



Making Waves: Marine Citizen Science for Impact

Marie-Lise Schläppy^{1,2}, Jennifer Loder^{2*}, Jodi Salmond², Alexandra Lea², Angela J. Dean³ and Chris M. Roelfsema⁴

¹ Environmental Research Institute, North Highland College, University of the Highlands and Islands, Thurso, United Kingdom, ² Reef Check Australia, Brisbane, QLD, Australia, ³ Faculty of Humanities and Social Sciences, School of Communication and Arts, University of Queensland, QLD, Australia, ⁴ Remote Sensing Research Centre, School of Earth and Environmental Sciences, University of Queensland, Brisbane, QLD, Australia

The benefit of engaging volunteers in marine citizen science projects goes beyond generation of data and has intrinsic value with regards to community capacity-building and education. Yet, despite the documented benefits of citizen science, there can be barriers to the process of developing strategic citizen science projects and translating data into valued results with natural resource management applications. This paper presents four case-studies from fifteen years of Reef Check Australia (RCA) marine citizen science research and education projects. These case studies convey approaches and lessons-learned from the process of designing, implementing and sharing citizen science programs with the goal to create valuable social and environmental outcomes:

- (1) Demonstrating citizen science data quality through a precision study on data and analysis of 15 years of standardized Reef Check (RC) reef health data in Queensland, Australia.
- (2) Identifying and responding to data gaps through volunteer monitoring of sub-tropical rocky reefs in South East Queensland, Australia.
- (3) Adapting citizen science protocols to enhance capacity building, partnerships and strategic natural resource management applications through reef habitat mapping.
- (4) Tailoring new pathways for sharing citizen science findings and engaging volunteers with the community via a Reef Check Australia Ambassadors community outreach program.

These case studies offer insights into considerations for developing targeted and flexible citizen science projects, showcasing the work of volunteers and project stakeholders, and collaborating with partners for applications beneficial to research, management and education.

Keywords: citizen science, coral reefs, sub-tropical reefs, reef management, Reef Check, Reef Check Australia, community engagement, reef monitoring

INTRODUCTION: REEF CHECK AUSTRALIA

The Great Barrier Reef (GBR) of Australia is the largest barrier reef in the world, spanning 346,000 square kilometers along the Queensland coast (Great Barrier Reef Marine Park Authority, 2014). In 1981, the outstanding universal value of the GBR was acknowledged with the UNESCO World Heritage designation. The GBR is managed by the Great Barrier Reef Marine Park Authority,

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Meeresforschung, Germany

*Correspondence:

Jennifer Loder
support@reefcheckaustralia.org

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created in 1975. The Australian Institute of Marine Science long term monitoring program is one key dataset used for evidence-based management in the GBR. In addition to the Australian Institute of Marine Science data, the Great Barrier Reef Marine Park Authority coordinates the “Eye on the Reef” monitoring program, in which management agencies, tourism operators and reef visitors contribute data to a suite of monitoring programs (Great Barrier Reef Marine Park Authority, 2014). Despite these efforts, the sheer size, cost and logistical restrictions of accessing the marine environment pose a challenge for comprehensive monitoring. The Reef 2050 Plan, which was developed in 2015 as a response to UNESCO’s examination of whether to inscribe the GBR as being in-danger, further increases the monitoring and data requirements in the GBR to assess progress and support adaptive management. Additional human capacity to collect reef health data, as well as enhanced community understanding of reef health, can complement best-practice science-based management strategies for this substantial marine icon.

Reef Check Australia (RCA) is an environmental charity that aims to empower people to champion healthy Australian reefs through marine citizen science, educational experiences, and tangible local conservation action. This grassroots approach provides complementary data that can fill spatial and temporal data gaps, highlight local sites of community interest with globally comparable data, and build capacity to engage in both science and marine conservation activities.

In 2001, RCA was initiated through a masters project (Hill, 2002) to quantify observer-related error in the RCA coral reef monitoring program. The Australian Institute of Marine Science and the Great Barrier Reef Marine Park Authority were consulted regarding relevant regional indicators that may be included in the globally-standardized RC monitoring protocols to enhance science and management relevance. Since that time, the program has developed into a respected citizen science program with strong ties to the tourism diving industry and regional partners.

RCA aims to coordinate robust citizen science. Volunteers are trained to collect data about reef composition, visual signs of reef stress and abundance of indicator organisms through a rigorous volunteer training program. Numerous quality assurance procedures help to ensure high-quality citizen science data. For many years, RCA concentrated on collecting coral reef health data (e.g., coral cover, fish/invertebrate counts, impact counts), with the assumption that, by focusing on data gaps and ensuring data quality, end-users would value and use the data produced.

Over time, it became apparent that availability of citizen science data alone was not leading to data uptake for science and management applications. This prompted RCA to re-assess the approach for stakeholder engagement, including (i) ascertaining quality of collected data, (ii) identifying data-poor marine locations that could benefit from citizen science data, (iii) finding opportunities to expand data applications, and (iv) communicating data through innovative approaches.

Abbreviations: GBRMPA, Great Barrier Reef Marine Park Authority; RC, Reef Check; RCA, Reef Check Australia; SEQ, South East Queensland; UQRSRC, University of Queensland Remote Sensing Research Centre.

This paper aims to utilize case studies from RCA’s development to document this particular growth trajectory, which hopefully provides insights into approaches and learnings that may be constructive for other citizen science initiatives seeking to maximize social and environmental outcomes. A review of past marine citizen science projects to inform future engagement is particularly timely given the documented increase in the number of marine citizen science projects in Australia (Sbrocchi, 2014). Within this context, citizen science has been identified as having significant potential to contribute to increased understanding of the marine environment and potential changes through data collection (Dickinson et al., 2012; Martin et al., 2016), and there are calls for more meaningful community engagement in both marine science research and science knowledge (Chilvers et al., 2014; Commonwealth of Australia, 2015). The 4 case-studies below outline various steps in the growth of RCA and provides examples of how the organization and citizen science initiatives have evolved over the past 15 years.

CASE-STUDY 1: DEMONSTRATING CITIZEN SCIENCE DATA QUALITY THROUGH A PRECISION STUDY ON DATA AND ANALYSIS OF 15 YEARS OF GLOBALLY STANDARDIZED REEF CHECK REEF HEALTH DATA IN QUEENSLAND, AUSTRALIA

Fostering the use of environmental monitoring data to inform management decisions is a challenge for citizen science (Freitag, 2016; Vann-Sander et al., 2016), and science more broadly (Brodie and Waterhouse, 2012). A key factor influencing use of citizen science data is perceptions about data quality. To increase legitimacy and acceptance of RCA data for science and management applications, RCA undertook a study to identify how data collection methods and surveyor precision influences the data collected by RCA volunteers (Done et al., 2017). This study quantified the variability inherent in the standardized Reef Check point-intercept sampling method, including transect deployment variation, site characteristics and the variability created by different observers collecting substrate percent cover data.

An initial study conducted in 2007, supported by further replication in sub-tropical reef ecosystems in 2014 revealed a high degree of accuracy in trained volunteer estimates of benthic cover ($\pm 93\%$ of the absolute value). Coral cover estimates were shown to be more precise at homogenous sites than at heterogeneous sites (Done et al., 2017). This evaluation of RCA data limitations, defines the strength of interpretation for long-term trends and enhances knowledge about data utility for suitable applications. Peer-reviewed assessments of data quality create a stronger foundation for integrating data into management applications and shape how information about sites of public interest is shared with communities.

An emerging body of research shows that citizen science programs can generate data that meets or surpasses generally accepted quality standards (Kosmala et al., 2016). Ideally, design and implementation of data validation processes would occur from project inception through allocation of time, financial resources and personnel to support this outcome. However, not all citizen science organizations have the consistent and secure resources to conduct the necessary work to enable reporting on data quality, especially long-term or grassroots citizen science projects. It is vital for funding bodies to recognize the importance of allocating human resources to support data validation processes and other core data management and reporting activities. In practice, many funding sources suitable for citizen science seek innovation through “new activities,” and may not support funding for existing human resource costs that are critical for long-term initiatives. This chronic limitation of resources can result in staff or volunteer burn-out, reduced partnership outcomes, non-essential reiterations and mission shift. Overcoming such funding challenges is imperative to improve the social and environmental impact of citizen science.

CASE STUDY 2: IDENTIFYING AND RESPONDING TO DATA GAPS THROUGH VOLUNTEER MONITORING OF SUB-TROPICAL ROCKY REEFS IN SOUTH EAST QUEENSLAND, AUSTRALIA

The capacity to address spatial gaps in monitoring data has been identified as a strength of citizen science programs (Cigliano et al., 2015). In 2007, limited long-term monitoring data on sub-tropical reefs in South East Queensland (SEQ), Australia, prompted RCA to introduce regular volunteer monitoring to the region. Research sites were selected in consultation with regional stakeholders. Since 2009, volunteers trained in the RCA method survey more than 20 priority reef monitoring sites annually, from the Sunshine Coast to Gold Coast (~200 km). From 2007 to 2014, more than 140 Reef Check surveys were conducted by trained volunteer teams, creating a unique long-term data set assessing reef health across the region (Loder et al., 2015). These surveys ($n = 142$) showed an average of 24% hard coral cover and 8% soft coral cover, higher than commonly perceived by the wider community to exist at this latitude (Reef Check Foundation and the Marketing Garage, 2010). From 2007 to 2014, RCA survey data documented minimal net changes in hard coral cover at the sub-regional level. These results align with a broader Australian East-coast study, which documented relatively stable benthic composition for sub-tropical coral communities over the past two decades (Dalton and Roff, 2013).

The sub-tropical reef health dataset is now being utilized in regional planning and is helping to target on-ground conservation activities (South East Queensland Catchments, 2015). Findings are regularly reported to relevant stakeholders, prompting collaborative action on certain issues. For example, dissemination of SEQ sub-tropical reef impact summary maps, highlighted a marine debris hotspot at a popular Gold Coast

site (with marine debris abundance levels of 0.8/100 m² and discarded fishing gear levels of 2.7/100 m, **Figure 1**). This data helped to catalyze projects to investigate coastal and marine debris sources by partnering with the Tangaroa Blue Foundation to undertake detailed assessments of debris types, review available data with key stakeholders, and create source-reduction plans in 2014–2016.

With strategic support from regional stakeholders, citizen science programs like RCA are well-placed to enhance understanding of the ecology and biology of these sub-tropical reefs, and to highlight how these habitats may change over time. This is important, given the scientific uncertainty about how transitional marine habitats like those of SEQ may be impacted by both regional pressures and changing climate regimes (Figueira and Booth, 2010; Graham et al., 2011; Lybolt et al., 2011; Munday et al., 2012). Ongoing monitoring can inform best-practice science and management at the regional level. Moreover, volunteer training facilitates accrual of social capital. This provides opportunities for social learning and activation of social norms about conservation, thereby increasing support for other conservation initiatives (Dean et al., 2016).

CASE-STUDY 3: ADAPTING CITIZEN SCIENCE PROTOCOLS TO EXPAND PROJECT OPPORTUNITIES THAT ENHANCE CAPACITY BUILDING, PARTNERSHIPS AND STRATEGIC NATURAL RESOURCE MANAGEMENT APPLICATIONS THROUGH REEF HABITAT MAPPING

Maps describing the spatial extent of sub-tropical reefs in inshore Moreton Bay (Australia), were created in 2004 and set the baseline for natural resource management decisions in the region. In 2015, RCA, The University of Queensland Remote Sensing Research Centre (UQRSRC) and Healthy Waterways and Catchments united citizen science, research and management, and worked in partnership to revise this baseline. This collaborative project adapted the RCA benthic habitat assessments for use with UQRSRC and Healthy Waterways and Catchments benthic habitat mapping protocols to collect revised data on the spatial extent and inventory of reefal habitats to review the 2004 baseline.

To create new benthic maps, UQRSRC identified target locations for benthic spot-checks based on: (i) the 2004 survey sites (ii) high spatial resolution satellite imagery, and (iii) local knowledge. UQRSRC and RCA provided training for the volunteers to adapt their survey skills to collect geo-referenced habitat data at identified spot-check locations. The trained RCA volunteer teams visited more than 600 sites across the nearshore reefs to record the major benthic cover types (e.g., hard coral, soft coral, algae, sand, rubble, and rock) and the percentage composition of those categories at each site (**Figure 2**). Visual estimates of benthos were collected on snorkel or from the boat, using a drop-down video

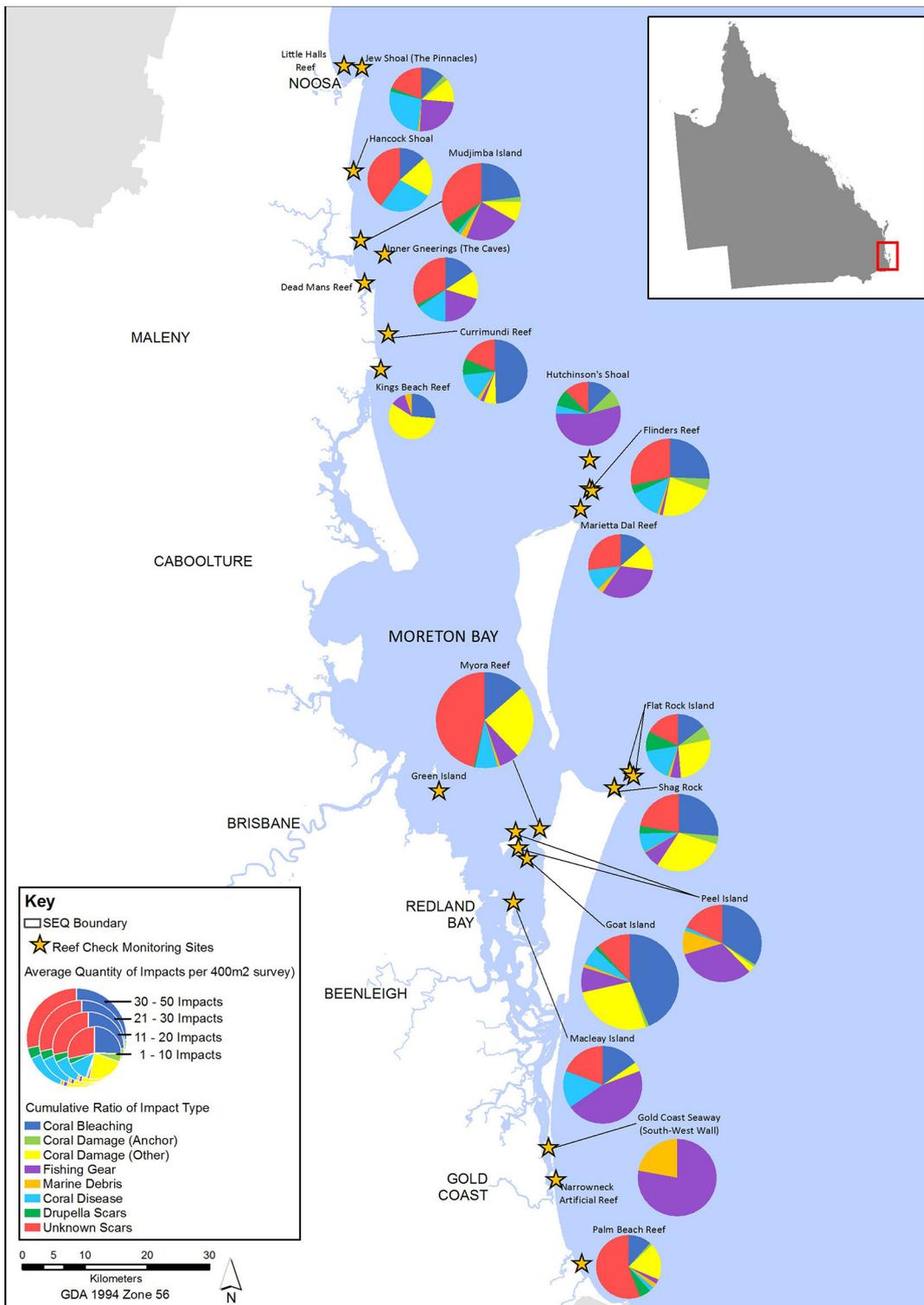
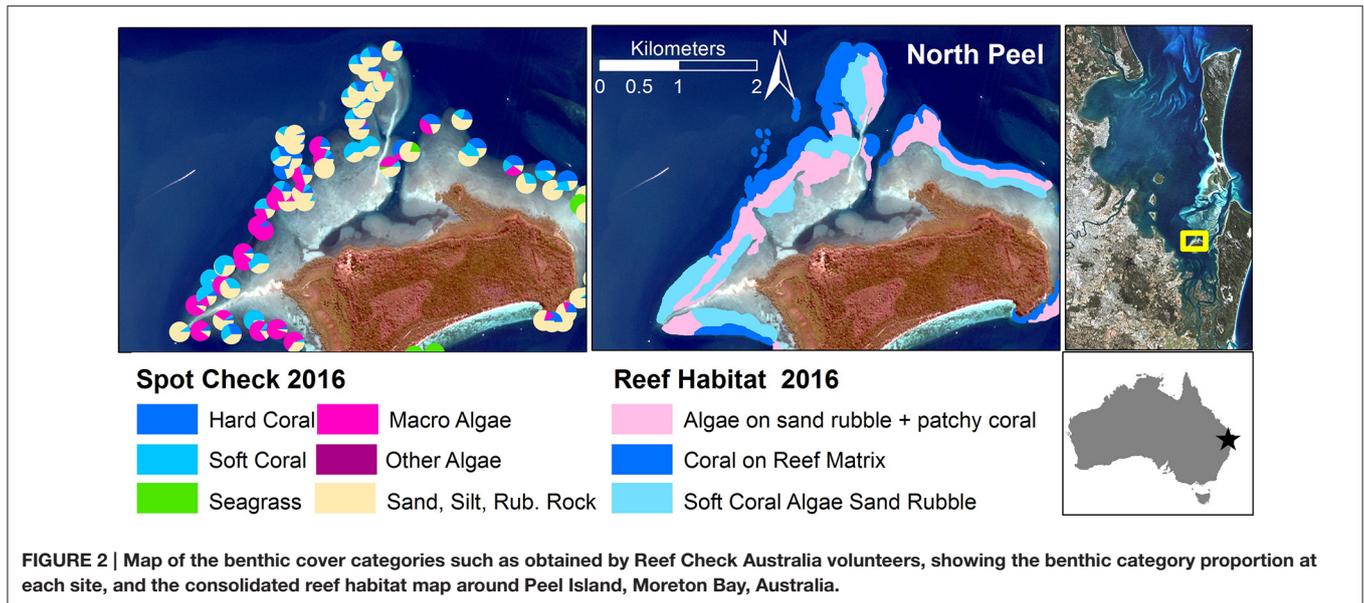


FIGURE 1 | Map of cumulative reef health impacts recorded at Reef Check Australia monitoring locations in South-East Queensland, Australia (2007–2014). Note the Gold Coast Seaway (South-West Wall) with high levels of recorded fishing gear and marine debris (no coral has been documented at this location, therefore there are no coral impacts either). Map by S. Mooney, M. Petter, M. Walker from SEQ Catchments Ltd, using RCA data.



camera or underwater viewer (depending on water clarity and depth) at georeferenced locations. Field data was overlaid on a high resolution (5×5 m pixel) satellite imagery ZY-3 (Figure 2). Polygons were manually digitized by UQRSRC staff around areas with similar texture and color through visual interpretation of satellite images, followed by assignment of benthic category based on georeferenced field data and expert image interpretation. Benthic mapping categories included coral on reef matrix, soft coral on sand/rubble, and algae on sand/rubble (Figure 2). The map and field data provide important information on Moreton Bay reefal areas, including the proportion of habitat at each location, and consolidated habitat polygons (Figure 2).

Although a comparison between 2004 and 2015/16 data was intended, expert visual inspection indicated that the technology used to generate the 2015/16 map resulted in more refined habitat assessments than the 2004 baseline, precluding direct comparison. It is expected that the 2015/16 map more closely represent the spatial extent of coral areas and should be treated as a revised baseline.

Up-skilling of trained RCA volunteers was cost-effective, as their existing skills enabled volunteers to easily and accurately identify benthic features relevant for this study. Importantly, the project also offered ongoing capacity-building training for volunteers, by further developing volunteer knowledge and skills. Because the program was designed in collaboration with end-users, the data outputs addressed a specific management need, highlighting the benefits of working closely with end-users when designing projects. The revised reef habitat map will be utilized for the annual Healthy Waterways and Catchments Report Card, a key policy and decision-making tool for the region, which helps to evaluate the effectiveness of catchment-level management actions. Beyond direct natural resource management application, datasets such as the Moreton Bay benthic cover map can create community interest and increased understanding of local marine

environments. Communication about use of the RCA data is vital to ensure continual engagement of RCA volunteers to maintain an interest in marine science and contributions of volunteer skills and time.

CASE-STUDY 4: TAILORING NEW PATHWAYS FOR SHARING CITIZEN SCIENCE FINDINGS AND ENGAGING THE COMMUNITY

Over the last 15 years, Reef Check Australia has amassed a collection of locally-relevant reef health data. Many monitoring sites were selected based on significant community interest (such as key SCUBA dive sites or nearshore marine environments). In addition to data collection, an important role of citizen science programs is to communicate results to the broader public and provide opportunities for engagement in science literacy and conservation. There is increasing recognition of the importance of building active community support for conservation activities. For example, a key target of the Australian Biodiversity Strategy is increasing the number of Australians participating in biodiversity conservation (Natural Research Management Ministerial Council, 2010). From a global perspective, the United Nations Sustainable Development Goals promote greater community participation in decision-making, and incorporate targets requiring active community support (United Nations, 2015). This emphasis on community outreach can benefit from a consistent framework to help RCA volunteers share information with communities.

To broaden the potential for effective community engagement, RCA launched the Reef Ambassador program in 2015. This program trains and supports volunteers to provide reef education experiences in the community and act as role models for environmental engagement. This grassroots

education and outreach program aims to build capacity for communities to become informed, engaged and empowered to actively participate in protecting reef health. Program goals include fostering ocean literacy, building a network of engaged community members, extending partnerships, and providing data to support community action. The Ambassador program has been designed not only to provide action pathways to translate citizen science data for the community, but also support government policy targets such as the “Reef 2050 Long Term Sustainability Plan” (Commonwealth of Australia, 2015). Through this program, Reef Ambassadors can directly deliver policy targets related to fostering an engaged community that plays an active role in reef protection, while building social capital. Ambassadors also develop their own capacity in the areas of reef ecology, science communication, leadership and partnerships. RCA partners benefit through a consistent and high-quality channel to deliver key messages for stakeholders.

From August 2015 to December 2016, the Reef Ambassador pilot program for Moreton Bay recruited and trained 29 Ambassadors. Post-training-workshops evaluation surveys demonstrated positive outcomes. For example, all 29 Ambassadors indicated their desire to participate in future events and continue developing skills. After completion of training, Ambassadors reported increased knowledge about sub-tropical reefs (85% of participants), reef threats (82%), and actions that individuals can take to protect reefs (93%). From August 2015 to November 2016, Ambassadors engaged more than 4,000 community members in reef-related activities, through 24 diverse events. After the successful launch of the Reef Ambassador program in SEQ, RCA is seeking to scale-up the initiative for broader implementation across Queensland.

Many citizen science programs focus on *science* and its potential for informing environmental management; fewer programs focus on the *citizen* and using science engagement to foster social change. The early success of the Reef Ambassador program highlights the important role for citizen science programs to build environmental stewardship. Research indicates that participation can generate a range of individual and societal benefits (Jones et al., 2012; Dean et al., 2016). Ongoing evaluation will quantify long-term impacts of the Reef Ambassador program and identify which elements of such programs are necessary to achieve meaningful change.

REEF CHECK AUSTRALIA 2001–2016: LESSONS-LEARNED

The lessons learned from the 4 case-studies outlined above shows that, since its inception, RCA has undergone a process of continual adaptation and development by responding to the changing context of marine ecological research needs, stakeholder interests, program resourcing, and conservation needs. The case studies highlight some examples relevant to the diverse considerations of maintaining a long-term citizen science program and may foster the ability of other citizen science programs to plan their growth rather than solely adapt to new circumstances. Some of the key lessons-learned are likely to be

common to many programs and enunciating them may help others decide if they warrant planned action.

Reflecting on this process, key lessons-learned include:

- Systematic long-term citizen science monitoring data is not sufficient to produce data applications for natural resource management applications. A documented quality assurance statement and identification of suitable data applications for end users appears paramount to foster data uptake. Engaging data end-users in program development from the outset can further strengthen potential applications and credibility.
- By their very nature, citizen science programs must continue to evaluate their strategy, and in response to such evaluation, adapt to fill spatial or temporal data gaps, maintain engagement and match those projects with the needs of partners that are not being actively addressed through other channels.
- The capacity-building benefits from citizen science projects offer value beyond the data: such as a skilled task-force and an ocean literate community. These principles can be strengthened through projects that offer ongoing learning and experiences for participants; and
- Part of the citizen science definition includes sharing data: building capacity of volunteers to share results can foster a sense of ownership, builds diverse skill sets (e.g., science communication), and closes the gap between science and citizens.

These four case studies highlight some important considerations in the development of marine citizen science programs. The constantly shifting dynamic of the citizen science sector requires that programs be adaptable and responsive, while also maintaining consistency for both data and participation. This multi-faceted nimbleness, particularly in an under-resourced sector, presents challenges. Given the growing recognition of the value of citizen science, and the under-realized potential of citizen science to make notable contributions, it is an important time to review and attune in order to maximize how we help more people meaningfully contribute to natural resource management.

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