GREAT BARRIER REEF
foundation

Citizen Science in the Great Barrier Reef

A scoping study

Report commissioned by the Great Barrier Reef Foundation, study undertaken by the Great Barrier Reef Marine Park Authority.

Australian Government
Great Barrier Reef Marine Park Authority

Preface

This scoping study report was commissioned by the Great Barrier Reef Foundation. It provides the results of consultation with Reef-based citizen science groups regarding needs and opportunities and provides recommendations for integrating citizen science into the eReefs[1] Program.

eReefs aims to combine data and information on the Reef and its catchments and display this information in easy to use visualisation products. This will provide the most comprehensive picture of the Reef – as it is, has been and will be – to managers policy makers, government agencies, researchers, industry and the community. The engagement of the community (from tourists to fishers to councils and schools) in the evolution of this comprehensive Reef picture through Citizen Science initiatives has the potential to enhance economic, social and environmental outcomes for the Reef and Reef communities.

There are many Reef-based citizen science programs operating on the Great Barrier Reef, run by Reef management, tourism operators, researchers, dive enthusiasts and members of the general public. These programs build strong links with local communities and provide volunteers with a hands-on opportunity to collect information that contributes to the protection of the Great Barrier Reef ecosystem.

The proposed eReefs citizen science initiative vision is for a more coordinated approach to citizen science across the Great Barrier Reef with the aim of enhancing the visibility and profile of existing programs and increasing access to, and usage of, citizen science data.

The Great Barrier Reef Foundation proudly endorses this scoping study report, undertaken by the Great Barrier Reef Marine Park Authority. Specifically, the Foundation would like to acknowledge Dr Andrew Chin, from GBRMPA, for leading this study and the individual citizen science groups who have contributed to this work. The recommendations provided in this report will assist in shaping the eReefs citizen science initiative to address the needs and opportunities identified by citizen science groups and brings us closer to creating integrative approaches for understanding, managing and protecting the Great Barrier Reef.

Claire Hanratty
Managing Director
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[1] eReefs is a collaboration between the Great Barrier Reef Foundation, Commonwealth Science and Industry Research Organisation, the Queensland Government, the Bureau of Meteorology and the Australian Institute of Marine Science initiative, supported by funding from the Australian Government Caring for our Country Program, the Queensland Government, the Science and Industry Endowment Fund and the BHP Billiton Mitsubishi Alliance

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Executive summary

Citizen science generally involves the systematic collection of information about natural phenomena by unpaid volunteers, and technology plays an important role in enabling citizen science activities. Many citizen science groups operate in the Great Barrier Reef (GBR) Region and collect a diverse range of data. The *eReefs* Program provides a valuable opportunity to help citizen science groups manage and disseminate their data, and to improve the uptake and application of this information by end users. This scoping study describes the results of consultation with citizen science groups, natural resource managers and the scientific community regarding citizen science in the GBR Region, and provides recommendations about the integration of citizen science with the *eReefs* Program.

Key results

- There is growing awareness and acceptance of the potential for citizen science to provide useful information and improve management outcomes.
- Citizen science projects in the GBR Region provide numerous benefits that extend beyond providing data.
- Concerns about data quality limit the uptake and application of citizen science data by managers and scientists. Uptake and application is also reduced by a lack of awareness about what data are available, how to access these data, and/or uncertainty about the quality of these data.
- Citizen science groups make concerted efforts to ensure data quality. Most efforts are directed towards quality assurance (QA) (e.g. training) and there is less emphasis on quality control (Q/C) processes (e.g. data verification and validation).
- Few citizen science groups have formally documented their QA/QC procedures.
- Citizen science groups, managers and scientists agreed that spatially representing citizen science data alongside other data sets in *eReefs* could be very useful in helping end users to locate, view and interpret citizen science data and information.
- The *eReefs* Program could further improve uptake of citizen science data by clearly documenting the scope and quality of the citizen science data presented.
- The *eReefs* Program could also improve collaboration and coordination between citizen science groups, and enhance communication between citizen science groups and communities.
- Careful consideration needs to be taken to manage data ownership issues and access to data collected by citizen science groups and community volunteers.
- Effective use of citizen science projects and data in the GBR Region will require effective communication, partnership and trust between citizen science groups, communities, scientists and natural resource managers.

Key recommendations

Recommendations for the *eReefs* Program include recommendations for (1) administrative processes, (2) short-term priorities and (3) long-term priorities.

Processes

- Agreements should be developed between the *eReefs* Program and Citizen Science groups to formalise collaborations, clarify benefits and obligations, and describe terms and conditions for data ownership and use.
- Agreements should discuss long term maintenance issues and include monitoring and evaluation steps to document how *eReefs* is enhancing the use of citizen science data.
- Socio-techno issues involved in developing new tools and functionalities should be identified and specifically addressed in an Implementation Plan to roll out *eReefs* products effectively.

Short-term priorities (*eReefs* Phases 1 and 2)

- *eReefs* should provide mapping functionality that spatially represents citizen science data on interactive maps alongside other data sets.
- Additional information about these data (i.e. meta-data) should be available by clicking icons on the map.
- A standardised metadata and QA/QC form should be developed that allows users to easily view information pertaining to the quality of the citizen science data.
- Enhanced visualisation tools should be developed which present patterns and trends in the data.
- Functionality or tools should be developed to enhance collaboration and coordination between citizen science groups and communities.
- Wherever possible, tools and functionality developed should adhere to principles of Web 2.0 (i.e. enable users to easily create and manage content).

Long- term priorities (*eReefs* Phase 3 and outside the *eReefs* program)

- *eReefs* facilitate interaction between citizen science groups and the e-research and information technology communities to scope development of specific tools and functionalities that are outside the scope of the *eReefs* Program.
- Scope the feasibility of a single, centralised on-line data system for GBR citizen science data.
- Develop formalised systems to document the uptake and application of citizen science data, and efficacy in improving end-user outcomes.
- Develop systems and processes to enhance and automate data QA/QC and document data quality (e.g. trust metrics, validation projects).
- Explore potential to develop and enhance social media for application in citizen science projects.

Introduction and background

Citizen science: definitions, applications, benefits and challenges

There is growing recognition of the role and potential applications of "Citizen Science", and there is a large amount of information available on citizen science programs. A search of scientific literature using ISI Web of Science (3 September 2012) using the key term "citizen science" returned 2,133 articles, and a search using the key terms "Citizen Science"' and "environment" returned 266 articles. The development and application of citizen science projects has been increasing in recent years[1,2,3,4] and citizen scientists currently collect information on a great diversity of variables and phenomena ranging from earthworms and insects to weather and astronomical observations.

Nevertheless, there is ongoing confusion and debate over what citizen science is, and several definitions have been proposed. For the purposes of this study, citizen science is defined as:

Participation in efforts to systematically collect and analyse data; test natural phenomena; and/or disseminate these activities by non-professional scientists, usually on an unpaid basis.[2]

This definition encompasses structured monitoring projects carried out by the community as well as unstructured, opportunistic observations and information submitted by community members in a structured way (e.g. 'sightings reports'). Under this definition examples of citizen science would include:

- Community based monitoring projects where individuals collect and manage data and information, with or without expert participation (*e.g. a community driven monitoring project to record anchor damage*)
- Community based monitoring projects where community members partner with experts to collect data and information (*e.g. community monitoring of sea turtle nesting sites together with park rangers*)
- Community members providing occasional/opportunistic information to scientists and/or managers (*e.g. injured marine animal hotline; fish tagging hotline; bird sightings reports to an on-line database*).

[2] Adapted from www.openscientist.org/2011/09/finalizing-definition-of-citizen.html and www.birds.cornell.edu/citscitoolkit/about/defining-citizen-science

In the biological and ecological sciences, citizen science projects have been successfully applied in terrestrial, aquatic and marine environments, especially in the study of birds (ornithology) which has a long history of citizen science participation dating back to the late 1800s [1,3]. More recently, citizen scientists have been monitoring bird distributions [5], plants [6], insects[7], coastal habitats [8] and even marine habitats using SCUBA divers [9,10]. In general, citizen science monitoring programs can be divided into two categories. **Targeted monitoring** which is focused on a specific question; and **surveillance monitoring** which is broader monitoring used to identify wider patterns, trends, behaviours and anomalies in the natural environment [3].

Citizen science has been practiced for decades to monitor a great variety of species and phenomena at scales that traditional science cannot replicate. In recent years there has been increasing interest in Citizen Science and its potential to supplement scientific information and inform policy and management decisions.

Citizen science projects can provide many benefits such as:

- Increased spatial and temporal coverage of data
- Collecting data to supplement formal monitoring programs that may be constrained by limited funds or capacity
- Engaging communities in science, monitoring and natural resource management
- Empowering communities to participate effectively in natural resource management
- Educating communities and the general public
- Improving the well being of participants
- Building social capital which can improve management outcomes
- Potential cost savings.

Nevertheless, citizen science projects may also face numerous challenges and the resulting data may have several disadvantages:

- Insufficient and inconsistent funding can limit the scope and completeness of citizen science projects and the resulting data
- Lack of capacity and technical expertise in designing monitoring programs and data analysis can compromise data
- Groups may face organisational issues including staff capacity and availability, coordination of volunteers and between groups and stakeholders, and governance issues
- Data collected by citizen science groups can be difficult to analyse (especially surveillance monitoring data)

Citizen science monitoring projects can be broadly categorised into two groups: (1) *targeted monitoring* and (2) *surveillance monitoring.* Targeted monitoring data are easier to analyse but are more restrictive, while surveillance monitoring data are more difficult to analyse, but can provide useful baseline data and early warning of unanticipated phenomena.

- Reliance on volunteers can introduce biases in sampling and analysis
- There are perceptions (sometimes unwarranted) that the data collected are of poor quality
- Challenges in managing organisational data and knowledge
- Social and cultural barriers in using and applying citizen science data.

The role of technology in citizen science

Technological advances have provided many benefits to citizen science, especially in the collection and management of data. The widespread use of mobile devices and advent of GPS technology, high quality imaging equipment and computing power has made it easier for community based observers to record information in a variety of formats and with improved accuracy. The internet has made it possible to rapidly share, manage and disseminate information to large audiences [2,5,11,12]. Technology has allowed for automation of data verification and validation, and social media provides a valuable means for crowd-sourcing and for rapid information exchange [12,13]. It seems likely that new and emerging technologies will enable citizen scientists to collect increasingly sophisticated and complex data with increasing levels of accuracy.

Nevertheless, new enabling technologies will not be a panacea for some of the issues facing citizen science groups. Developing information technology solutions for data and information MUST include careful consideration of the social and cultural context [14,15]. Many information technology projects fail, often because technology solutions are rejected by the intended recipients as they fail to take into account socio-technological considerations (see Appendix 1) [16,17] .

Further information about citizen science and technology

Numerous projects have explored the roles, benefits and performance of citizen science projects in natural resource management and the roles technology can play in enabling citizen science. **Appendix 1** presents an overview of these topics and provides case studies and references that explore these issues further.

The eReefs program

eReefs is a major collaborative project between private organisations and government institutions to develop a comprehensive coastal information system for the Great Barrier Reef and coastal catchment (henceforth referred to as the GBR region). This collaborative partnership includes the Great Barrier Reef Foundation (GBRF), the Bureau of Meteorology (BoM), the Commonwealth Science and Industrial Research Organisation (CSIRO), the Australian Institute of Marine Science (AIMS) and the Queensland Government. The project

receives funding support from BHP Billiton Mitsubishi Alliance, BHP Billiton, the Australian Government Caring for Country Initiative, the Queensland Government and the Science and Industry Endowment Fund.

The *eReefs* project commenced in 2012 and over five years will focus on developing new tools and technologies that will enable natural resource managers, communities and scientists to:

- identify and locate data sets and data collecting programs in the GBR Region;
- understand data trends through visualisation and data integration tools;
- run integrated models to explore interactions and effects of impacts and environmental factors; and
- perform user driven data queries and use reporting and analysis tools.

eReefs also aims to provide enhanced communication and education tools to improve understanding of processes, impacts and management of the GBR Region. Importantly, *eReefs* will also facilitate active public engagement in monitoring and learning about the GBR Region through interactive technologies that allow the public to submit their own photographs and observations, and to use new technology to learn about the Region. A major part of efforts to engage communities in *eReefs* is to investigate what community groups are already working on environmental issues in the GBR Region, and to assess the potential for including information about their activities and potentially; assist these groups by providing tools and functions in the *eReefs* system that support their operations.

Citizen science in the GBR region

There is a long history of citizen science research and programs in the GBR region. There are many active citizen science projects, including small scale projects operating in individual communities. Some of the larger-scale, formal citizen science projects are described below. These organisations have an established history of operating in the GBR region, have multiple activity/monitoring sites across the GBR region, and are formal, organised entities (e.g. are registered organisations with financial and administrative identities, project staff and external funding and support).

- **Integrated Eye on the Reef program**: funded and coordinated by the Great Barrier Reef Marine Park Authority (GBRMPA); participants include general public and tourism industry; data includes long=term monitoring at fixed survey sites as well as ad hoc sightings and report from across the GBR; activities include education and training of tourism industry: http://www.gbrmpa.gov.au/about-the-reef/how-the-reefs-managed/our-monitoring-and-assessment-programs/eye-on-the-reef.
- **Infofish Services**: independent organisation based in Rockhampton; several funding sources; participants are mainly recreational fishers; multiple projects in many areas across the GBR Region, QLD, WA and NT; activities include fish tagging, community

awareness of fishing and sustainability issues, representing recreational fishers, several focused projects (e.g. CapReef, Crystal Bowl); http://info-fish.net/.

- **Seagrass Watch**: coordinated by the Queensland Department of Agriculture Fisheries and Forestry (DAFF) but may be moving to James Cook University (JCU). International program with many sites across Queensland; participants are scientists and trained community members, includes long term monitoring sites; includes formal education programs; http://seagrasswatch.org/home.html.
- **Mangrove Watch**: coordinated from JCU (Norm Duke); several funding sources; participants are community members; projects in Bundaberg and Torres Strait regions, project activities in Cairns; monitoring at participant selected sites using video; includes education programs; http://www.mangrovewatch.org.au/.
- **Coral Watch**: coordinated from the University of Queensland (UQ); several funding sources; participants are general public and community, especially snorkelers and recreational SCUBA divers; data are reports of coral bleaching, global scope; emphasis on education and awareness raising; http://www.coralwatch.org/web/guest
- **ReefCheck Australia**: independent organisation based in Brisbane; several funding sources; participants are trained recreational divers; many long-term monitoring sites across the GBR and SE QLD; specific education programs and awareness raising, local clean up events; http://www.reefcheckaustralia.org/
- **BirdLife Australia:** large independent organisation based in Melbourne with several local branches in the GBR Region; participants are bird enthusiasts; many different survey programs including fixed survey sites and ad hoc sightings programs; national scope but regional data can be accessed; conservation, advocacy and research projects; status reporting for State of the Environment; http://www.birdlife.org.au/
- **Queensland Turtle Research Program**: coordinated by the Queensland Department of Environment and Heritage Protection; participants include scientists and trained volunteers from several community branches; turtle tagging and long-term surveys of nesting sites; formal research and education projects; (no program website identified, several local group websites e.g. Mackay sea turtle watch)
- **Project manta**: coordinated from UQ; participants are recreational divers and the dive tourism industry; sightings from across GBR and east coast – photograph required to identify individual rays and track movements; research focused; http://www.uq.edu.au/ecology/project-manta
- **Australian marine debris initiative**: project coordinated by independent organisation Tangaroa Blue; several funding sources; participants are communities and schools etc; several sites across Australia and the GBR Region; activities are marine debris beach clean ups, monitoring marine debris, awareness raising: http://www.tangaroablue.org/amdi/amdi-program.html.

The Cooperative Research Centre for Estuary, Coastal Zone and Waterway Management (Coastal CRC) was established to conduct research on managing the coastal zone. The Coastal CRC's research program was developed in close collaboration with research 'end-users' to ensure that the research products delivered could be applied in natural resource

management. Coastal CRC included citizen science as one of its five theme areas, and established a dedicated citizen science research team. The goal of the Coastal CRCs Citizen Science theme was to “develop theoretical frameworks, practical tools and education activities to integrate social and economic understanding into decision-making and thus bridge the gaps between decision making and research, policy and planning.” This interpretation extended the definition of 'citizen science' "well beyond its more frequent reference to research, monitoring and data collection strategies that actively involve community members".

A synopsis of Coastal CRCs citizen science research was presented in Whelan (2006) Community decision-making and empowerment: findings from six years of Citizen Science research. At the conclusion of Coastal CRC elements of the citizen science research program were migrated to Griffith University. Some of the main products relevant to this scoping study include the development of an online citizen science toolbox https://app.secure.griffith.edu.au/03/toolbox/index.php, and an annotated bibliography of citizen science.

The findings from Coastal CRC's research on citizen science are broadly consistent with those from assessments elsewhere. Citizen science can deliver a wide range of benefits to Queensland communities and environmental management, but faces multiple challenges in the GBR Region.

One project specifically focused on the relationship between formal science and citizen science, and included comparative surveys to identify attitudes of citizen scientists, 'expert' scientists and managers to community based research [18]. The main findings of this work included observations that community based research (a form of citizen science) can:

- ensure access to local knowledge
- increase the relevance of research
- facilitate increased connections between communities and the environment
- increase collaboration between citizen scientists and expert scientists is a key part of successful community based research
- provide rewarding social interactions and relationships between participants are central in maintaining participation in CBR

This research also revealed that:

- collaboration is best achieved where expert scientists and community members engage as co-collaborators in an atmosphere of mutual respect
- there is increasing evidence that data from community based research (citizen science) can be relevant for decision making
- citizen science provides a means of empowering communities to participate in environmental management

- the importance of ensuring the data is of good quality [19].

This work also developed guidelines for effective collaboration between citizen scientists and expert scientists in catchment issues. However, as with citizen science projects elsewhere, there are numerous barriers to the uptake of citizen science data and projects in Queensland[18].

- An entrenched culture where "positivist science" (i.e. data and analysis produced by formal research using systematic methods, logic and mathematics) are emphasised to the exclusion of other forms of knowledge (e.g. traditional ecological knowledge, community observations)
- Belief that only trained experts can deliver useful knowledge
- Social contexts where community members are more removed from decision making processes
- Perceptions that investment in participatory programs such as citizen science projects may not deliver acceptable returns on investment.

Objectives and scope of the eReefs Citizen Science Scoping Study

The GBRF has contracted the GBRMPA to carry out a scoping study on citizen science in the GBR region. The aim of the study is to collect information about citizen science programs in the GBR region; what data they collect, how these data are managed and transmitted, and how information and projects are used by target audiences and end users. Specifically, this scoping study aims to provide information about **(1)** end user needs (scientists and natural resource managers), and **(2)** the capabilities and operations of citizen science groups in the GBR region.

Specific information needs concerning end users include information about:

- How scientists and natural resource managers already use, or could use, information generated by citizen science programs to inform management decision or support main-stream science and research activities;
- Practical actions such as integration of data, that could enhance the uptake and use of citizen science information and programs by scientists and natural resource managers;
- Background knowledge and understanding of the experiences, knowledge, attitudes and behaviours of scientists and natural resource managers to citizen science. This information is crucial in interpreting current behaviours and patterns of use, identifying barriers that inhibit the uptake and use of citizen science, and identifying practical actions that could increase uptake.

Specific information needs concerning citizen science groups include information about:

- What citizen science programs are currently active in the GBR Region;
- The current capabilities and resourcing of citizen science groups;
- Operational features such as data collection, management and analysis processes, reporting and communications mechanisms;
- Citizen science group needs regarding data collection, data management, data integration, process automation and communication and education; and
- The efficacy of information and knowledge transfer to target audiences and end users.

This information will be collated and analysed to provide the following outputs:

- An assessment of how *eReefs* could enhance current citizen science initiatives in the GBR region including developments in data visualisation and integration;
- An assessment of how innovative technologies (e.g. mobile devices; online automation and data validation) could provide efficiency gains to citizen science groups, and increase uptake and use of citizen science programs
- Recommendations about future development options, tools and functionalities for *eReefs* that would enhance the uptake of citizen science data and activities by end users and target audiences, and help citizen science groups meet their current operational requirements and future goals.

It should be recognised that this is **scoping study**, and the study is focused on providing specific information for the specific information needs of the *eReefs* program. As such, this study is a **descriptive study** intended to collect specific information for a specific information techno logy project.

This study is not intended or designed to be a review of citizen science programs in the GBR region or to explore the relationships between citizen science groups and scientists, managers, or other stakeholders. This study is not intended to provide advice or guidance regarding if or how citizen science programs should be maintained or modified, or about how the data should be used by end users.

Methods: data collection and verification

The project brief for the Citizen Science Scoping Study stipulated consultation with natural resource managers and the scientific community as key stakeholders in citizen science projects, and consultation with citizen science groups in the GBR region to identify operational requirements and opportunities for linkages with *eReefs*. Data collection proceeded in three stages:

- Identifying individual informants - managers, scientists and representatives from citizen science groups for consultation
- Engaging informants through targeted surveys - first consultation phase
- Providing timely feedback to informants to invite feedback and to facilitate structured interviews – second consultation phase.

A full description of the methods used in this study is supplied at **Appendix 2**. An overview of the data collection, analysis and review proceeded as follows:

- A targeted list of scientists and natural resource managers was compiled using organisational resources (e.g. contact lists) and by employing 'snowball sampling' to extend the 'reach' of the sample.
- Managers (n=134) and scientists (n=75) were contacted via e-mail to describe the nature and scope of the study, and to invite them to participate.
- A select sample group of citizen science groups were also invited to participate. Selected groups were those which were active at regional scales and had an established track record of working in the region.
- Preliminary results from the surveys of managers and scientists were also used to identify additional citizen science groups to contact.
- Ten citizen science groups were contacted and invited to participate. These groups included:

  - Eye on the Reef Program
  - Infofish Services/CapReef/Crystal Bowl
  - Mangrove Watch
  - Queensland Turtle Research
  - Project Manta
  - ReefCheck Australia
  - Seagrass Watch
  - Tangaroa Blue/Australian Marine Debris Initiative
  - Coral watch
  - BirdLife Australia

- An online survey was developed for each stakeholder group (i.e. managers, scientists and citizen science groups) using SurveyMonkey. Participants were invited again to participate and sent a link to the survey tool.
- The project used iterative feedback similar to the principles of a Delphi study. The results of each survey were rapidly collated and presented back to key informants to elicit further information and comment.

- Citizen science groups were also invited to participate in structured interviews to discuss the themes and issues arising from the survey results.
- The conclusions and recommendations arising from consultation were provided back to citizen science groups for comment and review.
- Ad hoc review and verification of results was also provided by an additional citizen science group who were contacted near the end of the study (see **Appendix 2**).

The *Survey for managers*, *Survey for scientists* and *Survey for citizen science groups* are provided at **Appendix 3**, **Appendix 4** and **Appendix 5**. The questions used in structured interviews with citizen science groups are provided at **Appendix 6**.

Results – surveys of managers and scientists

Synopsis – surveys of scientists and managers

- Managers and scientists had similar views and perspectives of citizen science, although scientists tended to have a greater range of views about the value and use of citizen science than managers
- Managers and scientists were generally supportive of citizen science projects and many had been involved in citizen science in some capacity
- Many managers and scientists had used citizen science data, and some had also used citizen science projects for other purposes (e.g. community engagement, education)
- Managers and scientists generally felt that citizen science was best used in conjunction with formal research and monitoring programs
- The main barrier to up-taking and applying citizen science information was concern about data quality, which included a lack of documentation about data quality
- Other barriers included difficulties in finding out what data and information were available, poor access to data and information, and limited reporting
- Managers and some scientists also commented that a lack of funding and support affected the ability of citizen science groups to train observers and maintain operations, and these factors reduced the utility of their data
- Managers and scientists agreed that improving data quality or improving documentation about the quality of data, would increase uptake and use of citizen science data. Improved access to information and awareness of what data were available would also increase uptake
- There was general support for a centralised system to house citizen science information
- These concerns need to be balanced by the consideration that for some programs, managers and scientists are not identified as key end users and thus, current products and outputs are not intended to meet managers' or scientists' needs.

Survey response

Managers: 28% response rate (38 responses from 134 survey invitations: 76% marine managers, 11% coastal managers, 13% other)

Scientists: 40% response rate (30 responses from 75 survey invitations): main areas of research were 41% marine ecology; 29% fisheries; 29% social sciences; 19% conservation; 15% natural resource management; 11% marine biology; 10% other areas.

Knowledge and understanding of citizen science

Many managers agreed with a broad definition of citizen science projects (as defined by recent literature), and many had direct experience with citizen science

- 63% indicating that citizen science includes a range of project types (i.e. citizen science includes more than just community based monitoring projects)
- 70% have had some involvement, or are currently involved in citizen science projects

Scientists provided a range of agreement with a broad definition of citizen science projects (as defined by recent literature), and many had direct experience with citizen science

- 57% indicating that citizen science includes a range of project types (i.e. citizen science includes more than just community based monitoring projects)
- 77% have had some involvement or are currently involved in citizen science projects

Attitudes towards citizen science

Respondents were asked to describe their perceptions of and experiences with citizen science projects

Managers were strongly supportive of citizen science projects

Dominant themes from managers' comments described the importance of citizen science in community engagement, education, stewardship, and community ownership of environmental issues and management.

Scientists were mostly supportive of citizen science projects

Dominant themes from scientists' described the importance of citizen science in promoting stewardship, providing greater spatial and temporal coverage of data, facilitating cost effective data collection, filling monitoring gaps and drawing attention to emerging issues. Respondents highlighted the strength of citizen scientists in collecting presence/absence data, but indicated that data quality issues (including training, monitoring protocols, sampling design, sampling bias etc) are issues that need careful consideration. Scientists recognised the importance of citizen science projects in engaging communities.

However, both managers and scientists rationalised the importance of citizen science against the limited resources available, with comments regarding the need to use the limited funding and resources carefully. This is reflected in lower levels of agreement about supporting resourcing of citizen science projects.

	Managers	Scientists
agreed or strongly agreed that citizen science can provide meaningful contributions to science and monitoring	75%	77%
agreed or strongly agreed that citizen science can provide meaningful contributions to management and decision making	76%	63%
agreed or strongly agreed that supporting citizen science is a good use of public funds and resources	67%	55%
agreed or strongly agreed that citizen science groups provide benefits above and beyond providing data	94%	89%
felt that citizen science could contribute to their work	95%	85%

Uptake and adoption of citizen science

Respondents were asked to consider which benefits/outcomes of citizen science projects were the most important to them, and to relate how citizen science projects contribute to their work

Managers indicated that the most important outcomes of citizen science projects are their abilities to facilitate community engagement in environmental management; increase community education and awareness; and provide additional data.

When asked to rank seven potential benefits provided by citizen science groups (1 = highest priority, 7 = lowest priority) according to how important they are to management:

- 54% of managers said that *community engagement* was the **most important** or **second-most important benefit** (mean priority rating **2.86**)
- 49% of managers placed *relationship building* in the top three most important benefits (mean priority rating **3.54**)
- 57% of managers ranked *education* as one of their top three most important benefits (mean priority rating **3.68**)
- However, opinions differed widely about the importance of citizen science groups in *providing additional data* (1st priority for 24% of managers, 7th priority for 19% of managers).

Scientists had a much greater range of views than managers about which outcomes from citizen science projects were the most important, with no one 'benefit' strongly prioritised over the others. Scientists ranked community education and engagement as the most important benefits delivered by citizen science projects, very closely followed by the potential for forging links and collaborations between scientists and the community, and expanding the spatial and temporal coverage of data.

When asked to rank seven potential benefits provided by citizen science groups (1 = highest priority, 7 = lowest priority) according to how important they are to science and research:

- 48% of scientists ranked community *education* as the **most important** or **second-most important** benefit (mean priority rating **3.26**)
- 52% of scientists said that *community engagement* was one of their top three most important benefits (mean priority rating **3.44**)
- 55% of scientists placed *relationship building* in the top three most important benefits (mean priority rating **3.78**)
- Scientists also valued the ability of citizen science projects to provide data across greater spatial and temporal scales, with 45% placing *providing additional data coverage* as one of their top three most important benefits (mean priority rating **3.81**).

Many managers were willing to use citizen science with most managers responding they would use, or had used citizen science data or projects in their work. **Scientists also showed evidence of uptake and application of citizen science data and projects, although at lower rates than managers**. Managers and scientists used citizen science for different purposes (top three responses for potential uses of citizen science data highlighted in bold). Both managers and scientists placed value in expanding the spatial and temporal scope of data.

	Managers	Scientists
citizen science could contribute to their work	95%	85%
Of these respondents, citizen science could help to		
engage communities in management issues and/or research activities	**86%**	70%
identify emerging issues and threats	**80%**	35%
expand the spatial and temporal scope of available data	**77%**	**78%**
identify community/local knowledge	54%	**74%**
Disseminate information about management or science	66%	**74%**

*Comments from **managers** highlighted specific benefits and outcomes such as increasing community stewardship of the environment, influencing behavioural change, collecting*

additional data or information which could not otherwise be obtained, providing early warning and situational awareness, linking science to the 'real world', and cost effectiveness.

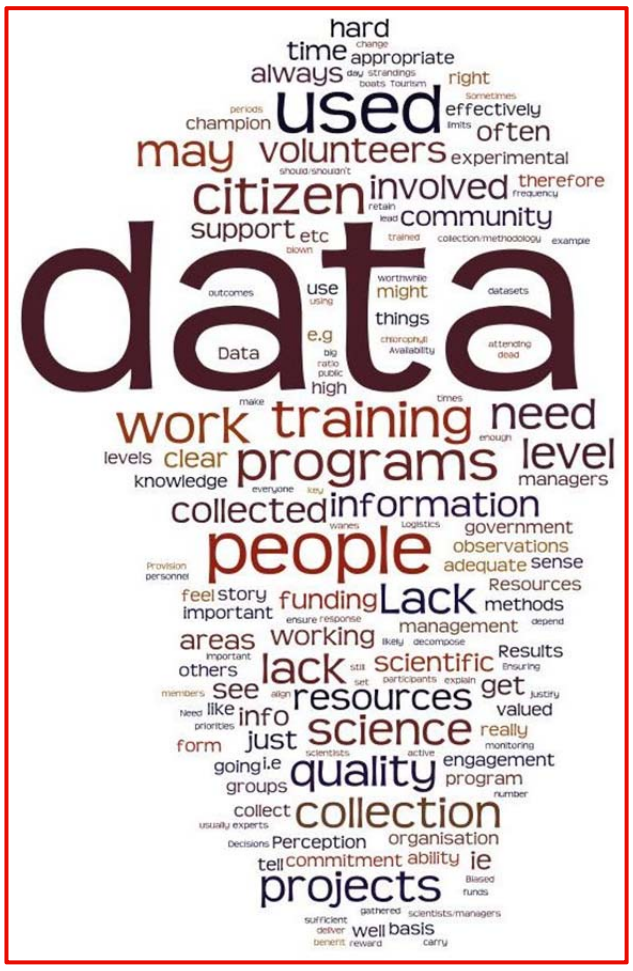
*Comments from **scientists** included the potential benefits of increasing community stewardship, engaging communities in science and the environment (including identifying the community's research needs), building the capacity of communities to respond to threats and emerging issues, and providing cost effective data. Citizen science projects were also used to collect field samples and biological data.*

Many managers and scientists had directly used citizen science in some way, although use was lower in scientists. The main use between the two groups was using data.

	Managers	Scientists
directly used citizen science in some way	78%	66%
Of these respondents		
used data from citizen science programs	**83%**	**72%**
used projects as mechanisms to engage communities	76%	56%
used projects to seek information from the community	58%	61%
used citizen science projects as a means to disseminate information	48%	44%

Limitations of citizen science and barriers to uptake

Respondents were asked to identify reasons for not using citizen science, and for their views on the major issues and barriers that reduced their uptake and use of citizen science



Managers frequently stated that concerns about data quality and/or documentation that describe how reliable the data are, limited how citizen science could be used. They generally felt that when making management decisions, citizen science needs to be considered alongside formal research and monitoring data or conducted with scientific expert advice. Some managers

never used citizen science due to their inability to access and use the information, or due to concerns about data quality. Managers also expressed concern about the amount of resources available to citizen science groups and the effects this had on training, engagement and subsequent data quality.

When managers were asked about how they used citizen science in decision making:

- Overall agreement to the suggestion that citizen science cannot be used as the *primary* source of information for decision making: somewhat agree (24%); agree (19%) or strongly agree (19%)
- most managers agreed that citizen science data should only be used in decision making in conjunction with scientific data, advice or partnerships between citizen science groups and scientists: somewhat agree (22%); agree (35%) or strongly agree (19%)

Of the managers who did not/would not use citizen science data (22% of respondents), the main reasons for not using citizen science data or projects were:

- did not know which projects or data existed (38%)
- did not know how reliable the data were (38%)
- the data could not be easily accessed in a useable form (38%)

Fig. 1. *Wordle*™ showing the dominant themes and subthemes emerging from managers' comments about the main limitations and barriers in using citizen

Dominant themes from managers' comments: citizen science is most powerful when teamed with or interpreted with formal research and monitoring programs; utility of citizen science depends on data quality (training, collaboration), but can be useful as early warning. Data quality is an important issue, and quality may vary between groups.

Wordles™ are a simple means of representing the most frequently used words in a text. The more a word is used, the larger it becomes in the Wordle™, highlighting the dominant themes in the text which can then be interpreted using the content of the text.
http://www.wordle.net/

When managers were asked to describe the main barriers and issues that limited their uptake of citizen science, several recurring themes emerged as illustrated in the Wordle™ in Fig. 1. Wordles illustrate the main themes or issues occurring in a text (see box). The dominant theme in managers' comments was about data, with managers citing concerns about the quality of data provided. They also commented that they were concerned that groups did not have the capacity or resources to ensure reliable data collection (training, data management, expertise, staff turn-over), or to maintain project activities. Some managers also cited a lack of clear documentation about projects and how data were collected, and a lack of awareness and communication about what citizen science was happening and what data were available.

Scientists shared similar concerns to managers, frequently stating that their uptake and use of citizen science data is affected by concerns about data quality and documentation that describe how reliable the data are. Scientists felt that citizen science needs to be considered alongside formal research and monitoring data when making management decisions, and should be conducted with scientific expert advice. Data quality was the main issue identified by scientists, with comments about training, quality control, consistency, sampling design, and analysis and interpretation of data.

When scientists were asked about how citizen science should be used in decision making:

- There was general agreement with a statement that citizen science cannot be used as the *primary* source of information for decision making: somewhat agree (27%); agree (22%); strongly agree (15%). However some scientists (19%) disagreed, indicating openness of some respondents to using citizen science as a basis for decision making
- Most scientists agreed that citizen science data should only be used in decision making in conjunction with scientific data, advice or partnerships between citizen science groups and scientists: somewhat agree (15%); agree (48%); strongly agree (19%)

Scientists identified slightly different barriers to uptake than managers. Of the scientists who did not/would not use citizen science data (33% of respondents), most (56%) indicated that they did not use the data because they were uncertain of the data quality. Other reasons for not using citizen science data were:

- unsure about which data were available (22%)
- data too difficult to work with (data heterogeneity etc) (22%)
- unsure of whether it would benefit their work (22%)

Dominant themes emerging from scientists' comments suggest that most scientists feel that citizen science is most useful when paired with formal research and monitoring programs, or collecting targeted data such as species presence/absence or distribution. Scientists frequently cited issues in data quality, consistency, methods, sample design and training. Some respondents also stated that these issues need to be considered on a case-by-case basis, with much variability evident between different citizen science programs.

Fig. 2. *Wordle*™ showing the dominant themes and subthemes emerging from scientists' comments about the main limitations and barriers in using citizen science

When scientists were asked to describe the main barriers and issues that limited their uptake of citizen science, the dominant theme related to data (Fig. 2). Scientists repeatedly cited concerns about the data quality, which related to a wide range of QA/QC issues such as consistency and reliability of data which in turn, related to training, standardisation of sampling effort, data accuracy, sampling design, sampling methods, and the lack of expertise or resources to maintain consistent and reliable data collection. In other instances, citizen science simply wasn't considered to be applicable to the research. Similar to managers, some scientists cited a lack of clear documentation about projects and how data were collected.

Some citizen science groups did not identify managers or scientists as key end users or target audiences. Consequently, the products and outcomes from these groups are not directed to meet the needs of managers and scientists. This must be considered when interpreting these survey results and considering the concerns of managers and scientists.

Improving uptake and use of citizen science

Respondents were asked to identify the improvements or changes that would be most likely to increase their uptake and use of citizen science

Managers indicated that their uptake and use of citizen science data and projects would increase if data quality was improved. Managers also indicated a need for better access to information about group activities and their data, and improved reporting by citizen science groups.

When asked how important eight different improvements or developments would be in increasing their uptake citizen science, managers identified four main improvements.

- Improved data quality (very important to 46%, important to 38%)
- Improved information dissemination (very important to 32%, important to 38%)
- Ability to download and analyse data (very important to 24%, important to 51%)
- Centralised system for information about citizen science (very important to 24%, important to 46%)

When asked which single improvement would provide the greatest benefit in increasing uptake of citizen science:

- 35% of managers chose improved data quality;
- some managers selected the ability to easily access data (14%) or view data alongside formal research and monitoring data (14%);
- some managers indicated a preference for a centralised system for citizen science information (11%) and;
- some managers selected increased contact with citizen science groups (11%).

Managers' *comments highlighted the potential value of having citizen science information from several different projects displayed in a single system; raised the need for mapping and on-line data entry or reporting; discussed the benefits of linking this to other on-line systems and databases; and how linking information could benefit other data users including scientists, other citizen science projects and community groups.*

Responses from scientists were similar to managers with scientists stating that improving data quality would be the main improvement that would increase their uptake and use of citizen science data, although improvements in accessing data and information about citizen science projects were also important. Scientists indicated support for a centralised information system for citizen science information.

When asked how important eight different improvements or developments would be to increasing their uptake citizen science, scientists identified the same four main improvements as managers although in a different order of importance.

- Improved data quality (very important to 44%, important to 41%)

- Centralised system for information about citizen science (very important to 26%, important to 48%)
- Improved information dissemination (very important to 19%, important to 41%)
- Ability to download and analyse data (very important to 15%, important to 44%)

When asked which single improvement would provide the greatest benefit in increasing uptake of citizen science, scientists showed a range of preferences but the most frequently selected preferences were:

- 30% chose improved data quality;
- 25% indicated a preference for a centralised system for citizen science information;
- improved ability to access, download and interrogate data (15%) or better understanding of the way citizen science groups operated (15%)

Scientists' *comments highlighted the potential value of having citizen science information (projects, activities, data, methods) displayed in a single system; potential benefits in identifying patterns by bringing together different data streams, and discussed the need for citizen science projects to have clear objectives and linking these to project methods, and quality assurance/quality control protocols. However, citizen science may not be universally applied to research activities with some respondents identifying that citizen science is not applicable to some research projects*

Managers and **scientists** were generally supportive of the idea to develop a centralised information system for citizen science projects and data, although scientists were less supportive of this idea than managers.

bringing together information about citizen science projects into a single website or on-line system would be:	**Managers**	**Scientists**
Useful	49%	37%
Very useful	27%	26%
Total (useful or very useful)	76%	63%

Results – survey of operations, capabilities and needs of citizen science groups

Synopsis – surveys of citizen science groups

- The majority of citizen science groups in the GBR Region are relatively small organisations (≤ 10 staff, < 100 participants, 50 activity sites)
- Citizen science groups are focused on providing data to target audiences, and engaging and educating communities. Priority audiences are community participants, natural resource managers, as well as funding bodies and specific stakeholder groups
- The main challenge facing citizen science groups in the GBR region is insecure or insufficient funding. Limited human resources and capacity also affects some groups
- All groups had quality assurance and quality control (QA/QC) procedures to increase data reliability. Most groups focused on QA procedures (e.g. training), and few groups had formalised their QA/QC procedures as written AQ/QC plans
- Most groups indicated that their web-based data visualisation consisted of photographs or static graphs. Some groups used interactive maps to visualise data and activities
- All groups indicated that their data had been used by external users in some capacity. However few groups specifically and actively monitored uptake and application of their data
- Most groups believe that scepticism and reluctance of some potential end users reduced uptake and application of their data. Other issues included time lags in reporting data, rigidity of end users and poor awareness amongst end users about what data are available
- Respondents indicated that tools/systems that would help them to spatially present their data/activities would be the most useful improvement in helping their operations and in communicating their results. Other important tools/improvements include systems for managing communications (with project participants and with end users), web-based educational tools, and tools that allowed users to search and query data.
- Respondents also identified specific tools such as web-based data entry and automated verification systems, new websites and data management systems, as important future systems and tools for individual groups.

Survey response

Eleven valid responses were received from citizen science groups (seven respondents started the survey but did not complete it). Responses were received from representatives from:

- BirdLife North Australia
- BirdLife Capricornia
- Coral Watch
- Eye on the Reef
- Infofish Services/CapReef/Crystal Bowl
- ReefCheck Australia
- Seagrass Watch
    - Project Manta
- Tangaroa Blue/Australian Marine Debris Initiative

Responses were not received from Mangrove Watch or from groups affiliated with the Queensland Turtle Research program.

About citizen science programs

Respondents were asked to describe aspects of their group's operations

Some citizen science groups agreed with a broad definition of citizen science (as defined by recent literature), but some groups also restricted the definition of citizen science to only projects that included community monitoring.

- 53% indicating that citizen science includes a range of project types (i.e. citizen science includes more than just community based monitoring projects)
- 42% indicating that citizen science projects are those that are community based monitoring projects.

Most citizen science groups had less than 100 participants in the GBR region.

- 21-50 participants (**37%**)
- 51-100 participants (**27%**)
- 101-500 participants (18%)
- 501-1000 participants (18%)

Most citizen science groups were small organisations with ≤10 project staff working for the group (where project staff were defined as paid or unpaid participants that were responsible for performing essential functions of activities for the organisation).

- 1-3 staff (**45%**)
- 4-10 staff (**45**%)
- 11-20 staff (10%)

Goals and objectives of citizen science groups

Priority activities

*Citizen science groups had fairly consistent views about the activities that were most important to achieving their organisation's goals – **providing data**, **engaging communities**, and **community education**. These views were broadly consistent with those of managers and scientists who responded that community engagement and education are some of the most important outcomes of citizen science projects.*

When asked to prioritise seven **activities or outcomes** performed by citizen science groups according to how important they are in **achieving their organisation's goals** (1 = highest priority, 7 = lowest priority):

- 64% of citizen science groups said that *providing data* to supplement scientific data and/or inform management was the **most important** or **second-most important activity/outcome** (mean priority rating **2.27**)
- 72% of citizen science groups placed *community engagement* in the top three most important activities/outcomes (mean priority rating **2.91**)
- 54% of citizen science groups ranked community *education* as one of their top three most important activities/outcomes (mean priority rating **3.41**)
- After these activities/outcomes, citizen science groups prioritised *opportunities to build relationships* between the community, managers and scientists (mean priority rating **4.45**).

However, there was disagreement between citizen science groups and managers/scientists about the *importance of providing data*, with citizen science groups rating data provision as the most important function they perform while managers and scientists viewed data provision as moderately important. This was largely due to individual variation amongst managers and scientists with a range of views expressed about the importance of citizen science data.

Priority audiences

*Citizen science groups had similar views about priority audiences and key stakeholders. Most respondents identified **natural resource managers** and the **community members** participating in the program as priority audiences. Most citizen science groups listed **funding bodies** as important target audiences and groups also considered **specific stakeholders** (e.g. industry groups, recreational organisations) as priority groups. Scientists were not considered priority stakeholders by most of the respondents.*

When citizen science groups were asked to rank eight key end users or target audiences from 1 to 8 (1 = highest priority, 8 = lowest priority) according to how **important it was to effectively communicate** with those audiences:

- 70% of citizen science groups responded that communicating with *community participants* was one their three most important audiences (mean priority rating **3.10**)
- 70% of citizen science groups considered *natural resource managers* as one their three most important audiences (mean priority rating **3.10**)
- 60% of citizen science groups considered *funding bodies* as moderately important or important target audiences (mean priority rating **4.20**)
- 60% of citizen science groups also considered *specific stakeholders* as priority audiences, but there was variation between groups, with 30% responding that specific stakeholders groups were a low priority audience (mean priority rating **3.80**).

Resourcing and capacity of citizen science groups

Citizen science groups were asked to provide information about funding, resources and capacity, and how these affected their day-to-day operations and their ability to archive their goals over the next five years.

Citizen science groups provided consistent responses regarding their current funding and resourcing, and about the challenges facing their continued operation. Almost all groups indicated concerns about having insufficient funding and resources to maintain operations and meet future goals. Half of respondents also stated that they also have insufficient human resources to meet their needs over the next five years. However, most groups responded that they had adequate infrastructure and technology to meet current and future operational needs.

When asked about their level of agreement with value statements about **funding and capacity**:

- 81% of citizen science groups *disagreed* or *strongly disagreed* that they had sufficient funding or resources to **maintain current activities** and operations over the next five years
- 81% of citizen science groups *disagreed* or *strongly disagreed* that they had sufficient funding or resources to **achieve their goals** over the **next five years**
- 36% *disagreed* that they had sufficient human resources to meet their needs over the next five years.

However,

- 73% *agreed* or *strongly agreed* that they had adequate systems and technology to maintain operations and meet future goals

- 36% of citizen science groups *agreed* or *strongly agreed* that they had sufficient human resources to meet their needs.

Strengths and challenges

Citizen science groups were asked to describe their greatest strengths and challenges that would enable or hinder them in achieving their goals over the next five years.

The most **commonly cited strengths** were:
- Enthusiasm and commitment of volunteers and champions (64% of respondents)
- The commitment and abilities of project staff and management (55% of respondents)
- Support from organisational structures such as host institutions (e.g. universities) and management boards (36% of respondents).

Other strengths included participation of scientists, partnerships with other organisations and stakeholders, enabling technology, the organisation's reputation, and secure funding (a minority of respondents).

The **most commonly cited challenge was funding.** Most groups are funded by external grants and funding limitations affected almost all groups. This is illustrated in the *Wordle*™ (Fig. 3). Insufficient funding posed problems in retaining staff and participants, and carrying out activities and operations (e.g. training, data collection).

Fig.3 Wordle™ illustrating the dominant themes emerging from respondents comments about challenges facing citizen science groups

A wide range of other challenges were identified including regulations and occupational health and safety issues, turnover of staff and volunteers, difficulties in influencing management and decision making, operational challenges caused by limited time coupled with large areas of operation, and managing data and communications.

Sampling design, data collection, quality and management

The citizen science groups surveyed had a very wide range of activities and collected a diverse range of types of data. There were numerous activity and survey sites in the GBR Region. Most sites were selected by agreement with project staff and volunteers but also considered logistical constraints. Most groups used paper data sheets to record field data, but some also used electronic tools such as digital cameras and video recorders or automated data loggers. All groups had electronic databases either on desktop computers or on web-based servers.

All groups had quality assurance and quality control (QA/QC) procedures. However, groups tended to focus more on QA (e.g. training) than on QC (e.g. validation and verification), and most groups did not have these procedures formalised as written QA/QC documents.

The majority of citizen science groups had between *11 and 25 activity sites* in the GBR Region (activity sites are locations where participants participate in group activities such as surveys or clean-ups), although one group had over 500 activity sites (Fig. 4).

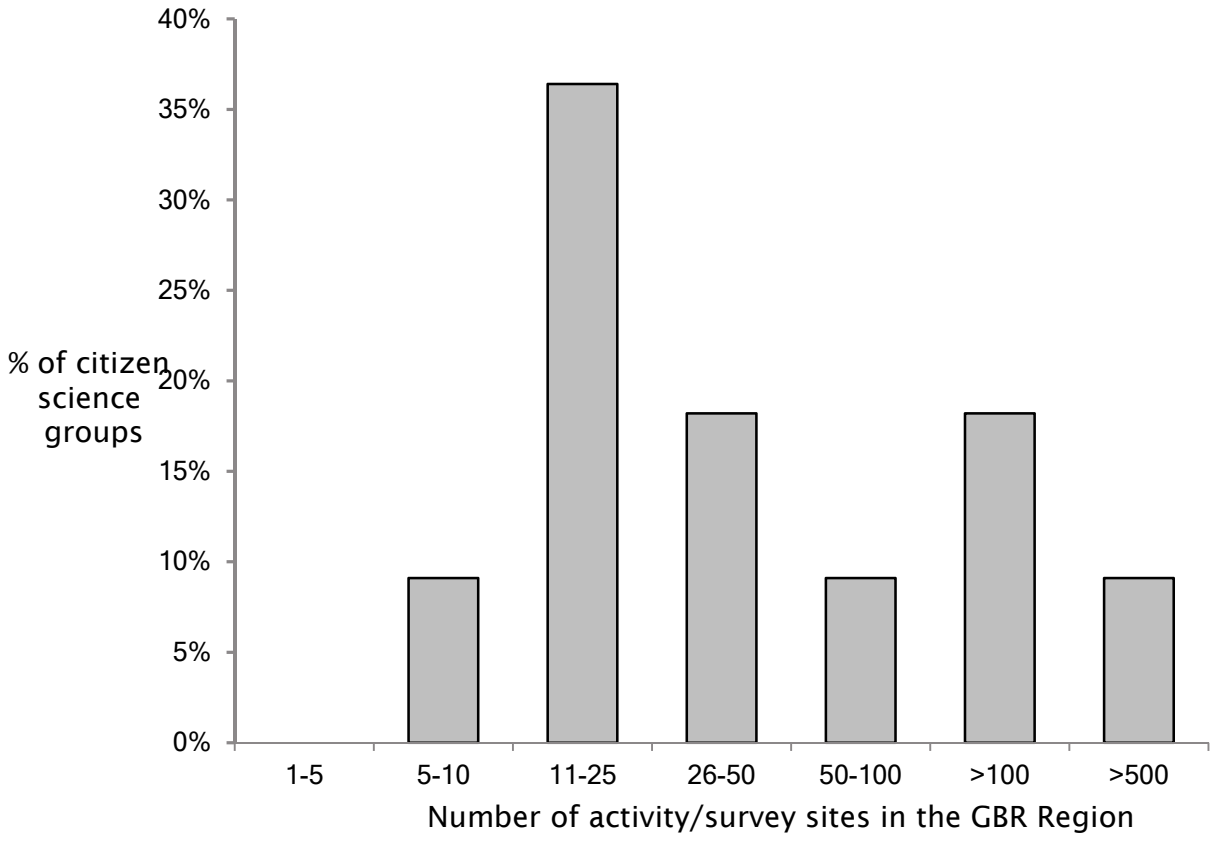


Fig.4. The number of activity sites in the GBR region per citizen science group

In most cases, the **location of activity or survey sites** was selected by project staff in accordance with logistical opportunities and constraints (46% of respondents), or selected by volunteers in consultation with project staff (36% of respondents). This suggests that most of these programs would be categorised as 'surveillance monitoring' according to Dickinson *et al* (2012), with one only group having a survey regime designed to answer a specific question/test specific hypotheses as indicated by (e.g. monitoring control and impact sites before and after an impact or intervention).

Respondents indicated the use of several types of media for **recording data in the field**:

- Paper based datasheets were used by all (100%) groups for recording observations in the field
- Photographs were also collected by most groups (81%)
- Electronic devices to collect and upload data (e.g. apps, data loggers) by a few groups (27%)
- Physical samples (specimens, tags etc) were only collected by one group (9% of respondents)

All citizen science groups surveyed **stored their data electronically**, either on:

- desktop databases and spreadsheets (36%); or
- web-based servers (64%).

All groups had some form of **quality assurance and quality control (QA/QC)** protocols. Most groups used *multiple quality assurance tools* including specific training programs, partnerships with expert scientists and standard survey techniques and protocols to train volunteers in data collection. However, few groups had these tools and procedures documented in a written quality assurance plan (Fig. 5).

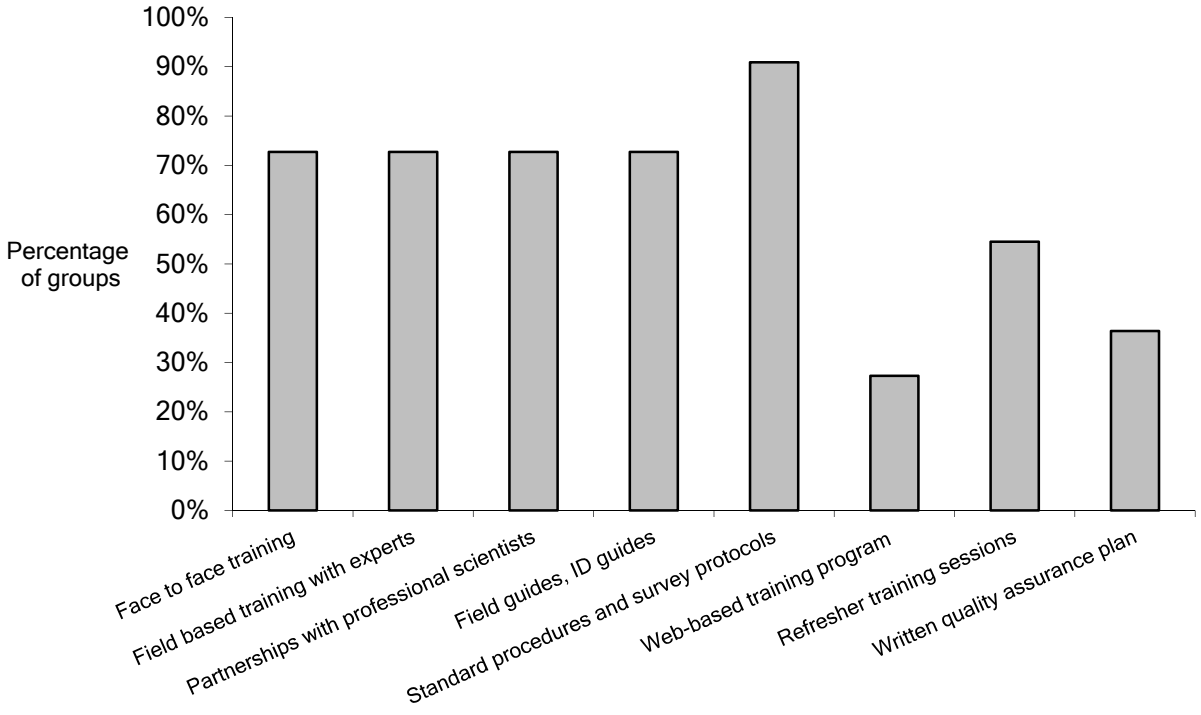


Fig.5. Quality assurance tools and procedures used by citizen science groups in the GBR region

Most groups also had **quality control** procedures which usually consisted of data *verification by manual checking of data*. Few groups had automated QC procedures, or data validation steps where data were assessed by, or compared with, independent experts or data sources. Few groups had formalised their QC procedures in a written QC plan.

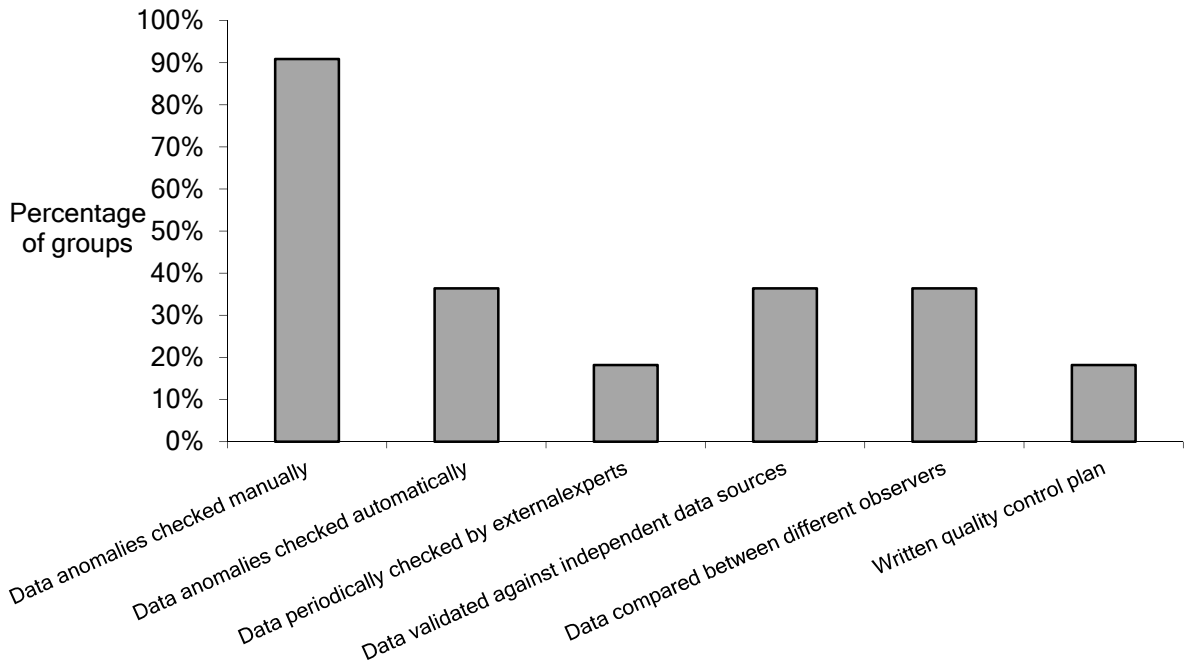


Fig.6. Quality control tools and procedures applied by citizen science groups in the GBR region

Communication and uptake of data and information

Citizen science groups used a variety of media and mechanisms to communicate with their priority audiences. Most groups cited the importance on traditional electronic communications methods (e.g. e-mail, websites, reports), as well as face to face communications (meetings, briefings). Web-based data visualisation tools were mostly photographs and graphs, although some groups used interactive maps. Almost all respondents provided examples of uptake and use of their data, and most had some means of measuring this uptake and use. However, monitoring the uptake and use of their data did not appear to be specifically monitored and investigated on an ongoing basis (e.g. targeted satisfaction surveys). Respondents identified numerous barriers which they perceived limited the uptake and use of their data. These barriers corresponded closely with the survey responses from managers and scientists.

Citizen science groups identified *community participants*, *natural resource managers*, *stakeholders and funding bodies* as **important target audiences**. Groups were asked to describe the importance of different communication mechanisms and media in reaching their target audience. Groups consistently identified five communication tools as being particularly important:

- E-mail updates: important to (80%); very important to (20%)
- Popular media (TV, news etc): important to (70%); very important to (20%)
- Up-to-date website: important to (70%); very important to (20%)
- Briefings and presentations: important to (80%); very important to (10%)
- Reports and summaries: important to (60%); very important to (20%).

Newsletters and social media (Facebook pages) were also important to some groups.

When asked to identify the **web-based tools** they used to **present and visualise** their data:
- 80% of respondents used *photographs* to illustrate phenomena, site information or trends
- 70% used *graphs* that could be viewed on the web
- Some groups (50%) also presented their data *on interactive maps*
- Other visualisation tools (e.g. animations, videos) were seldom used.

All citizen science groups **demonstrated that their data had been used** by external parties **or communicated** to the broader community:
- Data used by scientists (100% of respondents)
- Data used to develop education products for schools or communities (100% of respondents)
- Appeared in popular media such as TV, magazine, newspapers: (90% of respondents)
- Data applied in natural resource management (80% of respondents).

Almost all respondents also provided **examples of how their data had been used** to inform communities, natural resource managers and/or scientists.

Most citizen science groups **monitor the uptake and application** of their data. However groups tend not to specifically and actively monitor and evaluate how their data are used or to document end user satisfaction. For most groups, monitoring is limited to passive monitoring activities such as recording:
- the number of website visits
- the number of data requests received or data downloads.

None of the respondents indicated that their organisation used tools such as targeted surveys to monitor the uptake and application of their data and information by end users.
When citizen science groups were asked to describe the **barriers they believe limit uptake and application** of the data they collect, respondents identified common themes and issues including:
- *Reluctance of end users* to use data due to scepticism and concerns about data quality,
- *Extended lag-times* between data collection and the analysis and reporting of these data,
- *Rigidity of end users* mean they cannot use or respond to data,
- *Poor awareness* of what data are available.

Citizen science groups also identified that the way data and information are reported may be a barrier if the information is not packaged to meet end user needs (may be too boring,

limited spatial and temporal scope of the data, limited integration with other data sets). Some respondents also believed that limitations in knowledge and skills about how to upload and report data, and a lack of demonstrated cases where their data had been used, also hindered uptake and use of their data.

Needs and opportunities

Citizen science groups identified a number of information technology tools or improvements that would help them in their day-to-day operations and would enhance their effectiveness. These included tools for spatially visualising their data, managing communications, educating participants and communities, and tools that allowed users to find and access data and information.

When asked to select the most **important products/tools** that a web-based information system could deliver **to assist their operations**, most respondents indicated that tools that would *spatially represent their data and activities* would be very important or important. Most groups also considered *improved systems for managing communications* with volunteers and target audiences as important or very important (Fig. 7).

However, respondents provided a range of responses about the importance of other tools or services. Many groups also selected *web-based systems for data entry* as an important tool that would assist their operations. Some groups considered data management and storage systems as very important while this was of low importance to other groups (Fig. 7).

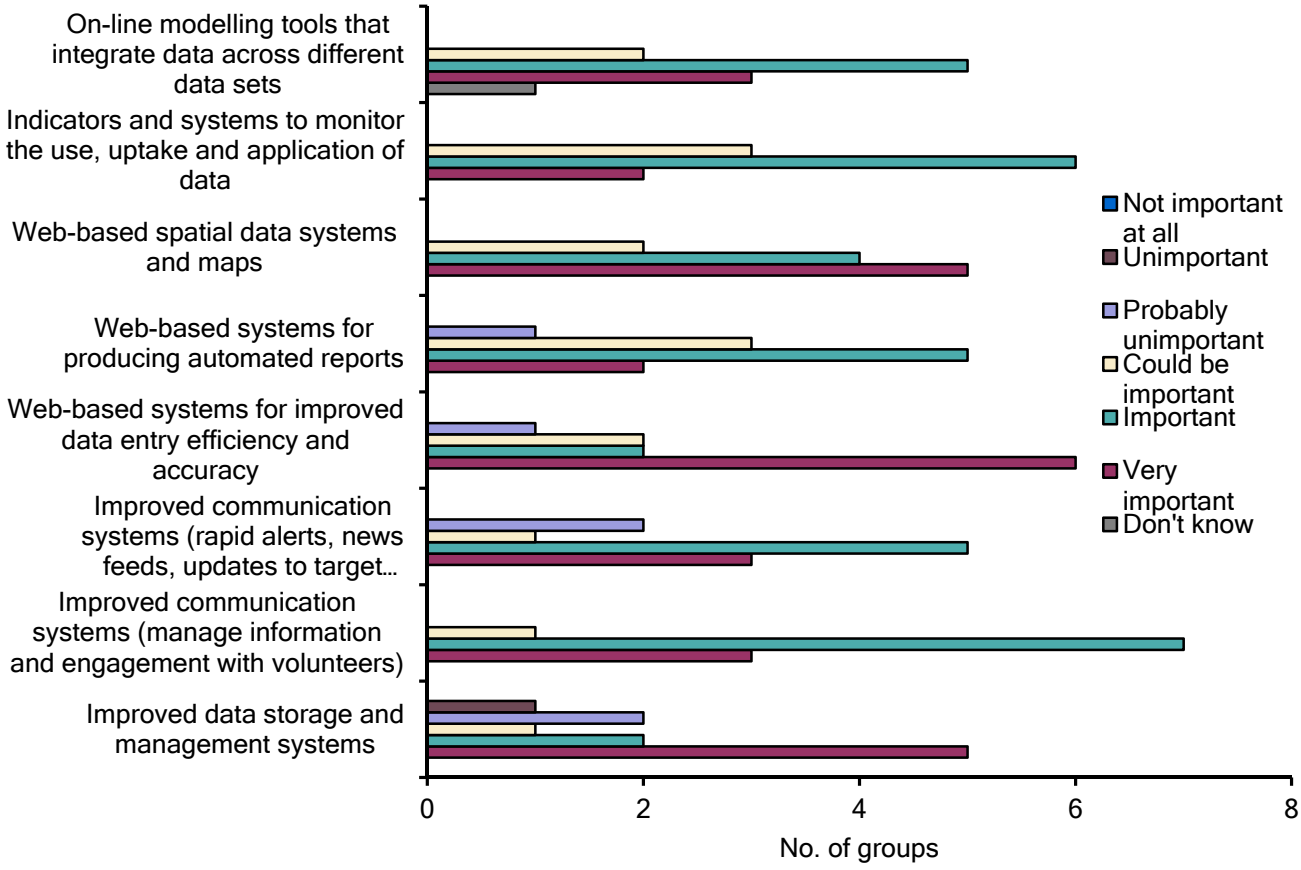


Fig.7 Respondent ratings of the importance of different information technology tools in helping citizen science groups operate effectively

Other suggestions for useful technological improvements or tools would be systems to hold web-based meetings, pattern recognition software for image analysis, and tools that assist with quality assurance and quality control (QA/QC).

Citizen science groups were also asked to identify the tools that would be most helpful to them to **organise, package and disseminate their information.** When respondents were asked to prioritise seven information technology tools from 1 to 7 (1 = highest priority, 7 = lowest priority):

- 60% of respondents indicated that *mapping or visualising their data spatially* would be their top or second highest priority (mean priority rating **2.30**)
- 60% of respondents indicated that *web-based interactive educational tools* would be one of their top three priorities (mean priority rating **3.00**)
- 60% of respondents indicated that tools that enables users to *search and query data* on-line would be one of their top three priorities (mean priority rating **3.40**)

Results – interviews with citizen science groups

Synopsis – themes and issues arising from interviews with citizen science groups

- Six interviews were held with representatives from five citizen science groups. It should be noted that this represents only half of the groups initially contacted and there has been attrition in response rate over successive consultation periods.
- The five citizen science groups interviewed were generally supportive of having some of their data spatially represented on *eReefs* including data such as survey and activity sites, data summaries and reports, and project information.
- Citizen science groups identified several potential benefits from their involvement in *eReefs* such as increased public visibility, and the ability to view their data alongside other datasets.
- However, groups emphasised that access to raw data would need to be controlled through data sharing agreements and processes so as to ensure the data were used ethically, analysed appropriately, and to help track data use and uptake. Issues of data ownership, access and use are the groups' main concerns regarding their potential involvement with *eReefs*.
- Groups were strongly supportive of ideas such as meta-data QA/QC statements, and automated prompts for data use and citations when users view or download data.
- *eReefs* could also provide a centralised citizen science hub that could increase collaboration and cooperation between different community groups.
- There was less interest in some information technologies such as developing apps for mobile devices (although this could be useful in some circumstances), and on-line 'clouds' for data management.
- A range of other ideas for new information technologies were identified such as voice recognition functionality for mobile apps, pattern recognition software for complex images, 3D underwater visualisation of dive/survey sites and calibration studies that validate community data against scientific research data.
- The costs and benefits of involvement need to be clearly stated, and the long-term, ongoing issues of data maintenance and management need to be considered.

Interviews

Six interviews were organised with representatives from five citizen science groups to collect more detailed information about potential areas for linkages between groups and *eReefs*, and to explore responses to specific tools and services that *eReefs* could deliver. The interview questions expanded on key findings of the *Survey for citizen science groups*. Response rates have declined during successive consultation phases, and while not unexpected, it should be acknowledged that groups have provided varying levels of input to these results. Some groups did not participate in the first survey, and some groups that did respond to the survey declined to be interviewed.

Interviews were organised with respondents who indicated willingness to be contacted for further information during the *Survey for citizen science groups*. Interviews were held with representatives from:

- BirdLife Australia
- Eye on the Reef
- ReefCheck Australia
- Tangaroa Blue/Australian Marine Debris Initiative
- Project Manta

Interviews ranged from 35 mins to 50 mins in length.

Response to managers and scientists views

Comments regarding the results of the managers and scientists survey results

Four interviewees had read the results of the *Survey for managers* and *Survey for scientists*. These respondents indicated that there "weren't too many surprises" in the results. Citizen science groups were aware of reluctance by some scientists and managers to use community based data. Some respondents were also disappointed at the lack of support expressed by some managers and scientists for funding being used to support citizen science initiatives.

Some respondents:

- were encouraged that many managers and scientists were familiar with citizen science, and were willing to use, or had already used, citizen science data in some way
- mentioned positive benefits from working with scientists, and the need for more partnerships and projects that analyse scientific data alongside citizen science data (data validation)
- commented that when researchers (especially PhD students) wish to engage the community to collect community knowledge or to train community members to

collect data, they should make better use of existing citizen science programs to avoid 're-inventing the wheel'
- would be interested in feedback from end users (managers and scientists) specific feedback about how to format and provide data and information so as to increase its useability
- felt that citizen science groups could collaborate better to coordinate efforts, reduce unnecessary repetition, build synergies and co-operation between groups, and present a united front about community data. *eReefs* could provide a centralised citizen science hub that may help to achieve this. A coordinated effort could increase end user awareness of citizen science groups and confidence about using data.

Potential for linkages with *eReefs*

Perceptions about having group data and information available on the eReefs system

Almost all respondents indicated strong support to having some of their group's information presented on the *eReefs* system. Reasons for support included:

- increased exposure for the group
- increased access to data and information for target audiences
- ability to compare trends between data sets and environmental variables
- reduced time spent on generic information requests (assuming this information is available through *eReefs*)
- increased overall availability of what is the public's data

Generally, all respondents were very supportive of having generic or packaged information published on *eReefs* including:

- location of survey sites, activity sites, hotspots of sightings
- project information and contact information
- spatial shape files (e.g. boundaries of important habitats or areas)
- static data summaries and existing reports
- data about flagship species (spatial data and static information) that highlight data and key messages.

However, respondents indicated that information sharing and packaging through *eReefs* needs to be carefully considered:

- ensuring that users who download or access data acknowledge the data source
- ensuring appropriate use of data (use must be ethical and data must not be misrepresented or analysed inappropriately, limitations of data should be considered and acknowledged)
- the need for some form of data sharing agreement that users must agree to in order to access and use data

- privacy, confidentiality and ethical issues – e.g. all location data should have a 2 km radius buffer around specific location data to protect privacy, commercial in confidence and/or environmentally sensitive locations
- costs and processes in maintaining the currency of data on *eReefs*. Double handling data must be minimised, and the currency and longevity of data must be maintained.

The potential for end users to access each group's raw data through *eReefs* will require further discussion and analysis about the costs and benefits of such arrangements, the processes that determine the level of access permitted to data, and the format of specific data sharing arrangements.

Representing spatial data on *eReefs*

Spatial data was a key issue in survey responses: current presentation of spatial data and opportunities to present group data spatially on eReefs

Some groups had spatial data publically available on the internet. Spatial visualisation included interactive web-based maps such as Birdata (http://birdata.com.au/homecontent.do) which represents data from the Atlas of Australian Birds. Registered users can submit data but all visitors can view data summaries and list and locations of species sightings (presence/absences in 1 degree grids). Other spatial visualisation options (e.g. ReefCheck Australia) included downloading KML data files for display using Google Earth™. Other groups were still exploring potential mapping and visualisation solutions, while other groups had systems close to completion and public launch (e.g. Eye on the Reef).
All groups expressed interest in having information such as data summaries and activity/survey sites spatially presented on *eReefs*. These sites could be represented as icons that appear at user defined zoom levels in the map window. Groups also expressed interest in the ability for users to create thematic maps on particular issues that show relevant records of particular species, habitats, phenomena, sites etc. Icons could have 'pop up' windows with information that included links to groups to facilitate data access (or trigger data requests) for more specific data.

Some groups mentioned that these spatial products would be important tools in visualising their data and activities for funding applications and reporting. Nevertheless, representing spatial data on *eReefs* must consider the data sharing and access issues previously discussed.

Metadata descriptions and QA/QC

Perceptions and comments regarding a standardised meta-data statement available that explains your group QA/QC procedures

All groups were supportive of this idea, responding that this could be beneficial in helping end users/target audiences better understand how data were collected, and the 'limits of use' for the data. In doing so, it could help end users extract data at confidence levels that suit their needs.

Some groups already have vigorous QA/QC procedures that could be described in the form of a QA/QC meta-data statement. The QA/QC statement could also include the names and affiliations of partner scientists and examples of publications using the data – this could provide end users/target audiences with and idea of how the data can be, and has been used. A different QA/QC statement should be developed for each group.

Data quality could be represented as 'stars' with the metadata statement having a key that describes how data reliability 'star ratings' are assigned. A separate rating system would need to be developed for each dataset. Observer specific rating processes could also be developed that calculate the confidence of submitted data according to the skills and qualifications of registered observers, the number of observations they make, and the frequency at which an observer submits accurate observations (calculated from data accept/reject frequencies arising from verification/vetting processes).

However, some groups also highlighted that while a QA/QC statement could certainly describe the quality control elements (training etc), documenting quality assurance (data validation and verification) could be more challenging as this is less frequently done.

Data access and attribution

Data access and use, perceptions about automated data citation prompts when users download data

Respondents were strongly supportive of this idea with some groups citing examples where their data had been used without their knowledge, agreement and/or without attribution of the source of the data.

All groups cautioned again that public access to raw data would need to be considered on a case-by-case basis to ensure that data were being interpreted appropriately (including recognising the limitations of the data) and used ethically. Data sharing and access would also have to consider privacy and commercial-in-confidence issues to make sure that public access to data did not compromise community members participating in citizen science projects, or breach existing data agreements. These conditions of use would have to be clearly

described in data sharing agreements. Nevertheless, some 'types' of data could be made publically available without the need for specific data sharing agreements (e.g. pre-agreed species hotspot data).

For data that could be publically accessed and downloaded without , interviewees provided other ideas regarding data citation and downloading:

- pop ups that describe conditions of use for data (user clicks "Agree" to get access to data)
- automated notifications that provide feedback to group representatives when data (or data summaries) are viewed or downloaded

Web-based education tools

Interest in internet based educational tools or products

There was a range of responses regarding internet based educational tools. Most groups already had public education materials available from their websites, and some groups already have substantial amounts of educational materials available on-line such as ID guides, education kits, training manuals, data collection guides and curriculum materials for schools. These materials could be linked to project information published on *eReefs*.

Nevertheless, some groups expressed interest in enhancing existing, or developing new web-based education tools or products to upgrade training materials for community participants, or provide innovative ways of delivering information and to increase the 'stickiness' and appeal of on-line material (e.g., on-line 'tests' to train [and grade] community observers, more interactive PDF files that include 'pop ups' of information, interesting stories and visualisation of data and trends). Materials could also be enhanced to entice visitors to website to become involved.

Social media is a powerful communication tool for some groups. Perhaps there could be scope for *eReefs* to explore how to develop educational products for distribution through social media sites such as Facebook. Social media could also help coordination and collaboration between citizen science groups in the GBR region.

Development of apps for mobile devices

Interest in development of a mobile device app that could send data directly to on-line databases

Groups provided varying levels of interest in developing apps for mobile devices. Generally, apps were considered useful where:

- data collected were simple (e.g. presence/absence, numbers seen, weather conditions) and suited to touch-screen interfaces on mobile devices
- data collection was focused on a specific issue (e.g. a defined list of species, a specific phenomena or type of observation)
- the variables monitored are simple and unambiguous (i.e. low chance of species misidentification or data inaccuracies).

Mobile apps were perceived as being less useful where:

- detailed data are collected which requires users to enter lots of text, complete many different fields (requiring multiple ticks and swipes)
- data are collected in difficult conditions in the field (issues of weather proofing devices, screen glare, mobile reception range).

Some respondents mentioned that mobile apps were already being developed for some projects either by their own groups or other efforts. Where possible, efforts should be coordinated to avoid replicating efforts in developing multiple apps for different groups which could fragment data, complicating data analysis and confusing participants. However, the costs of app development would need to be carefully weighed against the potential benefits of having apps available.

Centralised data systems

Interest in a shared, centralised system for storing data such as an on-line data 'cloud'

Responses to this question varied between groups. Groups with existing web-based information systems and databases were less inclined to migrate their data to a shared on-line cloud given the resources they had already invested, especially where the group's needs were already being met by existing systems. Overall, there was a reluctance to commit to future shared systems when existing, reliable and safe systems are already in place and provide the required functionality.

It appears that there would need to be significant incentives and demonstrated benefits for groups to migrate their data to a shared on-line data cloud.

Most important benefits of involvement with *eReefs*

Group's views of the benefits that may arise from integrating citizen science groups and their data with the eReefs system

When citizen science groups were asked to discuss the most important benefits they perceived their involvement with *eReefs* might deliver, respondents indicated several key benefits and functions that would be of most value to their groups including:

- on-line interactive maps that spatially represented activity sites and survey data. This could include simple GIS tools (e.g. measure distance, area)
- the ability to overlay the data collected with other datasets (e.g. environmental information, habitat information, scientific monitoring, data from other citizen science groups)
- increased public exposure of citizen science projects that could result in increased community education about issues, and increased participation in group activities
- identifying spatial gaps in data and encourage community members to collect information from these areas
- increased engagement with researchers leading to increased collaboration and uptake of data
- better coordination between different citizen science groups (and less public confusion).

Concerns regarding current and future involvement with the *eReefs* program

When groups were asked to discuss their key concerns about their potential involvement with *eReefs*, all groups raised similar concerns regarding access to and use of their data. Specific concerns were:

- making sure data is used appropriately – limitations and caveats are acknowledged and considered, proper citation and attribution of data sources, protection of privacy and environmental sensitivity (e.g. buffer zones around specific location data)
- controlling access to data – ensuring that data is used ethically and allowing groups to track use and uptake of data.

Some groups mentioned that they had concerns about potential errors in representing data from different groups on the same system, and mentioned the need to clearly define location data (e.g. what is a site, what is a location, what is the 'buffer zone' around specific location data). These definitions need to be explicitly stated and where possible, standardised within *eReefs* to avoid confusion and misinterpretation.

A few groups mentioned concerns about the time and resources needed to participate in *eReefs* and to maintain the accuracy, currency and longevity of their data represented on the *eReefs* system. The costs and benefits of their involvement would need to be clearly specified.

Priorities for new and innovative technologies that *eReefs* could provide

Groups provided a range of responses regarding the most useful tool, widget or functionality that *eReefs* could deliver that they would be able to use 'tomorrow'. Some of these are already under consideration for development in the *eReefs* project.

- strong support for spatial representation of data and/or activity sites
- spatial layers of habitat data or environmental data so that activity/survey sites and data and trends can be viewed against environmental variables. This could aid survey design (e.g. move from location based designs using grids or latitudes/longitudes to surveys structured by habitat types), and in interpreting data trends over time, or interpreting differences in trends between sites. Data included habitat types/biodiversity zones and oceanographic data (currents, SST, upwellings, chlorophyll, turbidity) and fine scale habitat data, vegetation maps, fire history maps and animations (e.g. vegetation maps from NRM bodies, local councils and Qld management agencies)
- ability to overlay spatial environmental data over time (e.g. find and overlay maps of sea surface temperature maps from specific periods)
- user scalable zoom levels (so users can view data from areas they define)
- mobile app for data collection
- on-line data entry forms that link to existing databases. This should include an auto-conversion system to convert different input coordinate systems into a standardised coordinate format
- real time or near real time environmental and oceanographic data

Other ideas included tools for better coordination between groups. *eReefs* could develop a *Citizen Science Hub* with centralised information on citizen science in the GBR Region, and tools to improve coordination and collaboration. E.g. a citizen science activities calendar where registered users can upload events and viewers can see what citizen science events and activities are taking place in the GBR Region. The hub could also show the relationship between different projects to reduce confusion about group identities and activities.

Ideas for new and innovative technologies that the information technology community could provide

Groups were asked specifically to approach this using 'blue sky thinking' and not to be constrained by what they thought *eReefs* could deliver. Groups provided a range of ideas about new and innovative technologies that could be developed.

- A fully integrated data management system where data can be viewed and downloaded in numerous formats (without double handling) – data are stored on a centralised system and retrievable and as tables, graphs, maps, with data. Volunteers would be able to submit data on-line to a master database. The system would run

automated data checks. This would reduce double handling data, time spent on data entry, and data entry errors

- voice recognition technology for mobile apps - move data entry away from touch screen keys and icons to voice. This would greatly increase the potential for collecting field data using mobile apps
- advanced image/pattern recognition software (app or desktop) that automates the identification of species or individuals (includes optically challenging subjects such as manta rays)
- sound recognition software for identifying birdcalls
- more calibration studies that compare community based data with other data sources such as scientific surveys to identify confidence limits of community data (i.e. increased data validation)
- 3D underwater visualisation of dive/survey sites like Google street view. This would be an excellent training and educational tool, viewers could go on a virtual dive, collect survey information (training), test species identification, learn about the species in view. This could potentially lead to crowd-sourcing image analysis (saving resources and time required for image analysis).

Conclusions and recommendations

This scoping study provides important information that will help guide the future development of the *eReefs* program. The study examines the operational characteristics of regional-scale citizen science groups in the GBR Region and identifies their operational needs regarding information technology. These needs could be met by enabling technologies (tools, systems and functionality) developed through the *eReefs* program. The scoping study also describes what types of information citizen science groups would like to have integrated within the *eReefs* environment, and explores the conditions and processes through which this information sharing could begin. As such, this scoping study is an important first step in developing long-term collaborations with *eReefs* to integrate and visualise community data and information within the wider context of research, monitoring and management in the GBR Region.

Citizen science in the GBR Region: characteristics, issues and challenges

This scoping study illustrates the scope and diversity of citizen science projects in the GBR Region. Programs range from local activities organised by regional branches of national scale projects and organisations, to grass-roots organisations dependent on two or three individuals. The number of community members participating in these groups ranges from less than 50 to over 500. Aims and objectives range from education and raising awareness to collecting long-term robust data about regional issues and to advise national environmental policy. This diversity is reflected in the sizes of the organisations and their participants and the enormous diversity in the types of data they collect and subsequent sampling designs and reporting methods. This diversity also means that a single information technology approach may not suit all groups, and that integrating citizen science into *eReefs* may require an individual approach with each group to establish communications and build collaboration.

In spite of this diversity, groups shared similar goals, strengths and challenges. Results from surveys, interviews and informal feedback about objectives, activities and target audiences suggest that most groups have similar objectives and desired outcomes:

- Providing useful data to inform management and decision making processes
- Increasing community stewardship of the environment
- Increasing community awareness and education regarding environmental issues
- Building community capacity to effectively participate in environmental management
- Improving environmental outcomes through the groups' activities.

Citizen science respondents also commonly stated that relationships with key individuals and the community were a significant strength. These relationships harnessed the skills, enthusiasm and energy of their volunteers and staff and were crucial to the organisation's success. Some groups also mentioned strong relationships with collaborating scientists and stakeholders as significant strengths. Many groups also have demonstrated track records of successful operations in the GBR Region with groups providing examples of activities, data collection, and uptake and application of their data by end users.

Almost all groups identified resource and funding limitations as their greatest challenges that compromised their ability to achieve goals and objectives. These resource limitations appear to be largely in areas affecting staffing and operations (e.g. salaries, field work, and training for volunteers). While some groups identified the need for new information technology, over half the groups indicated that they had adequate information technology and infrastructure to meet their needs over the next five years.

Citizen science groups also identified common barriers that appear to reduce the uptake and application of the data they collect – perceived reluctance of some natural resource managers and scientists to use these data because of uncertainty and distrust regarding data quality. Citizen science groups had accurate perceptions of these barriers with managers and scientists citing data quality as a major issue that limits use and uptake of citizen science data. However, many managers and scientists also stated that they would be more willing to use these data if they had more certainty about how the data were collected and about the quality of these data. Many managers and scientists also stated that it was difficult to determine what data were available from citizen science initiatives. Meanwhile, all citizen science groups have some form of quality assurance and quality control (QA/QC), but few groups document these protocols in formal QA/QC statements and plans. Consequently, improved communication of metadata and QA/QC and could improve managers' and scientists' awareness of what data are available and their understanding of data quality.

Citizen science groups in the GBR Region are very diverse, and integrating citizen science data and information with *eReefs* will require the development of collaborative relationships with individual groups. Nevertheless, citizen science groups in the GBR share common strengths and challenges which provide opportunities for *eReefs* to develop new enabling technologies that all groups could find useful.

In spite of these difficulties, many managers and scientists are familiar with and supportive of citizen science. Managers and scientists also stated that citizen science data are most useful when they are presented together with other data sets for cross referencing and corroboration. These challenges and miscommunications provide opportunities that could be addressed through enabling technologies developed by the *eReefs* program.

The role of professional scientists in citizen science

The results revealed that some citizen science groups had different views about key target audiences than managers or scientists with some groups considering the professional scientific community to be a low priority audience. However, this does not mean that the scientific community has little importance in citizen science projects as the scientific community plays an important role in citizen science in the GBR region:

- managers (who citizen science groups did identify as key target audiences) often stated that citizen science data was best used in conjunction with scientific information, and relied on scientific information to gauge the reliability of citizen science data
- some citizen science groups listed strong partnerships with scientists as one of their most important assets
- scientists may be important even if they were not considered to be 'target audiences', i.e. partner scientists are participants in the project and not recipients of the information, hence they were not considered as key target audiences
- some groups noted the importance of having their data validated against scientific data to define the data's confidence limits and demonstrate its reliability, and one group stated that more work needs to be done in this area.

Professional scientists have a long history of collaboration and involvement with citizen science (see Appendix 1). Thus, while scientists may not be considered as key target audiences, scientists provide important partnerships with citizen science groups and provide comparative data for validating citizen science data, and for corroborating and interpreting trends.

Implications for *eReefs*

Many of the goals, challenges and barriers cited by citizen science groups are related to the availability, packaging and transfer of the information they collect and the knowledge they produce. Similarly, the barriers commonly cited by many managers and scientists involve the availability of and knowledge about the information citizen science groups collect. These findings suggest that the *eReefs* program can be a powerful tool in enhancing communication and information dissemination between citizen science groups, target audiences, and end users of the data. As an information portal that collates, integrates and visualises several different data streams, *eReefs* could function as a single centralised location that facilitates access to data, meta-data and information by target audiences and end users. Additionally *eReefs* could provide functions that actively disseminate information to these audiences through subscriptions and automated alerts.

In general *eReefs* can provide enabling technologies to:

- help citizen science groups communicate with target audiences by better presenting and contextualising their data (e.g. spatial representation and visualisation of data and trends)
- promote collaboration and coordination between different citizen science groups
- assist managers and scientists in locating information, understanding its quality and accessing data of interest
- provide citizen science groups, managers, scientists and the wider community with a centralised portal to view data and analyse trends between data sets
- help communities understand the value of this knowledge and information within the wider context of research and management in the GBR

eReefs can be a powerful tool in connecting target audiences and end users to the knowledge and information provided by citizen science groups. In doing so, *eReefs* can help to address some of the barriers affecting the use and uptake of community based data, and can also help citizen science groups reach their target audiences.

This scoping study identified numerous options and ideas for developing enabling technologies. Some of these ideas for enabling technologies (tools, systems and functionality) lie within the scope of the *eReefs* Program and could be considered for development in the short term (*eReefs Phases 1 and 2)*. Other enabling technologies are beyond the scope of *eReefs* but are included in this report for consideration by the wider information technology community.

Opportunities for eReefs

The following enabling technologies would address many of the needs identified as important issues by most citizen science groups. Addressing these needs could also increase uptake and application of citizen science data by target audiences and end users. Development of these enabling technologies through *eReefs* would be of considerable use to citizen science groups, their target audiences, and the end users of these data.

1) Functionality to spatially present and visualise the activities, data and knowledge collected by citizen science groups. This functionality would produce:
    a. Interactive maps where viewers could zoom into user defined areas
    b. Icons that represent activity sites or survey sites for different citizen science groups
    c. The ability to view multiple data layers on the same map (e.g. view survey sites of different citizen science groups overlayed on top of maps of SST, vegetation type or upwelling hotspots)
    d. Novel ways of visualising citizen science data (e.g. animations)
    e. Links from icons on maps to photographs and videos of the site
    f. Links from icons on an interactive map to static data summaries (provided by citizen science groups)

2) Development of a standardised meta-data form that presents viewers with information including generic information about the project, the date the data were collected, the temporal extent of data available from this location, the methods used to collect, examples of how the project's data have been used, conditions of use and a citation, links to a QA/QC statement, and links to more project information
3) Development of a standardised QA/QC statement *for each project* that describes the data collection protocols, training, processes for data verification and data validation, data analysis, details of partnerships and collaborations (part of validation), examples of how data have been/are being, an explicit description of the potential biases and limitations in the data, and a statement specifying how data should and should not be used. This could include development of a rating system (e.g. different codes or descriptors to represent the appropriate uses of data according to data reliability)
4) A "citizen science search" function allowing users to search *eReefs* for citizen science data by location or by topic
5) A "Citizen Science Central" hub to improve coordination and collaboration across citizen science groups. The Hub could provide an overview of citizen science projects in the GBR Region, links to the websites of various groups, and interactive tools such for citizen scientist to use such as a calendar, blogs and wikis.

Opportunities for the wider information technology and e-research community

Citizen science groups identified a wide range of specific information technology needs that would assist their operations. Development of enabling technologies to address these needs is likely to be outside the current scope of the *eReefs* Program, but they comprise potential opportunities for research and development in the wider information technology community.

1) Applications for mobile devices. Some citizen science projects already have apps for iPhone and Android devices that allow users to submit data directly to on-line databases from the field using mobile devices (see www.iNaturalist.org). These apps can expand the observer pool by appealing to new participants, simplify data entry and verification processes, reduce data entry error and reduce lag-times between data collection and reporting. While, some citizen science groups in the GBR Region are already developing apps to provide this functionality, other groups expressed strong interest developing mobile apps. However, groups stressed that only some types of data would be suitable for entry via mobile apps.
2) One group stated that developing voice recognition technology could greatly increase the useability of mobile apps to collect field data, and would broaden the scope of the data that could be collect by apps.

3) One group stressed the need for advanced image and pattern recognition software that could recognise patterns from curved surfaces (i.e. the undersides of manta rays).
4) Bird groups mentioned the potential useability of an application that could analyse bird calls and provide a species identification. This could then be matched to existing Bird ID guide apps that already contain bird calls.
5) Social media (e.g. Facebook) are very important to some citizen science groups. The use of social media by citizen science groups could provide research opportunities to develop novel educational products, tools for visualising data or means for disseminating information.
6) Development of systems that allow remote data entry to on-line databases and include automated data verification and validation protocols to improve data entry accuracy and to flag anomalies or alert administrators of other notable 'alert' events
7) Development of 'trust metrics' systems similar to those developed by the e-Research Lab at the University of Queensland or applied in iNaturalist. These systems provide a clear process for data quality control (including both data verification and validation). This could include peer review of data by independent reviewers. These processes should culminate in quality ratings for independent observers, the data they submit, or for entire data sets.
8) An integrated information and management system for citizen science in the GBR that combines elements of data entry, automated data verification, validation, analysis and visualisation, and systems for managing communications.

Socio-techno considerations for eReefs

Developing enabling technologies through *eReefs* should carefully consider socio-techno issues that can significantly affect outcomes (see *Introduction: human elements in developing new technologies*). Several socio-techno issues emerged during this study and need careful consideration in future technology development through the *eReefs* Program.

Citizen science groups are committed to their volunteers and communities, and place high priority of maintaining trust and open communications. Accordingly, citizen science groups are wary of having the data they collect misused, misrepresented or used without due acknowledgement and attribution. Groups universally cited concerns about inappropriate use of data and cited the need for clear agreements about how data would be represented and used in *eReefs*. Consequently, data sharing agreements may need to be developed with individual groups to specify and document how data are to be used.

Citizen science groups also face resource limitations that affect their ability to engage in projects and activities that are not 'core business'. These limitations in time and staff may reduce the capacity for some groups to engage with the *eReefs* Program, and some groups may be resistant to further participation due to resource constraints. To address these concerns, *eReefs* may need to provide explicit descriptions of the tools and functionalities the

Program will deliver for citizen science groups in the GBR, and what involvement and input will be required from groups during the development of these tools.

Resource limitations also have longer-term ramifications. Some groups have invested significant resources into existing data and information systems, and many groups seem to prefer scenarios where *eReefs* links to existing systems and website rather than creating new systems. Long-term maintenance issues also need to be discussed. Clarity is needed about the roles and responsibilities of different parties in the long-term maintenance and upkeep of citizen science data and information on *eReefs*. Information on *eReefs* needs to be kept accurate and up-to-date to maintain its useability but regular maintenance will incur resource costs. These costs should be explicitly described, maintenance roles need to be attributed to different parties, and wherever possible, system architecture should minimise the time required to maintain and update information. This could include systems that remind registered users to update data, and provide users with the access and tools needed to efficiently maintain their data.

In spite of the innovation or technical success of newly developed technologies, socio-techno issues can affect the outcomes of *eReefs*. These issues include concerns over data sharing, limitations in capacity and resources to effectively engage with *eReefs*, and long-standing cultural issues that may affect user acceptance or rejection of new technologies. These issues should be carefully considered during program implementation and strategies developed to address the issues.

There are also apparent cultural differences between and amongst managers, scientists and citizen science groups that can create issues and barriers in trust, communication and knowledge transfer. While many of these issues lie outside the scope of the *eReefs* Program, these factors may affect the success of *eReefs* outcomes and thus should be considered and planned for during the 'roll out' of *eReefs* technology solutions and other program outputs.

Caveats and limitations

While the results and recommendations of this scoping study may accurately reflect the feedback provided by managers, scientists and citizen science groups, several issues may affect conclusions drawn from these data. As a scoping study, this study was devised to specifically inform the future development of the *eReefs* project. Data were only collected from a selected group of individuals and groups that were within the scope of the *eReefs* Program – managers, scientists and citizen science groups working at regional scales in the marine and coastal regions of the GBR. Consequently, the conclusions and recommendations presented here may not be applicable in other contexts such as different regions or for different types of community groups. Furthermore, this study should not be considered as a comprehensive review of citizen science in the GBR region, or an assessment of the effectiveness of these initiatives. While the study does highlight some important regional issues facing citizen science, this study makes no recommendations as to how specific parties

(managers, scientists or citizen groups) should alter their operations or manage their relationships.

The study only presents data provided by respondents. Almost all citizen science groups contacted provided feedback, and these groups have been provided with numerous opportunities to view the results of the surveys and interviews and to send further feedback or corrections. Informal validation of the results was provided by the Queensland Waders Study Group (QWSG). The QWSG was contacted after surveys and interviews had been completed, and provided with the results of the surveys and interviews and asked whether this information accurately reflected their issues, needs and perspectives. While the QWSG response suggests that these results accurately reflect the issues and information needs of citizen science groups in the GBR Region, this may not be the case for other groups in the GBR Region. Two groups did not provide a response and it is unclear whether the findings and recommendations are appropriate to these groups. Similarly, response rates were only 28% for managers and 40% for scientists. While these are generally considered to be favourable response rates for surveys, many managers and scientists did not respond to the survey and it is possible that non-responders hold different views and perspectives to those reported here.

Although all potential participants (including non-responders) were provided with the results of surveys and interviews for verification, very little feedback was generated from this process. There was high interest in the results with results documents downloaded by 104 individual users (representing ~40% of potential participants), but feedback was only received from five individuals who stated that the work and results were "interesting". Citizen science groups indicated that the results of the surveys for managers and scientists were consistent with their perceptions. While the lack of feedback could be interpreted as tacit agreement with the results by potential respondents, it could equally be interpreted as meaning that potential participants downloaded the results but did not read the material, or that they read the materials, agreed or disagreed with the results, but decided not to comment due to other factors (e.g. time, availability, 'consultation fatigue').

Lastly, many of the issues that affect the uptake and application of community data and determine the effectiveness of citizen science groups are far beyond the scope of the *eReefs* Program. Issues such as funding, institutional and organisational limitations and cultural differences between managers, scientists and the community exert external pressures and conditions that can affect the gains achieved through *eReefs*. These issues should be recognised and explicitly considered in the implementation and 'roll out' of any enabling technologies developed through the program. There are many examples of information technology projects that have failed because they did not adequately account for external factors and socio-techno such as user resistance and organisational culture [16,17].

Recommendations

Progressing collaboration and integration between citizen science groups and the *eReefs* program will require development of processes to facilitate these relationships, as well as incremental development and testing of new enabling technologies. This process could begin with formalising agreements with citizen science groups which lead to the development of first generation enabling technologies (tools, systems, functionality) during Phases 1 and 2 of *eReefs* development. These processes and initial development should be viewed as the first steps in integrating citizen science data within the *eReefs* environment.

In the longer-term, there are opportunities both within and external to the *eReefs* program to develop second generation technologies and to conduct research to further validate citizen science data. While some of these longer-term needs could be planned for *eReefs Phase 3* in 2015 (and build on feedback collected during 'roll out' of Phases 1 and 2), some long-term needs also represent research and development opportunities that are immediately available to the wider e-research and information technology communities. Additionally, some functionality (e.g. remote data entry, querying tools) would not be possible without migrating citizen science data to a centralised data hub. Citizen science groups are currently not receptive to this concept and consequently, these functions have been included as long-term potential technologies that are outside the current scope of *eReefs*.

Specific recommendations for developing **processes**, **short term** (first generation) and **long-term** (second generation) enabling technologies are identified below. First generation technologies consist of products that could be considered as extensions to the existing *eReefs* Program, while second generation technologies could require significant additional investment of time and resources that may be beyond the current scope of *eReefs*.

Process

Collaborative agreements and system maintenance and implementation

P1: The citizen science groups identified in this study should be systematically engaged to formalise *Collaborative Agreements* with each group. These agreements should clearly specify the objectives of the collaboration, the services and deliverables *eReefs* will provide, specify the provisions and input citizen science groups need to commit, and describe the process for ongoing communication and collaboration between the parties.

P2: *Simple* data sharing agreements should be developed with each citizen science group that describe what types of data will be integrated with *eReefs*, and conditions and processes for accessing data to ensure that use of data is ethical, appropriate and properly attributes the data source(s) and considers confidentiality and intellectual property issues.

P3: *Collaborative Agreements* should describe the long-term arrangements for maintaining the currency and accuracy of citizen science data and information integrated into the *eReefs* system.

P4: *Collaborative Agreements* should include explicit 'criteria for success' which form benchmarks for evaluating how *eReefs* has helped citizen science groups meet their objectives.

P5: An evaluation plan should be developed that describes how 'criteria for success' are monitored and assessed. This should specifically detail evaluation metrics and assessment processes.

P6: An overarching implementation plan should be developed that describes how any enabling technologies developed through the *eReefs* Program will be developed and rolled out to ensure that users (citizen science groups, target audiences and ends users) accept and begin using these tools. This plan should explicitly consider socio-techno issues such as communication, cultural differences and organisational culture. Relevant aspects of this plan should be integrated into *Collaborative Agreements*.

Short-term development priorities

1st generation enabling technologies

The *eReefs* program and participating citizen science groups should collaborate to develop:

ST1: mapping functionality that allows the locations of citizen science activity sites and survey sites appear as group-specific icons on *eReefs* interactive maps, alongside other data sets and layers of environmental information. Additional information on citizen science

projects, or links to additional information (e.g. project website, contact information, meta-data, static data summaries) should be available by clicking the icons

ST2: a standardised meta-data form and QA/QC statements that describe how the data were collected, the quality assurance and quality control (QA/QC) protocols associated with those data, biases and limitations of the data, and examples of how the data should be used

ST3: functionality that automatically advises users of the citation requirements and format for using the data

ST4: enhanced visualisation tools to illustrate patterns and trends in citizen science data through animations and interactive graphs and PDF documents, or other means

ST5: a *Citizen Science Hub* to improve coordination and collaboration between citizen science groups. This would include a synopsis of the Citizen Science groups contact details, and could include interactive tools (e.g. a citizen science calendar).

When developing these enabling technologies within the *eReefs* environment:

ST6: Wherever possible, the enabling technologies developed should adhere to the principles of Web 2.0 and allow citizen science groups to easily update, maintain and manipulate their information within the *eReefs* environment.

Long-term research and development opportunities

Scientific research and 2nd generation enabling technologies

Long-term development opportunities include potential enabling technologies that could provide valuable functionality and efficiencies to data collection, analysis and visualisation, but are outside the current scope of the *eReefs* program. These developments could be considered as potential areas of research and development for the information and communications technology community. There is also scope for the research community to conduct further research to verify and validate data collected by citizen science groups.

LT1: Work with specific citizen science groups to explore the development of specific enabling technologies that meet specific needs and

While this report provides recommendations regarding potential enabling technologies that could be developed, it does not make any recommendations as to the feasibility of these potential innovations. Decisions to invest in any of these enabling technologies should consider cost and benefits of development, useability to end users and potential impact/outcomes on a case by case basis.

functionalities identified by citizen science groups (see *Future enabling technologies and innovations*).

LT2: Explore the potential to develop a centralised, integrated data and information management system for citizen science in the GBR Region. The system would include the following functionalities:

- on-line data entry by remote users
- automated data verification processes during data entry
- tools enabling access to and querying of data
- automated reporting (including graphs and maps)
- metadata registry
- data archiving and backup
- enhanced communications management (e.g. RSS feeds, e-mail lists).

LT4: Work with specific citizen science groups to develop on-line educational products and tools that meet specific needs.

LT5: Develop metrics and tools that monitor uptake and use of citizen science data, and explore end user perceptions, experiences and satisfaction in using these data.

LT6: Develop systems and tools that automatically assess the quality of data provided by observers. This may include peer to peer assessments that contribute to an assessment of data quality for each observation.

LT7: Specific research to compare citizen science data against formal research and monitoring data to quantify the reliability and accuracy of the different datasets compiled by citizen science groups in the GBR Region.

LT8: explore the potential role of social media to assist citizen science in the GBR Region and deliver environmental outcomes.

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