

Understanding drivers, barriers and information sources for public participation in marine citizen science

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Abstract

Interviews were conducted with 110 marine users to elicit their salient beliefs about recording marine species in a citizen science project. The results showed that many interviewees believe participation would increase knowledge (either scientific, the community's, or their own). While almost half of the interviewees saw no negative outcomes, a small number expressed concerns about targeting of marine species by others, or restrictions on public access to marine sites. Most of the people surveyed ($n = 106$) emphasised the importance of well-designed technological interfaces to assist their data collection, without which they would be unlikely to engage in the project.

Keywords

Citizen science; Environmental communication; Public engagement with science and technology; Public perception of science and technology

Context

Research on environmental issues such as climate change and genetically modified foods has provided plenty of material for scholarly discussion about the most effective ways to publicly communicate the science behind these topics, and the reasons why the public may or may not accept this information [see for example, Finucane and Holup, 2005; White and Wall, 2008]. Another area of global interest is the health and state of our marine environment and the ecological changes being detected and predicted for the future [Brierley and Kingsford, 2009; Brown et al., 2010; Halpern et al., 2008; Hobday and Pecl, 2014; McCauley et al., 2015]. No matter how far we live from the coastline, the ocean dictates our climate, accounts for a large share of our food supply, and plays an important role in the economic prosperity of many nations [Kaiser et al., 2011; OPSAG, 2013]. Yet our knowledge about this valuable environment is relatively limited; it is said we know more about space than we do about life in our oceans [Copley, 2014; NOAA, 2013]. There is clearly an urgent need to increase our understanding of the oceans at a greater rate. Public participation in marine research has enormous potential to contribute substantially to data collection effort, given the considerable number of people who use the ocean for recreational or commercial purposes.

There is also growing recognition of the need for more meaningful public engagement with scientific research and the knowledge it contributes to the way humans use, manage and protect natural ecosystems such as the marine

environment [Chilvers et al., 2014; DIISRTE, 2012; Ressurreição et al., 2012]. Scholars studying the relationship between science and society talk of the 'participatory turn' in acknowledgement that the public can, and should, make important contributions to scientific knowledge [Burgess, 2014; Jasanoff, 2003; Jasanoff, 2014; Lengwiler, 2008]. Increased interest in public science engagement has helped drive a recent surge in the 'citizen science' movement, in which the lay public (citizens) facilitate scientific processes in some way [Bonney et al., 2009; Crall et al., 2010; Roy et al., 2012].

Reflecting a global trend, the number of marine citizen science projects in Australia has dramatically increased in recent years [Sbrocchi, 2014] and continues to do so. The public can now become involved in a wide range of marine research, such as recording out-of-range species [Robinson et al., 2015], collecting observational data on marine species [Beeden et al., 2014] and monitoring marine debris [Smith and Edgar, 2014]. Internet searches and an analysis by Sbrocchi [2014] reveal the number of Australian marine citizen science projects appears to be at least several dozen (and growing), with most having a local or regional focus and only a small handful operating at a national or global level.

One marine citizen science project with a national focus is Redmap (Range Extension Database and Mapping project, www.redmap.org.au), which is hosted nationally by the Institute for Marine and Antarctic Studies at the University of Tasmania. Redmap invites Australian marine users to report sightings of marine species that are uncommon to a particular area i.e. species that may be 'range-shifting' in response to environmental change [Robinson et al., 2015]. The national focus of Redmap provides a useful case study to examine public responses to marine citizen science.

With the amount of interest, effort and resources going into marine citizen science, it is timely to ask: what are the key drivers and barriers for public participation? The challenge for scientific organisations and scientists is to design citizen science projects to engage lay people in research effectively, yet few have paused to consult the public about their interests in citizen science. Nisbet and Scheufele [2009] emphasise the importance of understanding the audience's perspectives and communication preferences for more effective engagement in science. Audience research will enable a more strategic direction for citizen science, and ensure that projects are designed for, and target, the interests of the community for maximum uptake and engagement.

Objective

The aim of this paper is to report on the breadth of issues about drivers and barriers for public participation in marine citizen science. For the purposes of this research, the marine environment encompasses oceans, coastal beaches, and estuaries. The results presented here are the first stage of a social psychological investigation into Australian marine users to uncover the most relevant factors influencing their involvement in marine research. This stage involves eliciting the key issues for the study group (marine users) from a sub-sample, to develop pertinent questions for a subsequent survey of the larger population of marine users. We also report here the preferred media and information sources — an important consideration in gaining the attention of the audience in the first place. The findings are discussed in light of the formative purpose of the interviews, and future research directions are suggested.

Method

Participants

The key target audiences were defined through an analysis of the characteristics of the audience currently engaged with the Redmap project. Three groups emerged from this analysis. Two priority groups, SCUBA divers and fishers, were identified as the most frequent contributors to data collection efforts. The third group encompassed all 'other' marine uses (such as beach walking, boating and sailing, etc.).

While activity type was the primary focus for targeting respondents, potential for regional differences also existed (such as seasonal effects on participation rates and acceptance of prevailing marine estate management regimes). In addition, latitudinal differences exist in climate change effects on marine ecosystems [Poloczanska et al., 2007]. For example, temperate southern regions are experiencing much greater rates of ocean warming than the tropical north of Australia [Hobday and Pecl, 2014]. As a consequence, the public in these areas may be more aware of the changes not only through their own observations, but also through increased media attention to these issues.

Since the aim was to gather a broad range of beliefs about participation in marine research, and that these beliefs may vary between regions, the decision was made to interview respondents in four key areas across Australia. These were the towns of Brunswick Heads, Byron Bay and Ballina in northern New South Wales (herein called the NSW sample), Townsville in Far North region of Queensland (herein called the QLD sample), Hobart and surrounds in Tasmania (herein called the TAS sample), and Perth and Busselton in Western Australia (herein called the WA sample).

Sampling instrument

A face-to-face structured interview [Bryman, 2012] was developed to ask questions around the following themes:

- use of the marine environment (activities, frequency, preferences etc.);
- beliefs about participating in a sightings-based marine citizen science project;
- current, preferred and trusted information sources;
- demographics.

Measure development

Marine use questions were developed to determine participation rates in marine activities, location and frequency. An additional question asked interviewees: *Of all the activities you do in the marine environment, which one is the most important to you?* This question was used to identify which activity group the respondent would most identify with, and was used as the key grouping variable in the data analysis.

Questions on beliefs about participation in marine citizen science were developed using the Reasoned Action Approach/Theory of Planned Behaviour (RAA/TPB) elicitation methodology [Ajzen, 1991; Fishbein and Ajzen, 2010].

This approach is useful in helping understand the factors which influence behaviour. In this case, the behaviour is reporting sightings to a marine citizen science project. During the interviews respondents were presented with a hypothetical project modelled on Redmap. According to Fishbein and Ajzen [2010], a hypothetical situation can be a valid approach to understanding behaviour.

Using the RAA/TPB framework, open-ended questions were asked concerning the respondent's beliefs about the *behaviour* (participating in the marine citizen science project by reporting sightings of marine species), *injunctive and descriptive social norms* and *control*. *Behavioural beliefs* are beliefs a person has about the outcomes (the advantages or disadvantages) of a particular behaviour. *Injunctive norms* are, in essence, the pressure a person feels from others who are important to them to perform the particular behaviour (in this case, it means the ability of others to influence whether you would report a sighting or not). *Descriptive norms* reflect the *perception* that others are behaving a certain way, whether they are or not (in this case, it is the perception that important people in your life are reporting sightings, or not). *Control beliefs* are beliefs about the degree to which a person can actually perform the behaviour, and the strength of their control over performing the behaviour (which in this case includes beliefs about factors which may help or prevent them from reporting sightings of marine species).

Interviewee's information sources were asked about in four different ways. First, respondents were asked on which online platforms (web sites, forums etc.) they see images of marine species posted by other marine users. This was to determine the popular methods for spreading information about sightings of marine species outside of a scientific context. Second, respondents were also asked where they currently receive 'correct' information about the marine environment. The term 'correct' was used to imply perceived truthfulness in the information, rather than strictly scientifically accurate information. This distinction is important to understand who and what sources of information are considered by marine users to be truthful or accurate. The third question asked them for their preferred way to receive correct information about the marine environment; while the fourth question asked which sources they trust the most for correct information. The list of possible sources were drawn up from information gained in recent Australian public opinion polls on science and technology [DBI, 2012; Searle, 2014] and an 'other' category was provided to capture any additional sources.

The majority of demographic questions were taken directly from the latest national census conducted in 2011 (retrieved from <http://www.abs.gov.au>). The questions used in the interviews are presented in the supplementary material.

Pilot testing and clarification of questions

Once the survey instrument was developed, it was pilot tested on 12 people who were known to the lead researcher to be involved in a variety of marine activities. Some minor adjustments to wording of the questions were made at this point, and the survey was sent to Liam Smith, Director of BehaviourWorks (a team of behaviour change researchers, based at Monash University) for comment. Following this, further minor changes were made to the order and wording of some questions.

Table 1. Preferred activity group and gender.

Activity Group		State interview took place							
		NSW		QLD		TAS		WA	
		Count	Column Total N %	Count	Column Total N %	Count	Column Total N %	Count	Column Total N %
Fishers (n = 38)	Female	0	0.0%	0	0.0%	1	20.0%	1	7.1%
	Male	6	100.0%	13	100.0%	4	80.0%	13	92.9%
Divers (n = 39)	Female	6	54.5%	2	20.0%	1	20.0%	10	76.9%
	Male	5	45.5%	8	80.0%	4	80.0%	3	23.1%
Others (n = 33)	Female	3	37.5%	2	28.6%	3	33.3%	4	44.4%
	Male	5	62.5%	5	71.4%	6	66.7%	5	55.6%

Sampling procedures

Number of interviewees. A minimum number of 25 respondents in each target group (fishers, divers and other marine users) were required to run statistical analysis on differences between the groups [Fishbein and Ajzen, 2010]. The sampling matrix achieved can be seen in Table 1. While the majority of respondents were unaware of the Redmap project prior to the interview, 12 people who had previously logged sightings in Redmap were also interviewed to determine whether there were any different issues for this group. Of these, eight were in the Western Australian sample and four were in the Tasmanian sample.

Sampling approach. All interviews took place between May – August 2014. The stratified random sampling approach [Bryman, 2012] worked well for reaching 60% of the respondents directly. Respondents were identified according to their observed activity in the marine environment. This involved approaching people at fishing locations, boat ramps and through marine-related businesses (e.g. customers or staff in shops or clubs). Care was taken to talk to a wide range of ages, interests (e.g. people who fish occasionally from shore through to people who are heavily involved in professional or game fishing) and locations around the region. The additional 40% of respondents were gained through snowball sampling [Bryman, 2012]. This method was especially necessary for most of the diver interviews as it was difficult to access divers during the winter months of the sampling period.

Analysis

Use of the marine environment, information sources, and demographics.

Simple frequencies and percentages were used to gain an overall picture of the types of activities, use of the marine environment, information sources and demographics of the sample group.

Beliefs about participation in marine citizen science. In this first stage of the application of the RAA/TPB, the researcher is concerned more about eliciting the *range* of beliefs from the sample population rather than being able to draw conclusions about the *importance* of each belief uncovered in the interview process [Fishbein and Ajzen, 2010].

The *behavioural*, *normative* and *control* beliefs elicited during the interviews were subjected to a content analysis to draw out the salient themes [Fishbein and Ajzen, 2010]. To strengthen the reliability of the results, three researchers independently coded the open-ended responses to these questions [Bryman, 2012; Krippendorff, 2004b]. An inter-coder reliability test was performed using Krippendorff's alpha α [Krippendorff, 2004a], and confidence was determined by a bootstrapping routine using 10,000 samples. The results of each reliability test are presented at the end of each table of beliefs about participation.

Some caution may need to be applied in the interpretation of the results for the *advantages of logging* (i.e. reporting sightings) question as this was the only variable in the inter-coder reliability test which scored $\alpha < 0.8000$. Further investigation of the coding revealed that one coder consistently coded this variable differently to the other coders. Time and funding restrictions meant that retraining and recoding were not possible, so the decision was made to drop this coder from the analysis for this variable only. When the reliability test was run on the two remaining coders, agreement between coders was found to be within acceptable limits ($\alpha = 0.8254$).

Results

Background factors of respondents

Demographics. The sample of respondents varied widely in their age (15–74 years) and tertiary qualifications (43.6% had university-level qualifications). There were more males ($n = 77$) than females ($n = 33$), and female fishers were particularly difficult to locate (Table 1).

Use of the marine environment. The reported activities were wide-ranging; with beach walking/beach combing being the most frequently mentioned activity in NSW (64.0%), TAS (73.7%) and WA (66.7%). The most popular activity in QLD was recreational fishing (83.3%). After beach walking, popular activities included fishing, snorkelling, SCUBA diving and swimming. The high popularity of fishing and diving is no surprise in this result, as fishers and divers were specifically targeted for the interviews.

Most respondents were very active in the marine environment, with the majority (63–76%) using it at least once a week in all states except Queensland where 43.3% visit at least once a week, and 43.3% visit at least once a month.

Beliefs about participation

Perceived advantages and disadvantages of reporting sightings. When asked what they saw as the advantages of logging (reporting) sightings of uncommon species, the majority of responses referred to increasing knowledge (Table 2). Many interviewees thought that it would increase scientific knowledge, provide information for the 'greater good', or increase their own knowledge. Raising public awareness about the marine environment was also seen to be a positive outcome, as was the protection or management of the ocean.

Almost half of the interviewees thought that there would be no disadvantages resulting from logging uncommon marine species (Table 2). The remaining half

Table 2. Perceived advantages and disadvantages of reporting sightings.

Advantages	Example comments	Frequency	Valid Percent					
Increasing scientific knowledge	<i>"the information would be useful to the scientific community over the long term", "assisting with research in migration of species"</i>	79	31.9					
Provides information for greater good/everyone	<i>"contributing to knowledge of the community", "everyone would learn about what's going on"</i>	53	21.4					
Increasing my own knowledge	<i>"Me learning the identification of different species", "learning about the changing environment of the oceans"</i>	35	14.1					
Increasing public awareness of marine environment	<i>"encourages other people's awareness of changes in the marine environment", "gets people engaged with their surroundings"</i>	27	10.9					
Helps to protect/manage marine environment	<i>"it would be rewarding to feel I'm playing a part in the protection of the marine environment", "helping identify invasive species early on"</i>	24	9.7					
Something interesting to do	<i>"it's interesting", "gives purpose to my activity"</i>	14	5.6					
Other	<i>"being recognised as the [person who discovered] the new species", "feeling good about it"</i>	16	6.5					
Total		248	100.0					
Disadvantages	Example comments	Frequency	Valid Percent					
None		48	39.3					
Could harm species	<i>"people targetting unusual specimens for their collection or fishing", "could bring too many people to the area and hurt the habitat"</i>	15	12.3					
Could impact on access to sites	<i>"potential for restrictions to access", "Fisheries might put a no fishing zone in the area that the uncommon fish was sighted in"</i>	10	8.2					
Unsure/untrusting of how data will be used to infer scientific results	<i>"if the data/information is misinterpreted", "what the Greens make of it - they'll make unscientific assumptions that lead to politics"</i>	10	8.2					
Logging could be really time consuming	<i>"the time it takes", "time it takes and potential pain it takes to log"</i>	9	7.4					
Could log wrong information	<i>"wasting the marine scientists' time by logging common species", "I might be providing false evidence"</i>	8	6.6					
Other	<i>"if I'm not recognised as the discoverer of the new species", "could frighten some people if they knew it was out there"</i>	22	18.0					
Total		122	100.0					
Results of Krippendorff's alpha inter-coder reliability tests								
Variable	α	q^* (α min = .8000)	LL95%CI	UL95%CI	Units	Observers	Pairs (n)	Bootstraps
Advantages	.8254	.1648	.7705	.8753	248	2	248	10,000
Disadvantages	.8182	.2024	.7728	.8637	122	3	366	10,000
*Probability (q) of failure to achieve an alpha of at least α min = .8000 (q = .0000 for all variables at α min = .7000)								

most often named only one or two disadvantages. Some were concerned about the impact on species should information on their location be made public, thereby resulting in species being targeted by poachers or collectors. A few respondents were concerned about the provision of information resulting in restrictions to their access to marine areas should the species or location be identified as needing protection. Several people also thought that the information provided by the public may not be all that useful from a scientific perspective. A few people also thought that logging sightings could be really time consuming or were concerned that they might log incorrect information and therefore waste scientists' time.

Table 3. Perceived social norms of reporting sightings (injunctive and descriptive).

Who approves (injunctive norm)		Frequency	Valid Percent					
Family		88	28.2					
Friends		80	25.6					
Colleagues (e.g. boss/workmates)		43	13.8					
Recreational peers e.g. other divers/fishers		31	9.9					
Club members		25	8.0					
Other		45	14.4					
Total		312	100.0					
Who disapproves (injunctive norm)		Frequency	Valid Percent					
None		95	82.6					
Certain fishers		10	8.7					
Family/friends		6	5.2					
Other		4	3.5					
Total		115	100.0					
Results of Krippendorff's alpha inter-coder reliability tests								
Variable	α	q^* (α min = .8000)	LL95%CI	UL95%CI	Units	Observers	Pairs (n)	Bootstraps
Who approves	.9316	.0000	.9103	.9525	312	3	936	10,000
Who disapproves	.9043	.0032	.8284	.9604	115	3	345	10,000
*Probability (q) of failure to achieve an alpha of at least α min = .8000 (q = .0000 for all variables at α min = .7000)								

Perceived social norms (injunctive and descriptive)

Respondents mentioned a range of people who may or may not influence their logging behaviour (Table 3). People who would *approve*, or encourage, the interviewee to log a sighting (the positive injunctive norm) were thought to be primarily family and friends. While a clear majority of respondents (95 of the 110 interviewees) said there were no important people in their lives who would discourage (or disapprove of) them from logging a sighting (the negative injunctive norm), some fishers mentioned that certain other fishers in their social circles might discourage them from reporting uncommon species.

There was some confusion over the question of descriptive norms, and it became clear that although interviewees could identify others types of marine users who may be likely or unlikely to log sightings, it is not a commonly observed behaviour amongst marine users and therefore there are effectively no important people in the marine users' social networks who are demonstrating the desired behaviour. Therefore, the descriptive norms are irrelevant to this audience and this construct has been removed from the analysis.

Perceived facilitating factors and barriers to participation

Interviewees reported factors which would facilitate them to report sightings of uncommon marine species, as well as perceived barriers to logging (Table 4). The overwhelming majority of facilitating factors listed were to do with the design of the technological interface, that is, the website or mobile app. People said that it needed to be easy, user-friendly and quick to use, and have no problems or glitches in the system. Twelve percent of the comments were about information to help

Table 4. Facilitating and inhibiting factors influencing the reporting of sightings.

Facilitating factors	Example comments	Frequency	Valid Percent					
Technical design issues	<i>"having a stable platform to use, i.e. no glitches or crashes, they're annoying", "being a quick process, and it was simple"</i>	106	38.0					
Having better knowledge of species /ID charts	<i>"if you had a pictorial guide to the species of interest", "I'd need information otherwise I'd be sending pics of common fish"</i>	34	12.2					
Mobile reception/internet connection	<i>"having internet access", "having wifi connection near sighting area"</i>	28	10.0					
Having camera	<i>"having my camera there and functional (charged)", "divers don't always have their camera on them"</i>	23	8.2					
In situ issues	<i>"conditions in the ocean e.g. good visibility, no surge", "animal is not shy so you can get a good picture"</i>	20	7.2					
Other	<i>"having time to do it", "knowing I'll get feedback"</i>	68	24.4					
Total		279	100.0					
Inhibiting factors	Example comments	Frequency	Valid Percent					
Technical design issues	<i>"asking me for my details; don't torture me with having to give details", "a website which is hard work"</i>	49	20.3					
Not having mobile reception/internet access	<i>"depend on where you were, because of the mobile reception", "problems with WiFi or communication"</i>	43	17.8					
In situ issues	<i>"bad sea conditions", "if I can't get the photo, especially if it swims past"</i>	43	17.8					
Not having time	<i>"time, you get busy", "time factor - study, work, play makes it difficult"</i>	32	13.3					
Not having camera available	<i>"if I don't have my camera on me", "not having waterproof case on my phone"</i>	21	8.7					
Not knowing uncommon species	<i>"if I'm not sure about the identification of the species", "I don't want to feel like a goose, not knowing what's uncommon"</i>	19	7.9					
Other	<i>"processing too many photos, as I take up to 400 per day so it takes a lot of time", "if I didn't get any confirmation/acknowledgement/feedback"</i>	34	14.1					
Total		241	100.0					
Results of Krippendorff's alpha inter-coder reliability tests								
Variable	α	q^* (α min = .8000)	LL95%CI	UL95%CI	Units	Observers	Pairs (n)	Bootstraps
Facilitating factors	.8204	.1293	.7849	.8539	279	3	837	10,000
Inhibiting factors	.8676	.0000	.8398	.8937	241	3	723	10,000
*Probability (q) of failure to achieve an alpha of at least α min = .8000 ($q = .0000$ for all variables at α min = .7000)								

them work out whether a species was uncommon or not. Some interviewees also mentioned that mobile reception or internet connection at the time of the sighting would be necessary (it had not been explained to them that they could log sightings when they were back in mobile range). Having a camera available at the time of the sighting was seen to be an issue for some, especially since many do not take their cameras with them whilst diving or participating in other water-related activities. Other comments related to *in situ* issues such as having good weather, or good visibility (either under or above the water), to see the species in the first place.

Inhibiting factors, or barriers, are those which would make it difficult or prevent the person from logging a sighting. The results from this question are largely the reverse of the facilitating factors. That is, the most frequently mentioned potential barriers were considered to be the technical design (if the web site or mobile app is too difficult, time consuming etc), the availability of the internet connection, and *in*

situ issues (such as weather). One exception is 'having time', which was reported by 32 respondents, meaning that these people felt the general 'busy-ness of life' could prevent them from logging a sighting. Interestingly, fewer people considered their knowledge of marine species to be a barrier than those who reported 'having better knowledge of species/ID charts' as a facilitating factor.

Information sources

The results from the questions about currently used and preferred information sources show interesting differences between preferences and actual use (Table 5). While the majority (75.5%) of marine users appeared well connected via Facebook (reporting this is where they most often see others' images of marine species online), only 35.5% currently used Facebook as a source of 'correct' information about the marine environment. The internet featured as the most frequently mentioned (76.4%) source of correct information, while around half of the interviewees mentioned government agencies, friends and family, and television programs. The results of the most preferred method to receive correct information about the marine environment showed disparate responses. The most popular preference was for information on the internet (40.0%), followed by face-to-face interactions with others (14.5%). A little over half (52.8%) of the respondents listed government agencies, scientists or scientific organisations as their most trusted source of correct information.

Discussion

The results from the present study demonstrate the potential, as seen through the eyes of the public, for their participation in marine research to make genuine contributions to knowledge for science and society at large. The interview responses also strongly emphasise the importance of well-designed web sites and mobile apps for those who are voluntarily contributing data. When it comes to communicating information about the marine environment, this research also reminds us that although the internet now plays a key role in communication, face-to-face communication remains important to marine users.

The interviewees in this study, although relatively small in number, covered a broad range of interests in the marine environment. The larger number of males in the sample is not surprising given that other studies have also reported higher participation rates in marine activities for males than females [Australian Bureau of Statistics, 2012; Henry and Lyle, 2003]. The majority of respondents were highly active in the marine environment, and it is likely that their frequent use of the ocean may have made it easier to identify them in the sampling process. As a result, the sample is likely to under-represent people who are less active in marine settings, but for whom the oceans and beaches are no less important. Whether or not these people are interested in participating in marine citizen science is another question.

Beliefs about participation in marine citizen science

When asked about outcomes from logging uncommon marine species, many interviewees listed altruistic motivations. That is, many thought the main advantage was to increase knowledge for science or for the greater good. This

Table 5. Information sources used and preferred by interviewees.

Source(s) of images of marine species	n	% of sample	Current source(s) of correct information	n	% of sample	Most preferred source of correct information	n	% of sample	Most trusted source of correct information	n	% of sample
Facebook	83	75.5%	People	44	40.0%	Internet	44	40.0%	Govt agencies	21	19.1%
Specific websites	37	33.6%	Friends / family	60	54.5%	Others e.g. shop staff	16	14.5%	Scientists	20	18.2%
Forums	19	17.3%	Scientists/experts	52	47.3%	Scientists/experts	8	7.3%	Science orgs	17	15.5%
Instagram	10	9.1%	Others e.g. shop staff	41	37.3%	Government agencies	6	5.5%	Family/friends	9	8.2%
Citizen Science projects	9	8.2%	Organisations	65	59.1%	Print media	5	4.5%	Others e.g. shop staff	9	8.2%
Internet	6	5.5%	Govt agencies	43	39.1%	TV (programs/news)	5	4.5%	Internet	8	7.3%
Email	4	3.6%	Scientific orgs	33	30.0%	Documentaries	5	4.5%	Print material	7	6.4%
YouTube	4	3.6%	Clubs	24	21.8%	Science journals	5	4.5%	Documentaries	6	5.5%
Apps	2	1.8%	Marine sci centres/aquariums	21	19.1%	Other	14	12.7%	Sci. journals	6	5.5%
Clubs	2	1.8%	Environmental organisations	18	16.4%	Missing	2	1.8%	Clubs	2	1.8%
Other (not online)	7	6.4%	Museums	84	76.4%	Total	110	100.0%	Environ'l orgs	2	1.8%
			New/social media*	39	35.5%				Museums	1	0.9%
			Internet (generally)	17	15.5%				Radio	1	0.9%
			Facebook						Missing	1	0.9%
			Newsletters online						Total	110	100.0%
			Print media								
			Books	49	44.5%						
			Magazines	47	42.7%						
			Newspapers	29	26.4%						
			Science mags/journals	28	25.5%						
			Printed material	26	23.6%						
			Mainstream Media								
			Television	56	50.9%						
			Documentaries	46	41.8%						
			Radio	20	18.2%						
			Other								
			Other	27	24.5%						

* there were no significant other new/social media recorded in 'other' category.

finding is similar to that of a survey of people already participating in citizen science, albeit an online astronomy project [Raddick et al., 2013]. These findings bring up another question: *why* do they see this as a good outcome or advantage of their contribution? Perhaps it is linked with the high level of public interest in science and technology information in Australia [DBI, 2012; Lamberts, Grant and Martin, 2010; Searle, 2014]. The ability to increase one's own knowledge was also seen to be an advantage, and interviewees' passion for the marine environment was evident in their thoughts that their contribution would help raise awareness and help manage or protect this resource. The inclusion of these perceived outcomes may be beneficial in future communication strategies for increasing public engagement in projects.

Reporting sightings was generally seen as a good thing to do, with almost half of the respondents saying they did not perceive there to be disadvantages to logging uncommon species. A few people were worried about the potential for the information to be used to target species for poaching or collection, or to restrict access through the implementation of marine protected areas (MPAs). MPAs have become a contentious subject, particularly for recreational fishers, in several regions across Australia [Gledhill et al., 2014; Voyer, Gladstone and Goodall, 2014] and could possibly present a very real barrier for contribution of sightings from some fishers. This is an important consideration for marine citizen science projects, many of which aim to make the information they collect publicly available for the benefit of all.

Additionally, some respondents thought publically-collected data would not be robust enough to make scientifically sound decisions about changes in the marine environment. The interviewer noted that this attitude was largely held by those with a background in science. Riesch and Potter [2014] found that this attitude toward citizen science is relatively common amongst scientists, despite evidence to the contrary showing that public data collection can be a valuable and sometimes necessary tool for improving understanding of natural environments [Azzurro et al., 2013; Devictor, Whittaker and Beltrame, 2010; Dickinson et al., 2012; Jarvis et al., 2015; Robinson et al., 2015].

An important element of project design which managers should be mindful of is the technological aspect. Marine users said they would need a simple, quick, user-friendly website or mobile app which was free from glitches. Should technological problems be encountered, many interviewees felt they would discontinue with the project. This presents a significant challenge for many marine citizen science projects which are often operating with low levels of funding, and sometimes a lack of technological expertise.

Other facilitating factors included the provision of information about marine species under investigation, and highlighting the importance of clarity of what the contributor is being requested to do for the project. By providing more information, not only is the citizen scientist more certain about what is required, but the project will be providing an opportunity for people to learn more, which was seen as an important reason for citizens to participate.

Inhibiting factors, or barriers, were largely the reverse of the perceived facilitating factors. The marine users were most concerned about the technical aspects of the project website or mobile app, once again highlighting the importance that systems operate easily for the end user. Some of the interviewee's concerns were to do with issues beyond the control of a citizen science manager (e.g. lack of internet connection (especially for mobile apps), *in situ* conditions such as the weather, or not having time to participate). In a practical sense, internet connection should not be an issue for people since most citizen science mobile apps are designed to store sighting records and send them once internet connection is established. However, what is important here is the interviewees' *perception* that a sighting would have to be logged at the exact time and location of the event. This is not the case in Redmap, or other similar projects, but is something which citizen science projects should be mindful of in their recruitment communication. Although most Australians have convenient access to the internet [Internet World Stats, 2012], marine users who prefer to log sightings through a website may encounter unstable internet connection (particularly in regional and remote locations). If connectivity issues become too frustrating, people are unlikely to continue in their attempts to record species. While there is nothing a manager can do about this, or other perceived barriers (such as *in situ* or time pressures), they are nevertheless important to consider in the project design. Clearly, should these barriers present too much of a problem for people, the project will struggle to succeed.

Social norms (i.e. the influence of others) offer the possibility to generate more interest in citizen science participation; and in a marine setting, family and friends could be particularly influential. Communication strategies utilising these connections, such as encouraging the sharing of the project information via social media platforms such as Facebook, may prove to be a fruitful approach in a low-budget citizen science operation. While seeing other recreational peers logging sightings was rare, project communicators should consider showcasing the latest sightings. Research by Mugar, Osterlund, DeVries Hassman, Crowston, and Jackson [2014] demonstrates that new users can be drawn into participating in a citizen science project through seeing others' contributions to the project, thereby understanding the norms of practice within the group.

Information sources

Understanding the information sources used and preferred by the target audience for any communication of science is essential for successful engagement [Fischhoff, 2013]. The differences in responses to four different questions about information sources emphasise the importance of asking the right question in the first place. Most of the marine users in this study showed a high level of sharing marine species information on Facebook in a non-scientific context. Yet in their reporting of current sources of 'correct information' about the marine environment, Facebook was mentioned by only half of these people. This means that while Facebook may have an important role in spreading information, particularly through the social influence of family and friends, it should be used with some caution about the perceived accuracy of the information.

Government agencies, scientists and scientific organisations play an essential role as preferred and trusted sources of information, which comes as no surprise given

the high level of trust Australians place in the information provided by scientists and scientific organisations [Searle, 2014]. However, it is important to note that although government agencies, scientists and scientific organisations were cited most frequently, only half of the respondents listed these as their most trusted source. The other half put their trust in a much wider pool of information providers, highlighting the importance of understanding trust issues for any particular audience.

Future research

This study investigates only one element of public involvement in marine science, that is, the perceived drivers and barriers for participation. These insights are necessary for the development questions which are relevant to the broader target audience in future research. It also allows for the wording of questions to be in the vernacular of the target audience; an important element in the creation of useful and successful survey questions [Cialdini, 2003; Greenhill et al., 2014].

The next step in the application of the RAA/TPB (Fishbein & Ajzen, 2010) is to determine *how important* these drivers and barriers are to the wider target audience. When we understand this, we can adopt the course of action most likely to improve the degree and quality of public engagement through relevant messages and considered project design [Shirk et al., 2012].

If we are to determine the potential for marine citizen science to improve the public's relationship with science, we will also need to ask how many people are interested in participating in the first place, and which aspects of projects they would prefer to engage with (such as data collection, analysing results and so on). We will also need to understand differences between those who *are* interested in assisting citizen science, and those who are not [Cormick, 2014]. At this point in time, we are uncertain whether citizen science is likely to attract those who are currently unengaged or uninterested in science, or whether it is simply 'preaching to the converted'. In addition there are, of course, even more factors at play that help to explain public science engagement and it is encouraging to see social research being conducted around the globe on these matters [see, for example, Feist, 2012; Kazdin, 2009; Markowitz et al., 2013; Oppenheimer and Todorov, 2006; Stern, 2011].

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