

Exploring perceptions of marine biosecurity interventions: insights from the commercial marina sector.

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Manuscript Details

Manuscript number	JMPO_2019_187_R2
Title	Exploring perceptions of marine biosecurity interventions: insights from the commercial marina sector.
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Abstract

Recreational boating is a largely unregulated vector of non-native species and contributes to both initial introduction and secondary spread. As such, marinas and ports often experience high propagule pressure and are hotspots of non-native species. In many countries, there is little or no legal requirement for marinas to implement biosecurity in day-to-day operations to reduce the risk of non-native species introduction. Instead, biosecurity is often encouraged and implemented voluntarily meaning uptake may be limited. To understand the range of perceptions of biosecurity within the marina sector, focus groups were conducted as part of a workshop attended by operators from Ireland and Wales. In the first focus group, participants discussed the barriers and drivers to the overall process of designing a biosecurity plan for a marina. A second focus group asked participants to identify strengths and weaknesses of a range of biosecurity tools, such as risk assessments and in-water quarantine berths. Thematic analysis revealed lack of financial resources, in combination with doubt regarding the effectiveness of biosecurity interventions, to be the greatest barriers to uptake. Aligning with good practice and the perceived benefits of a clean environment for business were seen as drivers. Integrating biosecurity into normal marina operations requires bottom up and top down support from customers and relevant authorities respectively. We recommend that alongside testing the effectiveness of biosecurity interventions, researchers should also present robust evidence of cost-effectiveness, and consider and address any potential effects on marina businesses.

Keywords	non-native species; invasive species; marinas; ports; recreational boating; focus group
Corresponding Author	Siobhan Vye
Order of Authors	Siobhan Vye, Sophie Wynne-Jones, Patricia Masterson-Algar, Stuart Jenkins
Suggested reviewers	Rebecca Geisler, Emma McKinley

Submission Files Included in this PDF

File Name [File Type]

200502_CoverLetter.docx [Cover Letter]

200310_Response to reviewers_MPLineNumbers.docx [Response to Reviewers (without Author Details)]

Highlights (1).docx [Highlights]

Abstract.docx [Abstract]

TitlePage_Revised.docx [Title Page (with Author Details)]

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R.e: Response to reviewers' comments: JMPO_2019_187

Dear Dr Hanich,

Please find outlined in the attached document how we have addressed all the reviewers' comments in our revised manuscript.

Yours sincerely,

Siobhan Vye

On behalf of all authors

Reviewer: 1

This paper explores biosecurity in marinas used by recreational boaters, using focus groups to explore the perception of biosecurity amongst those working in the sector. The paper is timely- the 2014 EU invasion alien species legislation focuses on prevention. However, there is no legal driver for marine biosecurity regarding invasive species. The ms is clearly written and placed in the context of the literature. The data are clearly explored and interpreted. I have one major concern over the methodology that should be addressed/discussed in the manuscript. The workshop was immediately preceded by plenary sessions on non native species and biosecurity. These plenary talks are likely to increase the awareness of the participants, as well as to bias their conversations. The effect of this should be considered in the ms.

We considered the use of plenary talks at some length before running the workshop and felt that including them led to benefits which outweighed the potential disadvantages. We have added in further discussion of the potential bias that the structure of the workshop may have introduced in lines 180-182, and 184 to 190.

Minor comments.

Abstract-the final sentence is rather "throw away". Either include more material in the discussion that explores how the finding might inform development of biosecurity tools, or simply remove this sentence.

We have removed the sentence.

Practice is a noun, practise is a verb if using English spelling, or noun and verb are both spelled "practice" if using American spelling.

We have checked the manuscript and now use practice throughout (nouns) except in one case where we use practise as a verb.

More integration of table 3 into the text would be clearer

We have referred to table 3 throughout the results so the reader can link through from discussion themes presented to the table (Line 256, 303, 481)

-Reviewer 2

-

Overall, this paper is well written and clearly structured – and contributes to a wider discussion on the need for effective stakeholder engagement across marine resource use. As recreational boating across the UK continues to be impacted by challenging social and economic circumstances, the need to take a holistic approach to managing biosecurity issues is crucial. I am happy to recommend this paper for publication, subject to the recommendations and edits set out below.

Comments:

9: Delete 'and therefore' and replace with 'meaning'

This edit has been made (line 13)

13: Delete “activity”

This edit has been made (line 17)

16: Not sure ‘conversely’ is the correct word here.

The word has been removed for clarity (line 21)

Abstract overall – are there any recommendations that you could present based on the work you’ve presented? It would be good to have some strong concluding comments here.

We have added recommendations into the abstract (line 23-27) and the conclusion (line 705-720)

33: Edit to read as “...such as those within the commercial shipping and aquaculture industries....”

This edit has been made (line 75-76)

37: Effective doesn’t feel like the correct word here – perhaps just state that is a ‘known vector’

This edit has been made (line 80)

39: Replace ‘have an’ with undergo

This edit has been made (line 83)

40: Edit to read as “These vessels, therefore, pose a high risk....”

This edit has been made (line 84)

45: Add in “...often encouraged as general best practice...”

This edit has been made (line 89)

71: Wales is a nation/ country in it’s own right - it would be more correct to reference it as such here.

Clarification has been added (line 125)

71-79: I wonder if this section would be improved by starting off with an introduction to the EU legislation and wider governance landscape, before narrowing down to the national approaches in Ireland and Wales. It might also be useful to include some additional context, adding in some information about the shared maritime history and connectivity supported by the recreational boating industry.

We have restructured the paragraph and added in the recreational boating context (lines 125-138)

96: 7 is quite a low number of marinas – I understand that this can happen with this type of data collection, but I would suggest including some sort of comment on the limitation that this would result in.

We have added in a comment on the limitations in lines 160-164

129: Edit to read “interventions, proposed by the facilitator, considering them in the context of their own marinas”.

This edit has been made (line 205)

140-150: Detailed description of analysis – very good to see this!

184: Edit to read as “for some of the biosecurity interventions, examined in the workshop...”

This edit has been made (line 283)

187: Kinda lives where? Consider whether this is the best quote for this discussion.

We have added clarification to the quote on lines 291

197: edit to “A lack of existing knowledge....”

This edit has been made in line 307

201: Edit to “It was also that even if...”

This edit has been made (line 312-313)

203: add in “legislation”

This edit has been made in line 315

227: Replace highlighted with stressed

This edit has been made in line 321

231: What is the relevance of this quote? Sometimes the quotes that are being used have not been edited to fit the flow of the discussion. I would suggest considering changing the approach of presenting the quotes in certain places, or edit the quotes so that they fit the discussion better.

We have added in better links between the quotes and the text throughout the results section to ensure the quotes clearly demonstrate the ideas being discussed. The quote here has been deleted.

246-254: This whole section is a bit complex – I’m not sure the quote clearly supports the point you’re trying to make.

We have rewritten this section to clearly set out the point we are trying to make (lines 379-386)

276-279: split the sentence if you can. Edit so it reads as “...can get that position in your place. If they have...”

Unfortunately, splitting the sentence doesn’t accurately reflect the quote in the transcript.

287: add in (referencing... closed loop...)

This edit has been made (line 440)

302: edit to read as “the number of moving parts susceptible to breakage...”

This edit has been made (Lines 460)

307: Edit to read as “...were considered as harder to implement.”

This edit has been made (line 466)

346. *Split the sentence by making however – However*

This edit has been made (line 521)

362: *when you say use it, what do you mean? Legislation? Or the education?*

We have added clarification to the quote (line 546)

389 – *the comments on financial resources and cost are a bit repetitive as the point has been implied in every paragraph of the discussion so far. I would consider streamlining the discussion.*

We appreciate the reviewer's comment, however, financial resources were raised consistently across all discussions in the results, and we feel that this paragraph that discusses resources, including financial, pulls together that narrative and hence is warranted.

426: *edit to read as "...as good practice, it was clear that managing biosecurity issues..."*

This edit has been made (line 623)

459: *It would perhaps be useful to reflect a little more on the literature around effective science communication.*

We have now added in additional reflection around science communication more broadly as suggested (lines 670-678)

There is no concluding comments section – it would be useful to have recommendations or something summarising the key findings of the work and how it can be applied in a wider context. These are currently hidden in the text; it would be better to have them more explicitly presented the paper. This would strengthen the paper overall.

We have now edited the final concluding paragraph to summarise our recommendations and draw together our conclusions more effectively (lines 703-720)

Highlights

- Recreational boating is a vector for non-native species at local, regional and global scales.
- Marinas are hotspots for non-native species yet biosecurity is often voluntary.
- Marina operators identified cost and doubt of effectiveness as barriers to biosecurity.
- Alignment with good practice and maintaining the environment were drivers for biosecurity
- Bottom-up and top-down support is required to integrate biosecurity into marina operations.

Abstract

Recreational boating is a largely unregulated vector of non-native species and contributes to both initial introduction and secondary spread. As such, marinas and ports often experience high propagule pressure and are hotspots of non-native species. In many countries, there is little or no legal requirement for marinas to implement biosecurity in day-to-day operations to reduce the risk of non-native species introduction. Instead, biosecurity is often encouraged and implemented voluntarily meaning uptake may be limited. To understand the range of perceptions of biosecurity within the marina sector, focus groups were conducted as part of a workshop attended by operators from Ireland and Wales. In the first focus group, participants discussed the barriers and drivers to the overall process of designing a biosecurity plan for a marina. A second focus group asked participants to identify strengths and weaknesses of a range of biosecurity tools, such as risk assessments and in-water quarantine berths. Thematic analysis revealed lack of financial resources, in combination with doubt regarding the effectiveness of biosecurity interventions, to be the greatest barriers to uptake. Aligning with good practice and the perceived benefits of a clean environment for business were seen as drivers. Integrating biosecurity into normal marina operations requires bottom up and top down support from customers and relevant authorities respectively. We recommend that alongside testing the effectiveness of biosecurity interventions, researchers should also present robust evidence of cost-effectiveness, and consider and address any potential effects on marina businesses.

Title: Exploring perceptions of marine biosecurity interventions: insights from the commercial marina sector.

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Keywords: non-native species, invasive species, marinas, ports, recreational boating, perceptions, focus group.

Declarations of interest: None

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Abstract

Recreational boating is a largely unregulated vector of non-native species and contributes to both initial introduction and secondary spread. As such, marinas and ports often experience high propagule pressure and are hotspots of non-native species. In many countries, there is little or no legal requirement for marinas to implement biosecurity in day-to-day operations to reduce the risk of non-native species introduction. Instead, biosecurity is often encouraged and implemented voluntarily meaning uptake may be limited. To understand the range of perceptions of biosecurity within the marina sector, focus groups were conducted as part of a workshop attended by operators from Ireland and Wales. In the first focus group, participants discussed the barriers and drivers to the overall process of designing a biosecurity plan for a marina. A second focus group asked participants to identify strengths and weaknesses of a range of biosecurity tools, such as risk assessments and in-water quarantine berths. Thematic analysis revealed lack of financial resources, in combination with doubt regarding the effectiveness of biosecurity interventions, to be the greatest barriers to uptake. Aligning with good practice and the perceived benefits of a clean environment for business were seen as drivers. Integrating biosecurity into normal marina operations requires bottom up and top down support from customers and relevant authorities respectively. We recommend that alongside testing the effectiveness of biosecurity interventions, researchers should also present robust evidence of cost-effectiveness, and consider and address any potential effects on marina businesses.

1. Introduction

The introduction of non-native species through anthropogenic vectors, and their subsequent establishment and spread, is widely considered to be one of the greatest threats to ecosystems [1–3]. Once introduced, non-native species may have far-reaching economic and ecological consequences [4–6] and management or eradication of established populations in the marine environment, even those constrained to local areas, is extremely challenging [7]. Hence, prevention of initial introduction and secondary spread of non-native species through regulation of vectors is a major focus [8–11]. A range of vectors can introduce marine non-native species, including commercial shipping, aquaculture, and recreational boating [12]. In the marine environment, management of vectors has primarily focussed on those that already operate within a strict regulatory framework, such as those within the commercial shipping and aquaculture industries [13,14]. However, there has been increasing recognition of the potential role of recreational boating, a largely unregulated activity, in transporting non-native species [15,16].

Recreational boating links coastal areas at global, regional and local scales, and is a known vector for both initial introduction [17,18] and secondary spread of non-native species [15,16,19]. Recreational vessels often undergo infrequent voyages interspersed by long stationary periods in marinas and may not always undergo effective anti-fouling [20,21]. These vessels, therefore, pose a high risk for transfer of non-native species through hull fouling [22]. Marinas are often hotspots for non-native species [17,23] and may provide source populations for secondary spread [24,25]. Despite acknowledgement of the role of recreational boating in transporting non-native species, in most countries there is little or no legal obligation for marinas to consider non-native species biosecurity in day-to-day operations [15]. Instead, biosecurity is often encouraged as general best practice and implemented voluntarily, resulting in limited uptake and a dependence on the sector's perception of biosecurity [26].

Effective site-based biosecurity requires the formulation of a biosecurity plan that incorporates actions for different risk scenarios, and outlines the range of operational or infrastructure interventions that can be implemented to facilitate these actions [27,28]. Understanding the implications of biosecurity interventions for the commercial operation of marinas is crucial to encourage uptake where the implementation of biosecurity is voluntary. To date, research into marina biosecurity has focussed on quantifying the risk posed by vessels and operations [29–31], understanding non-native species awareness by marina owners and users [32,33] and the development and testing of novel tools, such as in-water quarantine systems [20,34]. However, there has been little in-depth investigation into marina operators' perceptions of biosecurity interventions beyond limited investigations into their current practices [32]. Marina operators' perceptions and experiences of biosecurity interventions are likely to influence their engagement with voluntary practices [35]. In particular, engaging with marina operators and understanding their perceptions of specific tools would allow general themes to be identified and focus ongoing research on developing tools that are feasible in the commercial operation of a marina.

In order to understand the perceptions of marina operators to biosecurity interventions, we conducted a workshop with marina owners and operators from Wales and Ireland, two highly connected countries but with different regulatory environments. The workshop aimed to engage with marina operators and owners from around the Irish Sea and better understand the drivers and barriers to biosecurity planning in commercial marina operations, and the strengths and weaknesses of various specific biosecurity tools and operations (hereafter referred to as interventions) that are either under development or in practice in other countries.

2. Methods

2.1. Context

Wales and the Republic of Ireland are separated by the Irish Sea, over a distance of approximately 47 miles at its narrowest point. This relatively short distance, and the presence of marinas and sailing clubs on both coasts, has resulted in a high number of recreational sailing and racing routes between the two countries [36]. Within both countries, implementing biosecurity in marinas is not legally required for day-to-day operations, although it may be a consideration by licencing authorities for specific activities, such as construction. Both countries have more general biosecurity obligations stipulated by international regulations, such as those required by the International Ballast Water Convention [37]. In Wales, implementing marine biosecurity is also considered best practice by the statutory authorities [28]. However, in the Republic of Ireland, national regulations around marine biosecurity practices are less well developed, although implementing the EU Regulation on the prevention and management of the introduction and spread of invasive alien species [38] will require further steps in the development of national policy.

2.2. Data collection - workshop for marina operators

The study aimed to understand perceptions of the barriers and drivers to the general concept of biosecurity planning, and utilise the experiences of marina operators to understand the range of practical challenges to implementing biosecurity. Capturing experiential knowledge of potential biosecurity practitioners is essential to understand context-dependent considerations and hence, facilitate the translation of biosecurity research into practice [35]. This study used qualitative methodologies, namely semi-structured focus group discussions, to enable the capture of experiential knowledge and perceptions [35,39]. The aim was to gain greater depth of insight into how participants conceptualised biosecurity issues rather than attempt to fully represent and quantify all perspectives [39,40].

Twenty seven coastal marinas in the Republic of Ireland and Wales were invited via email and telephone to a one day workshop. Invitations were addressed to marina operators and owners, and included a brief outline of the purpose of the workshop, i.e. for researchers to collect information on the drivers and barriers to biosecurity and to provide information to participants on non-native species and biosecurity. Marinas were selected on the basis of their location within, or near to, the research funding area (see Acknowledgements). Nine marinas accepted the invitation (reduced to 7 marinas, represented by 8 participants on the day, owing to inclement weather). Primary reasons for marinas not accepting the invitation included lack of response and calendar conflicts with prior commitments. Although the workshop was attended by a relatively small proportion (~20%) of marinas from the study area, attendees represented a wide range of marina types, from independent Yacht Clubs to marinas managed by larger harbour authorities and regional councils, and fulfilled a range of roles, including marina managers, management committee members, environmental managers and marina owners. All participants had understanding of the day-to-day operations of the marinas they represented, alongside some level of decision-making or management responsibility. Discussions throughout the day revealed that participants had a range of familiarity with non-native species, from a basic understanding of the issue through to direct interaction with non-native species management.

The workshop began with two plenary talks to provide information to all participants regardless of role or experience, followed by two focus group sessions. The first plenary covered an introduction to non-native species including definitions, vectors, example species and impacts. A second shorter plenary introduced the concept and practice of biosecurity planning [28].

These plenaries were delivered to ensure all participants had the baseline knowledge to understand the subject matter of discussion. Focus group sessions followed, and were facilitated by the authors, Siobhan Vye and Stuart Jenkins, who both have backgrounds in non-native species and biosecurity research. During focus group sessions, data were collected by independent note-takers for each group, dictaphone recordings, which were later transcribed, and participants' own notes captured on flipchart paper. To minimise the influence of the presence of expert speakers and researchers on marina participants' discussions, only the facilitators engaged with the marina operators' focus group discussions. Further discussions with experts and talks on non-native species legislation occurred after the focus groups. All participants were briefed on the purpose of the research and provided formal consent for anonymised quotes to be used in this research.

The core aims of the first focus group session (one group with 8 participants) were to explore the perceptions of biosecurity planning and to identify the barriers and drivers to creating a biosecurity plan. The facilitator (Siobhan Vye) was assisted by Sarah Brown, a co-author of the Marine Biosecurity Planning Guidance recommended by the statutory agencies in Wales [28], in answering questions regarding the process of biosecurity planning. The facilitator asked participants as a group to suggest what would be a driver in their marina and what would be a barrier, and then directed discussion around these subjects. Once the range of barriers and drivers was identified, the facilitator asked the group to deliberate and reach consensus through discussion on the most important driver and barrier to biosecurity planning.

During the second focus group session (two groups with 4 participants each), a variety of specific biosecurity interventions were proposed by the facilitators and participants were asked to identify strengths and weaknesses in the context of their own marinas. Providing these "real-life" scenarios or actions facilitates the collection of experiential knowledge that is often situation-specific in nature [35,41]. Intervention examples were sourced from the scientific and grey literature, and were chosen to represent a range of effort and commitment levels from marina businesses and customers. Information on the eight example interventions was provided at the start of the session through factsheets that followed a standardised layout and described the intervention, its current status, and, where possible, a descriptive image. Interventions were split into two main types: infrastructure or operations, and were based on established practices in other countries or interventions that were currently at the early research and development stage (Table 1).

2.3. Data analysis

All audio-recorded data from the focus group sessions was fully transcribed and hand-written notes were converted into electronic text. In order to draw out common themes, all qualitative data was analysed taking a thematic analysis approach [42]. All data was coded by the first author using an initial coding framework drawn from relevant literature. New codes were created for data falling outside the framework in order to avoid missing important concepts. Initial themes were then identified as meaningful patterns across coded data and were further refined until a final set were decided upon. To ensure analytical rigour, a second coder (*Name redacted for double blind review*) independently analysed approximately a third of the data and the results from this coding were compared with the first coder's results. Where there was significant deviation, or new themes were identified, these were refined until coders were satisfied the themes were sufficiently supported by the data.

3. Results

Three overarching themes relating to the participants' perceptions of marina biosecurity were identified: the impact of biosecurity on a marina business, the efficacy of biosecurity

interventions, and valuing the environment as a driver for biosecurity. Within these overarching themes, four sub-themes were drawn from the data (Table 2). In addition, a summary of the specific perceived strengths and weaknesses of each biosecurity intervention discussed is provided in Table 3.

Theme 1: Impacts of biosecurity adoption on a marina business

Sub-theme 1.1: Intervention requires resource investment (time, money and information)

Participants indicated that the financial resources required for biosecurity were the greatest barrier and a weakness in 7 of the 8 specific interventions that were discussed. Participants highlighted that biosecurity would be an additional financial burden alongside other financial pressures marinas are facing, such as a decline in the number of marina users. Participants recognised that, currently, the operator would be responsible for the cost of implementing biosecurity, emphasising high initial costs particularly for infrastructure interventions (Table 3). For example, one participant flagged the recent recession as a barrier for operators to invest in biosecurity:

“Any of these situations we’re talking about will have to be funded by the operator. And we’ve gone through 10 years, of a very hard recession, there is not an awful lot of spare cash out there” Participant D

Yet, participants articulated that the cost of dealing with an incursion of a non-native species was potentially more expensive than taking preventative measures through implementing a biosecurity plan. This indicates an expectation or perception that the financial responsibility of species management would fall on the marinas rather than on the relevant authorities. This is particularly illustrated by the following quotes, that reference weighing up the costs of dealing with an incursion against implementing the biosecurity to prevent it:

“[...] If you put that [biosecurity] down as a cost, then you end up in a situation where you’ve got to bag all your piles, haul all the boats where you’ve got to get rid of something, then that’s not a cost. So depends how you look at it” Participant F

“Well, value for money vs financial risk of the consequences of an invasive species being introduced. So in order to make any headway, you actually need as a business to face up to the fact that these things do present a business risk.” Participant A

The focus groups generated ideas to raise private and public revenue, such as grant aid from the government, or including a surcharge in their own berth leases. This suggests participants were not adverse to investment in biosecurity providing there is support available to generate the additional financial resource needed.

Closely related to financial resource, participants discussed staff time that would be required for some of the biosecurity interventions examined in the workshop, such as the time required to turn rotating pontoon floats on a regular basis. Interventions perceived to require minimal staff input beyond initial set up, such as developing risk assessments, were often seen as attractive, as illustrated by the following participant:

“[...] and there’s quite a bit of work getting a risk assessment procedure off the ground you know so in the initial stages you’re dedicating time, staff in setting it up and afterwards it kinda lives there.” Participant C (referring to the creation of the risk assessment being the most effort)

In contrast, an intervention that required similar amounts of time to an already established approach that may serve the same purpose, was perceived as unappealing. For example, one

group discussed that using the quarantine berth to decontaminate vessels, which could take up to 1-2 hours, was not of great benefit when hauling the vessel out for a scrub could be done in the same amount of time (Table 3):

“What would the difference be to take the boat in, haul it, wash it down, and keep all the fouling, sweep it up and dump it?” Participant G

A lack of existing knowledge within the sector was identified as a weakness particularly in cases where the intervention represented an emergency action after the detection of a non-native species. In this scenario, participants raised concerns that marina staff would not have the knowledge to identify the species. As demonstrated in the following quote, one participant suggested that it was not just specific knowledge or information that was lacking. It was also that even if information or knowledge was freely available, it may not be accessible to individuals without detailed understanding and knowledge of technical terminology, concepts and legislation associated with biosecurity:

“[...] Because that’s a really big, you know, for people who, like myself, wouldn’t know how to do something like that, I’d be looking for templates, or I would be trying to tell the boss how to put the 6, 10 step process in place. Because it has to comply with legislation and everything else which I wouldn’t be familiar with.” Participant I

Participants stressed that although the existing knowledge base within the sector may not be sufficient to attain effective biosecurity, there are resources available that can help break down this barrier, such as online courses for marina managers.

Existing infrastructure resource can also restrict the use of interventions or be perceived to make some interventions redundant, depending on the local context. For example, introducing enforced haul-out protocols would be a challenge in some marinas that do not have haul-out facilities. In contrast, those marinas with haul-out facilities may not promote in-water hull cleaning or the use of a quarantine berth decontamination system because, with the local facilities and the correct anti-fouling regime, the intervention should not be needed. Biosecurity interventions that would require new infrastructure led to discussions on related difficulties, for example, one participant highlighted planning restrictions at marinas that were listed sites:

“Lots of ports in [a region of Wales] are listed structures, there’s no way you’d be able to excavate for that purpose.” Participant H

Beyond the modification of local planning regulations, participants identified a more general need for legislation or policy resources to support marinas implementing biosecurity actions. One participant explained how such external drivers could enable marinas to explain the new measures to their customers:

“[...] then you can say to the members “by the way, we must from such a date, we’re obliged to do this”. If you put the charges up a couple of extra euro for your lift up and wash down, but that covers that.” Participant G

Participants highlighted that legislation and policy should not be restrictive and alternative solutions or activities should be possible. Furthermore, legislation should be joined up across authorities responsible for the different aspects of marina operations, such as marine licencing and planning departments.

Sub-theme 1.2: Intervention can have an impact on how customers and peers within the sector perceive and interact with the marina.

A barrier to biosecurity was the impact an intervention could have on interactions between the marina and customers, from direct conflicts with marina staff to reducing the customer base. Participants showed concern about potential conflicts with customers where the need for an intervention may be subjective. This is illustrated by the hypothetical situation the following participant describes:

“Can you imagine standing on a dock arguing with a customer over the state of his boat?”

Participant D (referring to enforced haul out protocols)

Participants raised concerns that some interventions would not only erode relationships between the marina and customers, but also make recreational boating less attractive, reducing custom for the marina. For example, where an intervention, such as enforced haul out protocols, requires additional cost or hassle then customers may not visit the marina, as illustrated by this participant’s comment:

“It’s just another reason not to go, isn’t it?” Participant C

Participants acknowledged that specific interventions could improve the facilities available at some marinas and that leadership by individual marinas could be important in driving behavioural change in the sector. However, this was contrasted against concerns about the negative effects of biosecurity interventions not being implemented universally across the sector. Here, the primary concern was that customers were likely to favour marinas that did not require the perceived hassle of additional biosecurity interventions. Hence, although behavioural change may require leadership from individual marinas, those marinas leading the way were likely to lose customers and, therefore, their businesses would be negatively impacted. One participant summarised this trade-off between showing leadership and losing customers in the following comment:

“And you see word of mouth, if I introduce [inaudible] the first thing I will be asked what are [other yacht] clubs doing, what are they doing in [...], well [they] aren’t doing anything, then why are we doing it, someone will say, well that [other marina] are they doing it? Then why do we want to do it? Well if everybody starts...” Participant G (identifiable information retracted)

However, there was also acknowledgement that doing nothing and risking a non-native incursion could lead to negative impacts for the business. In particular, one participant highlighted current difficulties with marine licencing owing to the presence of non-native species. Other participants raised concerns about the reputational damage associated with having a non-native species in the marina. The fear of reputational damage is demonstrated by this following quote:

“Look, if I sit down in a pub [...] and say [...] don’t go to [...] guys, it’s got all these nasty bugs up there, what’s the effect? You know it’s the harsh reality” Participant C (identifiable information redacted)

Theme 2: Efficacy of biosecurity interventions

Sub-theme 2.1: Does the intervention actually reduce the risk of non-native species?

Participants expressed doubt over the effectiveness of a site-based approach to biosecurity, especially where the marina operates in a busy multi-use coastal environment:

“[...] regardless of what we do and I suppose from listening to what protective things we could put in place, because we have commercial shipping in up to 100 liners a year coming in over the harbour. And they are the biggest at pumping out the ballast, they have to be the

ones to target, initially, us helping as well. That's what most of this stuff must be coming from." Participant F

Within the marina sector, participants noted that the biosecurity efforts invested by one marina may be offset by another connected marina that does not actively promote biosecurity awareness. Hence the proactive marina's risk of non-native species may not be reduced despite the implementation of biosecurity interventions:

"Because some of your people on your waiting list are going to be neighbouring marinas waiting until they can get that position in your place if they've been completely negligent in another marina and they just come to you not aware of this, that's the only weakness I can see" Participant H

Variation in the strength of evidence and the magnitude of the effect were seen as key weaknesses for specific biosecurity interventions, such as promoting native species and in-water cleaning. Interventions that were discussed as being effective at reducing risk were those that arguably are more easily evidenced, such as by causing mortality of visible biofouling. For example, although closed loop wash-down systems had many weaknesses, such as cost, the intervention was perceived to be effective at reducing the risk of non-native species:

"Proven. It will work. It's going to have to be cost, where to find the money" Participant F (referencing closed loop wash down system)

In contrast, participants expressed scepticism around those inventions that were more preventative, such as raising biosecurity awareness, suggesting more evidence for their effectiveness is required or that existing evidence should be better communicated:

In many of the examples, and in the overall discussion of the interventions, effectiveness was constantly linked to cost and financial resource, suggesting participants considered there to be a trade-off between these two aspects of an intervention. One participant highlighted the importance of demonstrating cost effectiveness to the corporate side of the business:

"[...] actually being able to sell, um, you know, a cost effectiveness position on a corporate level so this isn't that we can adopt a policy about, as corporate entity that we accept that there is a risk here." Participant I

Sub-theme 2.2: Is the intervention easy to implement alongside normal operations?

Participants raised doubts about whether some of the prototype stage interventions would function in the marina environment, regardless of their effectiveness at reducing the risk of non-native species. For example, participants discussed whether rotating pontoon floats would be feasible in a marina owing to the number of moving parts susceptible to breakage and concern over the robustness of the design in large swell conditions:

"It would damage robustness. I mean, Storm Ophelia and all that goes with that" Participant C (referring to the potential for rotating pontoon floats to be damaged by large storms)

Where interventions were perceived to mismatch with expected vessel owner behaviour, they were considered harder to implement. For example, the quarantine berth was unlikely to be viewed positively by boat owners because it does not visibly clean the hull, removing biofouling, and therefore a haul out would still be required. Similarly, it was argued that enforced haul out should not be required for those vessels that have cruised long distances and may harbour new non-native species. The hulls of such vessels are likely to be maintained in very clean condition to maximise efficiency, and therefore, probably have overall hull fouling below limits that would trigger a haul-out.

Positive comments around ease of implementation came where participants perceived the operation as easily fitting in with existing operations, such as rotating pontoon floats negating the need to manually scrub fixed floats (Table 3):

“[...] but I can see an advantage to it. We go out and manually scrub out blocks during the summer months when we get a lot of growth. We obviously can’t get the undersides so we’ve got a labour input anyway so.” Participant C (referring to pontoon floats)

Participants also identified methods of incorporating some interventions relatively easily, such as using the quarantine berth as a shared portable resource among several marinas in an area:

“Well presumably you could contract that. If you had a group of marinas within your locality, they would be able to pool the resources like that or if they could contract they would be able to call on the contractors and say “look we’ve got this boat in”. Participant H

In several cases, marinas had already considered or partially implemented some of the interventions for other purposes. For example, one participant highlighted that their marina had been considering the installation of a holding tank for washing down vessel hulls:

“All our boats would be lifted, we have 2 cranes left and right. And we’re considering about putting a holding tank under our, under where the crane is.” Participant G

For some of the interventions, participants identified entirely new secondary purposes for the interventions, such as identifying that the quarantine berth could also be used as an oil or fuel leak containment system and highlighted this as a strength:

“If in an emergency, say a diesel or an oil leak, that’s come from under the water, containment, you can put the boat into it, zip it up.” Participant G

Theme 3: Valuing the environment as a driver to engage in biosecurity

A “good environment” was identified as one of the most important drivers of biosecurity in consensus discussions and an indicator of good practice. For example, some biosecurity practices were seen as fulfilling an environmental responsibility:

“I suppose the strengths are that if you’ve disposed of it properly you’ve done your bit for the environment.” Participant F (referring to enforced haul out)

“It’s showing awareness of the environment. We work and live with the environment, it’s important to protect the environment.” Participant D (referring to biosecurity planning)

Environment was clearly considered in a very holistic sense. Participants demonstrated a connection to the ecological environment, particularly within one discussion about the variable environmental impact of chemicals (such as sodium hypochlorite used in the quarantine berth) in different marina scenarios, e.g. closed coast to open coast. However, environment also had a wider meaning, comprising both the ecological environment and the general environment in the marina. One participant identified the importance of this holistic environment to their business through the following statement:

“And whatever they do, whether they just go down and sit and read the paper, put the kettle on, that’s their place. So it is very important to keep the environment right, in all ways, you know noise, everything” Participant D

Customer engagement with the environment, and the link between the environment and biosecurity, was a common topic. Discussion primarily focused on how participants perceived the role of education in leading to effective action. Participants discussed how behavioural

change in their customer base could occur through the sharing of insights and demonstration of direct personal impacts of non-native species. However, there was also recognition that education, although a good starting point, was not always effective. Participants considered that education could not work in isolation, but could potentially lower barriers to behavioural change and reduce the level of enforcement needed:

“[...] if you can bring them with you from an educational point of view it’s the best way to do it. With the legislation coming in the background, just sitting there you have to use it [the legislation].” Participant C

Participants raised examples of where environmental issues have risen to prominence in society, such as the media focus on marine litter, and highlighted these as examples of where individual behaviour change has occurred:

“If you just look at plastics in the environment at the moment, with the micro plastics and the microbeads. That has exploded, purely because of Facebook and the whole social media platform that it’s on. It is phenomenal.” Participant I

This suggests that participants are aware of the need to change the societal context surrounding an issue in order to drive behavioural change.

4. Discussion

This study identified drivers and barriers to implementing biosecurity within the commercial marina sector by engaging with marina operators and exploring their perceptions of biosecurity interventions. The three overarching themes arising from focus groups were the impact of adopting biosecurity on marina businesses, the efficacy of biosecurity tools, and valuing the environment as a driver of behavioural change in the marina sector. Financial cost was consistently put forward as the key weakness or barrier to the implementation of biosecurity interventions while compliance with good practice and the maintenance of a good environment were seen as the main drivers for implementation of biosecurity measures. The findings of this study demonstrate a range of perceptions about biosecurity in the marina sector that both conform and contradict with findings in other sectors that practise biosecurity on a voluntary basis.

Resources, financial and other, were a core cross-cutting theme across all discussions, with high resource cost referred to exclusively as a weakness or barrier for implementing biosecurity. The focus on resource cost suggests the marina sector conforms to the low-cost hypothesis of environmental behaviour, where the investment of resource into environmental behaviours occurs primarily in scenarios associated with low resource cost [43]. Unsurprisingly, financial resources were a constant theme across all discussions. Similar to previous studies across wider stakeholder networks, it was often considered in relation to the perceived effectiveness of interventions [44]. Where marina operators perceived the intervention to be effective, investment of financial resource was considered as more worthwhile, preventing potential costly management or eradication procedures. Resource investment in biosecurity is also likely to be influenced by current economic conditions in the sector. Both the UK and Ireland have faced economic downturns in the past decade with associated drops in disposable income [45,46]. As a consequence, the significant cost of recreational boating has led to an aging customer base with fewer new, younger customers and downsizing of vessels and berths [47,48]. Voluntary uptake of costly biosecurity interventions without external financial support is likely to be minimal while the industry faces these economic challenges. However, the resource cost of biosecurity should not be considered in isolation, as economically rational decisions are likely to be heavily linked with, and

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confounded by, social and behavioural drivers, such as reputation and accepted normal practises [49,50].

This study has revealed that marina operators place a high level of importance on perceived effectiveness when considering biosecurity interventions, suggesting that voluntary investment of resource is likely to be aligned with the perceived effectiveness of an intervention. Those interventions that were easy to evidence through visible effects, such as killing organisms often had effectiveness assumed, where as those interventions that were more preventative, such as raising biosecurity awareness and risk assessments were less associated with effectiveness. Previous research has also demonstrated that practitioners require accessible and well-communicated evidence of effectiveness, in order to move away from experience-based conservation decisions and adopt evidence-based interventions [51,52]. Unfortunately, the preventative nature of many aspects of biosecurity means that it is almost impossible to evidence the effectiveness of actions in clear and tangible terms, such as direct measures of percent mortality. Furthermore, biosecurity primarily operates on a precautionary principle, where the impact of a potential incursion is relatively unknown, yet a small percentage of incursions could result in serious ecological and economic impacts [53]. As such, highlighting those case studies that demonstrate clear ecological and economic costs of non-native species incursions to marina businesses, such as the introduction and attempted eradication of *Didemnum vexillum* at Holyhead Marina [7], combined with a clear outline of the mechanisms by which the intervention lowers the risk of non-native species may increase the perceived effectiveness and uptake of biosecurity.

The results from the workshop revealed the importance of incorporating biosecurity into normal practice in the marina sector, yet also identified major barriers to moving past the perception of biosecurity as an additional burden. Although participants identified biosecurity as good practice, it was clear that managing biosecurity issues was perceived as above and beyond normal marina operations. The importance of leadership and pioneering change was mentioned, but the majority of participants were concerned about the reputational damage and loss of business that could occur if individual marinas, rather than the entire sector, adopted more rigorous biosecurity practices. Interventions that place additional burdens on the customers or marina staff pose a threat to reputation if not introduced universally across the sector and, as such, are unlikely to be adopted in a voluntary scenario. Within the agricultural sector, greater knowledge of biosecurity by the individual decision makers has been shown to be a stronger driver of the adoption of biosecurity practices than economic factors [40,50]. Increasing knowledge and understanding of non-native species could also increase voluntary uptake because it may generate approval from within the sector or from customers [54,55]. As such, generating greater non-native species and biosecurity awareness in marina operators could be crucial for integrating biosecurity into normal practices. Although some marina operators are aware of tools to improve knowledge, the discussions in the workshop highlighted issues with accessibility and the level of expertise needed to implement effective biosecurity. More conscious and proactive engagement of marina operators by researchers during non-native species research and biosecurity tool development could be one potential avenue of increasing knowledge and awareness within the sector, especially as research within marinas is relatively common around the UK and Ireland.

Bottom up or top down drivers may stimulate behavioural change across the marina sector and disrupt established normal practices [49]. Bottom up drivers that may lead to greater adoption of biosecurity measures could include the increased biosecurity awareness of customers. Our data suggests marina operators perceive the value of the environment to customers and marina businesses could have a role in breaking down barriers to biosecurity. However, the role of

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652 raising awareness of the threat of non-native species as a method for biosecurity was a
653 contentious point. Firstly, workshop participants expressed scepticism in the effectiveness of
654 traditional biosecurity awareness raising initiatives among their customers. Indeed, this is
655 supported by evidence from New Zealand where, despite a much greater national awareness
656 and emphasis on biosecurity than in the UK and Republic of Ireland, many marine users were
657 unclear on biosecurity messages they had been exposed to through education campaigns [33].
658 Workshop participants also highlighted a concern that awareness raising initiatives may risk
659 reputational damage to individual marinas. This suggests biosecurity messages need to be
660 framed carefully and delivered using neutral sources. Currently, biosecurity messages are
661 framed primarily around potential negative impact and fear [56]. Limited evidence from the
662 freshwater boating community has shown negative messaging framed around regulatory
663 penalties can affect intended biosecurity practices more than messages associated with
664 normative behaviour [57]. Yet it is unknown what impact positive messaging could have on
665 the adoption of biosecurity practices. Evidence from communicating climate change messages
666 suggests shifting discourse towards that which outlines the positive changes for the individual
667 associated with biosecurity actions may be more effective [58]. Developing more effective
668 strategies for communicating conservation science, such as biosecurity, is a growing field of
669 research and follows increasing acknowledgement that changing environmentally damaging
670 behaviours is highly dependent on environmental literacy [59]. Future research should aim to
671 identify how to use effective science communication strategies to communicate biosecurity
672 messages and increase non-native species awareness without compromising marinas'
673 reputations.
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676 Marina operators also identified the need for top down drivers provided by clear and
677 coordinated legislation and guidance from authorities. Over recent years there has been an
678 increased regulatory focus on biosecurity. At an international level, the full implementation of
679 the EU regulations on invasive alien species occurs in 2021 [38], suggests more biosecurity
680 regulations are likely to filter down to the day-to-day operations of marinas and ports over
681 coming years. Our findings support the premise that environmental regulations should match
682 the needs of the local stakeholders and regulatory action should empower managers to make
683 decisions that are able to take into account local context [60]. For example, discussions during
684 the workshop about the ease of implementing biosecurity often focused on local issues, such
685 as space to install infrastructure. Effective environmental regulation can also be achieved
686 through empowering stakeholders to influence policy, providing expectations are managed and
687 suitable frameworks are in place [61]. One method of empowering marina operators would be
688 through the development of stakeholder groups, a method that is viewed as effective for
689 communication and consultation [44]. Although our workshop attracted only a proportion of
690 marina operators in the study region, their attendance and active participation in discussions
691 demonstrates willingness within the sector to engage with the issue. Recent developments in
692 marine biosecurity planning in the UK has focussed on developing regional plans in
693 consultation with local stakeholders (e.g. Solway Firth Partnership 2018). This regional
694 approach may address concerns about overall impact of biosecurity measures in the wider
695 coastal usage environment, alongside empowering marina operators to input into local and
696 regional policy.
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699 By using qualitative techniques, this study has moved beyond assessing current practices or
700 attitudes to biosecurity, and takes a step towards understanding motivations that could increase
701 the uptake of biosecurity measures. We recommend that developers of biosecurity
702 interventions should consider the potential impact of the intervention on marina businesses
703 from an early stage in the research process. By giving consideration to the potential motivations
704 for marinas to adopt interventions, and ensuring intervention efficacy is well evidenced,
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appropriately communicated and can integrate with current operations, innovative interventions are more likely to move beyond the science community and be adopted by industry. Furthermore, by focusing on effective dialogue with marina operators, researchers may help to streamline the pathway between the research and development of biosecurity interventions and their implementation within the marina sector, where these interventions could make a real impact on limiting the spread of non-native species.

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Intervention	Current status	Description	Reference
In-water quarantine berth	Prototype tested	A quarantine berth is an in-water encapsulation system. It allows hull fouling to be treated in water without the need for vessel haul out. In order to speed up treatment, a chemical (acetic acid or sodium hypochlorite) is added into the berth. The total time to drive the vessel in, treat it and drive out would be approximately an hour	[20]
Rotating pontoon floats	Prototype built	Pontoons are installed with cylindrical float that is operated on an axel system. The float is turned every one to two weeks, either manually, or through an automated system. The fouling on the part of the float out of the water is killed.	[63]
Closed loop wash down system	Systems commercially available and utilised.	A system that collects the water & biofouling from the wash down procedure and removes the particulates, such as paint flecks and biofouling. There are a number of systems that range in cost from £10,000 - £30,000. The systems normally come into 2 parts – a mat or lagoon that collects the runoff from the wash and a filtration system that cleans the water before discharge into drains or for reuse in other washings.	[64]
Promoting native species	In early development stage	A number of techniques can be used to promote native species and reduce non-natives by between 28-90%. These include: building with special concrete (e.g. EConcrete); reducing shading by adding light-penetrating features (e.g. metal grills in walkways etc.) reduces non-native species dominance through promoting native seaweed; “pre-seeding” structures with native fouling species; increasing native predator abundance by increasing connectivity to the seabed.	[34]
Risk assessment	Established practice across sectors	<p>As vessels arrive in the marina, they are assessed by marina staff on their risk of introducing non-native species. This risk assessment includes things such as:</p> <ul style="list-style-type: none"> ➤ Port of last call ➤ Anti-fouling regime ➤ Long stationary periods ➤ Obvious fouling <p>If they are designated as high risk, a number of actions could be taken, including: moving vessels that are stationary for long periods or which are from high risk areas to areas of the marina with freshwater inflow; or encouraging heavily fouled vessels to get a wash down / include biosecurity information in communications with vessel owners.</p>	[11,28]
Enforced haul-out	In practise as described in New Zealand, however, restricted to certain arrival ports	Vessels without an acceptable standard of hull maintenance or that are deemed to be too heavily fouled (more than a slime layer on the hull) have to be hauled out and cleaned within 24 hours of arrival into the country. The vessel owner pays for the haul out and cleaning.	[65]

Promoting biosecurity awareness	Voluntary practise in the marina sector in Wales and RoI although region specific materials are readily available online. More commonly promoted by NGOs and user groups rather than marinas themselves currently	Marina staff promote biosecurity awareness through materials such as “Check, Clean, Dry” posters and materials, berth holders’ communications etc.	[66]
In-water hull cleaning	Subject of debate in biosecurity aware countries, such as New Zealand. Illegal in Wales but not enforced.	Promotion of in-water cleaning for lightly fouled vessels on a regular (i.e. monthly) basis. In-water cleaning is promoted by the provision of in-water cleaning tools.	[67]

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2 Table 1: Example biosecurity interventions used in workshop

Theme	Impacts of biosecurity adoption on a marina business	Efficacy of biosecurity interventions	Valuing the environment as a driver to engage in biosecurity
Sub-themes	Intervention requires resource investment (time, money and information)	Does the intervention actually reduce the risk of non-native species?	No sub-themes
	Intervention can have an impact on how customers and peers within the sector perceive and interact with the marina.	Is the intervention easy to implement alongside normal operations?	

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4 Table 2: Themes and subthemes drawn from the data.

Intervention	Strengths	Weaknesses
In-water quarantine berth	<ul style="list-style-type: none"> Cheaper option than hauling out the vessel and scrubbing. Viewed as a successful biosecurity intervention. A resource that could be shared amongst multiple marinas if portable. 	<ul style="list-style-type: none"> Would require risk assessment and decisions of vessels requiring treatment. Takes up a berth while in operation or space if in storage. Does not provide the additional benefit of removing fouling – vessels would still need a scrub after treatment.
Rotating pontoon floats	<ul style="list-style-type: none"> Easier than scraping floats to rid them of fouling. Could potentially be more stable than traditional pontoon floats. 	<ul style="list-style-type: none"> Design may not be compatible with rough seas. Expensive to install, especially to retrofit into existing marina. Viewed as ineffective at controlling non-native species spread.
Closed loop wash down system	<ul style="list-style-type: none"> Effective biosecurity intervention and also good for the environment. 	<ul style="list-style-type: none"> Cost of the system . Restrictions on land and the installation of a system.
Promoting native species	<ul style="list-style-type: none"> Potentially cheap method. Some of the suggested strategies could have secondary benefits, such as installation of light penetrating grilling would provide more grip while walking. 	<ul style="list-style-type: none"> Very experimental with many unknowns at the moment. Marina environments do not wish to encourage growth of any marine life.
Risk assessment	<ul style="list-style-type: none"> Relatively easy to implement and easy to make proportionate to each marinas situation. 	<ul style="list-style-type: none"> Requires training to implement and would be relatively subjective depending on assessor. Appropriate procedures and guidance need to be in place to deal with high risk vessels.
Enforced haul out	<ul style="list-style-type: none"> Viewed as an effective biosecurity measure that can contribute to the overall goal of having a clean marina. 	<ul style="list-style-type: none"> Subjective approach that would have to be supported by legislation. Likely to have negative impacts on customer relations . Resource constraints such as the cost of disposal of waste and the land to install a system.
Promoting biosecurity awareness	<ul style="list-style-type: none"> Low cost intervention that requires minimal effort. Could help overcome barriers to other biosecurity intervention. Raises awareness with both staff and customers. 	<ul style="list-style-type: none"> Not viewed as an effective biosecurity measure. Potential for the raised profile of non-native species to cause reputational damage with knock on impacts for business.
In-water cleaning	<ul style="list-style-type: none"> Cheap method that may promote customer engagement with biosecurity. Would help as part of a routine maintenance regime. 	<ul style="list-style-type: none"> Physical ability and available time to regularly visit vessels would restrict the uptake of the intervention. Viewed as an ineffective biosecurity practise as the waste remains in the water.

5 Table 3: Summary of the strengths and weaknesses of example biosecurity interventions emerging from marina operators' discussions.

Author statement: Siobhan Vye: Conceptualization, Methodology, Formal Analysis, Writing – Original Draft, Writing – Reviewing and Editing. Sophie Wynne-Jones: Methodology, Formal Analysis, Writing – Reviewing and Editing. Patricia Masterson-Algar: Formal Analysis, Writing – Reviewing and Editing. Stuart Jenkins: Conceptualization, Methodology, Formal Analysis, Writing – Reviewing and Editing, Funding Acquisition.