



Full length article

Getting on board with biosecurity: Evaluating the effectiveness of marine invasive alien species biosecurity policy for England and Wales

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ABSTRACT

Marine Invasive Alien Species (IAS) can have devastating impacts on the environment, infrastructure and human well-being. Prevention measures, such as biosecurity, are essential to reducing the introduction and spread of IAS and are central to international and national IAS policy. Understanding the motivations of stakeholders can help determine the effectiveness of existing policy instruments on behaviour. 14 semi-structured interviews were conducted between two case study stakeholder groups in England and Wales (marine shellfish aquaculture industry and the recreational boating sector) in early 2018. Biosecurity practices were deeply embedded in the heavily regulated practices to control shellfish disease within the shellfish industry. Motivations to undertake biosecurity were driven by economic incentives, and penalties for non-compliance with legislation controlling disease. In contrast, there are little regulatory policy instruments to drive IAS biosecurity within the recreational boating sector, which instead relies heavily on voluntary instruments to motivate stakeholders and encourage behavioural changes. Behavioural changes, however, were restricted by lack of infrastructure and enforcement. Our findings suggest it is important to use a combination of approaches to achieve behavioural changes but recognising where regulations and penalties cannot be enforced, voluntary instruments are likely to be most effective. Existing social norms and investment into infrastructure should 'nudge' individuals into socially desirable behaviours, especially in the recreational boating sector. For policy makers and regulators, this research reveals the importance of tailoring biosecurity strategies to different stakeholder groups as motivations and collective experience differ.

1. Introduction

Invasive Alien Species (IAS) are species that have been moved into new areas outside of their natural range by human activities (intentionally or unintentionally), and have negative ecological, economic or social impacts [1]. According to the Convention on Biological Diversity (CBD), IAS are considered to be one of the main drivers of biodiversity loss globally [2]. In the European Union (EU), IAS are estimated to cost approximately €12.5 billion a year [3], and the cost to UK and Ireland is £2 billion a year [4]. Negative impacts of IAS in the marine environment include ecosystem change, biodiversity loss, disease introduction, restricting navigation, clogging propellers and smothering aquaculture stock ([5–7]). It has been estimated that the direct cost of IAS to marine industries in Great Britain is approximately £40 million per year [5].

Marine IAS have been introduced into the UK intentionally and unintentionally. For example, *Ruditapes philippinarum* (manila clam) was introduced into England in the 1980s for aquaculture and by 2010 the species had spread along the southern coast of England [8]. Similarly, *Magallana gigas* (Pacific oyster) was introduced into England in 1960 to counteract the decline of the native oyster and improve the oyster industry [9]. However, since its deliberate introduction, wild settlements of Pacific oysters can be found around much of the UK [10]. In contrast, some IAS are introduced unintentionally. For example *Sargassum muticum* (invasive wireweed) was accidentally introduced with the commercial oysters trade (either attached to boats or attached to shellfish) and has had negative environmental and economic impacts through fouling oyster beds and fishing gear, as a nuisance in harbours and control costs [5,11]. Boats and ships may also accidentally

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introduce/spread IAS via ballast water or as fouling (i.e. attached to hulls, anchor chains and other parts of the vessel), with fouling being the more relevant pathway for the recreational boating sector. Hull fouling is the most likely pathways for the unintentional introduction of the IAS *Didemnum vexillum* (carpet sea squirt) into England and Wales [12]. *D. vexillum* can grow and smother native reef habitats and cost mussel farming in Great Britain between £1.3 and £6.8 million due to cleaning costs to vessels and equipment [5,13].

Preventing the introduction and spread of marine IAS is recognised by the CBD as one of the most cost-effective and efficient methods in combating IAS. Prevention can occur at different stages in the introduction process, such as pre-movement, at borders, or post movement [1,14]. Biosecurity is a key component of pathway management [15]. Biosecurity includes measures that aim to prevent the accidental introduction and secondary spread of IAS. Implementation of biosecurity requires changes in human behaviour to apply good practices hygiene practices that aim to reduce the risk of fragments being moved from one place to another. This study is the first evaluation of the effectiveness of existing biosecurity policies in relation to the biosecurity behaviour of stakeholders in the marine environment in England and Wales.

Changing behaviour depends on a combination of interventions (e.g. education, training, policy instruments, and incentives) which aim to increase perceived behavioural control and intention to behave [16,17,63]. Interventions attempt to increase knowledge and awareness around particular issues and create positive attitudes towards management. Policy instruments are interventions that attempt to change behaviour through establishing rules or principles through implementing laws or voluntary agreements. There are a number of laws and regulations in place to manage the introduction and spread of IAS in England and Wales. For example, the EU IAS Regulation 1143/2014 and more recent national legislation such as the Invasive Alien Species (Enforcement and Permitting) Order 2019, which aim to restrict the import, keeping, transport, release, reproduction and sale of high risk IAS. (Table 1). Since policy instruments attempt to change behaviour, understanding stakeholders' knowledge and attitudes towards IAS and policy instruments and the motivations to change behaviours is critical to successful policy planning and implementation (Table 1). A better understanding of stakeholders' knowledge, attitudes and motivations have aided and supported the creation of effective IAS policy campaigns and strategies [18–20]. Stakeholders may be motivated by the policy instruments themselves or by other human dimensions such as their beliefs, values, economic incentives, social pressures [20,21].

Table 1
Relevant marine legislation for England and Wales.

Scale	Document
International convention	The Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) 1982
	The Convention on Biological Diversity (CBD) 1992
	Ballast Water Management Convention (BWM) 2017
European legislation	Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (Habitat Directive)
	Water Framework Directive (WFD) 2000/60/EC
	Marine Strategy Framework Directive (MSFD) 2008/56/EC
	Council Regulation (EC) No. 708/2007 concerning the use of alien and locally absent species in aquaculture
National legislation	Regulation (EU) No 1143/2014 on the prevention and management of the introduction and spread of IAS
	The Wildlife and Countryside Act 1981
	The Conservation of Offshore Marine Habitats and Species Regulations 2017
	The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017
	Marine Strategy Regulations 2010
	The Alien and Locally Absent Species in Aquaculture (England and Wales) Regulations 2011
	The Invasive Alien Species (Enforcement and Permitting) Order 2019

Knowledge is often seen as key to changing behaviour; if an individual does not know the impacts of their actions then they cannot be expected to change their behaviour. In the case of IAS, Eiswerth et al. [22] found that knowledge (or awareness) of IAS was an important antecedent to participation in biosecurity behaviours to reduce IAS introduction/spread. Similarly, Seekamp et al. [23] found that knowledge/awareness of IAS was significantly related to up-take of prevention behaviours. However, Schultz [24] argues that it is not knowledge alone that provides a motive for behaviour, but instead, a lack of knowledge is a barrier to behaviour and other factors are responsible for direct changes in behaviour e.g. legal requirements or incentives. Attitudes are often linked to knowledge/awareness as it is assumed that as an individual becomes more knowledgeable on an issue, their attitude will become more positive and thus in turn they will become more motivated to act toward the environment in more responsible ways [25–27]. Here we explore stakeholders' awareness in the marine environment of biosecurity policy to slow the spread of IAS and disease.

According to Ajzen's Theory of Planned Behaviour, attitudes toward behaviour, subjective norms and perceived behavioural control shape an individual's behavioural intentions and behaviours, 1991 [63]. There is an increasing body of research exploring and evaluating public attitudes towards and support for IAS management (including prevention). For example, Humair et al. [28] found the attitude of horticulturalist's towards IAS regulations was supportive, which in turn lead to participants reporting they were also willing to engage in various voluntary actions to mitigate risks from trade in ornamentals. Similarly, Wald et al. [29] found increased public awareness of IAS management lead to public support for conservation action. On the other hand, despite high levels of awareness of regulations and supportive attitudes among horticultural industry managers, Cronin et al. [17] found that actual compliance with the regulations was low and many nurseries were stocking regulated IAS. Attitudes are affected by numerous determinants, such as trust, communication, enforcement and experience [17,29].

The motivations to change in an individual's behaviour is another key component [30,63]. Social norms are predominant behavioural patterns within a group that are supported by a shared understanding of acceptable actions, sustained through social interactions [31]. Social norms rest on the assumption that people want to fit in with what most people do and what 'should be done' [30,32]. For example, within the plant and animal farming sector, Mankad [33] found that social norms were a strong predictor of biosecurity engagement as individual were more likely to undertake biosecurity when they perceived a social consequence. Social norms may also play an important role within the marine environment where different groups/activities may have shared norms that influence behaviour [33]. Other key motivators may include monetary or legal incentives.

Understanding knowledge and attitudes of IAS policy instruments and motivations to undertake biosecurity among stakeholders can help determine the effectiveness of policy instruments and the most appropriate measures to encourage up-take [33,34]. Since the implementation of IAS regulatory and voluntary instruments, there has been no evaluation on the efficacy and effectiveness of these instruments in relation to biosecurity behaviours of stakeholders in the UK marine environment. Further understanding what influences an individual's motives to undertake (or not undertake) biosecurity measures may help to better inform the future management of marine IAS and encourage up-take in key areas. Using two marine case studies in England and Wales (the shellfish industry and the recreational boating sector) the current study determines the effectiveness of existing (at time of interviewing) policy and policy instruments on behaviours within the marine environment using semi-structured interviews [35]. The study has two goals: (1) to reveal motivations for undertaking biosecurity and understand whether this is as a result of policy instruments or other factors (2) to understand what extent the current behaviours of stakeholders are achieving the goals of good biosecurity practice.

2. Methodology

2.1. Study area

This study focuses on England and Wales only as they are covered by the same policy framework and excludes Northern Ireland and Scotland which are covered by different policies dealing with marine IAS.

2.2. Sampling

We applied mixed methods to stakeholder identification; predefined categories and snowball sampling. First, predefined categories were used to focus the stakeholder identification process to the research aim and allow a representative sample to be identified. The predefined categories included: local councils, regulators, marine governing bodies, initiatives/campaign organisers, scientific research, conservation body/authority and industry (owners and managers). These categories were applied to both case studies.

The research team searched existing policy and policy instruments for names and organisations of relevance. If no name was given but an organisation was, the researchers used an online search to identify relevant individuals. Participants within organisations were identified by their job description as those that had an interest in biosecurity due to their role [36]. In addition to the policy document and online search, the research team (which includes regulators and academics) used their own knowledge and existing contacts in this field to identify organisations and individuals that would be affected by or have an interest in biosecurity.

We aimed to identify and approach at least one organisation/individual in each category. All individuals from the initial stakeholder identification (identified participants $n = 25$) were invited by e-mail to take part (Table 2). Those that accepted were sent an information sheet about the project one week prior to interview and were also given the opportunity to read this again before the interview began. The information sheet provided a background to the study and sector specific text in relation to IAS (A1). Informed consent was obtained on the day of interview and the study satisfied the University of Leeds' guidelines on ethical conduct (Ethics reference AREA 14–121) with regards to anonymity and confidentiality for research participants.

After each interview was complete, participants were asked to identify any contacts that they considered relevant to the study (snowball sampling) (snowball sampling increased the total of identified participants to $n = 30$). This, in combination with the original list developed by the researchers, was used to identify further respondents

Table 2
Identified and final interview participants according to pre-defined categories.

	Recreational Boating Sector		Shellfish Industry	
	Identified participants ($n = 16$)	Final interview participants ($n = 8$)	Identified participants ($n = 14$)	Final interview participants ($n = 6$)
Local Council	3	1	2	
Regulators	1	1	2	1
Governing bodies	2	2	1	1
Initiatives/campaign organisers	2	1	1	
Scientific research	2	1	1	
Conservation body/authority	2	1	2	1
Industry (owners and managers)	4	1	5	3

and reduce bias in stakeholder identification. Interviews continued until a saturation point was reached where no new participants were identified and all approached participants had either been interviewed or had declined [37,38].

2.3. Interview process

We applied a qualitative approach to data collection and data analysis, which allows for a deeper evaluation of the drivers and motivations of stakeholders, and the effectiveness of biosecurity policy implementation in the marine environment. We devised a semi-structured interview topic guide, using standardised open-ended questions. The topic guide allowed the interviewer to guide the discussion and remained sensitive to the fact that participants' initial understandings and opinions may change as the interview progresses [35]. The first topic explored was the participant's activities undertaken in the marine environment allowing the participants to draw on experience of IAS and biosecurity practices; this topic was covered first to enable respondents to identify actual biosecurity practices without being influenced by the content of subsequent topics. The second topic related to knowledge (or awareness) of policy and policy instruments related to the marine environment and IAS, in addition to their attitudes toward policy and policy instruments. The third topic related to motivations for carrying out biosecurity and attitudes/feelings towards biosecurity advice/behaviour and if there were any consequences to not undertaking biosecurity. If suggestions/probes/prompts were needed to encourage the participant to speak about the topic, the same suggestions were used consistently with each participant to allow for greater comparability between interviews.

Following pilot testing of the interview questions, a total of 14 semi-structured interviews were conducted between March and May 2018 with stakeholders from the recreational boating sector ($n = 8$) and stakeholders within the marine shellfish industry ($n = 6$). All interviews were conducted and transcribed by the lead author. Conversations ranged from 45 min to 1 h and were audio recorded for transcription.

2.4. Data analysis

This study implemented a constant comparative method following a Straussian grounded theory approach [39] for data analysis. After the interviews were transcribed, the researcher examined the transcripts in depth and line by line using an open coding method which involved generation of descriptive labels in which text fragments received one or more labels which covered the content as well as possible concepts in order to elaborate a deeper understanding of the text [40]. Annotations and concepts (codes) were applied to single words and short sentences to identify events, incidents, ideas, actions, perceptions, similarities, differences and interactions of relevance (in vivo codes) [40,41]. In grounded theory, coding is used to help compare data set to data set, which in this case was the comparison of interview to interview.

Similar codes were retrieved and grouped into broad categories. These categories were: policy, conflicts, action and motivation. This process moved from describing the data to interpretation. Axial coding was then used to establish linkages between categories, some predetermined from the literature review with others emerging from the data [40,42]. Constant comparative analysis was applied until theoretical saturation was reached and no new codes, concepts or categories emerged from the data.

3. Results

3.1. Motivational factor: Policy instruments

Participants from the shellfish industry agreed that their activities were heavily regulated. Regulations for disease control were strictly enforced and so this affected biosecurity more than regulations for IAS.

Participants in the shellfish industry gave examples of the Aquatic Animal Health (England and Wales) Regulation (2009) and the Alien and Locally Absent Species in Aquaculture (England and Wales) Regulation (2011) as being particularly important determinants of behaviour within the industry. These regulations were used to regulate their activities and promote biosecurity behaviour to prevent the accidental escape of IAS or introduction and spread of disease in aquaculture. The shellfish industry is required under the Aquatic Animal Health Regulations (2009) to implement a biosecurity measures plan to prevent disease spread. The Shellfish Biosecurity Measures Plan has been provided by the regulators (Cefas) to help businesses identify biosecurity measures applicable to their individual site. Participants were motivated to follow the regulatory advice because the consequences of a disease outbreak would include economic damage, reputational damage and loss of business.

In contrast, participants from the recreational boating sector recognised that there was no direct regulation related to their activities including any that were related to IAS and biosecurity. Any regulatory instruments that did exist were only selective for certain boats and activities rather than for the whole sector (e.g. ballast water guidelines for commercial shipping). Nonetheless, they were aware of regulations such as the EU IAS Regulation (1143/2014) and the Marine Strategy Framework Directive (MSFD) (2008). It was recognised that these existing regulatory instruments were not specific to recreational boating activities, therefore motivation to undertake biosecurity was not in response to regulatory instruments.

Voluntary instruments to manage IAS were used by both case study groups. Some regions had created local voluntary biosecurity plans for stakeholders to address the issues of IAS in the marine environment. These plans promoted biosecurity measures aimed at preventing the introduction and spread of IAS for both the shellfish industry and the recreational boating sector. Plans highlighted the need for prevention and rapid response to IAS and disease in the marine environment and attempt to encourage a coordinated approach to management.

Where regional biosecurity plans exist, participants from the shellfish industry were aware of the plans as many had taken part in the creation process. Those participants expressed that they were happy to work alongside regulators and other stakeholders to produce regional and local voluntary advice for IAS biosecurity, mostly in an attempt to avoid further regulations for the industry. In addition to this, participants believed that there were additional benefits to being involved in the process. These participants expressed that involvement 'looked good' for their business and there was potential to build a good rapport with the regulators.

Participant 10: We're quite happy to work with X and X... Plus we want them to be on our side and it usually looks good when we work with them! We are the ones that know the business the best!

These regional voluntary plans for IAS and disease biosecurity centre on the *Check Clean Dry* campaign. The *Check Clean Dry* routine was considered to be a normal routine in the shellfish industry. Therefore, all participants were supportive of the campaign, as they believed the advice was simple to implement and they considered it to be no different to activities they carried out in response to regulatory measures for disease. Some participants also considered the advice to be 'common sense'.

Participant 10: We do that anyway! And that was how we shaped the advice. What I needed to do with the advice was make sure it was already done anyway and there was no stupid nonsense.

Due to a lack of regulatory instruments for recreational boating, there was a reliance on voluntary instruments to address biosecurity and IAS. Participants in this sector were also aware of regional biosecurity plans (where regional plans existed) and were also aware of the *Check Clean Dry* campaign and voluntary policy instruments such as the EU

code of conduct on recreational boating and IAS (2016). Because recreational boating is recognised as a possible vector for the accidental spread of IAS, the code of conduct was designed to provide voluntary best practice guidelines to the industry to reduce the risk of spread. However, although the code of conduct was implemented in 2016, alongside regional biosecurity plans, participants were unsure whether voluntary guidance was actually effective because of issues with practicality and economic barriers.

Nonetheless, similar to the shellfish industry, participants from the recreational boating sector were motivated to support these voluntary instruments because they wanted to avoid further regulation. However, there was a general consensus among participants that the boating sector would be too difficult to regulate as no individual could be made accountable for an introduction of IAS.

3.2. Other motivational factors

A range of other factors that affected people's motivations emerged from analysis including practicality, experience, responsibility and reputation, economic factors, conflicting advice and social norms.

3.2.1. Practicality

Practicality was described by participants as having the right infrastructure in place to carry out biosecurity practices as well as adequate enforcement to check uptake and practice.

There were no practicality issues identified within the shellfish industry. Much of the infrastructure to implement biosecurity for IAS (e.g. facilities to check, clean and dry equipment) was already in place due to existing procedures for shellfish disease control requirements.

However, in the recreational boating sector participants felt that there was a lack of infrastructure to clean boats, as well as issues with enforcement. Whilst participants were supportive of the aims of the *Check Clean Dry* campaign, they felt that in reality there would be few individuals actually cleaning boats because of a lack of infrastructure. In addition, the advice from the campaign was considered impractical for certain boat types as some cannot be removed from the water to clean easily. Nonetheless, where advice focussed on being as practical as possible and promoted checking and drying boats, this was recognised as something some boaters already did.

Participant 1: They haven't said they won't, but they have said it is impractical. So, we have emphasised that one of the most important things to do is to dry your boat out, which they can do and they do anyway, leave it at least a couple of weeks before you use it.

In addition to infrastructure and practicality acting as barriers to uptake of biosecurity, participants argued that the only time any cleaning measures would actually be applied was either when participants wanted to maintain their boat or if it was a requirement of a site/organisation where enforcement could be applied (e.g. during competitions or in certain high-risk areas with existing byelaws and wash down sites). However, consistent enforcement was considered to be too difficult, as without regulation, there was currently no defined penalties (at the time of interview). Therefore, any enforcement was impractical.

Participant 5: Once you put a marine biosecurity procedure in place, someone should be in charge of it. But you still can't force the people using the marina to play by the rules. The marina can only give the message across and do the best they can with biosecurity, but they can't punish, or enforce anything on the individual boat owner.

The final practicality issue with biosecurity for recreational boaters was due to the nature of recreational boating, many boaters did not use the same site daily, and many used multiple locations and sites in a day or a week. Therefore, the practicality of cleaning and enforcing cleaning was considered to be even more difficult.

3.2.2. Experience

Experience was an important motivation to undertake biosecurity measures within the shellfish industry. The small size of the industry and the close networks of members meant that experience of previous outbreaks was often shared. Participants gave examples of previous IAS introductions, not just on their own farms, but on farms close by; including *Sargassum muticum* (invasive wireweed), *Corella eumyota* (orange-tipped sea squirt), and *Didemnum vexillum* (carpet sea squirt). These events increased perceptions of risk and motivated individuals to undertake biosecurity practices.

In contrast to the shellfish industry, there was a lack of experience and limited examples of IAS events directly impacting the recreational boating sector. Whilst participants gave examples of IAS that could potentially pose a threat to the marine environment, many participants could not give examples of the impact they had on recreational boating in England and Wales and there were no known recent introductions. A lack of experience (and evidence) acted as a disincentive to behaviour change.

Participant 2: It is so difficult isn't it? When you have got litter, you can see it as an issue. But it is so difficult to explain invasive species as an issue when you can't see it and when there is no evidence. And the examples have to be in this country as well. You can show examples of Didemnum vexillum in New Zealand but... it's not relevant.

Participants recognised that due to this lack of experience, any practice was likely to be reactive in response to an outbreak rather than preventative in terms of biosecurity.

3.2.3. Responsibility and reputation

Participants within the shellfish industry were motivated to undertake biosecurity as they felt a sense of responsibility to neighbouring farms. The small size and connectedness of the industry meant events (such as the introduction and spread of disease or IAS) could be traced. Therefore, it was considered to be a community issue if there was an outbreak. If there was an issue with one farm, then there was potential for other farms to be affected. Therefore, each farm had a responsibility to neighbouring farms to practice good biosecurity.

Participant 9: Yes, for me it is common sense but if anything goes wrong you are the one responsible for it. Which in this industry that is the main thing. If there is someone to blame, then they will look for that.

Participants also indicated that there was an element of commercial reputation motivating them to undertake biosecurity, as participants within the shellfish industry recognised that to help sell their products, they needed to be seen to employ best practice.

Participant 9: Well ... We want to be setting the standard in the industry rather than following suit. We have got quite a bit of money behind us now, and we want to be the industry leaders and used as an example.

Similarly, some organisations within the recreational boating sector were also motivated to promote biosecurity to improve their reputation, and believed they were responsible as an organisation to be seen to be doing so. Some larger boating organisations recognised that they had a responsibility to address environmental issues such as plastics, sustainability, and IAS. Promoting awareness of a range of environmental issues together was the usual approach used by individual organisations, as many believed IAS alone would not be treated as a priority issue. Regulatory and member-based organisations took measures to promote the *Check Clean Dry* campaign and collaborate with smaller organisations to produce guidance documents and management plans focussed on certain boating activities. However, in comparison to the shellfish industry, participants from the recreational boating sector felt there was little individual responsibility to undertake biosecurity.

3.2.4. Economic factors

Motivation to undertake biosecurity in the shellfish industry was keenly driven by economic consequences. Economic consequences included loss of stock, large fines, and the potential for their farm to be shut down. Regulation for disease control motivated good biosecurity practice to avoid economic consequences, however, participants considered the consequences for disease and IAS to be the same. Therefore, motivation for undertaking IAS biosecurity was again a co-benefit of undertaking biosecurity for disease.

However, there were also economic costs to undertaking the 'cleaning' phase of biosecurity in the shellfish industry, for example one farmer discussed:

Participant 9: So we have implemented an EA application, so when we pump out our water... This is ridiculous... We pump the water out of the river, then we wash the shells off with the water. But we have to pay £8000 a year to put it back in!

Nonetheless, the consequences of not following the rules were considered too high and even when there were some economic costs to biosecurity, they were obliged to follow the rules and advice due to regulatory consequences for disease.

In comparison to the shellfish industry, motivation to undertake biosecurity within the recreational boating sector was driven by economic opportunities. In some geographic areas there were funding opportunities for projects, which involved collaboration between local regulatory and non-regulatory organisations. Funding opportunities enabled stakeholders to produce plans, guidance, training materials and run workshops. Economic opportunities were extremely important for encouraging and motivating stakeholders to act on IAS in the marine environment and participants believed that these projects had knock on benefits which included community engagement and awareness raising.

However, whilst economic opportunities (such as funding) were an important factor for motivation, there were issues with the longevity and legacy of these plans once the funding had stopped. It was argued that motivation was only short-term as few projects continued once funding had run out. There were only a few participants that continued to express interest in and 'champion' biosecurity after projects had ended. These individuals stressed how difficult it was to promote biosecurity on top of their existing workload and it would usually come low on their list of priorities. Therefore, after the funding for projects ended, it was considered that the outputs of the projects in fact had no impact on the ground.

Unlike in the shellfish industry, biosecurity could not be enforced through economic consequences such as penalties, fines and bans within the recreational boating sector. Participants raised concerns with enforcing biosecurity at a marina/site as some boaters would be inclined to go elsewhere (to avoid additional effort). Therefore, there were economic consequences to promoting and enforcing biosecurity as the business could lose money.

Participant 2: If you have a boat coming across to a marina, the guidance would say 'check out other boats coming into the arena [marina] and make sure they are not dirty'... Well, what do you tell them? You are not going to say go away because they want the money, and they are coming on holiday for a week, you are not going to say you don't want the fees.

Participants identified financial costs associated with IAS biosecurity implementation. These included the cost of enforcement (as this would require employing someone to check boats as they came in and out) and the cost of investing in infrastructure which was considered expensive, especially when this was not a legal requirement of a site, and also since boaters would be unlikely to use them.

Participant 1: We could possibly have byelaws to enforce it, but enforcement is going to cost money to implement as you have to have people and resources. But if it is going to be taken seriously, then I think you have to do that.

3.2.5. Conflicting advice

In both case studies there was confusion and conflicting voluntary or regulatory advice. Despite IAS biosecurity being a positive result from implementation of disease regulation in the shellfish industry, there was still some confusion around the reasons to implement biosecurity for IAS prevention, especially with some IAS that are used for cultivation. Participants were concerned with who's responsibility it was to deal with accidental escape, in particular, some participants mentioned the accidental escape of the Pacific oyster. Confusion was perpetuated by conflicting information from agencies regulating the sector.

In addition to this, there was some confusion and resentment among shellfish industry participants with recreational boating activities. Participants from the shellfish industry felt that the boating sector was a high risk of introducing/spreading IAS and therefore felt that voluntary measures were not enough.

Participant 12: There is some conflict between aquaculture and recreational boating. Especially around best practice...Look at what we have to do and then look at what the recreational boaters don't have to do.

At the same time, there were issues around unclear and conflicting advice between regulatory and voluntary policy instruments within the recreational boating sector, which seemed to influence motivation to undertake biosecurity practice. For example, some participants were aware of the conflict between voluntary cleaning advice for recreational boating (promoting the *Check Clean Dry* campaign) which encourages individuals to remove visible fragments and the Marine and Coastal Access Act which requires individuals have a licence to deposit any material or substance into the water:

Participant 2: I think it is still relevant, if we can make the cleaning a bit more clear. Because we can't say at the moment "clean your boat" because it is illegal, and we can't say "take your boat out and clean it" as that is just impractical.

3.2.6. Social norms

Due to the small size of the shellfish industry, behaviours had been developed and passed down and across the generations. This created a certain expectation among the industry that individuals would always undertake biosecurity measures as it was seen as normal behaviour.

In contrast, the large size and diffuse nature of the recreational boating sector meant there was no expected standard of behaviour in relation to IAS biosecurity, with any practice usually the decision of the individual rather than the community. Participants from the recreational boating sector suggested that in order to motivate and change behaviours, policy would have to build social norms and nudge individuals to change behaviours.

Participant 3: It goes back to the psychology of nudging, so if you encourage the community to own the place then there is pride and it almost ensures a level of expectation, and then it is the norm.

When asked about barriers to undertaking biosecurity and future opportunities, participants from the recreational boating sector argued that individuals would be motivated to change behaviours if they saw others undertaking biosecurity practices. Therefore, participants would be likely to copy the behaviour of others and they would feel pressure to do so.

Participant 3: Because I think everyone is looking at each other and I think if someone else is doing it then they feel empowered, and they will do it too.

Finally, when discussing how to encourage behaviour change and the uptake of biosecurity practices, participants recognised that changing behaviours would take a long time, just as they have in other areas such as plastics and recycling.

4. Discussion

Our results suggest motivation and intention to undertake biosecurity behaviour was influenced by the combination of factors such as reputation, economic drivers and social compliance in combination with policy instruments. Our work highlights the importance of these factors, which are crucial for improving the effectiveness and acceptance of policy instruments in order to achieve the goals of policy. The marine environment is used by many different sectors and industries and therefore managing these stakeholders is key to implementation of coherent management plans to reduce the impacts of IAS. However, we found that both the shellfish industry and recreational boating sector were subject to different drivers that influenced behaviour.

Firstly, the scale in which the stakeholders operated was an important factor for consideration in the analysis. Stakeholders from the shellfish industry were a mixture of regulators, governing bodies and business owners (farmers were the business owners). On the other hand, stakeholders from the recreational boating sector were mainly made of regulators, governing bodies and authorities; only one participant was a business owner. Therefore, interviewees from industry were speaking with different interests, where shellfish business owners were speaking in the context of their own business, compared to those from the recreational boating sector who focused on the context of the district or council. Whilst these case studies do not directly compare as a result of the composition of interviewees, the two cases are still able to highlight useful differences in motivations for behaviour and reasons for undertaking biosecurity which may illustrate differences in policy implementation success within the two sectors.

The shellfish industry was motivated by existing regulatory instruments used for disease control (e.g. the Aquatic Animal Health Regulations 2009 and the Alien and Locally Absent Species in Aquaculture Regulations 2011). Therefore, biosecurity behaviour within the shellfish industry was as a result of the regulatory instruments that directly targeted disease control. Biosecurity practice for IAS was ultimately a co-benefit from these regulations rather than the voluntary guidelines/plans that were created specifically for IAS. In contrast, there were limited regulatory policy instruments used to influence behaviour in relation to biosecurity in the recreational boating industry which meant that the industry relied heavily on voluntary instruments to encourage biosecurity behaviour change. These instruments were often regionally designed, where stakeholders had come together to produce local/regional biosecurity plans. Policy makers in the EU and UK have increasingly favoured the use of voluntary approaches, as a low cost, more flexible alternative to binding regulations which are often seen as a last resort [43]. However, there is evidence to suggest that voluntary instruments can often be limited and ineffective and participation and behaviour change is low. Voluntary measures assume that increased awareness is followed by concern (i.e. change in attitude), which then increases motivation and adoption of pro-environmental behaviour [44,45]. Floerl et al. [18] found that the uptake of antifouling practice among boaters was poor, despite a heavy reliance on voluntary measures and awareness of the problem. This was because individuals were more likely to change their behaviour when the costs of the behaviours were borne more explicitly by those who practiced them and there was a perceived lack of transparency and accountability [18]. Similarly, our results suggest that whilst awareness of IAS and voluntary policy instruments was high within the recreational boating sector, awareness was not translated into positive attitudes towards the instruments nor changes in behaviour and participants acknowledged that these instruments had little motivational influence. This is important as it relates to Ajzen's Theory of Planned Behaviour, which argues that attitudes are an important factor for shaping an individual's behavioural intentions and behaviour [63]. Other elements from the Theory of Planned Behaviour were evidenced from both sectors, which were considered important for influencing behaviour e.g. social norms.

Participants highlighted conflicts between existing law and the

newly created voluntary instruments within the recreational boating sector. For example, there were issues between Water Directives and Regulations that prohibited the deposit of substances into the water, and voluntary guidance which encouraged the cleaning of boats in the water. Caution must be taken when integrating two or more behaviour change approaches (regulatory and voluntary instruments) to avoid these kinds of conflicts that can limit effectiveness [46]. The issue of mixed messages is recognised as a barrier to behaviour change [18]. This highlights the need for context specific advice for recreational boaters (as also discovered by Floerl et al. [18]) and further investment by government and stakeholders into the creation of biosecurity facilities in order to meet the goals of policy instruments. In addition to the conflict between regulatory and voluntary instruments, recreational boaters were also restricted by a lack of infrastructure available to them to implement the cleaning guidance advised in the voluntary instruments. Owens and Driffill [47] argue that people can often be urged to do one thing but are constrained by practicality which can often lead to confusion, resentment or hostility. This is especially important in the case of biosecurity for the recreational boating sector which relies on voluntary uptake; any confusion could have negative results. Voluntary approaches have a part to play in the environmental policy mix but cannot be assumed to change behaviour alone. Better design of voluntary instruments and the introduction of sanctions to penalise nonperformers, could see their success rates improve.

The lack of regulatory instruments and conflicting voluntary advice creates challenges for future management of recreational boating and pose major collective action problems within the marine environment. Collective action problems are when a group benefits from the action but no individual has sufficient incentive to act alone [48]. Ostrom recognised the issue with governing common pool resources among a large number of users in a community and argues that when the group size is large, good-will alone will not be enough to get people to act for the common good [48,49]. Ostrom offered 8 principles for how commons issues can be governed; within larger communities monitoring and sanctions should be applied to ensure an increase in the importance of compliance [48]. Where individuals monitor and sanction (i.e., reward or punish) behaviours, a virtuous cycle of trust-building can develop such that they become more willing to reciprocate others' actions as a means of enhancing their reputation for trustworthiness in the eyes of their peers [50]. In large groups however, self-monitoring is difficult; participants in our study argued that biosecurity in the recreational boating sector would be too difficult to monitor and enforce due to the size of the industry, this increases the need for regulation rather than voluntary agreements. Often a key element in promoting collective action in large-group settings is governance by a third party [50]. It may also be beneficial for the recreational boating sector to create an institution which can increase compliance among recreational boaters to reduce the risk of spread [50].

Other factors such as trust [51,52], developing a sense of community responsibility [50], incentives [53] and social norms [54] are important to increase motivation. Subjective norms are also important for increasing an individual's behavioural intention and likelihood to change their behaviour. In particular, the shellfish industry relied on social norms as the practice was strongly linked to values and traditions which are important cultural components of social norms [65]. Our results highlight the importance of incentives to motivate behaviour which inevitably drives behaviour change. Not only was there a clear financial incentive to undertake biosecurity for disease control within the shellfish industry, there was also a financial incentive for the shellfish industry to undertake biosecurity for IAS, as it was understood that biosecurity would reduce the risk of production loss and monetary consequences of poorly managed threats to food production from IAS. Financial incentives may be in the form of either rewards or penalties; here financial incentives were in the form of penalties. The use of financial incentives and disincentives have proven useful in other industries to drive pro-environmental behaviour and compliance; for

example Mankad [33] found that agricultural farmers were motivated to undertake biosecurity due to financial penalties similar to those found in our study (e.g. production losses and monetary consequences) as well as non-financial consequences such as perceptions and approval of others. For economic activities (i.e. aquaculture) financial incentives are critical for driving behaviour because they ultimately affect the business and therefore the individual's livelihood.

In contrast, there were no financial incentives or penalties for recreational boaters to undertake biosecurity. There was a financial burden to many individuals as there were economic consequences of enforcing biosecurity as boaters may be more inclined to go somewhere else out of ease, therefore marinas would lose money by promoting biosecurity. Policy makers should consider incentivising biosecurity behaviour with a reward scheme as opposed to enforcement and penalties which could potentially economically impact marinas. The underlying assumption for incentivising behaviour is that people are most likely to respond if there is something to be gained (or a loss to avoid). In other areas of IAS management, financial incentives have been given to landowners to control IAS on their land; providing financial incentives was the main way that government tried to provide landowners with support to control serrated tussock in a qualitative study by Graham [55]. Incentives and disincentives are needed to increase ownership and accountability which in turn should increase compliance; for example Floerl et al. [18] suggest that a combination of the 'carrot and stick' approach, command and control systems and social marketing approach (to elicit voluntary action) should be an effective option for increasing the adoption of behaviours to reduce the spread of IAS among recreational vessels.

In addition to financial incentives and social incentives (individuals' perceptions of the behaviour of others) can also be used to foster socially desirable behaviours and increase compliance and willingness to undertake biosecurity among recreational boaters. In the field of recycling, social incentives play an important role in explaining the extent to which individuals choose to undertake pro-environmental behaviours, as individuals still choose to recycle even in the absence of any financial incentive. Barr et al. [56] concluded that as recycling is a visible activity then social norms are a key determinant; seeing people put out recycling can have a positive effect in encouraging others to recycle. Bedford et al. [57] argue that recycling has now become a 'pro-social norm' such that people can be stigmatised as selfish and anti-social for not recycling. Biosecurity is also a visible activity, therefore there is opportunity and potential for social norms to play an important part in behaviour change. Nyborg et al. [31] argue that social norms spread through social networks when a community is connected and therefore individuals see and copy behaviour to fit in. Social incentives rely on social networks which are extremely important as groups are influenced by social preferences and the strength of identity, social norms that exist within the community [20]. We propose that it is likely that social networks were hugely effective at reinforcing social norms and existing behaviours within the shellfish industry because of the small size of the industry and connectivity between businesses which facilitated cooperation among individuals. Therefore, a key challenge for encouraging biosecurity behaviours in the recreational boating sector is to identify and tap into existing social networks that may be able to spread knowledge about biosecurity, and to stimulate new networks where links are undeveloped (e.g. between different scales or between social groups that do not typically interact with one another) [66]. However due to the large size and disparate nature of the recreational boating sector, social networks are not necessarily the best means of communicating social incentives. Instead, the recreational boating sector should increase the visibility of biosecurity behaviour by implementing cleaning stations in popular areas, so they are visible to boaters and encourage boaters to use them. Nudges should be used to encourage voluntary compliance of biosecurity and cleaning stations.

Nyborg et al. [31] argue that often when a behaviour is easily observed and simple to follow, willingness to cooperate through moral responsibility increases. Nudges work by making the desired behaviour

easy, simple, and more engaging [58]. For example, simply placing fruit next to the supermarket till can nudge people towards healthy eating options. Nudges stand out in contrast to traditional policy tools, which change behaviour with mandates or bans or through economic incentives (including significant subsidies or fines) Benartzi et al. [64]. For example, nudges (installing waste bins) decreased littering by making the behaviour (disposing of rubbish in the bins) easier [58]. Whilst there is an initial cost, these relatively inexpensive types of nudges are attractive because they are cost-effective and allow the individual to change behaviours avoiding regulations and economic penalties that can negatively influence attitudes [67]. Worldwide, governments increasingly embrace nudges as a way of addressing a wide range of policy challenges. For example, households who received letters comparing their energy use to that of their neighbours were shown to reduce their electricity consumption [59]. These kinds of interventions harness both competitiveness and the power of social norms [59].

In an attempt to increase compliance with rules and regulations for overfishing in Australian recreational fisheries, nudges have been introduced to improve voluntary compliance (similar to this study) [60]. Persuasive messaging was printed on rulers used to measure fish, reminding fishermen of the legal minimum size [60]. Others have changed behaviour by displaying a pair of eyes at popular boat ramps by creating subtle cues of being watched and feeling seen which aim to make people act more honestly and pro-socially, as well as inducing a public awareness (as used by [61]). This approach could potentially be used to remind water users to use the wash down stations to clean boats and equipment before and after use and ultimately increase compliance [60]. argue that social norms themselves are an effective nudge to increase compliance, especially within the recreational fishing sector where community social norms have been developed. The impact of nudges is often greater, on a cost-adjusted basis, than that of traditional policy tools, such as bans and incentives Bernartzi et al. [64]. Nudges by contrast to traditional interventions, can succeed because they account for individuals' intuitions, emotions, and automatic decision-making processes Bernartzi et al. [64]. We therefore argue that implementing wash down stations coupled with nudges should target intuitive thinking without restricting choices, and therefore encourage pro-environmental behaviour. If the behaviour is visible and easy to copy, the faster and more widely the behaviour can spread [62]. Once wash down stations are implemented, nudges can be used to encourage boaters to wash their equipment which will inevitably foster social norms. As with any new technology, idea or approach, getting people to adopt biosecurity measures involves a gradual process of behaviour change that may take time to be adopted as a social norm. Nudges should not therefore replace traditional policy tools, but work together with these tools. Nudges should also be regularly and periodically updated to stay up-to-date and relevant in order to illicit a reaction [60]. We therefore make the following recommendation for policy makers. There should be investment from the government in implementing infrastructure (e.g. wash down stations) for stakeholders to practise biosecurity. This needs to be in addition to the investments made in creating voluntary guidance, which can often sit on the shelf (policy makers should avoid assuming that all policy instruments will directly influence behaviour). Visible infrastructure such as wash down stations, posters, and other changes to the physical environment should 'nudge' individuals into socially desirable behaviours which then encourage the behaviour to become a social norm within a community.

5. Conclusion

Marine IAS management requires change in human behaviour to prevent unintentional introduction and spread of IAS in the environment. The findings from this study can contribute to future research about the human dimensions of IAS and also help inform those wanting to create more effective IAS policy within the marine environment. Our research confirms that awareness campaigns and instruments that rely

on voluntary compliance are unlikely to be effective for the recreational boating sector, as knowledge alone does not necessarily translate into positive environmental behaviour for most people. In comparison, biosecurity behaviour for IAS in the shellfish industry was driven by economic and social incentives which were created as a result of the regulatory instruments that directly targeted disease control. We recommend that where there is conflict or lack of motivation, social incentives (and nudges) should be used to encourage socially desirable behaviours and increase compliance and willingness to undertake biosecurity within the recreational boating sector. Insights from the social and behavioural sciences are critical for scientists and practitioners to understand behaviour change in relation to biosecurity and to achieve the goals of international policy.

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CRediT authorship contribution statement

Caitriona Shannon: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft. **Paul D. Stebbing:** Conceptualization, Methodology, Writing - review & editing, Supervision, Funding acquisition. **Alison M. Dunn:** Conceptualization, Methodology, Writing - review & editing, Supervision, Funding acquisition. **Claire H. Quinn:** Conceptualization, Methodology, Writing - review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

None.

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References

- [1] D. Simberloff, J.-L. Martin, P. Genovesi, V. Maris, D.A. Wardle, J. Aronson, F. Courchamp, B. Galil, E. García-Berthou, M. Pascal, P. Pyšek, R. Sousa, E. Tabacchi, M. Vilà, Impacts of biological invasions: what's what and the way forward, *Trends Ecol. Evol.* 28 (2013) 58–66, <https://doi.org/10.1016/j.tree.2012.07.013>.
- [2] H.E. Roy, J. Bacon, B. Beckmann, et al., 2012. Non-Native Species in Great Britain: establishment, detection and reporting to inform effective decision making. 1–110.
- [3] M. Kettunen, P. Genovesi, S. Gollasch, et al. 2009. Technical support to EU strategy on invasive alien species (IAS) - Assessment of the impacts of IAS in Europe and the EU (final module report for the European Commission). Brussels, Belgium.
- [4] J. Kelly, D. Tosh, K. Dale, A. Jackson, The northern ireland environment agency and the national parks and wildlife service, in: *The economic cost of invasive and non-native species in Ireland and Northern Ireland*, 2013, pp. 1–95.
- [5] F. Williams, R. Eschen, A. Harris, et al., *The Economic Cost of Invasive Non-Native Species on Great Britain*, Oxford, UK, 2010.
- [6] S. Katsanevakis, A. Zenetos, C. Belchior, A.C. Cardoso, Invading European Seas: assessing pathways of introduction of marine aliens, *Ocean Coast Manag.* 76 (2013) 64–74, <https://doi.org/10.1016/j.ocecoaman.2013.02.024>.
- [7] D. Minchin, E.J. Cook, P.F. Clark, Alien species in British brackish and marine waters, *Aquat. Invasions* 8 (2013) 3–19, <https://doi.org/10.3391/ai.2013.8.1.02>.
- [8] J. Humphreys, M.R.C. Harris, R.J.H. Herbert, P. Farrell, A. Jensen, S.M. Cragg, Introduction, dispersal and naturalization of the Manila clam *Ruditapes philippinarum* in British estuaries, 1980–2010, *J. Mar. Biol. Assoc. U.K.* 95 (2015) 1163–1172, <https://doi.org/10.1017/S0025315415000132>.
- [9] J. Humphreys, R.J.H. Herbert, C. Roberts, S. Fletcher, A reappraisal of the history and economics of the Pacific oyster in Britain, *Aquaculture* 428–429 (2014) 117–124, <https://doi.org/10.1016/j.aquaculture.2014.02.034>.
- [10] R.J.H. Herbert, J. Humphreys, C.J. Davies, C. Roberts, S. Fletcher, T.P. Crowe, Ecological impacts of non-native Pacific oysters (*Crassostrea gigas*) and

- management measures for protected areas in Europe, *Biodivers. Conserv.* 25 (2016) 2835–2865, <https://doi.org/10.1007/s10531-016-1209-4>.
- [11] A.T. Critchley, W.F. Farnham, S.L. Morrell, An account of the attempted control of an introduced marine alga, *Sargassum muticum*, in Southern England, *Biol. Conserv.* 35 (1986) 313–332, [https://doi.org/10.1016/0006-3207\(86\)90092-3](https://doi.org/10.1016/0006-3207(86)90092-3).
- [12] K. Griffith, S. Mowat, R. Holt, K. Ramsay, J. Bishop, G. Lambert, S. Jenkins, First records in Great Britain of the invasive colonial ascidian *Didemnum vexillum* Kott, 2002, *Aquat. Invasions* 4 (2009) 581–590, <https://doi.org/10.3391/ai.2009.4.4.3>.
- [13] D. Minchin, J.D. Nunn, N.I.E. Agency, Rapid assessment of marinas for invasive alien species in Northern Ireland, *Res. Dev. Ser.* 116 (2013).
- [14] A. Macleod, R.D. Payne, E.J. Cook, 2014. Marine Biosecurity Planning: Guidance for producing site and operation-based plans for preventing the introduction of non-native species.
- [15] M.S. Reed, R. Curzon, Stakeholder mapping for the governance of biosecurity: a literature review, *J. Integr. Environ. Sci.* 12 (2015) 15–38, <https://doi.org/10.1080/1943815X.2014.975723>.
- [16] S. Michie, M.M. Van Stralen, R. West, The behaviour change wheel: a new method for characterising and designing behaviour change interventions, *Implement Sci.* 6 (2011) 42, <https://doi.org/10.1186/1748-5908-6-42>.
- [17] K. Cronin, H. Kaplan, M. Gaertner, U.M. Irlich, M. Timm Hoffman, Aliens in the nursery: assessing the attitudes of nursery managers to invasive species regulations, *Biol. Invasions* 19 (2017) 925–937, <https://doi.org/10.1007/s10530-016-1363-3>.
- [18] O. Floerl, G.J. Inglis, J. Diettrich, Incorporating human behaviour into the risk–release relationship for invasion vectors: why targeting only the worst offenders can fail to reduce spread, *J. Appl. Ecol.* 53 (2016) 742–750, <https://doi.org/10.1111/1365-2664.12609>.
- [19] M.J. Polonsky, W. Binney, J. Hall, Developing better public policy to motivate responsible environmental behaviour—an examination of managers’ attitudes and perceptions towards controlling introduced species, *J. Nonprofit Public Sect. Mark.* 12 (2004) 49–67, <https://doi.org/10.1300/J054v12n01>.
- [20] G. Prinbeck, D. Lach, S. Chan, Exploring stakeholders’ attitudes and beliefs regarding behaviours that prevent the spread of invasive species, *Environ. Educ. Res.* 17 (2011) 341–352, <https://doi.org/10.1080/13504622.2010.542451>.
- [21] A. Kollmuss, J. Agyeman, Mind the Gap: why do people act environmentally and what are the barriers to pro-environmental behaviour? *Environ. Educ. Res.* 8 (2002) 239–260, <https://doi.org/10.1071/WR14122>.
- [22] M.E. Eiswerth, S.T. Yen, G.C. van Kooten, Factors determining awareness and knowledge of aquatic invasive species, *Ecol. Econ.* 70 (2011) 1672–1679, <https://doi.org/10.1016/j.ecolecon.2011.04.012>.
- [23] E. Seekamp, A. McCreary, J. Mayer, S. Zack, P. Charlebois, L. Pasternak, Exploring the efficacy of an aquatic invasive species prevention campaign among water recreationists, *Biol. Invasions* 18 (2016) 1745–1758, <https://doi.org/10.1007/s10530-016-1117-2>.
- [24] P.W. Schultz, Chapter 4. Knowledge, Information, and Household Recycling: Examining the Knowledge-Deficit Model of Behaviour Change, *New Tools for Environmental Protection: Education, Information, and Voluntary Measures*, National Academy Press, Washington, DC, 2002, pp. 67–82.
- [25] H.R. Hungerford, T.L. Volk, Changing learner behaviour through environmental education, *J. Environ. Educ.* 21 (1990) 8–21, <https://doi.org/10.1080/00958964.1990.10753743>.
- [26] D. McKenzie-Mohr, P.W. Schultz, Choosing effective behaviour change tools, *Soc. Mar. Q* 20 (2014) 35–46, <https://doi.org/10.1177/1524500413519257>.
- [27] J.D. Rothlisberger, W.L. Chadderton, J. McNulty, D.M. Lodge, Aquatic invasive species transport via trailered boats: what is being moved, who is moving it, and what can be done, *Fisheries* 35 (2010) 121–132, <https://doi.org/10.1577/1548-8446-35.3.121>.
- [28] F. Humair, C. Kueffer, M. Siegrist, Are non-native plants perceived to be more risky? Factors influencing horticulturists’ risk perceptions of ornamental plant species, *PLoS One* 9 (2014), e102121, <https://doi.org/10.1371/journal.pone.0102121>.
- [29] D.M. Wald, K.A. Nelson, A.M. Gawel, H.S. Rogers, The role of trust in public attitudes toward invasive species management on Guam: a case study, *J. Environ. Manag.* 229 (2019) 133–144, <https://doi.org/10.1016/j.jenvman.2018.06.047>.
- [30] W. Abrahamse, L. Steg, Social influence approaches to encourage resource conservation: a meta-analysis, *Glob. Environ. Chang.* 23 (2013) 1773–1785, <https://doi.org/10.1016/j.gloenvcha.2013.07.029>.
- [31] K. Nyborg, J.M. Anderies, A. Dannenberg, T. Lindahl, C. Schill, M. Schluter, W. N. Adger, K.J. Arrow, S. Barrett, S. Carpenter, F.S. Chapin, A.S. Crepin, G. Daily, P. Ehrlich, C. Folke, W. Jager, N. Kautsky, S.A. Levin, O.J. Madsen, S. Polasky, M. Scheffer, B. Walker, E.U. Weber, J. Wilen, A. Xepapadeas, A. de Zeeuw, Social norms as solutions, *Science* 354 (2016) 42–43.
- [32] R.B. Cialdini, R.R. Reno, C. Kallgren, A focus theory of normative conduct: Recycling the concept of norms to reduce littering in public places, *J. Pers. Soc. Psychol.* 58 (1990) 1015–1026, <https://doi.org/10.1037/0022-3514.58.6.1015>.
- [33] A. Mankad, Psychological influences on biosecurity control and farmer decision-making. A review, *Agron. Sustain Dev.* 36 (2016) 1–14, <https://doi.org/10.1007/s13593-016-0375-9>.
- [34] S. Michie, R. West, Behaviour change theory and evidence: a presentation to Government, *Health Psychol. Rev.* 7 (2013) 1–22, <https://doi.org/10.1080/17437199.2011.649445>.
- [35] A. Morgan, *Investigating Our Experience in the World: A Primer on Qualitative Inquiry*, University of Tennessee Press, Tennessee, 2011.
- [36] R.M. Colvin, G.B. Witt, J. Lacey, Approaches to identifying stakeholders in environmental management: Insights from practitioners to go beyond the ‘usual suspects’, *Land Use Policy* 52 (2016) 266–276, <https://doi.org/10.1016/j.landusepol.2015.12.032>.
- [37] G. Guest, E.E. Namey, M.L. Mitchell, *Collecting Qualitative Data: A Field Manual for Applied Research*, Sage Publications, London, UK, 2012.
- [38] M.S. Reed, A. Graves, N. Dandy, H. Posthumus, K. Hubacek, J. Morris, C. Prell, C. H. Quinn, L.C. Stringer, Who’s in and why? A typology of stakeholder analysis methods for natural resource management, *J. Environ. Manag.* 90 (2009) 1933–1949, <https://doi.org/10.1016/j.jenvman.2009.01.001>.
- [39] A. Strauss, J. Corbin, *Basics of qualitative research: Grounded theory procedures and techniques*, Sage Publications, Newbury Park, 1990.
- [40] A. Bhattacharjee, *Social science research: principles, Methods, and Practices*, second edition., University of South Florida, Florida, 2012.
- [41] G.W. Ryan, H.R. Bernard, Techniques to identify themes, *Field Methods* 15 (2003) 85–109, <https://doi.org/10.1177/1525822x02239569>.
- [42] L. Howard-Payne, Glaser or Strauss? Considerations for selecting a grounded theory study, *S. Afr. J. Psychol.* 46 (2016) 50–62, <https://doi.org/10.1177/0081246315593071>.
- [43] D. McCarthy, P. Morling, 2015. Using Regulation as a Last Resort: Assessing the Performance of Voluntary Approaches. Bedfordshire: UK.
- [44] N. Gunningham, D. Sinclair, 2002. Voluntary Approaches to Environmental Protection: Lessons from the Mining and Forestry Sectors. Paris.
- [45] P.E. Hulme, G. Brundu, M. Carboni, K. Dehnen-Schmutz, S. Dullinger, R. Early, F. Essl, P. González-Moreno, Q.J. Groom, C. Kueffer, I. Kühn, N. Maurel, A. Novoa, J. Pergl, P. Pyšek, H. Seebens, R. Tanner, J.M. Touza, M. van Kleunen, L.N. H. Verbrugge, Integrating invasive species policies across ornamental horticulture supply chains to prevent plant invasions, *J. Appl. Ecol.* 55 (2017) 92–98, <https://doi.org/10.1111/1365-2664.12953>.
- [46] C.M. Taylor, S.J.T. Pollard, A.J. Angus, S.A. Rocks, Better by design: rethinking interventions for better environmental regulation, *Sci. Total Environ.* 447 (2013) 488–499, <https://doi.org/10.1016/j.scitotenv.2012.12.073>.
- [47] S. Owens, L. Driffill, How to change attitudes and behaviours in the context of energy, *Energy Policy* 36 (2008) 4412–4418, <https://doi.org/10.1016/j.enpol.2008.09.031>.
- [48] E. Ostrom, Revisiting the commons: local lessons, *Glob. Chall. Sci.* 284 (80) (1999) 278–282, <https://doi.org/10.1126/science.284.5412.278>.
- [49] E. Ostrom, *Governing the Commons: The Evolution of Institutions for Collective Action*, Cambridge University Press, Cambridge, 1990.
- [50] G.R. Marshall, M.J. Coleman, B.M. Sindel, I.J. Reeve, P.J. Berney, Collective action in invasive species control, and prospects for community-based governance: The case of serrated tussock (*Nassella trichotoma*) in New South Wales, Australia, *Land Use Policy* 56 (2016) 100–111, <https://doi.org/10.1016/j.landusepol.2016.04.028>.
- [51] S. Graham, A new perspective on the trust power nexus from rural Australia, *J. Rural Stud.* 36 (2014) 87–98, <https://doi.org/10.1016/j.jrurstud.2014.06.010>.
- [52] S. Graham, A.L. Metcalf, N. Gill, R. Niemiec, C. Moreno, T. Bach, V. Ikutegbe, L. Hallstrom, Z. Ma, A. Lubeck, Opportunities for better use of collective action theory in research and governance for invasive species management, *Conserv. Biol.* 33 (2019) 275–287, <https://doi.org/10.1111/cobi.13266>.
- [53] D.E. Ervin, G.B. Frisvold, Community-based approaches to herbicide-resistant weed management: lessons from science and practice, *Weed Sci.* 64 (2016) 609–626, <https://doi.org/10.1614/ws-d-15-00122.1>.
- [54] W. Minato, A. Curtis, C. Allan, Social norms and natural resource management in a changing rural community, *J. Environ. Policy Plan* 12 (2010) 381–403, <https://doi.org/10.1080/1523908X.2010.531084>.
- [55] S. Graham, Three cooperative pathways to solving a collective weed management problem, *Australas. J. Environ. Manag.* 20 (2013) 116–129, <https://doi.org/10.1080/14486563.2013.774681>.
- [56] S. Barr, A.W. Gilg, N.J. Ford, Differences between household waste reduction, reuse and recycling behaviour: a study of reported behaviours, intentions and explanatory variables, *Environ. Waste Manag.* 4 (2001) 69–82.
- [57] T. Bedford, P. Collingwood, A. Darnton, et al. 2010. Motivations for Pro-environmental Behaviour: A report to the Department for Environment, Food and Rural Affairs. London.
- [58] R. Thaler, C. Sunstein, *Nudge: improving decisions about health, wealth, and happiness*, Yale University Press, New Haven, CT, 2008.
- [59] Hunt Allcott, Todd Rogers, The short-run and long-run effects of behavioral interventions: experimental evidence from energy conservation, *Am. Econ. Rev.* 104 (10) (2014) 3003–3037, <https://doi.org/10.1257/aer.104.10.3003>.
- [60] M. Mackay S., E.I. Jennings, H. Sibly, S. Yamazaki, van Putten, When push comes to shove in recreational fishing compliance, think ‘nudge’, *Mar. Policy* 95 (2018) 256–266, <https://doi.org/10.1016/j.marpol.2018.05.026>.
- [61] S. Pfattheicher, J. Keller, The watching eyes phenomenon: the role of a sense of being seen and public self-awareness, *Eur. J. Soc. Psychol.* 45 (2015) 560–566, <https://doi.org/10.1002/ejsp.2122>.
- [62] T.E. Quedest, E. Marsh, D. Stunell, A.D. Parry, Spaghetti soup: the complex world of food waste behaviours, *Resour. Conserv. Recycl.* 79 (2013) 43–51, <https://doi.org/10.1016/j.resconrec.2013.04.011>.
- [63] I. Ajzen, The theory of planned behaviour, *Organ Behav. Hum. Decis. Process* 50 (1991) 179–211, [https://doi.org/10.1016/0749-5978\(91\)90020-T](https://doi.org/10.1016/0749-5978(91)90020-T).
- [64] S. Benartzi, J. Beshears, K.L. Milkman, C.R. Sunstein, R.H. Thaler, M. Shankar, W. Tucker-Ray, W.J. Congdon, S. Galing, Should governments invest more in nudging? *Psychol. Sci.* 28 (8) (2017) 1041–1055, <https://doi.org/10.1177/0956797617702501>.

- [65] Amanda Ravis, Paschal Sheeran, Descriptive norms as an additional predictor in the theory of planned behaviour: A meta-analysis, *Current Psychology* 22 (2003) 218–233, <https://doi.org/10.1007/s12144-003-1018-2>.
- [66] Lindsay Stringer C, et al., Unpacking “Participation” in the Adaptive Management of Social–ecological Systems: a Critical Review, *Ecology and Society* 11 (2) (2006) 39, <https://doi.org/10.5751/ES-01896-110239>.
- [67] S Jennings, et al., When push comes to shove in recreational fishing compliance, think ‘nudge.’, *Marine Policy* 95 (2018) 256–266, <https://doi.org/10.1016/j.marpol.2018.05.026>.