Ocean & Coastal Management 115 (2015) 77–87

Contents lists available at ScienceDirect

Ocean & Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Making marine and coastal citizen science matter

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ARTICLE INFO

Article history:
Received 16 December 2014
Received in revised form
4 June 2015
Accepted 9 June 2015

Keywords:
Citizen science
Marine conservation
Coastal conservation
Toolkit

ABSTRACT

Against the backdrop of a dramatic increase in citizen science activity worldwide, we convened a combined symposium and focus group at the 2014 International Marine Conservation Congress to consider the challenges and opportunities for mobilizing citizen science in the marine and coastal environment. Highlighting the diversity of existing models and approaches to citizen science, participants focused on six different conservation-related outcomes that citizen science projects can potentially support: policy, education, community capacity building, site management, species management, and research. We provide two example case studies of projects and summarize the key themes and recommendations associated with each of those outcomes. The result is a series of "toolkits" that can help to guide new and existing citizen science projects that aim to support management and conservation of ocean resources, as well as providing insights and recommendations to stimulate further research on and assessment of marine and coastal citizen science programs. Citizen science is an effective approach to conservation and it is time for this underutilized resource to become a more prominent approach for marine and coastal conservation.

1. Introduction

The number of projects globally that engage the public in scientific research (i.e, citizen science) has dramatically increased in recent years (Conrad and Hilchey, 2011). Citizen science can be defined as scientific research and monitoring projects for which members of the public collect, categorize, transcribe or analyze scientific data (Bonney et al., 2014). Although not as prevalent as in other systems (Theobald et al., 2015), citizen science projects in marine and coastal systems worldwide provide opportunities for individuals to engage in marine conservation-related activities, such as monitoring reef systems (Pattengill-Semmens and Semmens, 2003) and species (Cigliano and Kliman, 2014), categorizing whale calls (Shamir et al., 2014), and tracking marine debris (Hidalgo-Ruza and Thiel, 2013; Smith and Edgar, 2014) and invasive species (Delaney et al., 2008). The use of citizen science in marine and coastal contexts can impact marine conservation more broadly by influencing management (of, e.g., fisheries) and policy, improving stewardship, and strengthening community capacity to address environmental problems (Conrad and Hilchey, 2011; Danielsen et al., 2013).

1.1. Challenges for marine and coastal citizen science

Roy et al. (2012) put forward a framework focused on the scale of participation (local to mass participation) and degree of investment (from simple to thorough, referring to both project managers and participants). In a broad international survey of more than 200 citizen science projects, they found that marine and coastal citizen science is underrepresented in general (comprising only 14% of their sample), and biased toward either thorough and local programs, or simple mass participation programs. This result, they argue, suggests an opportunity for marine citizen science to expand and diversify.

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http://dx.doi.org/10.1016/j.ocecoaman.2015.06.012

There are many explanations for the pattern they observed, some rooted in the challenges of the marine environment. Citizen science projects in marine contexts encounter challenges not faced in terrestrial systems. The primary challenges are logistical, stemming from the fact that humans, at best, spend only part of their life on the water. In many contexts, access for citizen scientists is more challenging than on land, often requiring expensive boats, diving gear, or transportation to the coast. Safety and liability issues of marine-based data collection can also be prohibitive and costly, especially when involving children. Relatedly, it is still uncommon in some cultures to learn to swim or incorporate marine activities into daily life, so it may be difficult to recruit citizen scientists in some regions without extensive training accompanying a cultural shift toward becoming more comfortable with the ocean. Other potential factors include unclear resource rights and the lack of visibility and site definition, i.e., it may be harder for citizen scientists to "take ownership" of a site without obvious demarcations or recognizable boundaries. These and other factors may contribute to the apparent under-representation of marine and coastal projects in citizen science in general (Roy et al., 2012, Theobald et al., 2015).

1.2. Why work with citizen scientists in marine and coastal conservation research?

The purpose of this paper is to demonstrate a variety of ways in which citizen science can be an effective and rigorous method for advancing marine conservation and management, using case studies of citizen science projects that have successfully fulfilled their conservation-related goals and outcomes as examples. We also provide a typology of marine conservation outcomes that can be effectively addressed using citizen science and scientists, and, finally, a set of "toolkits" for each category of marine conservation outcome through which citizen science can be implemented. Our goal is to make it feasible and useful for marine conservation scientists and practitioners to use citizen science, and to discern when citizen science is appropriate to address marine conservation and management issues.

This paper is the product of a combined symposium and focus group, *Making Marine Citizen Science Matter*, held at the 3rd International Marine Conservation Congress (IMCC). The symposium consisted of seven presentations by an interdisciplinary group of researchers and practitioners that provided an overview of marine citizen science and case studies of projects that have successfully fulfilled their conservation-related goals. The symposium set the foundation for the accompanying focus group that was attended by 35 participants ranging from deeply experienced practitioners and scholars of citizen science to relative newcomers to the field. The focus group built on the discussion from the symposium to apply and further refine a typology of marine conservation outcomes that could be addressed using citizen science and scientists. The focus group discussion was framed by six types of conservation outcomes determined to be related to conservation effort success: policy, education, community capacity-building, site management, species management, and research (Kapos et al., 2009). Using discussion notes from the focus group, we developed "toolkits" for each of the conservation outcomes to further support the development or adoption of citizen science in marine contexts.

In the next section we describe two of the seven case studies from the symposium to demonstrate the variety of cases that were presented in terms of structure and conservation-related goals and outcomes. We then move on to the toolkits developed from focus group discussions that involved more than 35 participants over the course of a full day.

2. Case studies

2.1. Engaging citizen scientists in surveying and monitoring queen conch (Strombus gigas) in Belize

Fisheries around the world are in decline (FAO, 2012). One such fishery is queen conch, *Strombus gigas*, a large marine gastropod found throughout the Caribbean from Venezuela to southern Florida, Bermuda and throughout the Caribbean (Theile, 2001). In response to this decline, most countries have imposed management regulations on the harvest of queen conch, primarily minimum length, gear restrictions, and seasonal closures. In Belize, management of the queen conch fishery consists of size limits (at least 17.75 cm in length with a minimum weight of 86 g for cleaned meat), a closed season corresponding to peak reproduction (July 1 – September 30), and a prohibition on the use of SCUBA (Pérez, 1997). Belize has also established a network of 13 marine protected areas (MPAs) to protect queen conch and other fisheries (Cho, 2005). One such MPA is the Sapodilla Cayes Marine Reserve (SCMR), a 119 km^2 reserve located at the southern end of the Mesoamerican Barrier Reef. The SCMR is a zoned-reserve with varying levels of protection: (1) General Use Zone (GUZ): commercial extractive activities are allowed but managed; (2) Conservation Zones (CZ): no commercial extractive activities are allowed; and (3) Preservation Zone (PZ): entry is prohibited except with a special permit for research. The reserve was declared in 1996 but was not enforced until April 2009 (J. Finch, pers. comm).

Because there had been no systematic survey of queen conch populations in the SCMR, the project team conducted a shallow-water survey of conch aggregations from 2006 to 2012 inside and outside protected zones before and after enforcement began. Shallow-water sites are important to the life history of queen conch as nursery areas (Stoner, 1997; Posada et al., 1999). The project was developed during a community workshop convened in May 2005 by Earthwatch Institute and the Toledo Association for Sustainable Tourism and Empowerment (TASTE; now Southern Environmental Association [SEA]), the NGO responsible with co-managing the reserve with the Department of Fisheries. This workshop brought together key stakeholders, scientists and research organizations to prioritize issues relevant to the sustainability of the SCMR and to formulate research questions to address these issues. Thirty-five individuals representing 19 organizations participated in the workshop. The queen conch survey project was an outcome of this workshop. The conservation goals of this project included: (1) determining the effectiveness of the SCMR in protecting and replenishing queen conch populations, (2) providing information for adaptive management of the reserve, and (3) building capacity in stakeholders.

Citizen scientists, participating through the Earthwatch Institute, were engaged in most aspects of this co-created project. Co-created projects are designed by scientists and members of the public together with some of the public participants actively involved in most or all steps of the scientific process (Bonney et al., 2009; Shirk et al., 2012). In addition to collaborating on the planning of the project, local citizen scientists (fishers, Department of Fisheries officers, TASTE) helped locate sample sites (current and historical aggregation sites) and both the local (including undergraduate students from the University of Belize Natural Resource Management program) and international citizen scientists surveyed transects, either while snorkeling or diving, and recorded size (length) and age (lip thickness) of conch, and also tagged conch with unique alphanumeric tags (Floy Tag Inc.).

One benefit to using citizen scientists in marine conservation projects is the ability to increase the temporal and spatial scale of a project (Miller-Rushing et al., 2012; Ward et al., 2015) and this was certainly true for this project. Over the 6 years of the study, the project team was able to survey over 5000 conch (approximately 4200 were tagged), in 11 aggregations throughout all 4 zones of the reserve, as well as in 3 deep-water (15–30 m) breeding aggregations in and adjacent to the reserve and in 24 additional randomly chosen sites to search for unknown aggregations (Cigliano and Kliman unpubl. data). Without the assistance of the approximately 80 citizen scientists, the spatial and temporal scope of this project would have been more limited.

The conservation goals of the project were fulfilled. Data were used to determine age structure and density of aggregations (Cigliano and Kliman, 2014) and the effectiveness of the reserve (Cigliano and Kliman unpubl. data). The results of the study suggest that some of the aggregations have begun to recover since enforcement of the reserve, though additional surveys are required to confirm this (Cigliano and Kliman, unpubl. data). To provide information for the adaptive management of the reserve, all raw and analyzed data and published and unpublished papers and reports have been shared with the Belize Department of Fisheries and TASTE/SEA. The project team also met regularly with Fisheries and TASTE/SEA to present and discuss findings from the surveys, which led to a modification of the placement of the preservation zone and assisted in the planning of ranger patrols in the reserve. The project also contributed to capacity building through the co-creation of the project with stakeholders (see 3.3 community outcomes toolbox) and through the Earthwatch Fellows program, which provided field training for Fisheries officers, TASTE/SEA scientists, and U. Belize Natural Resource Management students. Fisheries officers continued to work with the project team throughout the project and two Natural Resource Management students conducted their senior thesis research as part of the project. We also engaged the local community in informal and formal discussions about the project to help maintain support for the reserve.

During the project, several "lessons-learned" were identified that should be applicable to other similar projects: (1) Developing the project as a co-created project with the major stakeholders led to early buy-in among stakeholders and helped build trust and collaboration between the researchers and stakeholders (see 3.3 community outcomes toolbox). Additionally, because stakeholders were part of the planning project from the beginning, project logistics (e.g., field site accommodations, boat drivers, etc.) were established quickly; (2) Because citizen scientists came with a wide variety of snorkel and diving experience and general comfort-level with being in and on the water, it was necessary to be strategic in assigning research tasks as well as having well-planned safety procedures in place. It was also necessary to be sensitive to how tasks were assigned so that all citizen scientists felt equally involved in the project; and (3) Training (started on land and then done in the water) and, to a lesser extent, in-field oversight were necessary to ensure accurate data collection.

2.2. Engaging citizen scientists in marine protected area monitoring in California

California has established a network of more than 100 marine protected areas in state waters under the auspices of the Marine Life Protection Act, passed in 1999 (MLPA, 1999). Among numerous implementation and management concerns for this new network is long-term monitoring to inform adaptive management across four designated regions. A public–private partnership known as the Monitoring Enterprise was established to lead the design and implementation of partnerships-based monitoring, which leverages the great breadth and depth of scientific work already occurring in California. The Monitoring Enterprise is a program of the California Ocean Science Trust (OST), an independent non-profit with a unique, legislatively established role in bringing scientists and decision makers together around important marine and coastal issues facing the State (CORSA, 2000; Pietri et al., 2011). Working together with state agencies, scientists, and stakeholder communities, OST designs and implements monitoring that meets the needs of MPA managers, while also contributing to a wide range of issues such as ocean acidification and climate change, fisheries management, and water quality.

Citizen science has played a role in the MPA monitoring program from the beginning, and a state-adopted monitoring framework explicitly calls out the potential role for citizen science to contribute useful information for adaptively managing the MPAs (OST, 2014a). A handful of citizen science programs participated in the initial "baseline" period directly following the establishment of MPAs, whose citizen scientists collectively include high school students, volunteer SCUBA divers, and recreational fishermen. Experiences partnering with these programs led to important lessons about the promise and challenge of incorporating citizen science into a larger monitoring community.

To further explore these lessons systematically, OST staff characterized the coastal and marine citizen science capacity in the Central Coast region and engaged all regional projects in a collaborative learning process. This effort was timed to coincide with a transition in the Central Coast from baseline MPA monitoring to a new long-term monitoring phase, which includes a variety of opportunities for scientists and stakeholders to contribute to the design and implementation of monitoring.

The research was designed to be a collaborative and open process. The first step was a census of all coastal and marine citizen science activity in the Central Coast yielding a total of 30 projects. OST staff then interviewed the program coordinator of each project, and, for seven of them, conducted focus groups of heavily involved citizen scientists to learn more about participant experiences and motivations. A document based on the information from this engagement was produced to give ocean resource managers and citizen science programs guidance about the challenge and opportunity of partnering with one another. A workshop for citizen science program leaders and managers provided an opportunity for feedback on the accuracy and utility of the guidance document.

There are four main themes reflected in the guidance document: (1) one must recognize that citizen science is comprised of many approaches and many kinds of people; citizen science is diverse both in terms of program structure and who participates, (2) successful collaborations are built on mutually beneficial partnerships, (3) citizen science groups, especially those that exist outside of known institutions of expertise like universities, must find ways to establish and demonstrate credibility. Partners should establish shared expectations about credibility early in their relationship, (4) decisions about partnering with a management audience may have repercussions for program design and vice versa. The decision to engage with resource managers should not be taken lightly and should entail carefully planned synergies and tradeoffs with other program priorities. These results are discussed further in the final version of the guidance document (OST, 2014b).

This project has both informed the implementation of MPA monitoring in California, and expanded the network of partners participating in that process. For the Central Coast of California, lessons about citizen science and ocean resource management are directly applied to an updated Central Coast MPA monitoring plan (OST, 2014a), which was recently adopted as state policy by the California Fish and Game Commission. Findings will also be applied in other regions, where citizen science groups are both contributing to and sharing the results of MPA monitoring. This work demonstrates the strong potential role that citizen science can play in ocean resource management and provides a tangible first step for partners throughout California to realize that vision.

3. Toolkits

The toolkits described below are meant to serve as the foundation for people interested in creating or supporting a link between citizen science and a particular conservation outcome. For example, if a citizen science group is focused on affecting policy, they can refer to the policy section that speaks to how best to influence policy change. The essential components of our toolkit include: (1) identifying the challenges in achieving the desired conservation outcome, (2) guidelines and recommendations on how to best pursue a particular outcome, and (3) identify, if any, the unique aspects of the marine science context that deserve extra attention in implementing these guidelines and recommendations. In the future, these toolkits would also benefit from a set of indicators of success to use for program evaluation and a self-assessment tool to help determine if citizen science is the best approach to meet the desired outcome(s).

3.1. Policy change toolkit

Policy change can happen in many different ways and there is a vast array of models and theories that describe this process (e.g., Lindblom, 1959; Kingdon, 1984; Clark, 2002), and the role that science (citizen or otherwise) can play in it (e.g., Guston, 1994; Jasanoff et al., 1998; Pielke, 2007; Weible, 2008; Kirchhoff et al., 2013). IMCC focus group participants identified three important modes in which marine citizen science may lead to positive outcomes related to policy change: (1) informed advocacy, (2) co-created/cooperative policy change, and (3) policy evaluation.

3.1.1. Informed advocacy

Citizen science data and resulting analyses can educate advocates and help them argue effectively for a desired policy outcome. For example, citizen science data about the prevalence of plastic bags in the marine environment could help to inform a campaign to establish a ban of plastic bags in grocery store check-out lanes.

In this mode, citizen science is mobilized as one piece of an argument made in a political venue where the fundamental impediment is often a values-based dispute. While these kinds of campaigns often rely on scientific data, it is also important to maintain an awareness of the contingent and contested nature of science that gets mobilized in this way (Sarewitz, 2004; Pielke, 2007). Scientific credibility is extremely important in these cases, as political opponents are likely to scrutinize methods, data, and analyses in great detail. Regardless of credibility, political opponents are likely to exploit scientific uncertainty to their advantage (Sarewitz, 2004; Weible, 2008).

Focus group participants identified the following as potential marine-conservation outcomes that might be achieved through informed advocacy; these can be considered as recommendations for future studies on how informed advocacy can affect marine-conservation outcomes:

- Citizen scientists themselves may become more active and effective advocates because of their participation in a citizen science program. In this way, both the data and the learning outcomes synergistically support advocacy;
- More informed advocates may be more likely to push for change, causing change to occur more quickly (see Toomey and Domroese (2013) for a discussion on the link between engaging in citizen science and future conservation action of citizen scientists);
- Communication channels to policy-makers can be established, especially where the political interests of policy-makers align with the advocates;
- Issues previously unknown to or discounted by policy-makers may gain a higher political profile;
- Citizen science programs may be embedded in an organization that pursues advocacy goals and professionals in the organization can help design citizen science projects that directly inform the broader advocacy agenda;
- The constituency for the advocacy organization may expand;
- External advocates may make use of citizen science data without any other connection to the project or organization.

3.1.2. Co-created/cooperative policy development and implementation

Citizen science can respond to a demand for information from managers or policy-makers. In this case the impetus comes from within the system and citizen scientists work in partnership with the policy-makers and/or managers. This model is especially relevant in the context of data-intensive, systems-based environmental policies such as ecosystems-based management. To continue the plastic bag example from above, a citizen science group might enter into an agreement with an agency to monitor changes in plastic bag occurrence across a geographic area and generate data about compliance patterns that could inform enforcement of the new plastic bags ban, or updates to the ordinance in order to improve effectiveness. The case study on marine protected area monitoring in California, discussed above in Section 2.2, is another example of a collaborative approach in which many different partners coordinate to provide monitoring data for adaptive management called for by state law.

Focus group participants noted that the necessary criteria for this model include an established relationship with decision-makers, shared expectations around time-frame, transparency in data collection and analysis, a plan for delivering results, involvement of appropriate stakeholders and policy-makers, and an understanding of existing governance.

Focus group participants posited that the following marine conservation outcomes could be achieved through co-created/cooperative policy change:

- developing mutual awareness and understanding on the part of collaborators of policy/management issues and of the need for change;
- establishing communication channels to policy-makers, which expand opportunities for collaboration;
- improved management effectiveness, leading to improved conservation outcomes; and
- changes in policy and management.

3.1.3. Policy evaluation

Focus group participants suggested that Citizen science can help evaluate the effectiveness of a policy that has already been legislated and implemented, leading to validation of current policy or demonstrating a need for policy change. This mode may overlap significantly with either of the two modes described above and it can be done cooperatively with an implementing agency, or to inform advocacy for or against an existing policy.

3.1.4. Policy change categories

All three modes of policy change share several potential outcomes, which can be grouped into three general categories:

- *Inspiring effective advocacy:* By being directly involved in the process, participants will feel an ownership of the data and would more likely be inspired towards advocacy and action. Moreover, by being part of the process, advocates will be better informed and more effective in their advocacy (Toomey and Domroese, 2013).
- *Increasing public awareness of the issue*: Because citizen science often includes a broad range of stakeholders, public awareness of, and involvement in, the issue can be greatly enhanced (McKinley et al. submitted for publication).
- *Increasing likelihood of policy change*: An additional outcome of an expanded and more informed constituency is that policy-makers will see that a significant number of people care about the issue. This can lead to influence across many layers of governance (i.e., local to national). And probably most important, in some cases it can develop effective communication and trust among advocates, stakeholders, and policy-makers (Danielsen et al., 2005).

3.1.5. Recommendations for implementation

To apply this toolkit, focus group participants noted that an understanding of the policy needs, process, and policy context is important. The process will likely require mobilizing partnerships and effective communication. Scale matching is an important concern. Does the citizen science project take place at a temporal and spatial scale that is relevant to the policy problem? The biggest challenge to overcome identified by focus group participants is a lack of trust by policy-makers and opponents in the process and data. It is critical, therefore, that the relevant partners are included in all aspects of the project, whether the project is initiated by the advocates (informed advocacy) or policy-makers or managers (co-created/cooperative projects), and whether the project is designed to inform development of a policy (informed advocacy or co-created/cooperative projects) or to evaluate an existing policy (policy evaluation).

3.2. Educational outcomes toolkit

Citizen science can result in powerful cross-cultural and multi-generational learning outcomes beyond simple acquisition of content knowledge (Kountoupes and Oberhauser, 2008; Crall et al., 2013; Phillips et al., 2012). Adults participating in citizen science projects are self-selected, often taking part in their free time on topics that are of interest to them. Youth citizen science projects occur in formal K-12 environments, as well as informal learning settings such as after school programs and science and nature clubs. Although educational outcomes can be diverse, focus group participants identified three general categories specific to citizen science in marine and coastal systems: (1) awareness and inspiration, (2) individual behavior change, and (3) science literacy and critical thinking.

3.2.1. Awareness and inspiration

Any opportunity to be outdoors is a potential opportunity to be inspired and awed by the natural world; this is particularly true for marine environments. Emergent research termed “neuro-conservation” has shown that being near oceans can nurture strong emotional connections to water and improve human well-being (Nichols, 2014). There was general consensus among focus group participants that environmentally-focused citizen-science projects get people outdoors, increasing their chances of noticing, observing, appreciating, connecting with nature, and gathering meaning, as also noted by Louv (2012). These connections are essential aspects of “sense of place,” i.e., the emotional intensity and attraction to places, facilitated by individual experiences in those places (Kudryavtsev et al., 2012; Haywood, 2014). Powerful experiences and emotional connections can increase interest and motivation for engaging in pro-environmental behaviors and actions to protect individual species and ecosystems (Grob, 1995; Kals et al., 1999; Cornwell and Campbell, 2011; Kudryavtsev et al., 2012; Hartley et al., 2015).

3.2.2. Individual behavior change

Focus group attendees agreed that citizen science projects can serve as an important catalyst to individual behavior change linked to environmental stewardship of coastal and marine systems. Meaningful engagement can lead to pro-environmental practices such as coastal habitat restoration, making sustainable consumer buying choices, and reduction in the use of harmful materials that make their way into the ocean (Cornwell and Campbell, 2011). Among adults in particular, citizen science may help inform decision making in everyday activities as well as influencing civic engagement and taking part in local environmental causes (Fernandez-Gimenez et al., 2008; Cornwell and Campbell, 2011). Focus group participants also emphasized the role of individuals who are empowered to protect local resources and habitats, and serve as community leaders to communicate and disseminate information, leading to a shared sense of responsibility, ownership, and co-management of resources among stakeholders (Fernandez-Gimenez et al., 2008; Nisbet and Kotcher, 2009; Johnson et al., 2014).

3.2.3. Science literacy and critical thinking

Several of the focus group participants discussed how the hands-on and contextual nature of citizen science aligns well with inquiry-based learning, which can encourage rich discussion, student-driven questions and critical thinking (Krasny and Bonney, 2005; Jordan et al., 2011; Trautmann et al., 2012). Focus group attendees commented that children participating in citizen science are motivated by the fact that they can and do contribute to scientific and conservation outcomes. Classrooms also can take advantage of existing technologies to access and communicate directly with scientists. When situated within the context of real world issues, citizen science can be used in schools to increase science literacy by connecting curricular content to current environmental issues. For example, lessons on climate change can be enhanced through the use of publicly available datasets that provide online tools for anyone to ask and answer their own questions and query temporal and geographic comparisons (see Trautmann et al., 2013 for examples).

Focus group attendees also described the unique challenges that facilitating marine citizen science projects with large groups can present. Whereas terrestrial projects are much more accessible, getting groups of students outside to marine environments can be fraught with barriers having to do with transportation, group logistics, water safety, and liability issues in and around water (see 1.1 Challenges for marine and coastal citizen science). In cases where access to coasts is not possible, leaders/teachers can model marine ecosystems and incorporate simple water skills in indoor environments. Also, leaders can take advantage of the many online marine citizen science projects like Seafloor Explorer or WhaleFM, which use visual and audio technology respectively, to immerse participants in marine simulations. Another issue brought up during the focus group is that many leaders do not feel confident in supporting inquiry-based learning. As a first step, leaders need to understand that not knowing the answer is okay. Additional training and resources to facilitate an inquiry-based paradigm are needed, and in schools, efforts to align with curricula, state, and national standards must be considered.

3.2.4. Recommendations for implementation

Focus group participants suggested several recommendations for maximizing the educational potential of citizen science across diverse audiences. Within formal school settings, providing real world contexts and problems are key (see Bouillion and Gomez, 2001; Trautmann et al., 2013) and students should understand why they are participating and how the data are being used. Whenever possible, teachers should strive for long term exposure and immersive outdoor experiences where students are engaged in activities that help to demystify science (Kountoupes and Oberhauser, 2008) and demonstrate the process of science, content, and context within the ecosystem (Jordan et al., 2011). When accessing the outdoors is not possible, teachers can capitalize on technology and social media to bring the outdoors in, connect with scientists, and make science more accessible to students through the many virtual projects that exist (Wiggins and Crowston, 2011).

There is widespread consensus that outside of schools, empowering people to be stewards of the natural environment must begin well before adulthood (Wells and Lekies, 2012). Optimally, citizen science projects should aim to provide rich emotional connections and expose children to marine systems as often and as young as possible. Projects must also understand their target audience and how best to expose individuals to marine environments, keeping things such as age, geographic accessibility, and cultural barriers in mind. For projects interested in promoting behavior change, mounting evidence suggests that simply providing education and outreach is not enough for sustained pro-environmental behaviors (Hungerford and Volk, 1990; Schultz, 2011). Instead, practitioners may wish to consider social marketing campaigns to influence behavior change. Social marketing works by first identifying a target behavior for a specific audience, then understanding the barriers to the target behavior, and then determining whether adequate resources exist to overcome those barriers (McKenzie-Mohr, 2000). Andriamalala et al. (2013) successfully used social marketing techniques to not only increase local knowledge about destructive fishing practices in Madagascar, they also showed a decrease in harmful beach seine net practices and an increase in enforcement of local fishing laws. Finally, projects should seek out and leverage local sources of credible knowledge that serve as community organizers or opinion leaders and may have the greatest influence on local conservation efforts and cumulative impact (Bird et al., 2003; Cooper et al., 2007; Johnson et al., 2014).

3.3. Community outcomes toolbox

Groups of people participating in citizen science projects collectively in a local area can result in an overall increase in the community's capacity to address conservation problems (e.g., Aceves-Bueno et al., 2015). These community-level outcomes often occur as a result of collaborative monitoring that involves ongoing collaborative meetings, and is intertwined with community-based marine resource management (Ostrom et al., 2002). Community capacity-building for conservation can also occur when citizen scientists collectively mobilize for action, moving from data collection to organizing around an issue, e.g., from cleaning up trash on the beach to actively patrolling rookeries (Overdevest et al., 2004; Ballard et al., 2012). Focus group participants identified two overall community capacity outcomes from citizen science in marine and coastal systems: (1) foundations for collaboration and (2) integration of multiple knowledge sources.

3.3.1. Foundations for collaboration

Several focus group participants pointed out that the very act of conducting fieldwork together, where community members and scientists are making observations and collecting data using the same protocol, can increase trust and reduce conflict around resource management. In fact, the planning meetings, trainings, data collection efforts, and analysis discussions can provide a focus and structure for collaboration around a common issue of concern and inspire feelings of collective ownership of a conservation issue or natural resource, often in ways that more top-down monitoring programs cannot.

3.3.2. Integration of multiple knowledge sources

A key way that participants in the focus group saw citizen science contributing to community conservation outcomes is through the inclusion of local and traditional ecological knowledge in monitoring and research. Not only can integration of multiple sources of ecological knowledge expand the information from which conservation decisions are made, but it has been shown to improve a community's capacity to deal with environmental changes and threats (Donoghue and Sturtevant, 2007). Further, participants explained that when collaborative monitoring is incorporated as a public activity that is an inherent part of local natural resource management, it can improve social and ecosystem resilience through social and adaptive learning, which can lead to the shortening of feedback loops between stakeholders and management actions (Tidball and Krasny, 2012; Spellman, 2014). Participants also pointed out that citizen science provides a means through which local stakeholders can participate and have a voice in natural resource monitoring and decision-making that might otherwise exclude them.

3.3.3. Challenges to building community capacity

Focus group participants also identified several challenges that are not unique to marine and coastal citizen science, but are nevertheless important to overcome in any efforts to build community-capacity to address conservation problems. Communities are not often monolithic and can include many factions and sectors of society (Agrawal and Gibson, 2001), and citizen science efforts may actually bring to the surface conflicts between stakeholder groups if all are not engaged equitably and respectfully in the project (Long et al. in press). Further, it was also pointed out that community members who may have interest and local ecological knowledge to contribute to a citizen science project may have time and other constraints that make it difficult to participate; often projects may involve only people who have the time and means to volunteer. In these cases, special effort to include people from across the whole community can truly pay off in building trust in the project and capacity for future community projects (Long et al. in press).

3.3.4. Recommendations for implementation

Focus group participants offered several key recommendations for practitioners hoping to build community capacity through citizen science projects. The most basic recommendation is to start small. Rather than tackling a large and complex project, start with smaller projects or "quick wins" that can be a gateway to greater involvement that address larger community conservation issues and increase the likelihood that the project will be successful. Another way to increase the likelihood that a project will be successful is to build trust among and with local stakeholders. This requires identifying and engaging with local leaders, both formal and informal, as well as learning about local concerns that may relate to the conservation issue targeted by the citizen science project. Be targeted and thoughtful about who to involve in the project, particularly under-represented groups, so that many sectors and participant groups may engage and have a stake in the project and the issue. It is also critical to develop long-term goals and systems to ensure continued engagement and ownership by the community members. These should be developed and maintained from the earliest stages of the project.

To build capacity, participants suggested that it is important to partner with organizations from other sectors of the community such as fisher organizations, non-government organizations, diving and recreational groups, and the fishing and eco-tourism industries. Citizen science projects can also encourage bottom-up management by providing training for local people to not only participate in the project but also develop livelihood skills, including field data collection, fishing guiding and work at dive centers, naturalist and tourism guiding, and enforcement in protected areas. This reciprocity can impact the sustainability of the citizen science project as well as the resource management. Collaboratively defining the objectives of the citizen science project, if possible, can also significantly build capacity; data collection is often the limit of many people's participation in a citizen science project, but having a role in the design of the project can also create feelings of ownership and increase community capacity to create new projects to address future conservation concerns.

To build trust and capacity among stakeholders, several focus group participants attested that an effective mechanism is participatory workshops that bring together the various stakeholders in the marine resource to be monitored, such as fishers, resource managers, NGO staff, and tourism workers (see also 2.1 queen conch case study). These workshops can also develop shared understanding of ecosystems, build conceptual models to identify targets species and threats, develop novel strategies, and lead to new research questions that citizen science projects can help answer.

Finally, participants pointed out that it is important to share information with stakeholders and ensure data accessibility, especially if the goal is for community members to maintain the project into the future. For example, a focus group participant described her own experience with a fisher community in a South American community-based monitoring project that had to wait a year for the NGO to provide feedback about the data and results; the participants lost interest and commitment and abandoned the project. Therefore it's important to include results sharing with participants as part of the project design, which can be designed as a social event so that people talk about and become excited to share the results of the citizen science project with each other and outside the community.

3.4. Site Management outcomes toolkit

Citizen science can be an especially effective tool for site management because of the need to monitor species and habitats over the long-term and often over a large area (Aceves-Bueno et al., 2015). Using citizen scientists can help expand the temporal and spatial scale of monitoring studies (Miller-Rushing et al., 2012; Ward et al., 2015) especially if the site managers have limited resources. The queen conch case study discussed in Section 2.1 is an example of this; the spatial and temporal scope of that study would not have been possible without citizen scientists given the level of resources available to the reserve managers (Cigliano and Kliman, 2014). Community-based citizen science monitoring programs can also lead to more rapid and more sustainable actions (Danielsen et al., 2005).

The focus group participants identified several key themes and advantages related to working with citizen scientists to assist with site management. Citizen scientists may: (1) provide long-term data that address management needs, (2) improve rapid response to and detection of episodic or stochastic events, and (3) enhance the sustainability of monitoring, and overall management of sites.

3.4.1. Provide long-term data to address management needs

Focus group participants noted that citizen science projects have the capacity to provide long-term, spatial-data (including baseline) that is not ordinarily available for site management, which can be used to address gaps in information needed for proper management. The California MPA case study above (Section 2.2) is an example of a long-term, site-based ocean resources management project where citizen science is providing valuable information for marine management alongside other projects. Other examples include the Coastal Observation and Seabird Survey Team (COASST), Long-term Monitoring Program and Experiential Training for Students (LiMPETS), Beach Watch, and REEF (Reef Environmental Education Foundation). COASST, a program of the University of Washington, has been engaging state, tribal and federal agencies, environmental organizations, and community groups since 1998 to monitor seabirds along the coast of California, Oregon, Washington, and Alaska (depts.washington.edu/coasst/what/vision.html). LiMPETS has been using students and adult volunteers since 2001 to monitor rocky intertidal and sandy beach habitats in California's National Marine Sanctuaries (http://limpets.org/, Osborn et al., 2005). Beach Watch, started by the Gulf of the Farallones National Marine Sanctuary, has been using citizen scientists since 1993 to survey the shoreline of the north-central California to provide early detection of environmental perturbations, including epizootic outbreaks, El Niño-Southern Oscillation (ENSO) events, and oil spills, as well as provide a network of citizen scientists who can respond to oil spills (http://www.farallones.org/volunteer/beach_watch_2.php, Roletto et al., 2003). REEF has been conducting reef fish surveys using divers and snorkelers since 1993 (http://www.reef.org, Pattengill-Semmens and Semmens, 2003).

By conducting long-term surveys, these projects fill gaps in data and information needed for effective site management (Aceves-Bueno et al., 2015). For example, data collected by REEF citizen scientists were used to provide missing science-based data needed to determine whether Atlantic goliath grouper (*Epinephelus itajara*) populations in the southeastern United States were recovering as suspected based on anecdotal evidence (Koenig et al., 2011). It was found that after a fishery closure was enacted in 1990 there was a rapid population increase in juvenile groupers in the dominant nursery habitat (Ten Thousand Islands area of Florida) but slow recovery in other areas of the southeastern US. COASST, as part of a multi-organization effort, provided data for a study of entanglement by marine debris of seabirds and marine mammals from 2001 to 2005 (Moore et al., 2009).

3.4.2. Improve rapid response to and detection of episodic or stochastic events

Because citizen science allows for increasing the spatial and temporal scope of projects (see 2.1 queen conch case study; Miller-Rushing et al., 2012; Ward et al., 2015), focus group participants pointed out that the probability of identifying and responding to episodic or stochastic events can be increased. For example, Scyphers et al. (2014) compared observations of the invasive Indo-Pacific lionfish (*Pterois volitans/miles*) in the northern Gulf of Mexico by citizen scientists to observations made during traditional reef fish monitoring from the earliest reports to 2012 and found that citizen scientists reported the presence of lionfish 1–2 years earlier and more frequently than did traditional reef fish monitoring programs. Data from Beach Watch surveys were used to determine the impact of oil pollution on bird mortality from a sunken vessel and from spills from working vessels, as well as a negative effect on bird reproduction from ENSO (Roletto et al., 2003). Bird Watch also provided data on bird mortality following the M/V Cosco Busan oil spill, which occurred in 2007 (NOAA, 2013).

3.4.3. Enhanced sustainability of monitoring and management of sites

Focus group participants also suggested that citizen-science based site management programs could be more sustainable because the program would not necessarily be attached to a specific project or funding stream (e.g., COASST). And by including citizen scientists, the program could encourage ownership and better stewardship of a site, while building community (see 3.3 community outcomes toolbox). Focus group participants also suggested that such a program could encourage broad awareness of the need for management (see 3.2 educational outcomes toolbox) and "soften" the top-down nature of management while improving community relationships with managers (see 3.3 community outcomes toolbox), and possibly lead to self-enforcement of a reserve.

3.4.4. Recommendations for implementation

To assist in the successful site management, focus group participants identified several recommendations. First, methods must be consistent and standardized over time and space to ensure that managers collect usable data that can be comparable to other studies. Researchers also need to connect and work with managers from the earliest stages of project design and implementation so that managers "buy-in" to the project and to provide capacity-building opportunities for managers (see 2.1 queen conch case study; 3.3 Community Outcomes Toolbox). This will also allow researchers to understand the needs of managers, not just in terms of data and information, but also in the form and process by which those resources can be of use. Finally, projects also need to be at the appropriate scale: a global citizen science program may not be able to focus on specific local or regional management regimes without a separate effort. On the flip side, a small community effort may not be helpful for managers operating at the regional level.

3.5. Species management outcomes toolkit

Conservation citizen scientists rally around iconic species often termed 'charismatic megafauna' (Sodhi and Erllich, 2010), a trend that carries over into citizen science. Many established citizen science programs, including those represented in the focus group, focused on a single species or suite of related species. These programs often used the species status to argue for habitat conservation (Mueller et al., 2012) or as a sentinel species indicating broader ecosystem status (Porte et al., 2006). In shallow areas, many species are charismatic even if they don't fit the usual standards of cute and furry (Shackeroff, 2008). Focus group participants identified two main pathways for improving species management through citizen science: (1) aiding existing species management infrastructure and (2) galvanizing support among a stakeholder community to increase species management protections.

3.5.1. Aiding existing species management infrastructure

Focus group participants suggested that citizen science has the potential to increase the available information on which to base species management decisions. For example, citizens can gather data in areas that would otherwise be difficult or impossible, such as on private land, over large spatial and temporal scales (Miller-Rushing et al., 2012), and at high frequency (e.g., 2.1 queen conch case study). This capability allows citizen science to detect changes more quickly than traditional science, for example with invasive species (Gallo and Waitt, 2011), disease spread (LaDeau et al., 2007; Crowl et al., 2008), or changing climate (Parmesan et al., 1999; Hurlbert and Liang, 2012; see 3.4.2 Improve rapid response to and detection of episodic or stochastic events). Citizen science projects can directly support data gathering for species assessments such as fishery stock assessments or for data deficient endangered species listings (Ward-Paige and Lotze, 2011). Furthermore, data collected through local monitoring programs often lead to more rapid and sustainable actions (Danielsen et al., 2005).

3.5.2. Galvanizing support

Focus group participants also suggested that citizen scientists might galvanize support for a particular species or set of management actions by their participation in a citizen science program. The program can directly raise awareness of both the citizen scientists and managers through their visible community activities. The program might inspire citizen scientists to participate in more stewardship or advocacy activities (Danielsen et al., 2005; Toomey and Domroese, 2013) and to directly aid with compliance and enforcement (Danielsen et al., 2005). Citizen scientists may directly ask for action by resource management agencies or otherwise facilitate communication between stakeholders and managers (Danielsen et al., 2005). Focus on a particular species might also change people's perception of it or change the economic incentives around species management. All of these outcomes depend upon a citizen science program promoting a personal connection (see 3.2 educational toolbox) with a particular species.

3.5.3. Recommendations for implementation

The species management outcome relies on two key aspects of citizen science: the ability to collect data in more places and times and the personal connection to a particular species. Focus group participants recognized that species management is a prominent regulatory approach with a long history, but now widely seen as inadequate for addressing ecosystem-based management goals (Zhou et al., 2009). In order to increase the likelihood that species management is a successful outcome of citizen science, the focus group participants suggested that the following intermediate steps be met and that these should be defined or planned out before the program begins:

- Transparency in the citizen science program: make clear how data quality will be validated, such as volunteer training or quality assurance protocols;
- Adequate data collection tools: data collection tools should allow easy recording in the field and include easily understandable summary results for end users of the information;
- Analyst and point of contact: the citizen science program staff should include a designated point of contact, who may also be the data analyst, to explain the results and the analytical process to managers if asked; this person provides a human face for the program;
- Relevant managers: create an ongoing, open relationship with relevant managers (possibly not all managers that deal with a given species) so that when questions arise, there's a trusted relationship to rely upon.

3.6. Research outcomes toolkit

A key conservation outcome of citizen science projects is for research to inform natural resource management and decision-making, which inherently relies on credible data and analysis that researchers and managers can trust and use (McKinley et al. submitted for publication). While the toolkits discussed above focus on directly informing a variety of outcomes and processes related to natural resource management and conservation, focus group participants suggested that there is also the possibility for citizen science approaches to enhance traditional academic research, thus indirectly improving its effectiveness in linking with outcomes beyond the science.

There is a wide range of research topics that can be addressed using citizen science (Dickinson et al., 2010) including: (1) species range shifts, (2) phenology, (3) effects of habitat loss and fragmentation on biodiversity, (4) detection and tracking of infectious diseases, (5) distribution of invasive species, and (6) monitoring effects of bio-contaminants.

Focus group participants identified a broad set of ways in which citizen science can improve research outcomes: (1) quality and effectiveness of science; (2) programmatic innovation; and (3) accessibility and participation.

3.6.1. Quality and effectiveness of science

As discussed above, citizen science allows for better spatial and temporal coverage over a study area (see 3.4 site management outcomes toolkit), and can generate large amounts of high quality data (Delaney et al., 2008; Bonney et al., 2009; Aceves-Bueno et al., 2015), very cost-effectively (Aceves-Bueno et al., 2015). Focus group participants suggested that broad involvement can also help to make the case for research. For example, a greater participation base can increase the potential for fundraising, and thus feed into the overall quality of the research effort.

3.6.2. Programmatic innovation

Focus group participants also noted that involving citizen science in a larger research effort requires flexibility and creativity around program design. While this can be a challenge, it's also an opportunity to explore creative approaches to methods, analysis, collaboration, and communication. Participants in citizen science are all potential innovators when it comes to collection methods and analytical approaches. Participants also have the potential to identify new research questions that were not initially part of the program based on their participation and the data trends they observe.

3.6.3. Accessibility and participation

Focus group participants noted that citizen science can have benefits for the participants in terms of education and empowerment (see 3.4 2 educational outcomes toolkit). The focus group participants identified two important potential outcomes: “demystifying” science for the public while connecting scientists to the community and recruiting future scientists. But scientists can also learn about effective communication and collaboration in ways that improve their work. In other words, citizen science can temper the “elitist” nature of science which can then open doors for broader stakeholder involvement and an engaged, informed voting public.

3.6.4. Recommendations for implementation

Focus group participants suggested several recommendations that should be considered when targeting strong conservation research outcomes through citizen science. Many of these recommendations are simply consistent with good research design practices, but are at risk of being neglected when a citizen science project is designed with a variety of competing goals.

To ensure that the data collected meet the needs of the research project, research groups need to develop the research protocol, volunteer training program, and a QA/QC plan before starting the project; researchers could modify procedures developed in similar projects or develop a plan of their own (Danielsen et al., 2005). Once a QA/QC plan is developed it is advisable to test it with the project participants to ensure that the protocols match the abilities of the participants and that the data meet the desired quality standard (e.g., accepted level of accuracy of identifying correct species by citizen scientists) and to continually monitor and validate data quality (Danielsen et al., 2005). It is also critical to adequately train citizen scientists (Gallo and Waitt, 2011) and for researchers to be realistic in their expectations of their volunteers (Danielsen et al., 2005).

Focus group participants also suggested that it is critical to decide who the data collection participants are going to be before starting the project and to consider the following: (1) Who has the ability to collect the kind of data needed for the project; (2) What kind of training is required for accurate data collection; (3) What kind of supervision is necessary for accurate data collection; (4) What kind of participants are most effective to engage in this project; (5) What, if any, education and outreach goals, do you have as a part of your research that might help decide the ideal participant to engage? Focus group participants also emphasized that it is important for researchers to be sensitive to cultural differences between themselves and their volunteers.

After deciding on the target volunteer pool, focus group participants suggested that it is critical to have a well-developed plan for how to recruit, manage, and communicate with citizen scientists over the course of the project, as well as having clear research objectives, program goals and expectations for participants. Another point of emphasis identified by focus group participants is that it is important to remember that citizen scientists are not paid so that researchers will need to be clear about what the time commitment will be for the citizen scientists and that the citizen scientists will require training and guidance, which will possibly increase time commitment and cost for the research group. Furthermore, the research staff might require training, as well, on how to work with and manage citizen scientists.

Focus group participants also identified the need to communicate the results regularly with the citizen scientists and the local community. Regular and open communication can increase the effectiveness and sustainability of the research project (Danielsen et al., 2005).

4. Conclusion

The oceans and coasts are in peril and we must use the full range of resources to effect positive change. Citizen science is one such tool that has been underutilized (Roy et al., 2012; Theobald et al., 2015). One clear outcome of the combined symposium and focus group that we held at the 3rd International Congress for Marine Conservation is that there are unique challenges and great potential in using citizen science to advance marine and coastal conservation. In organizing our activity around distinct conservation outcomes that a citizen science program might address, we have emphasized the point that there are many different ways that citizen science can effect such change, and that a program should reflect carefully on these choices. However, it is also clear that a program can work toward multiple goals, and that there is strong overlap across some of them in terms of strategies and best practices. For example, working with decision makers in policy and management may take different forms for species management vs. site management, but many of the recommendations for those two areas are the same. The toolkits that we have developed should help stakeholders, policy-makers, educators, conservation practitioners, and researchers who wish to develop a marine or coastal citizen science program. We also hope that the insights and recommendations that came out of our discussions will stimulate further research on and assessment of marine and coastal citizen science programs.

Acknowledgments

We would like to the participants of the symposium and focus groups. Their dedication to and knowledge of marine and coastal conservation and to citizen science made this paper possible. JAC would like to thank Earthwatch International for funding and the amazing Earthwatch citizen scientists for their help. We would also like to acknowledge the two anonymous reviewers for the helpful comments, which greatly improved the manuscript.

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