Assessing behavioural and social responses to an eco-mooring trial for *Zostera marina* conservation management in Torbay, Southwest England

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Abstract

Seagrass beds are critically important habitats delivering a range of ecosystem service benefits that support human wellbeing. They are, however, declining globally at an unprecedented rate. The damaging effects on *Zostera marina* (Common Eelgrass) seagrass beds in UK waters from mechanical recreational boating activities, namely anchoring and traditional swing mooring scour, suggest that measures of implementing management to mitigate human impacts need prioritising. Eco-moorings, a design that reduces the abrasion pressure of anchoring and mooring on the seabed, are such a mitigation method. In the UK, limited test sites and a lack of social acceptance of the technology compounds the limited uptake of eco-moorings to date. To advance the evidence base, this study focusses on a bespoke eco-mooring design deployed in 2017 to protect seagrass beds within a popular anchorage in Southwest England. We assess the behavioural and social responses of recreational boaters to the trial eco-mooring through 1) mapping of boating activity pre- and post-deployment and 2) structured questionnaires both on-site and online to local and national audiences respectively. Results of mapped boating activity demonstrated a shoreward distribution shift of anchoring away from the deployed eco-mooring, with 45.4% of all anchoring vessels directly within or within a range of potential influence of the seagrass bed. Through the deployment of the eco-mooring (where no mooring previously existed), an estimated additional 20% of anchoring pressure was alleviated from the seagrass bed. A total of 89.6% of on-site respondents reacted positively to the prospect of further eco-moorings being deployed locally. When questioned, 74.6% of on-site and 82.8% of online respondents demonstrated a preference for the physical action of mooring a vessel over anchoring. This suggests that implementation of eco-

moorings in seagrass-dense regions could successfully alleviate anchor damage, especially where over half of respondents indicated an awareness of seagrass presence prior to anchoring their vessel and/or hesitance to cease visiting preferential anchoring sites (sheltered bays). This study recommends targeting conservation guidance at the powerboat community, the dominant group anchoring/mooring in the study area and identified as not currently engaged in seagrass education campaigns. It is proposed that management introduce incentives such as free of charge eco-moorings and/or anchoring charges in Marine Protected Areas/Voluntary No Anchor Zones to conserve and recover seagrass and other sensitive seabed habitats nationally.

1. Introduction

One of two seagrass species found in the UK, *Zostera marina* (Common Eelgrass) is a marine flowering plant (Davison and Hughes, 1998) found in sheltered subtidal and intertidal zones at flow velocities below 1.5 m/s, down to depths of 10-15 m dependent on water clarity (Borum et al., 2004; Hemminga and Duarte, 2000; Jackson et al., 2013). *Z. marina* is recognised as providing a critical functional role in the delivery of beneficial ecosystem services. For example, with roots and horizontal rhizomes located to a maximum 20 cm depth (Davison and Hughes, 1998), stabilisation of sediments secures long-term carbon burial to store 12-20% of global oceanic 'blue carbon' (Borum et al., 2004; Commission for Environmental Cooperation, 2016). As well as displaying significantly more biodiversity than that of bare sand (regardless of patch size) (Hirst and Attrill, 2008), *Z. marina* provides a habitat for rare marine species in the UK, such as the Short Snouted Seahorse (*Hippocampus hippocampus*) and the Spiny/Long Snouted Seahorse (*Hippocampus guttulatus*). Both seahorse species and their habitat are protected under an amendment to Schedule 5 of the *Wildlife and Countryside Act* (1981) (Garrick-Maidment et al., 2010). Seagrass also offers a vital nursery habitat for commercial fish species such as cod, pollock, bass (Cullen-Unsworth et al., 2014) and the Common Cuttlefish (*Sepia officinalis*) that use the beds as preferential spawning sites (Fletcher et al., 2012). Further, seagrass beds dissipate wave action to reduce erosion of coastlines, improve water quality by cycling nutrients, support primary production and provide a food source to wintering wildfowl (Borum et al., 2004; Hemminga and Duarte, 2000). Recognised for their importance, seagrass beds are often designated as protected sites – for example, at an EU level, *Z. marina* is listed as an Annex 1 habitat under the EU Habitats Directive (EU Commission, 1992). In the UK, they are listed for protection as a Habitat of

Principal Importance/Priority Habitat, OSPAR List of Threatened and/or Declining Species and Habitats (declining in Region II – North Sea and Region III – Celtic Sea, and threatened in Region V – Wider Atlantic) and as an important feature in estuary Sites of Special Scientific Interest, under the UK Wildlife and Countryside Act 1981 (JNCC, 2015). These legal/policy tools enable the creation of Marine Protected Areas (MPAs) where management can be initiated to protect *Z. marina* from human impacts.

Despite these measures for protection, seagrass beds are one of the most threatened ecosystems globally, declining at a rate of 7% per year since 1990 (Waycott et al., 2009). Strongholds now remain in limited regions of the UK such as Western Scotland and South West England (Davison and Hughes, 1998), with further densities in North Wales (Egerton, 2011) and on the Eastern Coast of England (Jackson et al., 2016). Although generally a quick growing species (Unsworth et al., 2017), *Z. marina* has never fully recovered in the UK after a wasting disease devastated the Northern European population in the 1930s (Davison and Hughes, 1998; Hemminga and Duarte, 2000). This lack of recovery is in part due to natural causes such as storms and grazing (Short and Wyllie-Echeverria, 1996); however, it is largely attributed to human disturbances such as coastal development, dredging, agricultural runoff and recreational boating activities (Borum et al., 2004; Hemminga and Duarte, 2000; Jones and Unsworth, 2016).

While not the major cause of seagrass decline, recreational boating in the form of anchoring and swing mooring scour have been found to cause significant damage and to restrict recovery of the habitat (Collins et al., 2010; Liley et al., 2012; Unsworth et al., 2017; Walker et al., 1989). This is due to the shallow, sheltered locations preferred by both recreational vessels and seagrass (Unsworth et al., 2017).

A single anchoring event can influence the physiognomy of an individual plant by pulling up leaves and rhizomes (Ceccherelli et al., 2007; Hastings et al., 1995; Montefalcone et al., 2008; Walker et al., 1989), altering the structure of a meadow (Francour et al., 1999; Montefalcone et al., 2008) during all three stages of an anchor cycle: anchor drop, drag/lock-in and retrieval (Collins et al., 2010; Milazzo et al., 2004). ‘Anchor scars’ that uproot rhizomes from below the sediment surface have been measured up to 0.16 m^2 (Liley et al., 2012), whilst combined anchor and chain impact has caused patches in beds measured between 1-4 m^2 (Collins et al., 2010). Predation of the exposed root systems by crustaceans adds further exacerbation (Collins et al., 2010), causing long-term physical disturbance from cumulative anchoring events (Collins et al., 2010; Hastings et al., 1995; Unsworth et al., 2017). Furthermore, traditional swing moorings, inclusive of ground weight, ground chain, riser chain and floating buoy, can scour the underlying seabed when tide and wind movements cause the chain to swing in a circular motion around the ground weight (Egerton, 2011; Unsworth et al., 2017). Based on a classification of <10% seagrass cover, a study by Unsworth *et al*. (2017) compared swing mooring scars around the UK and discovered that the average scar radius equates to 5.4 ± 3.5 m, with seagrass thinning a distance of 16-20 m from the ground weight indicating further influence of the chain. Each swing mooring was measured to cause a seagrass loss of 122 m^2, deemed small on a national scale, yet largely significant at a local scale (Unsworth et al., 2017).

Globally, eco-mooring designs are being tested in seagrass regions in an attempt to relieve swing mooring damage to seagrass beds, with leading studies currently underway in Australia (Egerton, 2011; Outerbridge, 2013). Designs are variable, featuring either a ground weight or sediment penetrating system and all featuring methods to eradicate chain drag on the seabed using bungees, riser buoys, floating rodes and other creative options (Crown Estate, 2011; Egerton, 2011; Lloyd and Marsland, 2013; Outerbridge, 2013).

Previous and current investigations have explored the potential to implement eco-moorings in UK waters (Axelsson et al., 2012; Egerton, 2011). However, due to limited UK-based testing and the differences in tidal range between the UK and Australia, where the majority of trials have taken place, uncertainty as to whether eco-moorings could be effective in the UK has remained (Egerton, 2011; Outerbridge, 2013).

It is recognised that public awareness and engagement is crucial to the success of seagrass conservation management (Borum et al., 2004). There are some examples of marine conservation charities attempting to engage the wider public in these issues through citizen science projects, including the Community Seagrass Initiative (CSI) and Project Seagrass, that place education and raising awareness of seagrass at the centre of their work. Initiatives like this provide further evidence that the success of eco-moorings lies not simply in their design, but in their implementation into management (Egerton, 2011) and whether they can receive social acceptance, particularly from recreational boaters, in place of anchoring within seagrass-sensitive sites in UK waters.

Despite a growing recognition of seagrass beds as coupled socio-ecological systems (Cullen-Unsworth et al., 2014), there has been a limited number of studies on the publics' perception of seagrass beds or how knowledge has influenced behaviour change. In a study of the UK publics' perceptions of seagrass beds, the results demonstrated that the general public are less enamoured by seagrass as an ecologically important marine plant species (Jefferson et al., 2014). However, other studies have noted that charismatic flagship species such as seahorses can invoke enthusiasm in conservation campaigns calling for protection of the habitat (Zacharias and Roff, 2001). Despite this, it must be recognised that enthusiasm does not necessarily translate in to action to instigate the necessary management interventions to secure protection of the habitat (Vincent, 2011). It is proposed that to further encourage both individual and community-led behaviour change for environmental protection, a tangible, relatable connection must exist or be made to the species or habitat under threat (Easman et al., 2018; Vincent, 2011).

To truly gauge the success of an eco-mooring trial in Southwest England, this paper examines the physical behavioural responses and perceptions of recreational boaters to understand if a bespoke eco-mooring design (Fig. 1) can reduce anchoring pressure on seagrass beds. Behavioural responses were studied by recording boating activity in 2015 and 2017 within the study site, with an aim to identify and map preferential anchoring areas pre- and post- deployment of the trial eco-mooring to explore behaviour change in a site where no moorings previously existed. Questionnaires were designed to ascertain the demographics of boaters, as well as their seagrass awareness, anchoring/mooring preferences and perceptions of the trial eco-mooring after its deployment in 2017. Given that social engagement is imperative to achieving conservation aims (Jefferson et al., 2015), it was considered crucial that this study collect responses to the deployment of the trial eco-mooring to assess whether future eco-mooring deployments in Torbay could be successful.

2. Methods and Materials

2.1. Case Study Site

Fishcombe Cove is located west of Brixham harbour in Torbay, Devon (Fig. 2), chosen for deployment of the eco-mooring as it is a popular anchorage site for recreational vessels due to its sheltered location, whilst also providing easy access for monitoring of the eco-mooring (Living Coasts, 2017).

Commercial divers assessed the spatial extent of seagrass in the cove on 25th January 2017, following which a location for the eco-mooring deployment was chosen 26 m east and 23 m north of the outer extent of the beds, ensuring a distance of 50 m from the shore. The configuration of the bespoke eco-mooring allows the chain to lift off the seabed using miniature buoys up the riser chain (Fig. 1). The design had undergone prior testing in two coastal and estuarine locations in Kingsand and Salcombe, Devon, UK. One of these eco-moorings had already been in regular use for over two years at the time of this study. The Salcombe eco-mooring had already proven its ecological value in direct comparison with a standard traditional swing mooring, with seagrass density recorded at over twice as high surrounding the eco-mooring, epifauna demonstrated twice the species richness, and significantly finer sediment composition was found surrounding the eco-mooring ground weight in comparison with the standard swing mooring (Luff et al., In prep). All three results demonstrate the increased levels of disturbance to the seabed from the chain of the traditional swing mooring (Luff et al., In prep).

As part of a collaborative effort to improve conservation in the Torbay area, the Torbay Coast and Countryside Trust was initiated in 1999 and within its first operational phase created a Marine Biodiversity Action Plan (Torbay Coast and Countryside Trust, 2004). The plan identified seagrass beds as a ‘National and Regional Priority Habitat’, initiating annual monitoring surveys that mapped and assessed the status of seagrass across many sites in Torbay (Cole, 2016), suggesting restricted anchoring to aid recovery in specific seagrass sites as a result of dive surveys undertaken in 2006 (Flint, 2008). In recent years, Torbay has been recognised for its marine biodiversity, designated a candidate Special Area of Conservation (cSAC) under the EU Habitats Directive [92/43/EEC]. The area was also enforced as a Marine Conservation Zone (MCZ) in 2013 (Fig. 2b) as part of the Marine Management Organisation’s (MMO) implemented management for the *Marine and Coastal Access Act* (2009). Although seagrass habitats have been included within all MPA designations for Torbay, their presence has not been the driving factor behind implementation. Rather, recent mitigation has aided some recovery at these sites after a restriction on scallop dredging was introduced in 2014 (Natural England, 2017).

Since 2013, coastal management has been conducted by SeaTorbay; a consortium of voluntary partnership organisations that have attempted to address the threats facing Torbay seagrass (SeaTorbay, 2013). Mitigation efforts have included implementation of ‘Voluntary No Anchor Zones’ (VNAZs) to discourage anchoring in sensitive seagrass sites, whilst also organising the deployment of the trial eco-mooring assessed in this study at Fishcombe Cove. VNAZs cannot entirely prohibit vessel anchoring (Axelsson et al., 2012; Egerton, 2011) in consideration of the public right of navigation[a] concerning anchoring in British coastal waters[b]. They do, however, lessen anchoring activity where voluntary restrictions are generally respected by the majority of the public.

2.2. On-site boating behaviour study

Behavioural responses were studied by observing recreational boating activity with aims to: (1) create and compare anchoring ‘hotspots’ pre- and post- deployment

[a] *Miles v Rose (1814). 5 Taunt 705 ed.*
[b] *Gann v Whitstable Free Fishers (1865). 11 HL Cas 192 ed.*

of the trial eco-mooring; and (2) calculate anchoring pressure relieved from the seagrass bed by use of the trial eco-mooring during the survey period.

Surveys took place between the 11th June and 7th August 2017 on 19 intermittent days to match the temporal commitment of the pre-deployment anchoring study conducted in 2015 between 25th June and 4th August 2015. Mapping of boating activity both in 2015 and 2017 offered direct comparisons of preferential anchoring areas within the study site before and after the deployment of the trial eco-mooring in a site where no mooring previously existed, allowing us to analyse recreational boater behaviour change between the two study years.

Boating activity in 2017 was documented manually by using still image photography to observe behaviour for 8 hours a day, whilst questionnaires were undertaken in parallel. In 2015, a fixed camera recorded still images of boating activity continuously at 10 minute intervals during all daylight hours. Every anchoring/mooring event (anchor dropped/retrieved, attached to/detached from eco-mooring) was recorded for use in Geographic Information System (GIS) mapping, whilst observational data such as vessel type (powerboat/sailboat) were recorded in 2017 for use in quantitative and qualitative analysis.

2.2.1. Desk-based boating activity & GIS analysis

Triangulation conducted using Google Earth Pro estimated anchoring co-ordinates of each vessel both in 2015 and 2017; this was only conducted for vessels located within the boundary of Fishcombe Point where questionnaires could be easily conducted, along a latitude of 50°24'11.67"N (Fig. 2c). Co-ordinates were then plotted in ArcGIS 10.5.1 to visualise vessel density. Of 161 anchoring events recorded in 2017, six could not be triangulated due to their hidden position in shallow waters at the southern end of Churston Cove beach (Fig. 2c).

Mapping analysis was conducted in ArcGIS 10.5.1 using point data of anchoring events from both 2015 and 2017 separately. Vessel density maps were created from point data with a linear unit distance of 17.14 m as an average radius of potential influence to the seabed, calculated from recommendations by the Royal Yachting Association (RYA) (Jinks, 2013). Maps were created separately for both 2015 and 2017, then the output layer for 2015 subtracted from the 2017 output layer to calculate variance.

Images of seagrass distribution from three volunteer diver transect surveys undertaken in 2017 were provided by the CSI with geotagged coordinates recorded using a Garmin e-trex Global Positioning System (GPS) unit, attached to the surface marker buoy of each diver. These coordinates were uploaded into ArcGIS 10.5.1 and a polygon created around the exterior data points depicting distributional extent only and not including internal density. Although diver survey data were limited within the scope of this research to allow for a more detailed analysis of seagrass bed spatial fragmentation, seagrass outer spatial extent allowed for direct annual comparison with anchoring distribution and provided the most accurate distributional conditions due to the inter-annual variability of seagrass distribution (Hemminga and Duarte, 2000). Time limited additional analysis of seagrass data, where future research could explore annual and perennial variability in seagrass distributions (Phillips et al., 1983) and recovery from anthropogenic impacts.

2.3. Questionnaires

Online and on-site questionnaires were developed that contained both qualitative and quantitative question formats to: (1) define socio-demographics of the recreational boating community; (2) ascertain seagrass awareness; (3) understand priorities and anchoring/mooring preferences of boaters in varied circumstances including restricted anchoring sites; and (4) explore social perceptions of the trial eco-mooring. Online and on-site questionnaires included Likert scale, ranked, closed- and open-ended questions. Likert scales between 1 (no confidence at all) to 10 (very confident) were used to gather information on levels of confidence in different mooring types, including the trial eco-mooring. Within the online questionnaire only, ranked scores between 1 (most likely choice) and 9 (least likely choice) identified the preferred actions of boaters when encountering restricted anchoring sites (e.g. VNAZs). Closed-ended questions obtained a variety of data including demographic, anchoring/mooring preferences and knowledge on previous seagrass anchoring actions. Open-ended questions offered respondents opportunities to clarify their responses to closed-ended questions, discuss their knowledge of the eco-mooring trial (on-site) and provide comments on both the questionnaire and wider eco-mooring project. The online and on-site questionnaires differed in length and style of questioning due to the theoretical existence of the trial eco-mooring in the former, and the physical presence of the eco-mooring at the study site in the latter. Both online and on-site questionnaires were developed in collaboration with local stakeholders and piloted on a subset of individuals with an interest in recreational boating. The final format of the questionnaire was approved by the University of Plymouth's ethical committee.

On-site questionnaires were conducted face-to-face by stand-up paddleboard between June and August 2017 over 19 intermittent days in parallel with the on-site boating behaviour study, prioritising calm weather in an attempt to ensure visits from recreational vessels into the cove. Each respondent read a question sheet, inclusive of consent information, with answers recorded on a separate answer sheet by the author to allow the respondent freedom to respond naturally.

The online questionnaire was disseminated through an online platform (Survey Monkey) and remained active between 27th May 2017 and 24th July 2017. Three avenues were utilised in an attempt to reach the recreational boating community including word of mouth, email and social media. Emails were sent to senior members of recreational boating groups based between Cornwall and Dorset. Social media enabled respondents from further afield inclusive of non-boating club members to contribute to the study.

2.3.1. Questionnaire data analysis

A total of 67 on-site questionnaire responses were collected from the field, with all included in this study. The online questionnaire received 245 responses; respondents indicating that they did not use anchors (dinghy sailors) were removed from final analysis to reduce bias towards moorings, resulting in a sample of 207 complete responses.

Likert responses were analysed using Microsoft excel and reporting the mean score and the standard deviation of the mean. The use of a Likert scale and ‘yes/no/unsure’ style responses in the closed-ended questions enabled the respondent to provide a positive, negative or uncertain comment to the question. Corresponding open-ended questions then enabled a broader exploration of the themes associated with the individual’s response. To reduce subjectivity in data analysis, the NVivo 11 content analysis method was used which facilitated the coding of open-ended comments into a thematic framework to explore rationalisations behind closed-ended answers (see: Rees et al., 2012; Rees et al., 2013).

Data were aggregated further from categories defined in both questionnaires for statistical analysis including age, postcode (for residency), days spent visiting Fishcombe Cove, etc.; available time restricted deeper analysis of these demographics for this study.

Ranked scores between nine options in response to the question, *‘What would you choose to do (or have previously chosen to do) in response to encountering a site of restricted anchoring in UK waters?*’, analysed only boater responses that provided scores for all nine options, as it was noted that many respondents provided scores for selected options only.

Statistical exploration of categorical data used non-parametric Kruskal-Wallis tests with Bonferroni adjustment for pairwise comparisons, or Mann Whitney U tests dependent on number of categories. Likert scale data were tested for normality using the Shapiro-Wilks test and relationships investigated using non-parametric Spearman (rho) product-moment correlation coefficient. IBM SPSS 24 enabled exploration of frequency and statistical analysis of closed-ended nominal, ordinal and scale data.

3. Results

3.1 Boating behaviour and seagrass mapping

Boating activity recorded in 2017 resulted in 161 anchoring events, 32 attachments to the trial eco-mooring and 3 vessels rafting, totalling 196 events with only one day resulting in no vessel activity. This is compared with 127 anchoring events recorded during 2015, with a total of 5 days receiving no activity. Over the 19 survey days in 2017, a decrease in anchoring events occurred that coincided with a decrease in temperatures and increasing wind speeds (Fig. 3).

Of the 196 events documented in 2017, 81.1% were powerboats with 84.9% recorded anchoring, 13.2% attached to the eco-mooring and 1.9% rafted to another vessel; 44.4% of those anchoring could have attached to the available eco-mooring upon entry to the cove where one vessel was observed attempting to attach before moving away to drop anchor. The remaining 18.9% of vessels were sailboats, of which 70.3% anchored and 29.7% attached to the eco-mooring; 50% of those sailboats anchoring could also have attached to the available eco-mooring upon entry to the cove. Of the 196 events, 170 vessels were documented in total where 23 vessels were recorded re-anchoring a maximum of 2 times during a daily visit.

Vessel density maps reveal a difference in cumulative anchoring from a northern spread of vessels in 2015 (Fig. 4a), to a clustered southern density along the inner shore after deployment of the eco-mooring in 2017 (Fig. 4b), with up to 19 fewer vessels in the north of the cove and up to 25 more in the south in 2017 (Fig. 4c).

Of the 161 anchoring events in 2017, 36 (22.4%) were recorded directly within the mapped seagrass outer extent. A further 37 (23%) anchored within a range of potential influence of the outer extent of the bed (Fig. 4d & 4e), totalling 45.4% of all anchoring events. Assigning a 45.4% percentage to the 32 eco-mooring events that have been assumed would have anchored without the eco-mooring available, an additional 20% (14.5 events) is the estimated percentage of alleviated seagrass anchoring events, either directly within the bed or within the range of potential influence. It must be noted that the mapped outer extent of the seagrass bed does not account for internal fragmentation of the bed; this is suggested as an area of research in need of further attention in relation to anchoring pressure.

3.2. Recreational boater perceptions

Of the 170 vessels visiting Fishcombe Cove during survey days, 55.9% participated in on-site questionnaires (including vessels 'questioned previously'). Of these vessels, 74.6% were powerboats, and 25.4% were sailboats. The remaining 44.1% were not questioned for reasons summarised in Table 1.

3.2.1. Recreational boating community demographics

Socio-demographic variables for both online and on-site questionnaires have been summarised in Table 2. Analysis found both online and on-site questionnaires were dominated by 81.6% and 53.7% male respondents respectively; 66.9% of online males were aged 55+ years, and 57.6% of on-site males were aged 34-55 years.

Club membership was noted as a major difference between online and on-site respondents where 88.9% and 22.4% confirmed club membership respectively, due to methods of contacting a significant number of sailing clubs for participation online.

The number of on-site respondents decreased with increasing distance from the Torbay coastal region (TQ1-TQ5), with 49.3% local, 34.3% regional to Devon county and 16.4% from other areas around the UK. The remaining 9% of on-site respondents were identified as not permanently berthed or moored in Torbay from open-ended comments, visiting from Dartmouth, Plymouth (both Devon, UK) and Poole (Dorset, UK).

3.2.2. Seagrass awareness

Of on-site respondents questioned, 77.6% (n = 52) were aware of the presence of seagrass around Torbay from various sources such as local knowledge/word of mouth (n = 20), reading signage on the VNAZ buoys (n = 9), reading seagrass awareness noticeboards around the coastal paths (n = 6) or from water sport activities such as snorkelling, diving and swimming (n = 6). A thematic framework detailing where previous knowledge of seagrass presence was gained is shown in Table 3.

Respondents to both online and on-site questionnaires were asked '*Have you ever anchored in a seagrass bed?*' and '*(If 'yes') Were you aware seagrass was in the area before you anchored?*' (see: Figure 5). Of the on-site respondents that advised that they had not previously anchored in seagrass, 72.5% were recorded anchoring during questioning, of which 27.6% advised that they visit Fishcombe Cove on average between 15 and 90 days of the year.

3.2.3. Anchoring and mooring priorities

Both online and on-site respondents were asked to identify their general preference for the physical actions of either anchoring (dropping the anchor of a vessel) or mooring their vessels (the use of a mooring rope to secure a vessel). Of on-site and online respondents, 74.6% and 82.8% respectively confirmed a general preference to moor. Reasons from on-site and online respondents respectively included security (on-site n = 26; online n = 63), ease of use (on-site n = 24; online n = 32) and previous anchor problems (on-site n=16; online n = 34), mainly for reasons of anchor drag or drift (on-site n = 14; online n = 22); e.g. "*Provides a secure place to stop without the worry of an anchor dragging*". A further 34 respondents anchoring during questioning stated that they prefer to moor rather than anchor, of which 61.8% had the opportunity to attach to the trial eco-mooring upon entering the cove. Of all anchoring boaters questioned, however, 82.6% were not aware of the eco-mooring trial. Regarding a preference for moorings, 18 online respondents cited a preference as they assumed this question was inclusive of the option to berth their vessel, highlighting that further clarity in the question could have led to a more accurate response. Anchoring was a preference for 10.5% on-site and 16.4% of online respondents, commented by on-site and online respondents respectively as preferential due to flexibility (on-site n = 12; online n = 19), mainly associated with locations of choice (on-site n = 8; online n = 14) and independence (on-site n = 6; online n = 6); e.g. "*It allows me more freedom to choose where I want to stay. Adds to the adventure*". Online respondents also highlighted the lack of costs associated with anchoring (n = 15).

Any respondents answering the questions regarding anchoring in seagrass were compared directly with their preferences for mooring and anchoring. For on-site and online respondents, 31.3% and 19.3% of respective respondents who had anchored in seagrass previously indicated their general preference to moor over anchoring (Fig. 6a & 6b). For individuals aware of the presence of seagrass before they anchored, 36.0% of on-site and 40.0% of online respondents also indicated their general preference to moor over anchoring (Fig. 6c & 6d).

On-site respondents were asked to express an honest opinion to the question '*Do you think VNAZs are necessary around Torbay where seagrass is present?*', to which 43.3% agreed they were, 35.8% were unsure and 20.9% did not agree they were necessary, although many commented that they had no awareness of VNAZs around Torbay (n = 26). Open-ended comments to this question were categorised into positive, negative and uncertain responses, based on the responses given to the corresponding closed-ended question, as shown in Table 4. Respondents identified as making positive themed comments towards VNAZs included reasons of seabed conservation (*n* = 23) and that the boaters in question would adhere to them (*n* = 11). Comments identified as uncertain mainly discussed the lack of advertising of VNAZs (*n* = 24) and that alternatives will be required if VNAZs are to be successful (*n* = 11). Negative comments were dominated by two major themes; identifying a want and need to anchor (*n* = 15), and that boaters would be unlikely to adhere to voluntary restrictions (*n* = 11).

Online respondents were also asked to rank their mooring or anchoring preferences in the instance that they encounter a restricted anchoring site (1 = most likely choice, 9 = least likely choice). A total of 46.9% (*n* = 97) respondents provided full rankings for each option, to which mean rankings are visualised in Fig. 7. A further 19.8% of all respondents provided only partial rankings for all options given and 33.3% didn't provide any response to the question.

3.2.4. Perceptions of the trial eco-mooring design

Online respondents were shown basic diagrams of a traditional swing mooring and the trial eco-mooring design for comparison, demonstrating a simple mechanism to suspend the riser chain above the seabed (Fig. 1). They were then asked to use a Likert scale to answer the question, "*How confident would you feel about using an eco-mooring such as the one in the image?*" (1 = no confidence at all, 10 = very confident), shown for comparison with confidence levels in traditional swing mooring reliability in Fig. 8. A mean of 7.27 (*n* = 199, s.d. = ±2.57) was given for the overall confidence of online boaters in the design of the eco-mooring, with scores ranging from 1 to 10.

The main themes highlighted from respondent uncertainty included questions about the design (*n* = 65), mainly apprehensions about adaptations to the riser chain (*n* = 45) including the floating chain making contact with vessels (*n* = 17), e.g. "*There is a slight challenge that the chain could be floated to the surface and catch my propeller*". Positivity towards the eco-mooring stemmed from appreciation of the design (*n* = 49) in that it was considered similar to a standard swing configuration (*n* = 28), or general positivity towards the concept and purpose (*n* = 22), e.g. "*No difference between the two as they both do the same thing*". Negativity from respondents largely disagreed with variable elements of the design (*n* = 12), such as "*The weight of the chain on the sea bed is fundamental to the holding capacity of a mooring*".

On-site respondents anchoring whilst taking part in questionnaires were asked to rate their confidence in the eco-mooring reliability (1 = no confidence at all, 10 = very confident) without being given any indication of the design configuration, to which the overall mean was 8.9 (*n* = 43, s.d. = ±1.32) with a range from 5 to 10 (Fig. 8). A statistically significant difference was found between on-site (median = 9.0, *n* = 43) and online (median = 8.0, n = 199) scores given for confidence using the eco-mooring (U = 2577, z = -4.15, p = <0.001, r = -0.27).

Respondents who had not used the trial eco-mooring on-site were also asked what their reasons were for not attaching to it. The main reasons included lacking awareness of its purpose (n = 26), that it was not available for use when they entered the cove (n = 15) and that the location of the eco-mooring wasn't ideal (n = 23), believed to be too far out from the shore (n = 11) and too exposed to environmental conditions (n = 10). A previous question asking why boaters visit Fishcombe Cove had identified it as a prime sheltering location from wind and waves (n = 37) and local to permanent berthings/moorings within Torbay (n = 16). However, 17.9% of those anchoring had previously attached to the eco-mooring between 1 and 10 times (mean = 2.5, s.d. = ±2.61) with a median of 1. Only 1 of these boaters had the opportunity to attach to the trial eco-mooring upon entering the cove, advising that he had chosen not to attach again due to the lack of a fender on the buoy, although he did advise that he had used the eco-mooring previously on 4 occasions.

Overall, 89.6% of on-site respondents agreed that eco-moorings within the context of the trial design provided free of charge for use, would be a worthwhile addition to seagrass areas around Torbay. Main themes identified for positivity were for seabed conservation (n = 28), security and/or safety (n = 16) and that the eco-moorings would be actively used by the respondents questioned (n = 14). No respondents disagreed with the idea of further eco-moorings of this type around Torbay, although 10.4% were unsure and expressed uncertainty about the trial eco-mooring design (n = 5) and potential increased boat traffic in Fishcombe Cove (n = 4).

General comments provided at the end of the on-site questionnaires appeared mainly positive, agreeing that the eco-mooring trial was a good idea (n = 19), that more eco-moorings were needed (n = 14) and that increasing awareness for the eco-mooring trial, VNAZs and seagrass were all necessary (n = 13). Many offered suggestions on how to improve the design of the buoy (n = 9), whilst a limited number offered varying negative feedback (n = 8).

4. Discussion

This study has demonstrated behaviour change in relation to anchoring distributions within the study site when comparing pre- and post- deployment of the eco-mooring in 2015 and 2017 respectively, as well as varied social responses from recreational boaters in response to the online and on-site questionnaires. This discussion will firstly review the changes to boating activity behaviour in relation to seagrass distribution within the study site. Following this, the social perceptions of recreational boaters will be explored, separating discussions on the varied themes of the online and on-site questionnaires including recreational boating community demographics, seagrass awareness, anchoring and mooring priorities, and perceptions of the trial eco-mooring.

4.1. Boating behaviour and seagrass mapping

This study recorded a considerably higher number of vessels visiting the study site in 2017 than in 2015, expected due to the calm weather conditions sought out in 2017 for on-site questionnaires by paddleboard. Previous studies (Demers et al., 2013; Unsworth et al., 2017) have indicated that both seagrasses and vessels favour locations with reduced water movements and wave action. Within this study, weather was a prime consideration for boaters, who generally chose to visit the cove because of its sheltered nature. Calm, south-westerly winds and air temperatures above 20°C led to the three highest daily vessel frequencies in 2017. Increasing wind speeds therefore resulted in a lower attendance of vessels since powerboats are assumed to prioritise calmer conditions than that of sailboats, the latter potentially spending more time ‘out sailing’ than visiting coves and bays due to the nature of the sport.

A higher percentage of sailboats than powerboats chose to attach to the trial eco-mooring. This could in part be due to a higher awareness of sailors from the environmental education efforts of sailing organisations such as the RYA, although due to the depth of water required for their keel, could equally be for reasons of security considering that the sailboats entering the cove were on average longer in length and therefore assumed heavier than the majority of powerboats recorded. The high percentages of vessels anchoring in the cove when they had the opportunity to attach to the eco-mooring, 44.4% and 50% of powerboats and sailboats respectively, suggests that recreational boaters either did not see the eco-mooring upon entry to the cove, chose not to investigate (as large lettering on top highlighted its purpose), or chose to ignore the eco-mooring in favour of preferential anchoring habits.

Although a 17.14 m radius was applied to each anchoring event to calculate a range of potential influence of the vessel rode on seagrass, strength of influence will undoubtedly decrease away from the anchoring point due to the lift of the chain’s catenary curve from the anchor point to the bow of the vessel. However, thinning of seagrass blades has been observed at a 16-20 m distance from traditional swing moorings caused by the mooring chain (Unsworth et al., 2017). Seagrass thinning is hypothesized to be mirrored by chains of anchoring vessels depending on the length of chain they deploy, if they have a chain or rope rode, and length of visit through changing tides; further study here is suggested. Anchor drag events would also add to both the spatial range of potential influence and strength of influence within the radii; another area suggested for further research as a large anchor relative to the size of the vessel is likely to create irregular tracks through the seabed and cause greater impacts (Francour et al., 1999). Larger anchors ~12kg have potential to damage an average of 34 shoots per anchoring event as measured in a *Posidonia oceanica* bed (Francour et al., 1999), although this is dependent on anchor style (Milazzo et al., 2004).

Vessel density maps appear to show an alteration in behaviour of anchoring vessels, shifting their distribution into a more southerly cluster away from the eco-mooring deployed in 2017. However, this cannot be confirmed without consideration of extraneous factors including weather conditions, as stronger wind conditions in 2017 could have persuaded vessels to anchor closer to the shore considering that respondents generally identified that they visit Fishcombe Cove for the shelter it provides. Published RYA advice (Evans, 2011) indicates that the first consideration when choosing any anchorage is “Shelter…ensuring good protection from all wind directions”. Vessel safety is therefore likely to have been the prime consideration for recreational boaters, thus creating a natural bias in the answers provided within this study. Shelter was also a priority for 86% of boaters in another study that specifically chose a seagrass dense area for mooring or anchoring (Lloyd and Marsland, 2013). Nevertheless, the resulting maps could indicate that eco-moorings placed strategically around or even within seagrass beds could alleviate impacts through anchoring vessel displacement whilst providing an alternative mooring system.

This study recorded a higher number of anchoring events in 2017 than 2015 using comparable methodologies, which is likely to have resulted in a greater level of damage to the seagrass beds in 2017 considering that a single anchoring event alone can be destructive (Ceccherelli et al., 2007; Collins et al., 2010; Francour et al., 1999; Hastings et al., 1995; Montefalcone et al., 2008; Walker et al., 1989). The percentage of anchoring pressure alleviated by the use of the trial eco-mooring, however, is anticipated likely to increase. This is due to the heightened awareness of boaters visiting the study site who were questioned in this study and made aware of the presence of seagrass, in addition to the repeated public use of the trial eco-mooring and anticipated spread of local knowledge regarding its free use.

CSI volunteer diver survey data were used to map the seagrass bed outer extent as opposed to that of a 2016 CSI study, due to the considerable natural annual variability in *Z. marina* distributions (Hemminga and Duarte, 2000) where beds die back every winter and regrow in the spring (Olesen and Sand-Jensen, 1994; Phillips et al., 1983). Using 2017 diver data therefore offered the most recent distributional data to best estimate the percentage of vessels possibly impacting the bed, as well as the percentage of anchoring damage alleviated through use of the eco-mooring during the study period.

4.2. Recreational boating community demographics

This study demonstrated that the boating community of Torbay that utilise anchorages around the MCZ are primarily male local or regional powerboat owners without membership to any local or national boating groups, and that could be reached through local harbours, mooring providers or more widely through local businesses including cafes, retailers or public houses. Understandably, seagrass awareness campaigns are currently targeted broadly at the general public unless they are aimed at specific age groups, such as children. Males of the general public have shown stronger utilitarian opinions about wildlife (Miller and McGee, 2000) including marine species in the UK where they demonstrated disinterest in many charismatic flagship species of seagrass conservation campaigns, such as seahorses (Jefferson et al., 2014). Presenting seagrass beds as a practical habitat by clearly defining their various ecosystem services as utilitarian functions, could therefore serve as an opportunistic angle to their portrayal, especially when attempting to educate and incite behaviour change in male powerboat owners identified as the majority of recreational boaters visiting the study site. Targeting education campaigns at specific demographic groups of local recreational boating communities could in turn increase community-driven conservation management and lead to an enhanced sense of marine citizenship (McKinley and Fletcher, 2010), especially where respondents in this study identified a sense of personal attachment to the study site.

The differences in club membership between online and on-site respondents does suggest that further ways of reaching the powerboat community could have been explored for the online questionnaire, since the majority of clubs contacted to participate were sailing-orientated.

4.3 Seagrass awareness

A high awareness of seagrass presence was confirmed by on-site respondents from a variety of outlets, mainly indicated as local knowledge. This could be linked to a rise in scientific study and local outreach, since other UK studies have found seagrass to be a recognisable marine plant to the wider general public (Jefferson et al., 2014), even if it is considered to be less charismatic (Duarte et al., 2008). Considering the high number of respondents aware of seagrass presence within the study area, questioning awareness of the threats to seagrass habitats and importance of ecosystem services they provide could have offered interesting insight to directly compare with boating behaviour during the study. Although seagrass historically has cultural and economic benefits to many worldwide communities, the value of seagrass habitats is not always recognised (Cullen-Unsworth et al., 2014). This has been clearly demonstrated by the removal of seagrass beds in tropical beachside resorts to maintain aesthetics for visiting tourists (Cullen-Unsworth et al., 2014). The development of snorkel safaris and seagrass walks in Wales and Tanzania respectively, however, have shown potential for seagrass eco-tourism as an outreach and educational tool (Cullen-Unsworth et al., 2014; Nordlund et al., 2013).

A higher percentage of on-site respondents compared to online respondents confirmed that they had previously anchored in seagrass, considered understandable since it was identified that the majority remain in the local seagrass-dense waters around the Torbay MCZ. It was, however, surprising to find that boaters recorded anchoring at Fishcombe Cove denied having ever anchored in seagrass, given the number of days that most spent visiting this location annually and the presence of seagrass in this location. It could be reasoned that this proportion of respondents might not be aware of seagrass below them if not hooked on the end of their anchor during retrieval. Alternatively, their response could have been induced by a social desirability bias of respondents who were aware of the conservation aims of the eco-mooring project, found more likely to occur in face-to-face social surveys (Duffy et al., 2005). For those generally aware of seagrass presence, information on the importance of seagrass beds and their locations around the MCZ can be obtained from the many noticeboards around the coastal paths or from Tor Bay Harbour who also include this information on their website (Tor Bay Harbour, 2016b). This signifies that boaters with an awareness of seagrass either lack an understanding of its importance and threats to the habitat, or prioritise their lifestyle choices to visit preferential anchoring sites over consideration for the environment. In order to encourage recreational boaters to prioritise conservation over their lifestyle choices, it has been suggested that positive messages are more successful in stimulating pro-environmental behaviour change over negative ones (Easman et al., 2018; O'Neill et al., 2013). Providing highly visible solutions, such as eco-moorings with positive messages of encouragement for their use, could therefore result in pro-environmental behaviour change within the recreational boating community and a higher public awareness of management strategies that is currently lacking (Easman et al., 2018).

Monetary incentives have been identified as appealing for boaters in this study. Offering eco-moorings free of charge could therefore be an attractive option, since cost was identified as a key priority by online respondents in this study (Fig. 7). A further monetary incentive could include charging fees for anchoring vessels in MCZs/VNAZs, funds from which could then contribute towards better enforcement and policing of byelaws in MCZs and aid the deployment and maintenance of further eco-moorings. To ensure successful uptake of monetary incentives such as these, consistency from governance spatially and temporally around the UK would be essential, as adaptations to or removal of incentives would likely be counterproductive (Gneezy et al., 2011).

Should free of charge public eco-moorings receive increased use (where none existed previously) and become socially accepted within a community as a mutually beneficial method of mitigating environmental damage, the choice to anchor may decrease as boaters aim to achieve social acceptance against a new ‘norm’. If eco-moorings become commonplace in UK coastal waters, community awareness of their environmental purpose would increase, potentially resulting in image motivated prosocial behaviour changes (Ariely et al., 2009; Gneezy et al., 2011) for those initially less willing to change anchoring behaviours.

4.4 Anchoring and mooring priorities

Already demonstrating that the majority of respondents generally prefer the physical action of mooring a vessel to anchoring, direct comparisons with seagrass anchoring responses implies that providing a mooring option in sensitive-seagrass sites around the UK could help alleviate cumulative impacts due to the overall preference to moor. However, the implementation of seagrass friendly eco-moorings is dependent on their social acceptance and widespread adoption (Egerton, 2011). Interestingly, over half of on-site respondents recorded anchoring had the opportunity to attach to the eco-mooring upon entering Fishcombe Cove, although this appears to have been connected to a lack of awareness on its free public use.

On-site respondents gave mixed opinions about the VNAZs in Torbay with over half providing uncertain or negative comments towards them. This may be due to the preference by boaters to continue visiting particular sites around Torbay without any restriction(s). This mirrors the results of research conducted in Studland Bay, Dorset, UK, where previous VNAZs had been implemented, with half of the respondents unwilling to relocate within the bay to avoid anchoring in seagrass (Lloyd and Marsland, 2013). A resistance to behaviour change highlights the need for alternative methods of management and/or mooring to alleviate anchoring and swing mooring damage to the seabed (Lloyd and Marsland, 2013).

Positivity for VNAZs mainly identified preservation of the seabed as a priority, although this could again have been a result of social desirability bias (Duffy et al., 2005) and might not necessarily translate into behaviour change (Vincent, 2011) regarding anchoring avoidance in VNAZs. A large number of respondents were not aware of the presence of VNAZs, leading to comments regarding the lack of advertising and recommendations for alternative options to be offered over anchoring. Confusion is understandable given the conflicting advice supplied to boaters. Previously Tor Bay Harbour highlighted Fishcombe Cove as a preferential anchoring site close to Brixham (Tor Bay Harbour, 2016a) whilst also providing conservation information and maps for seagrass beds in the bay (Tor Bay Harbour, 2016b), essentially highlighting a requirement for collaborative national and local governance to provide a clear message through all available channels. It must however be noted that Tor Bay Harbour have now updated their website to reflect the sensitive nature of Fishcombe Cove's seagrass beds as well as the implementation of further eco-moorings following this study (Tor Bay Harbour, 2018).

Ranked boating activity options highlighted that free of charge (FOC) options were a main priority for online boaters, with security of vessels also displaying importance since the top three preferential choices were ranked in order of assumed familiarity; '*berthing FOC*', '*traditional mooring FOC*' and '*eco-mooring FOC*' respectively. There was a distinct separation between the first six options and the latter three; '*raft to another vessel*', '*drop anchor*' and '*sail to another location*' sharing the highest means and lowest rankings (least preferential choices). '*Drop anchor*' as a least likely choice is understandable considering the design of the question pertaining to a restricted anchoring site. However, '*sail to another location*', as a least likely choice supports other findings that a proportion of boaters are likely to prioritise lifestyle choices such as visiting preferential locations, over relocation for an environmental cause (Lloyd and Marsland, 2013). This question admittedly alluded to VNAZs as an example of restricted anchoring sites, which could have made for a better comparison against on-site responses.

4.5 Perceptions of the eco-mooring trial

The contrast in positivity and uncertainty from on-site and online respondents respectively pertaining to confidence in the eco-mooring design, is likely to have stemmed from the visual 'working proof' of the trial eco-mooring in situ for on-site respondents. Online respondents were simply provided with a visual diagram of the basic eco-mooring configuration without evidence of its working use. It is no surprise that design raised much uncertainty in online respondents since a variety of eco-mooring configurations are still being tested worldwide (Egerton, 2011). Similarly, this was a key area of concern for influential stakeholders in an Australian study assessing various eco-mooring trial results (Outerbridge, 2013) where testing is currently more common than in UK waters. However, on-site respondents expressed a general welcome for the trial eco-mooring in Torbay, scoring their confidence in its reliability significantly higher than online respondents without a visual or verbal description of its configuration. The theory behind retaining imagery or a verbal description from on-site respondents was to test a hypothesis that boaters generally place trust in standard visitor moorings, giving an assumption that all is well beneath the surface of a mooring buoy. This trust from on-site respondents is comprehendible since there is physical evidence of design, planning and deployment efforts on site, influenced by an awareness that the eco-mooring was newly deployed and actively providing a service to visiting boats, whereas online respondents may have assumed the trial design was simply at a conceptual stage. To improve confidence in eco-moorings from the recreational boating community, further evidence and media attention is required on existing eco-mooring trials. Regional projects are gathering this evidence and creating local media interest, especially where recovery of seagrass ecosystems are a result of eco-mooring deployment (Luff et al., In prep), yet these projects are still few in number and take time to gather sufficient evidence from. National media coverage of local success stories like these is paramount in changing public perceptions, where seagrass currently receives the least media attention globally when compared with other coastal habitats including saltmarsh, coral reefs and mangroves (Duarte et al., 2008). Raising the profile of seagrass beds as critically important habitats, both for the ecosystem services they provide as well as for the natural biodiversity they support, is crucial to further public understanding of how ecologically and economically important seagrass beds are locally to the UK, as well as globally.

On-site respondents largely agreeing with the deployment of further eco-moorings around Torbay gives a strong indication of the success of this trial at Fishcombe Cove. It was encouraging to find that most recreational boaters cited seabed preservation as the main reason for extension of the eco-mooring project. Security of vessels was a second priority that would undoubtedly benefit the majority of boaters in both the on-site and online questionnaires who indicated a preference for mooring where security was a main theme of rationalisation. General comments from on-site respondents again presented the argument that further eco-moorings, awareness and conservation information would be beneficial to the recreational boating community in sensitive seagrass areas.

5. Conclusion

It is well cited that coastal habitat management in the UK is in need of improvement (Jackson et al., 2016; Jones and Unsworth, 2016; Langstone Harbour

Board, 2013; Unsworth et al., 2017), especially where locally important seagrass beds face further degradation due to anchoring activity (Egerton, 2011). However, as indicated by this study, there is an opportunity for eco-mooring deployment to be a mutually beneficial mitigation method. Where national conservation efforts are making slow progress to aid the recovery of seagrass beds in the UK to meet Good Environmental Status, urgent changes in top-down management are recommended to include providing public eco-moorings for the recreational boating community in seabed sensitive sites.

This study demonstrated that knowledge of seagrass importance does not always equal behavioural change, confirmed by nearly half of on-site respondents who anchored their vessels within the study site, already aware of the presence of seagrass. Most recreational boaters, however, revealed a preference for mooring over anchoring. Management should therefore prioritise the implementation of alternative mooring systems, such as eco-moorings in sensitive-seagrass sites. Mapping efforts suggest that deployment of eco-moorings could stimulate vessel displacement, indicating that strategic placement in or on the edges of seagrass beds could offer mutually beneficial mitigation (away from seagrass beds). In this study the prevailing weather may have influenced the choice of anchoring locations within the study site, therefore longer-term studies into boating behaviour at trial sites is recommended to enable the strategic placement of moorings; taking into account possible displacement effects and weather influence.

Incentives should also be considered to encourage the use of eco-moorings and discourage anchoring in sensitive sites. These could include complimentary use of public eco-moorings and/or charging fees for anchoring privileges in MCZs/VNAZs; the fees from the latter option could then improve policing of byelaws and monitoring in MCZs/VNAZs, as well as fund the deployment and maintenance of further eco-moorings. Deploying further free of charge eco-moorings nationally would inevitably increase their social acceptance and public understanding of their environmental purpose, likely altering long-term behaviour change through the pursuit of social acceptance in those initially less willing to adapt.

Improved collaboration from national and local governance giving clear and concise public messages are essential to avoid confusion between anchoring rights and conservation efforts. An example of conflicting advice previously given by a local harbour authority has been highlighted in this paper, having previously promoted anchoring in seagrass-sensitive sites whilst also providing seagrass conservation information. Clear environmental guidance should be aimed towards the wider general public, inclusive of the male powerboat community aged 35+ years that were highlighted in this study as the majority of boaters visiting the study site that were mainly non-boating club members. Local governance should aim to disseminate guidance on the importance of seagrass beds and anchor damage to these individuals through local harbours, mooring providers, vessel retailers and businesses including cafes, retailers or public houses.

Although top-down management is recommended as a matter of urgency for UK seagrass conservation, stakeholder engagement at the local community level is required to enhance understanding of new regulations imposed. Engagement with stakeholders using the marine environment is crucial and should be tailored to include individuals who may use particular sites for a variety of activities both commercially and recreationally.

Overall, this study has demonstrated that the deployment of a particular design of eco-mooring that has already begun proving its worth through a reduction in anchoring events as well as ecologically (Luff et al., In prep), can be socially accepted when trialled in situ, with strong potential for social acceptance within the wider recreational boating community. With additional measures in place to reduce harmful displacement of anchoring activity, improvements to local knowledge of the presence and need to use the mooring, along with concurrent trials to incentivise behaviour change, eco-moorings should be considered as an option to alleviate traditional swing mooring scour and anchoring damage to seagrass beds in subtidal waters of the UK.

Declarations of interest

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Figures

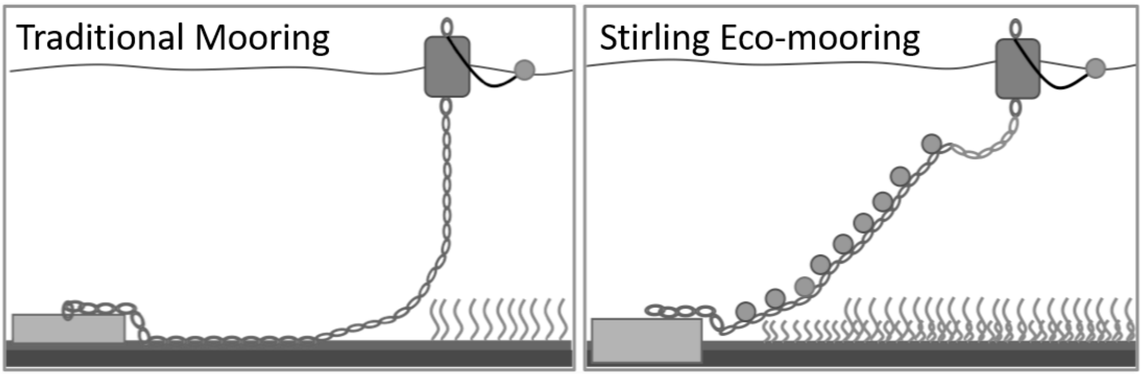

Fig. 1: ***Diagram of traditional versus bespoke Stirling eco-mooring***

Diagram depicting the differences between a) a general traditional swing mooring and b) the National Marine Aquarium's Stirling Eco-mooring with double the tonnage of a standard ground weight and buoys along the riser chain. Image adapted from that kindly provided by the National Marine Aquarium.

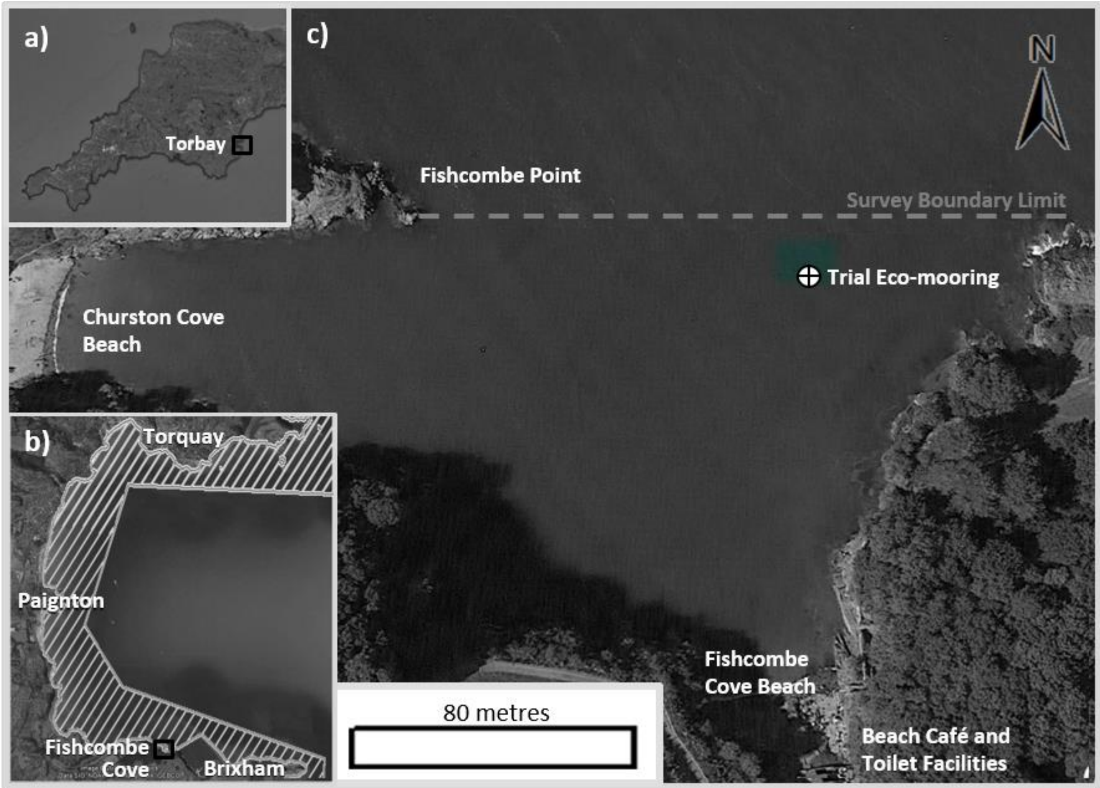

Fig. 2: ***Map of study site and eco-mooring location***

Location of study site in relation to (a) Southwest England (Devon and Cornwall) region and (b) Torbay region showing a section of the designated MCZ (hatched polygon). Figure (c) shows localised study site of Fishcombe Cove including polygons where location of trial eco-mooring identified with a ⊕ symbol. Devon and Cornwall, Torbay and Fishcombe Cove satellite images from Landsat/Copernicus satellites obtained from Google Earth Pro. Polygon mapping layer of Torbay MCZ from Natural England, accessed via MAGIC online mapping software.

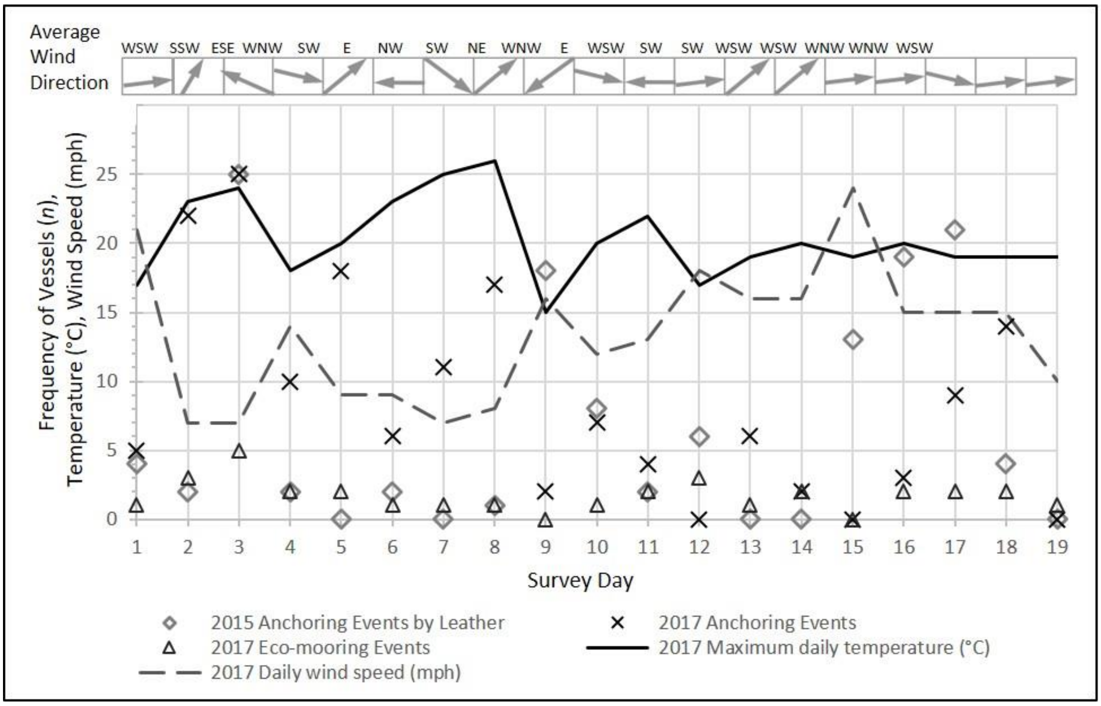

Fig. 3: ***Vessel frequency and weather comparison***

Scatterplot of vessel frequency presenting anchoring events (black crosses) and eco-mooring attachments (black triangles) in 2017, compared with anchoring events recorded in 2015 (grey diamonds). Weather elements including maximum air temperature (°C; black line), maximum wind speed (mph; grey dashed line) and average daily wind direction for 2017 survey days have been added for additional comparison, provided by World Weather Online (2017).

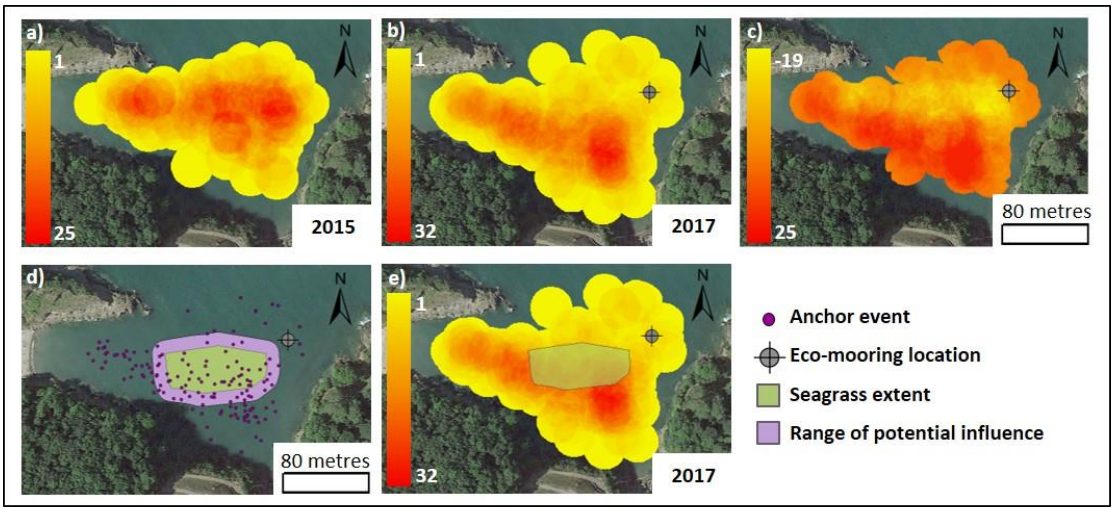

Fig. 4: ***Vessel density and seagrass extent maps***

Maps of Fishcombe Cove study site shown using point data for anchoring locations and 17.14 m radius of potential influence on the seabed, indicated with colour bars for pre (2015) and post (2017) installation of the trial eco-mooring including: a) vessel density of 127 anchoring events over 19 days in 2015; b) vessel density of 161 anchoring events over 19 days in 2017; c) anchoring density variance where positive and negative integers represent variance when the 2015 layer is subtracted from the 2017 layer (mean = 1.22, s.d. = ±8.12); d) 2017 anchor events mapped against 2017 seagrass distribution polygon created from data provided by Community Seagrass Initiative with a 17.14 m zone of potential influence where vessels anchored can affect the outer edge of the seagrass bed; and e) location of trial eco-mooring and 2017 vessel density in relation to 2017 seagrass extent. Basemaps taken from Google Earth Pro, created in ArcGIS 10.5.1.

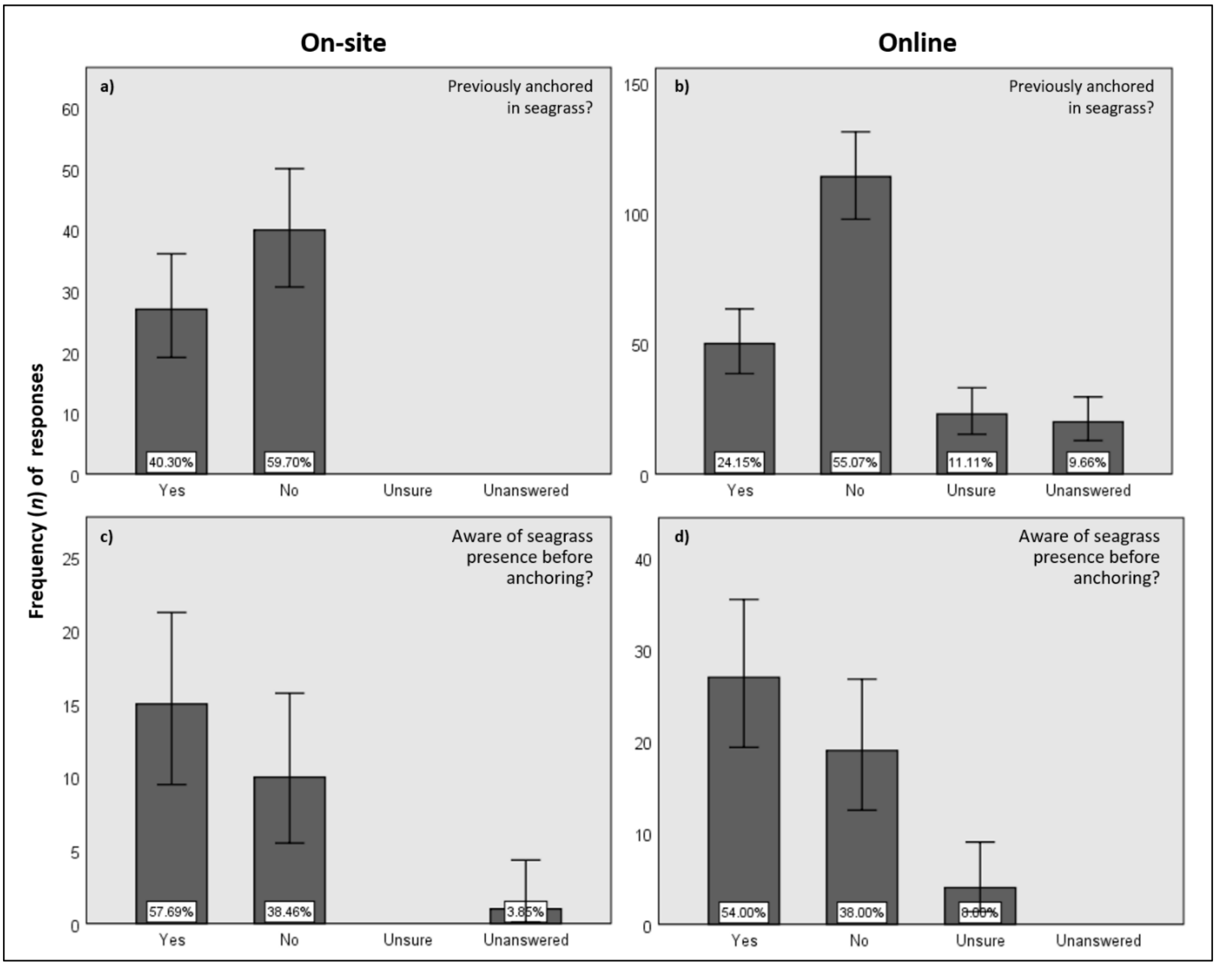

Fig. 5: *Recreational boater seagrass awareness*

Bar chart showing frequency and percentage of questionnaire responses to the questions (a & b) "*Have you ever anchored in a seagrass bed?*", and for those who had (c & d) "*Were you aware seagrass was in the area before you anchored?*". It should be noted that on-site questionnaires did not offer the option of 'Unsure' for the first question (a). Online questionnaires also did not offer respondents the option to provide no response for the second question (d) if they had responded 'Yes' to the first question (b), therefore leaving it impossible to result in any "Unanswered" responses. Error bars show confidence interval at 95% level.

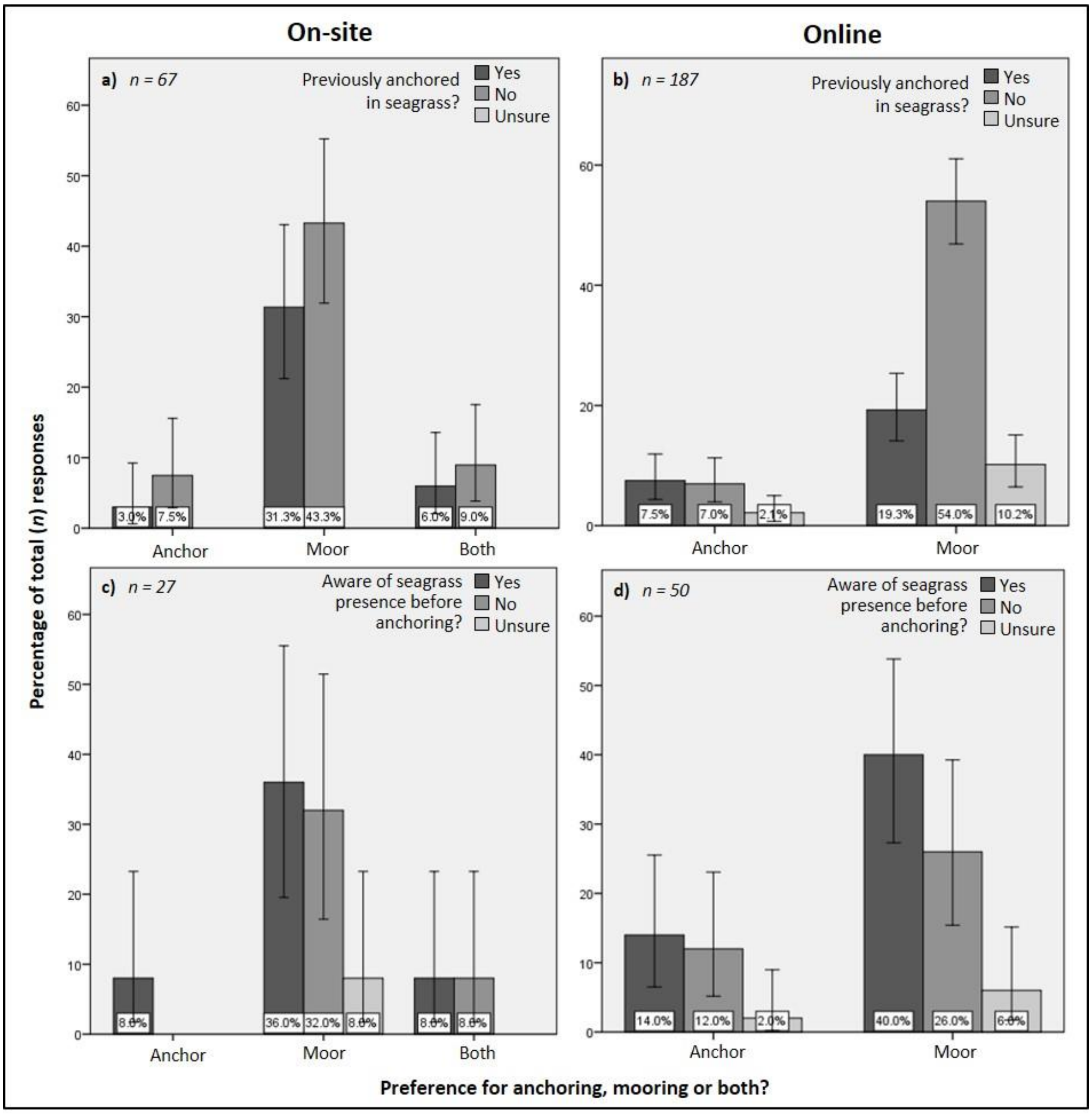

Fig. 6: ***Seagrass awareness against mooring preferences***

Clustered bar chart showing respondent preferences for anchoring, mooring or both, separated into percentages categorised by their answers to the question (a & b) "*Have you ever anchored in a seagrass bed?*", and for those who had (c & d) "*Were you aware seagrass was in the area before you anchored?*". Error bars show confidence interval at 95% level.

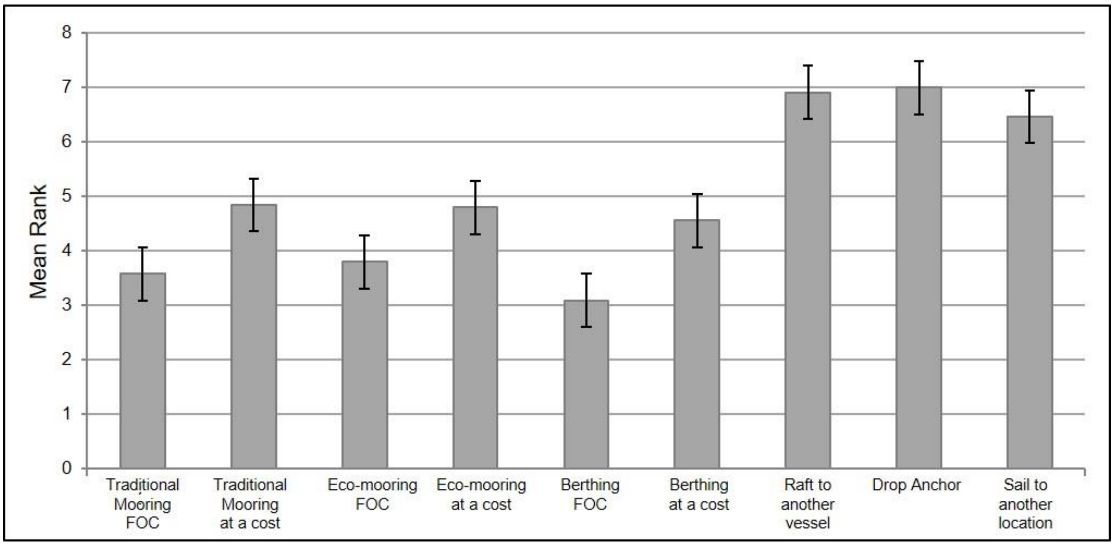

Fig. 7: ***Results from online respondents ranking preferential options***

Bar chart presenting means and standard errors for options ranked from 1 (most likely choice) to 9 (least likely choice) to the question, "*What would you choose to do (or have previously chosen to do) in response to encountering a site of restricted anchoring in UK waters?*", asked to online respondents (n = 95). Note that lower means and therefore smaller bars represent the most likely choices. FOC = free of charge.

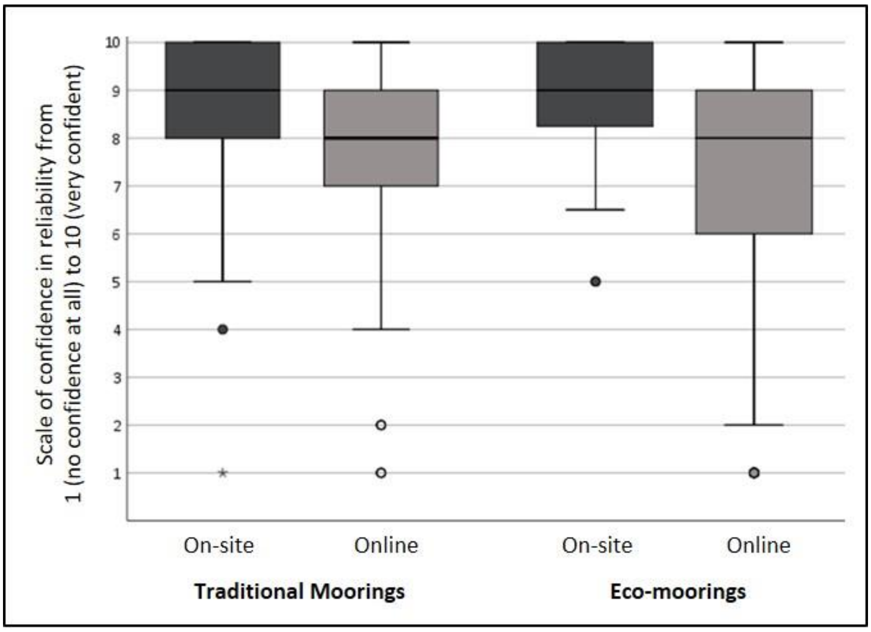

Fig. 8: ***Confidence levels in traditional and eco-moorings***

Box plots displaying scale of confidence in reliability of traditional swing moorings versus eco-moorings from both on-site (dark grey box plots) and online (lighter grey box plots) respondents. Boxes show interquartile range, thick black lines indicate median, t-bars show range, circles indicate outliers and asterisk indicates extreme outlier from the data.

Tables

Table 1: *On-site questionnaire participation*

This table shows the varying participation of recreational boaters to the on-site questionnaires from those recorded visiting the study site over 19 days between the hours of 09:30-17:30. The 'On-site vessel participation' column defines categories within which all visiting vessels recorded during the boating activity study have been sorted. The 'Total vessel frequency' column percentages are representative of the total number of vessels over the course of the surveying period of 19 days (e.g. *n* = 170). Anchoring, mooring and rafting vessel frequency percentages add up to their respective 'Total vessel frequencies' in bold.

On-site vessel participation	Total vessel frequency % (*n*)	Anchoring vessel frequency % (*n*)	Mooring vessel frequency % (*n*)	Rafting vessel frequency % (*n*)
Total Vessels	**100 (*170*)**	80.6 (*137*)	17.6 (*30*)	1.8 (*3*)
- Successfully questioned	**39.4 (*67*)**	68.7 (*46*)	29.8 (*20*)	1.5 (*1*)
- Missed	**34.1 (*58*)**	89.7 (*52*)	6.9 (*4*)	3.4 (*2*)
- Questioned previously	**16.5 (*28*)**	85.7 (*24*)	14.3 (*4*)	--
- Refused participation	**3.5 (*6*)**	83.3 (*5*)	16.7 (*1*)	--
- Already completed online questionnaire	**2.9 (*5*)**	100 (*5*)	--	--
- Under approachable age (18 years)	**2.9 (*5*)**	100 (*5*)	--	--
- Working vessels not approached	**0.7 (*1*)**	--	100 (*1*)	--

Table 2: *Demographics of on-site and online respondents*

Breakdown of demographics of both online (*n* = 207) and on-site (*n* = 67) recreational boating respondents after data aggregation. Where *n* is not equal to the maximum number of respondents questioned, responses were not given for that question and n is indicated in the demographic variable header. Variations did occur in demographics sought in online and on-site questionnaires separately where data is missing.

Demographic Variable	Online Respondents % (*n*)	On-site Respondents % (*n*)	Demographic Variable	Online Respondents % (*n*)	On-site Respondents % (*n*)
Gender	*(n = 207)*	*(n = 67)*	*Residency*	--	*(n = 67)*
- Male	81.6 (*169*)	53.7 (*36*)	- Local: (TQ1-TQ5)	--	49.3 (*33*)
- Female	18.4 (*38*)	7.5 (*5*)	- Regional: Devon	--	34.3 (*23*)
- Couple	--	38.8 (*26*)	- National: Rest of UK	--	16.4 (*11*)
Age Group	*(n = 207)*	*(n = 67)*	*Average no. days sailing UK coast*	*(n = 207)*	*(n = 67)*
- 18-34 years	5.8 (*12*)	13.5 (*9*)	- Low: 1-30 days	41.1 (*85*)	47.8 (*32*)
- 45-54 years	32.8 (*68*)	49.2 (*33*)	- Mid: 31-90 days	41.1 (*85*)	37.3 (*25*)
- 55+ years	61.3 (*127*)	22.4 (*15*)	- High: > 91 days	17.8 (*37*)	14.9 (*10*)
Member of a Boating Club/Group	(*n = 207*)	(*n = 67*)	*Average no. days visiting FC by sea*	--	(*n = 67*)
- Yes	88.9 (*184*)	22.4 (*15*)	- Low: 1-14 days	--	67.2 (*45*)
- No/No response	11.1 (*23*)	77.6 (*52*)	- Mid: 15-30 days	--	19.4 (*13*)
Vessel Type	--	*(n = 67)*	- High: 31+ days	--	13.4 (*9*)
- Power	--	76.1 (*51*)	*Average no. days anchoring in Torbay*	--	*(n = 65)*
- Sailboat	--	23.9 (*16*)	- Low: 1-14 days	--	46.2 (*30*)
Value of Vessel	(*n = 199*)		- Mid: 15-30 days	--	26.1 (*17*)
- < £24,999	59.4 (*118*)	--			
- £25,000-£99,999	30.6 (*61*)	--			
- > £100,000	10.0 (*20*)	**--**			

Table 3: ***Thematic framework of on-site respondent seagrass awareness***

A thematic framework of open-ended comments from on-site respondents when asked '*Are you aware seagrass is present in Fishcombe Cove and around Torbay and if yes, how were you made aware?*'. Frequency of respondents show the number of boaters who provided comments pertaining to each theme and are in descending order from most popular themed comment to least.

Themes identifying source of seagrass awareness	Frequency of respondents	Themes identifying source of seagrass awareness	Frequency of respondents
Word of mouth, local knowledge	20	Received email from marina	2
Read VNAZ buoys	9	Social media	2
Activities undertaken; diving, snorkelling, swimming	6	Through knowledge of Studland seagrass	2
Read billboards around Torbay	6	Watched eco-mooring deployment video	2
Read in newspaper or magazine	5	Work in marine industry	2
Informed at local event (Brixfest, Paignton Festival, etc)	4	Read eco-mooring buoy	1

Table 4: *Thematic framework of on-site responses to Torbay VNAZs*

A thematic framework of open-ended comments from on-site respondents when asked '*Do you think that 'voluntary no anchor zones' (VNAZs) are necessary in Torbay where seagrass is present?*'. Responses are in descending order from most popular themed comment to least. Themed comments entered into the main emotive categories (bold headers) of 'positive', 'negative' and 'uncertain' were validated by the corresponding closed question which identified comments as positive/negative/uncertain based on the framing of the question. Themed comments within each emotive category with higher frequencies are split into parent and child categories (child indicated in italics) where possible, to explore further details pertaining to popular themes.

Themed comments on Torbay VNAZs	Frequency of respondents	Themed comments on Torbay VNAZs	Frequency of respondents
Uncertain		**Negative**	
Not adequately advertised	24	Anchoring is preferential	24
Alternatives needed	11	- *Need and want to anchor*	*15*
Need evidence of seagrass importance and proof of anchor damage	7	- *Boaters won't adhere to VNAZs*	*11*
VNAZ buoys assumed only 5 knot buoys	2	- *Worried about complete anchoring restrictions*	*2*
Assumed seagrass surrounds VNAZ buoys	1	Boaters can be respectful of the seabed without VNAZs	2
Positive		Conflicts could arise	1
Conservation Avoids Seabed damage	23	Fishcombe Cove is on admiralty charts as an anchorage	1
Would adhere to VNAZs	11	VNAZs might scare tourists	1
Should enforce anchoring restrictions in VNAZs	1		
Will alleviate some anchoring	1		