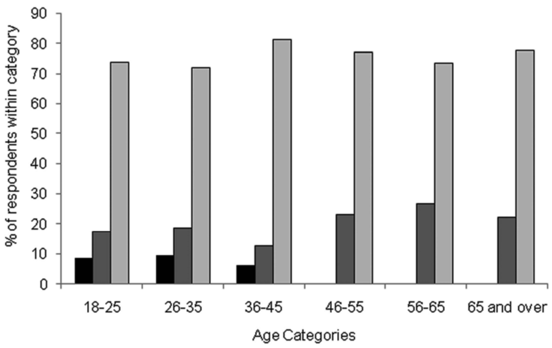

Figure 3 Differences in the perceived level of impact felt by people in different age categories when considering introduced marine species at the Rottnest Island Marine Reserve. Level of impact is denoted by black bars (low), dark grey bars (medium), and light grey bars (high).

females did (Figure 2a). At Hamelin Bay males represented 100% of the respondents that believed the level of impact of IMS would be low (Figure 2b). Female respondents were also more likely than male respondents to view the risk of IMS to Hamelin Bay as high (Figure 2b).

Similarly, age and the level of impact of IMS at Rottnest ($\chi^2_{[10]}$ = 20.00, p = 0.029) were dependent at this site, with the majority of respondents in each age category believing the impacts of IMS would be high. However, older respondents were more likely to perceive the risk of IMS as higher than did younger respondents (Figure 3). There were no statistically significant trends between the remaining demographic variables of income, status, knowledge and education, against the perception of risk of IMS.

No trends were found between the demographic variables examined and the acceptability of IMS risk, whether from an environment perspective or human risk perspective (see Appendix 2).

Discussion

In order to improve how IMS are managed in MPAs, we examined MPA stakeholders' knowledge of IMS, their perceptions to IMS, what demographics influenced those perceptions relative to impact, and the level of support stakeholders had for controlling IMS. This study focussed on three sites in Western Australia (Ningaloo, Rottnest Island, and Hamelin Bay). Positive management outcomes can be drawn from our findings, with an indication that respondents have knowledge about IMS and are willing to support control efforts; that they feel that IMS impact upon MPAs, but not necessarily their enjoyment of an MPA; and that males and people aged 18-45 are potential risk groups and therefore should be targeted for awareness raising and education about IMS. These aspects are discussed in more detail below.

Respondents' knowledge of introduced marine species

Self-rated knowledge of IMS was high (89%). Similar studies focussing on MPAs in Tasmania had high rates of self-rated IMS awareness (~70%), but the accuracy of this knowledge was low (Bryant 2011; Bryant et al. in review). The high level of self-rated knowledge may be attributed to respondents understanding based on their education and awareness raising programs that people have been exposed to within Australia and/or overseas. For example, some respondents visiting WA from south eastern Victoria were aware of the introduced Northern Pacific seastar, *Asterias amurensis*, as a result of aggressive public awareness programs (personal observations; Trenouth 2009).

Eleven percent of respondents were unaware of IMS examples, but were able to apply terrestrial knowledge and examples of introduced species (such as rabbits or foxes in Australia) to the marine environment. The authors cautiously suggest that in these cases, respondent's perceptions of impact may have been founded on an ability to apply knowledge of impact across ecosystems and an ability to visualise impacts in a broad sense (i.e., not restricted to a particular environment). However, due to the small sample size of this research, this theory requires further exploration. Imagery (e.g., Wahlberg and Sjoberg 2000), as discussed in Table 1, may also influence the ability to extrapolate and visualise impacts across ecosystems. Typically vivid images are remembered more frequently and at a higher rate than words or sentences (Paivio 1986; Schwartz and Heiser 2006). For example, rabbits in Australia have a symbolic influence in the social psyche as pest species that are synonymous with environmental destruction. This symbolism has been used as an allegory within Australian culture to such an extent that rabbits are vilified in some children's picture books (e.g., Marsden 2003).

Several respondents indicated that they believed the crown of thorns seastar (*Acanthaster planci* (Linnaeus, 1758)) (COTS) was introduced to the Great Barrier Reef (personal observations; Trenouth 2009). COTS are native to the north coast of Australia and only become a natural disturbance in outbreak conditions (Brodie et al. 2005). Although we did not assess respondent's knowledge of COTS, it was an interesting observation. This confusion between introduced species and outbreaks of native species may have implications for both the environment and the management of the region and could be related to the often interchangeable use of the term 'pest' or 'invasive.' Pest and invasive species are often regarded as being introduced species but they also represent native species that are a nuisance.

Unfortunately, confusion between native and introduced species can lead to public actions that have deleterious impacts upon native species. For example, in Tasmania and Victoria, *ad hoc* public eradications resulted in many native 11-armed seastars (*Coscinasterias muricata* (Verrill, 1870)) being killed following media coverage of the introduced five-armed seastar *Asterias amurensis* (Lutken, 1871) (DSE 2009). In Victoria, conflicting advice was provided to stakeholders on websites: the Victorian Department of Sustainability and Environment informed readers not to remove the introduced species because it is listed as a noxious pest under the *Victorian Fisheries Act* (1995) with permits being required for removal of the species (DSE 2009). In contrast, the Boating Industry Association (BIA) of Victoria asked readers to remove the seastar from the water and place it in a bin (BIA 2006). Similarly, recent research by Bryant (2011) and Bryant et al. (in review) has indicated that self-rated identification of introduced marine species is often faulty, with accuracy being low to moderate. Unfortunately, in this study we did not test for accuracy of identification or knowledge but feel that this aspect needs further investigation.

Ensuring that the public receive the correct information regarding new IMS is important to prevent detrimental practices such as these. Thus, in light of these occurrences, it is vital IMS awareness raising is increased in the study regions to ensure that people do not inadvertently move IMS or damage native species.

Respondents' perception of IMS and support to manage IMS

Perceptions of IMS

In general, respondents perceived IMS as having some level of negative impact on the marine environment of WA and felt that these environmental impacts were unacceptable (Table 2). However, these impacts were perceived as having a low chance of affecting visitor enjoyment of the WA marine environment and even though respondents agreed that IMS could have an impact on the environment, they perceived these impacts as acceptable from a human perspective (Table 2). Thus, our hypothesis that the lack of concern transference was due to low stakeholder risk perception of the IMS issue is not supported.

Respondents are clearly aware that IMS have impacts, suggesting that they have personal experience of, knowledge of, or can (or have) observe IMS impacts (*sensu* Stern et al. 1999; Stern 2000). Yet, they accept this impact on a personal scale because their enjoyment would not be affected. We suggest that if enjoyment was affected, the respondents' values or norms may be infringed upon (i.e., they would suffer a loss), which would result in a lower acceptance or tolerance of IMS (e.g., loss aversion; Kahneman et al. 1991) within the human risk context. Potentially, morality (linked to loss aversion) or ascription of responsibility is occurring in this situation. For example, people may understand that something "bad" (i.e., IMS in an MPA) is occurring (i.e., the environment risk is high and not acceptable) but it's not interfering with their enjoyment of the facilities and/or resources and therefore they do not feel a moral obligation regarding IMS. If this is the case, then managers need to 'scaffold' a link between IMS environmental impacts and personal risks (loss), to create a situation where MPA users are more aware of the links and therefore the potential losses they may incur.

Support to eradicate, control and prevent spread of IMS

A positive outcome of this research was that respondents showed willingness (93%) for the IMS issue to be managed effectively within MPAs. By supporting management initiatives MPA users are effectively shifting the responsibility of self-managing the IMS issue from themselves, or other users, to management agencies. This is notionally referred to as the 'blame game' or 'blame rituals' (e.g., Douglas 1992; Hood 2002; Susarla 2003) in the literature and is designed to shift responsibility and potential liability. This reiterates the concept that if someone else is responsible for an issue such as IMS, then a person does not have to alter their behaviours. As discussed above, this is particularly pertinent with regard to changing behaviours when no personal loss occurs. Within a marine biosecurity context, the public's willingness to support such efforts is often related to the perceived level of detriment (impact or cost) that these species will have (Bax et al. 2003; McFarlane and Witson 2008; Thresher and Kuris 2004). This impact is generally associated with each individual's level of concern that the impact will affect them personally (Hansson 2003). We found that while respondents believed IMS could have an impact on the environment, they felt that these impacts were acceptable as they were not personally affected.

Studies in terrestrial protected areas however, indicate that people are also influenced by pests that have commercial and aesthetic impacts (McFarlane and Witson 2008; Petrosillo et al. 2007). If we apply the concept of cost and benefits to our findings, what we have observed is that if people consider the risk to have greater costs to them then they are more willing to accept the management of that issue in the hopes of ameliorating the costs and perhaps obtaining a benefit (such as a pest free MPA). This finding is supported within the risk literature where risk taking is correlated with perceived benefit that outweighs the impact from the hazard (Hansson 2003; Renn 1998; Weber et al. 2002).

Within a terrestrial context, factors such as knowledge, residency, gender and impacts to ecosystem have also been demonstrated to influence respondents acceptance of and willingness to control pests within protected areas (Chang et al. 2009; McFarlane and Witson 2008). Further demographic variables reported to positively influence perceptions of pest control in forests have included gender (males), age (>55), education (>secondary school), and household income (>US$50,000) (Chang et al. 2009). Within a marine context, the demographic influences on perceptions of (introduced) pests and their management have not, prior to this publication, been published.

Demographic characteristics influencing perception

Demographic characteristics that influenced respondent's perception of risk of IMS varied between sites, yet two characteristics were common: gender and age. These two variables had a correlative relationship with IMS risk perception at one or more sites. We note however, that only examining demographic variables to determine what influenced the respondents perceptions may have been too limited an approach to explain all of the perceptions that were recorded.

The variables affecting acceptance were unclear, with no trends being apparent. Theories do exist that link behaviours with variables such as 'green' consumer behaviours; environmental citizenship; and policy support (Stern 2000), but these variables were not examined in this current research.

<u>Gender</u>

Our research identified gender as the demographic characteristic most likely to influence a respondent's perception of the impacts of IMS with female respondents showing more sensitivity to environmental impacts (perception of IMS impacts). These results are consistent with a variety of studies investigating gender differences in risk perception (Byrnes et al. 1999; Finucane et al. 2000; Kuhar et al. 2009; Riechard and Peterson 1998; Slimak and Dietz 2006; Zelenzy et al. 2000).

As IMS can be detrimental to the environment, gender differences in the perception of ecological risk of IMS could be attributed to the generalisation that females have stronger feelings of personal responsibility for improving the environment than males (Finucane et al. 2000). It is also suggested that female roles in motherhood (being sensitive and supportive of things other than self; Eagly 1987) can increase female concern about environmental risks (Cancian and Oliker 2000; Davidson and Freudenberg 1996; Stets and Biga 2003). This phenomenon is often stated as being related to differences in ecological and gender identity (Stets and Biga 2003; Thomashow 1996).

Recent research in MPA settings has also indicated that males tend to overestimate their ability to accurately identify introduced marine species (Bryant 2011). In general, males tend to be overconfident in their abilities in certain areas (e.g., Barber and Odean 2001; Bengtsson et al.

2005; Croson and Gneezy 2009) and are less willing to change (Kollmuss and Agyeman 2010). Research by Trenouth et al. (2012) on Tasmanian MPAs also indicated gender differences, with females having a positive correlation with environmental concern. The tentative management implications of our findings are that males need to be targeted for more aggressive awareness raising and education about IMS.

Age

Age was the second dominant demographic factor that influenced respondent perception of risk of IMS. Typically, the majority of respondents perceived the risk of IMS to the marine environment as high, although this trend was strongest in older respondents (>45). Previous findings suggest that older respondents are more concerned about ecological risks (Slimak and Dietz 2006), which may be related to a correlation between age and education. Thus, potentially our results could be interpreted that increased education tends to lead to an increase in the perception of the risk, as typically, the longer you live, the more educated (including both formal and informal education) you become and hence the more aware you might be. Yet, our demographic information that specifically measured formal education does not support this trend. Similarly, research by Buttel (1979) found an inverse relationship between age and environmental concern.

Although most respondents perceived IMS impacts to be high, a small proportion of respondents (all aged between 18–45) perceived IMS impacts to the marine environment as low. A number of possibilities exist for this trend: autocorrelation between age and education as discussed above, or the attrition of environmental values (environmental generational amnesia; Kahn 2002; Miller 2005). This suggests that younger generations do not believe that IMS affect them directly as they may have become estranged from nature. Typically, individuals act when they see what they value as being threatened (Stets and Biga 2003), however if an individual is estranged from nature then it’s less likely that they will recognise and react to environmental risks.

As the younger generations tend to be more technologically savvy than older generations (Skinner et al. 2003), it’s not surprising that they may be desensitised or overloaded with ‘bad news stories’ via increased access to and use of the internet, and information via mobile phones and computers as part of their everyday lives (Carroll et al. 2002; Lenhart et al. 2005), which can result in them disregarding or down-playing risks.

Other research suggests that the influence of age on risk or hazard perception is not easily defined. Graziano et al. (1979) showed that perception patterns relating to fear changed with age, but not in a simple linear relationship. Age differences also tended to be hazard specific and related to the cognitive development of the respondents (Graziano et al. 1979).

Management implications

Clearly, there is a need to develop policies and regulations that will enable response actions to IMS that enter MPAs in Australia and possibly elsewhere (Hewitt and Campbell 2007). These response efforts need to occur in a timely manner. This ability is limited in Australia at present. Although actions, such as declaring the kelp *Undaria pinnatifida* a “noxious fish” (see Hewitt et al. 2005) to thus enable its eradication from an MPA in Tasmanian waters is a step in the right direction.

To be consistent with MPA management plans and biosecurity regulations we suggest that MPA management plans need to be amended to reflect the environment risk posed by IMS in this context. This is particularly important given that IMS have been introduced into MPAs in Western Australia (e.g., Shark Bay World Heritage Property; Wyatt et al. 2005), and into MPAs in other Australian states (e.g., Tinderbox Marine Reserve in Tasmania; Hewitt et al. 2005; Schaffelke et al. 2005). IMS have also been introduced to high-value areas overseas, such as the Chatham Islands (now eradicated; Wotton et al. 2004), Stewart Island (e.g., Nelson and Maggs 1996), the sub-Antarctic Islands in New Zealand (e.g., Lewis et al. 2004). This would be consistent with our tentative findings that respondents perceived environmental risks from IMS as high and unacceptable, and are willing for MPA managers to effectively manage (eradicate, control and prevent) IMS within MPAs.

Based on our tentative outcomes, we suggest that targeted IMS management strategies within MPAs that focus on males in the 18-45 age-demographic may be a pro-active step towards improved management of this issue. The management strategies would need to ensure that the identified risk groups are aware of the issues and are educated about what they can do to help control or mitigate IMS. This is particularly relevant considering that males more commonly engage in boating activities (Bryant 2011; Bryant et al. in review; Johnson et al. 2001), are interested in recreational fishing (Henry and Lyle 2003), and hence are more likely to act as vectors of introduced marine species via recreational vessels. We suggest that specific perception research into aspects such as the cost-benefit of IMS within MPAs, perceived controllability (e.g., respondents can clean their boats hulls to reduce the threat of moving introduced species), variables affecting acceptability of impact, and the ascription of responsibility for managing IMS in MPAs will further enhance the outcomes of this demographic analysis.

Thus, to enable effective eradication or control efforts of IMS in MPAs will require proactive, flexible and adaptive management plans and legislation to prevent IMS from being inadvertently protected within these sensitive areas (Meliane and Hewitt 2005). Further examination of the roles the different perception variables play with regards to perceived impact and acceptability of IMS is fundamental to understanding the human role of IMS within MPAs, which has implications for the vectoring of pests into and out of protected areas.

Conclusions

We found that the self-rated knowledge of IMS was high and that within an MPA context respondents support the control, eradication and prevention of IMS spread. Respondents also felt that IMS caused environmental impacts within MPAs and felt that these impacts were unacceptable, yet they felt that these impacts were unlikely to affect visitor enjoyment. Exploring perceived risk of IMS in WA, in terms of demographic characteristics, has led to the identification of two potential risk groups (males and people aged 18-45) that management can target with educational and interpretation initiatives to reduce the risk of IMS incursions. An education program that targets MPA users fitting one or more of these high risk demographics could facilitate the management of IMS incursions in WA. These findings offer a starting point for both IMS and MPA managers to direct public education and interpretation efforts to improve MPA management.

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Supplementary material

The following supplementary material is available for this article.

Appendix 1. Summary data of the demographic variables collected from questionnaires undertaken at Ningaloo reef, Rottnest Island and Hamelin Bay.

Appendix 2. Chi-square values (χ^2) of tests of independence of variables associated with perception of risk to the marine environment from IMS in Ningaloo Reef Marine Park, Rottnest Island Marine Reserve and Hamelin Bay.

Appendix 1. Summary data of the demographic variables collected from questionnaires undertaken at Ningaloo reef, Rottnest Island and Hamelin Bay.

Demographic Variable	Description	Categories	Total # (%)
Age	Age of the respondent at last birthday	1 = 18-25	30 (21)
		2 = 26-35	42 (29)
		3 = 36-45	22 (15)
		4 = 46-55	18 (13)
		5 = 56-65	18 (13)
		6 = 65 and over	13 (9)
Gender	Asked respondents to state their gender; male, female or choose not to answer. Non response category was removed from further analysis due to low response rate.	1 = Male	60 (42)
		2 = Female	83 (58)
Income	Average income level in AU$. Original categories grouped due to low levels of respondents in some categories.	1 = $1-$34,000	48 (34)
		2 = $34,000 – 80,000	64 (45)
		3 = $80,000 +	14 (9)
		4 = Choose not to answer	17 (12)
Education	Highest level of education achieved. Original survey categories grouped due to low levels of respondents.	1 = Primary or Secondary	54 (37)
		2 = Tertiary or Postgraduate	89 (62)
Status	Determined whether respondents were local residents, visitors to the study site or in a position of coastal environment management.	1 = Local Resident	61 (43)
		2 = Visitor	64 (45)
		3 = Manager	5 (3)
Primary Residence	Where the respondent lived; local being classed as within 100 km of a study site, national, within another Australian state, or International.	1 = Local Resident	70 (49)
		2 = National Resident	68 (48)
		3 = International	5 (3)
Knowledge	Self rated level of knowledge considering Introduced Marine Species	1= Never heard of IMS	15 (10)
		2= Little knowledge of IMS	68 (48)
		3= Some knowledge of IMS	51 (36)
		4= A lot of knowledge of IMS	9 (6)

Appendix 2. Chi-square values (χ^2) of tests of independence of variables associated with perception of risk to the marine environment from IMS in Ningaloo Reef Marine Park, Rottnest Island Marine Reserve and Hamelin Bay. * represents significance at the 5% level.

	Impact			**Acceptability**		
	χ^2	**df**	**p-value**	χ^2	**df**	**p-value**
Ningaloo Reef						
Gender	0.71	2	0.702	0.26	2	0.877
Age	12.94	10	0.228	13.44	10	0.200
Income	6.78	6	0.342	2.37	6	0.883
Status	7.86	6	0.248	11.00	6	0.088
Knowledge	4.70	6	0.583	3.16	6	0.788
Education	0.19	2	0.910	1.47	2	0.481
Rottnest Island						
Gender	7.83*	2	0.02	0.4	2	0.712
Age	20.00*	10	0.029	12.23	10	0.27
Income	3.54	6	0.739	3.85	6	0.697
Status	4.53	6	0.605	9.46	6	0.149
Knowledge	3.46	6	0.749	7.83	6	0.25
Education	0.81	2	0.668	1.68	2	0.432
Hamelin Bay						
Gender	6.49*	2	0.039	0.68	2	0.712
Age	4.93	10	0.896	17.06	10	0.073
Income	3.67	6	0.722	3.44	6	0.752
Status	11.44	6	0.076	11.18	6	0.083
Knowledge	7.13	6	0.31	5.05	6	0.538
Education	2.38	2	0.305	0.17	2	0.918