Building an understanding of Moreton Bay Marine Park reefs through citizen science

Abstract
Moreton Bay Marine Park (MBMP) hosts a variety of subtropical reefs, including inshore reefs and offshore rocky reefs. These habitats provide refuges, nursery grounds and food sources for a diverse variety of flora and fauna. Monitoring of these reefal areas by local marine authorities is limited; hence, contributions from citizen science can help to fill spatial and temporal gaps. This paper will provide an overview of known citizen science monitoring of reefal areas in the MBMP, discuss the approaches used and applications. In the MBMP, Reef Check Australia has conducted annual ecological monitoring at fixed sites since 2009 and mapped inshore reefs with a high level of detail; Coral Watch has conducted monitoring as part of citizen science initiatives and capacity-building workshops that track the level of coral bleaching in the Bay over time; and the University of Queensland Underwater Club (UniDive) has created detailed maps and ecological assessments of the Flinders and Point Lookout offshore reefs of the MBMP. The examples provided demonstrate how citizen science groups record information that can be used to support conservation of the MBMP.

Keywords: Reef monitoring, reef mapping, Reef Check Australia, CoralWatch, UniDive

Introduction
Moreton Bay Marine Park (MBMP) reefs, provide a refuge, nursery ground and food source hosting a diverse variety of flora and fauna (1). These reefal areas include inshore reefs in central Moreton Bay/Quandamooka such as around Peel Island, and offshore rocky reefs such as Flinders Reef (2). Although academic studies have provided some insight into the factors affecting coral assemblages in Moreton Bay and the flora and fauna distributions within them (3-5), local marine authorities do not routinely monitor these reefal areas. Hence citizen science is valuable to help fill spatial and temporal gaps. This paper will provide an overview of known citizen science monitoring programs in the reefal areas in the MBMP, and provide a discussion on the approaches and applications used. The citizen science groups that focus on reef area monitoring in the MBMP include Reef Check Australia (Reef Check), CoralWatch and the University of Queensland Underwater Club (UniDive). The diversity, distribution and ecological
condition of reef communities in the Moreton Bay region are addressed in more detail in Pandolfi et al., Olds et al. and Gilby et al., 2019, this volume.

The MBMP reef communities include both inshore and offshore reefs (2), with inshore reefs found around Mud, St. Helena, Green, King, Peel, Goat, Russell and Macleay islands (4), as well as a patch reef at Myora (6) and some fringing areas along the mainland between Manly and Redland Bay (7). The reef areas are mostly hard substrate composed of a carbonate platform and while a few areas have highly concentrated coral growth (such as Myora (8) and Flinders Reef (9)), many areas have patchy or sporadic coral growth (10). The hard coral community is dominated by massive hard coral growth forms (8), alongside soft corals, sponges (1), and a variety of algae (11). The shallow waters of the MBMP are affected by the discharge of freshwater, pollutants and sediment from adjacent rivers (8). Hence, turbidity in Moreton Bay is often high, with visibility averaging 1–2m. This limited light availability means that coral growth is more common in areas shallower than 5m (7, 12).

Offshore rocky reefs are found along the eastern side of Moreton and Stradbroke islands, mostly around the northern points. The rocky reefs near Moreton Island are Henderson, Cherubs Cave, China Wall, Gotham City, Smith Rocks, and Flinders Reef north-east of Cape Moreton, with Flinders the only exposed reef. Stradbroke Island’s rocky reefs are Flat Rock, Boat Rock, Shag Rock, Middle Reef and The Group (includes Manta Ray Bommie) (2, 13). All these are emergent and above the low tide except Middle Reef. The rocky reefs of both Moreton and Stradbroke islands are mostly basalt substrate suitable for coral growth (10), with the highest coral cover and most diverse coral assemblages found at Flinders Reef (9). These offshore reefs can be exposed to the prevailing swell and variable tidal or ocean currents, making them regularly inaccessible for boats or for snorkelling or diving. Visibility is greater outside of the Bay, therefore coral growth is found in the deeper water surrounding these rocks, with some reaching down to 40m (14).

**Citizen science monitoring on MBMP reefs**

Government and academic organisations conduct detailed research studies and monitoring on the reefs in the MBMP, but consistent long-term reef health monitoring is limited. Researchers at the surrounding universities and research institutes conduct a variety of research projects in the MBMP that are discussed in other papers. However, Queensland Parks and Wildlife conducts annual Reef Health and Impact Surveys (RHIS)
at sites throughout the MBMP. In RHIS surveys, a trained observer assesses an area with a 5m radius, in which substrate composition and impacts are visually estimated (15).

Reef Check (16), CoralWatch (17) and UniDive (18) engage community volunteers in a diverse array of monitoring and mapping activities in the Moreton Bay region which are discussed below.

Reef Check Australia (Reef Check)

General
Reef Check is an environmental charity dedicated to protecting Australia’s reefs and oceans by engaging the community in hands-on citizen science research, education and conservation activities (16). Since 2001, Reef Check has trained and coordinated volunteers to conduct globally standardised reef health surveys along the Queensland coast. In 2007, the program expanded to monitor subtropical reefs in South East Queensland. Teams actively monitor 35 sites annually in the region from the Sunshine Coast to the Gold Coast, including multiple sites inshore and offshore in the MBMP (19).

Annual ecological surveys
Reef Check scientific methods have been peer reviewed to create a consistent global protocol for community-based reef health monitoring (20-23). A set of biological indicators (site description, reef health impacts, substrate type, invertebrates, fish identification) was chosen for Reef Check, to serve individually as indicators of specific types of human impacts, and collectively as a proxy for ecosystem health (22). A four-day course trains volunteers to conduct surveys, use survey materials and identify Reef Check indicators. Surveys are conducted along a transect line divided into four 20-m sections and laid along a constant depth and reef habitat (Fig. 1). Invertebrate abundance, reef impacts and fish data (when feasible) are recorded along a belt transect, whilst benthic composition of 25 substrate categories is recorded using point intercept transects to assess percent cover (Fig. 1a). A recent study demonstrated that the point intercept method for recording substrate data, despite observer and tape deployment biases, was highly accurate and capable of reliably documenting moderate changes in benthic cover (23). All Reef Check data are available as summaries and raw data through an online database, and an annual report is created to inform stakeholders on the status of reef health (https://www.reefcheckaustralia.org/data;
In 2015 and 2016, a collaborative project to inventory benthic reef habitat in the inshore MBMP was undertaken by Reef Check, The University of Queensland (UQ) Remote Sensing Research Centre, and Healthy Land and Water. This project generated a multipurpose dataset to revise a critical natural resource management dataset from 2004 for the spatial extent and condition of key reef areas (7).

For this project, more than 20 volunteer surveyors and staff conducted 610 georeferenced spot check surveys across fringing reef areas and eight inshore Moreton Bay reef areas to assess benthic composition by snorkeller, viewing bucket or using a drop camera. For these surveys, substrate percentage cover was estimated through
visual inspection in an approximate 10m diameter spot area. Each spot check survey was inventoried and the georeferenced data was overlaid on ZY-3A satellite imagery (5m x 5m pixel) by UQ Remote Sensing Research Centre staff. Boundaries of reef areas were manually digitised and labelled on the satellite imagery based on interpretation of the georeferenced field data, water depth and the underlying texture and colour of the satellite imagery (7). The largest reef area was located around Peel Island, with smaller fringing reefs occurring around the islands of inshore Moreton Bay, and the coastline between Wellington Point and Coochiemudlo Island. Only areas of relatively dense coral cover (>20%) were digitised. Using the spot check data, reef areas could be clearly distinguished from algae-dominated areas. This taken in conjunction with the higher resolution satellite imagery and advanced mapping software enabled more refined habitat assessments than the 2004 baseline maps. As such, areas of soft coral on sand/rubble, and algae on sand/rubble+patchy coral, could be clearly distinguished from coral-dominant areas. The 2016 revised spatial dataset offers a practical tool for supporting management decisions relating to marine park zoning and conservation in the catchment and the Bay.

CoralWatch Surveys

General
CoralWatch is a not-for-profit citizen science program based at The University of Queensland (UQ) in Brisbane, Australia (17). CoralWatch integrates global monitoring of coral health with education about coral reef conservation, and helps non-scientists around the globe to understand and support effective reef management by using survey and educational tools that provide ready access to information and hands-on-experiences collecting scientific data about the health of corals (24, 27). Currently there are 5,861 active CoralWatch survey members that have contributed data for 1,899 reefs globally (17).

Coral Health Chart surveys
The Coral Health Chart was developed in 2002 and is a well-recognised and validated method to monitor coral bleaching as an indicator of coral health (24). The chart standardises changes in coral colours, and provides a simple way for people to quantify coral health and contribute to the CoralWatch global database. Dive centres, scientists, school groups and tourists use the Coral Health Chart. The colour charts are based on
the actual colours of bleached and healthy corals (27). Each colour square corresponds to a concentration of symbionts contained in the coral tissue. The concentration of symbionts is directly linked to the health of the coral. It allows the user to easily match the lightest and darkest colour of a coral with one of the colours on the coral health monitoring chart and record the matching codes along with coral type (growth form). The collected data can be uploaded onto the CoralWatch database, which is publicly available (https://www.coralwatch.org/web/guest/map). The simplicity of the CoralWatch approach to gather information on coral health means that it requires less than an hour of training and any volunteer can collect field data.

In the Moreton Bay region, Coral Health Chart surveys have been conducted haphazardly as part of educational workshops for local and international students that raise awareness on ‘Coral at your Doorstep’, and by local divers and snorkellers on the various reefs (>350 corals surveyed inshore Moreton Bay; >1,300 surveyed offshore Moreton Bay) (17). In conjunction with Reef Check surveys, CoralWatch data are recorded via a belt transect along the length of each transect (Fig. 1a). The existing field data for a site are compiled and graphs are generated automatically to provide an overview of the health status of each reef and an indication of coral bleaching (27).

The University of Queensland Underwater Club

General

UniDive, is a recreational dive community located in Brisbane (18). UniDive has been involved in volunteer conservation projects that include clean-ups, ecological assessments and mapping of popular local dive sites within the MBMP.

As a result, some members of UniDive have gained skills, knowledge and experience in diving, marine conservation surveys, project organisation and logistics, data collection and analysis, report and scientific writing, videography, photography and presentations (13). This is further supported by members who focus their professional research and studies on the marine environment, whilst many members are also trained and involved in Reef Check and CoralWatch surveys.

Ecological surveys

Intensive ecological surveys were conducted with a focus on substrate, invertebrates, fish and reef impacts, using the same methodology utilised for Reef Check surveys (Fig.
1) (13). Indicator categories and survey methods closely aligned with Reef Check and CoralWatch protocols to enable valid comparisons. Survey methods included transect-based and quadrat surveys and, along with indicator categories, are described in detail in the methods manuals (25, 28, 29).

UniDive conducted seasonal (winter, autumn, summer and spring) ecological surveys in 2001, 2003 and 2014 at Flat Rock (2 sites), Shag Rock (2 sites), and Manta Ray Bommie (1 site), the latter as part of the Point Lookout Ecological Assessment (PLEA) (13, 28, 29). In 2003 one-off surveys were conducted at one site at each of Henderson Reef, Cherubs Cave, China Wall and Gotham (28), and then in 2017–18, as part of the Flinders Reef Ecological Assessment (FREA), at 10 sites at Flinders Reef (30).

**Mapping**

For both the PLEA and FREA projects, water depth, significant features and major habitat were mapped according to methods developed by UniDive in collaboration with the UQ Remote Sensing Research Centre. Feature mapping was undertaken on each transect by two divers. This buddy pair conducted a roving survey of each site to a maximum depth of 20m, and recorded characteristic features (Fig. 1b) (13). Feature location was mapped by cross-referencing the time each feature was recorded or photographed with GPS data recorded by a floating GPS towed by one of the two divers. Water depth surveys using single-beam echo sounders were conducted throughout the study areas to create contour lines. Satellite imagery was used to outline rocky areas, sandy patches and exposed rock (31).

**What did citizen science find out about the reef areas in the MBMP?**

Reef citizen science based projects in Moreton Bay have resulted in a wealth of data, including the first detailed habitat maps of Moreton Bay offshore reefs (31, 32), updated habitat maps of the main inshore reef areas in the MBMP (7), annual monitoring of many reefs (16), and intensive seasonal assessments of key tourism locations (13, 28, 31, 33).

**Reef monitoring**
Figure 2. (a) Nine years of Reef Check annual coral cover surveys for an inshore Moreton Bay Marine Park reef indicating trend in benthic cover (16).
Cover or change in impacts for reefs in Moreton Bay (for an example refer to Fig. 2). Summary reports are create
d at the end of each survey season.

For the 2017-18 season, more than 30 volunteer surveyors and staff were
involved in the surveys (19).
Overall, inshorereefs recorded an average of 12% hard coral
cover, whilst outer Moreton Bay reefs recorded an average of 27% hard coral cover. More specifically, for the
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en Island), as were low levels of coral cover (0–2% at Mud Island). Of the outer Moreton Bay reefs, however, mo
st site s recorded a decrease in hard coral coverage with the exception of Shag Rock, while Flinders Reef
Many sites monitored by Reef Check appear to have been relatively stable over the course of monitoring. Important reef health indicator signs were also documented during the surveys. These indicated high coral bleaching at Peel and St Helena islands (20% and 55% respectively), algal overgrowth at St Helena and Shag Rock West, and high coral damage at Flinders Reef from unknown sources (19). Invertebrate surveys indicated that the most abundant invertebrate was the *Diadema spp.* long-spined
urchin, with 356 individuals recorded predominantly at Shag Rock, Myora and Amity Point. Collector urchins (*Tripneustes spp.*) and anemones (various species) were recorded at all survey sites, with only one crown of thorns starfish (*Acanthaster planci*) recorded (Shag Rock). Butterfly fish (*Chaetodontidae*) were the most abundant target fish species with the greatest proportion observed at Myora Reef. Additionally, many animals considered as rare by Reef Check were recorded and included wobbegong sharks (*Orectolobidae*), tawny nurse sharks (*Nebrius ferrugineus*), turtles (*Chelonia mydas*) and stingrays (19).
UniDive has been contributing to inventories and detailed site assessments since 2003, including a baseline ecological assessment of Point Lookout dive sites (29) and the follow-up PLEA study (13). In 2016, UniDive initiated the FREA project, and expects results to be published in 2019. For the Point Lookout sites, seasonal changes were visible for macroalgal cover based on the 2014 UniDive Point Lookout surveys (30)(Fig. 3), and the largest amount of hard coral cover was

Figure 3. (a) Seasonal coral cover surveys for the Point Lookout dive sites during the 2014 Unidive Project, and (b) averaged seasonal CoralWatch Coral Health Chart readings indicating the average difference between lightest and darkest coral colour (Coral Health
Score) for the five sites surveyed during the 2014 Unidive Point Lookout Ecological Assessment Project (13).

observed at Flat Rock. A high degree of coral damage was recorded at all Shag Rock sites (where anchoring is permitted) relative to all other sites (13). This study identified the Diadema spp. long-spined urchin as the most abundant urchin, as well as a high frequency of collector urchins (Tripneustes spp.; Shag Rock), whilst pencil urchins (Phyllacanthas parvispinus) were more prevalent at Manta Ray Bommie. Additionally, all sites surveyed exhibited a diversity of fish
families with damselfish (*Pomacentridae*) and wrasse (*Labridae*) being in highest abundance, however, seasonal variation was observed for subtropical fish groups. CoralWatch seasonal Coral Health Chart surveys at Point Lookout in 2014 showed that the corals were relatively stable with no obvious bleaching detected (a score of 3 or more indicates a healthy reef; Fig. 3b, (13)).

**Mapping**

Multiple types of maps have been supported through regional citizen science initiatives. These maps have been used for grey nurse shark monitoring, 2009 marine park zonation, and monitoring design and/or management (2, 13, 28).

In 2015–16, Reef Check worked with the UQ Remote Sensing Research Centre and Healthy Land and Water to revise reef habitat maps for inshore Moreton Bay for the first
time in ten years (7)(Fig. 4a). The map provides a detailed and updated inventory of the coral habitat in Moreton Bay and was to contribute directly to the Healthy Land and Water Report Card (34). This would assist with evaluation of the environmental condition of South East Queensland catchments, and management actions to reduce pollution and maintain/restore key habitats.

Habitat maps created through multiple UniDive projects provided a level of detail not mapped before for local reefs (Fig. 4b, c). These maps describe different substrate cover types, significant features and depth, and include habitat mapping for the Critically Endangered grey nurse shark (28, 31, 32)(Fig. 4c).

Figure 4. (a) Citizen science reef mapping. Benthic habitat mapped for inshore Moreton Bay reef areas by Reef Check, location indicated by the yellow box (7). (b) Habitat map for Shag Rock, Point Lookout, surveyed during the 2014 UniDive Point Lookout Ecological Assessment Project (13), and (c) habitat map for Cherubs Cave, North Moreton Island surveyed by UniDive as part of the habitat mapping for the Grey Nurse Shark (GNS) Project 2003 (28).
Impact of MBMP reef citizen science

Citizen science projects have resulted in a broader ecological understanding of MBMP reefs, particularly with respect to abundance, composition and impacts, providing valuable information for marine authorities which they would otherwise not have access to. Citizen science supports conservation actions through, for example, the mapping of critical grey nurse habitat in accordance with the Australian Government’s recovery plan (35), and influencing marine park zoning and resource management (7, 36). Many citizen science datasets help fill gaps in spatial and temporal knowledge.

Citizen science has contributed notable data for (7, 13, 19, 24, 28-33):

- substrate cover – annual (Reef Check) and intensive (UniDive)
- invertebrate and fish composition – annual (Reef Check) and intensive (UniDive)
- invertebrate and fish abundance – annual (Reef Check) and intensive (UniDive)
- human and natural impacts – annual (Reef Check) and intensive (UniDive)
- spatial composition and characteristics of habitats – intensive (Reef Check; UniDive)
- photographic records – annual (Reef Check) and intensive (UniDive).

Volunteers provide extensive in-kind support to citizen science projects, providing commitments of time that would not be possible through government agencies. In addition to science and monitoring contributions, citizen science initiatives have increased community awareness through publication and presentation of results and data in: reports, websites, brochures, videos, coffee-table books, scientific publications, workshops, conference presentations, media, online data portals and/or inclusion in government-developed publications (Fig. 4) (7, 19, 25, 26, 28, 29, 31-33). Additionally, these initiatives have supported increased educational and capacity-building opportunities focused on the MBMP through training volunteer divers, workshops, and presentations at local dive clubs and high schools, conferences and community events.
Beyond regional data and awareness-raising, citizen science is contributing to positive policy and natural resource management outcomes on the international stage. In 2016, citizen science directly facilitated international recognition for the MBMP through an application to support a Mission Blue Hope Spot nomination (https://mission-blue.org/2016/12/citizen-science-supports-protection-in-the-moreton-bay-hope-spot/). Hope Spots are marine habitats recognised for their unique and critical value (biodiversity and important habitat) through a competitive assessment process managed by Mission Blue and International Union for Conservation of Nature (Sylvia Earle Alliance/Mission Blue; https://mission-blue.org). In addition to the unique natural environment, the Hope Spot reviewers stated that assignment of the MBMP as a Hope Spot was due to the active citizen science networks within the region.

Challenges and limitations for citizen
science programs on reef areas

Marine environments are challenging areas in which to conduct research for any organisation. The challenges are a result of the submerged and exposed nature of the reefs, often only accessible by boat, which determines the number of passengers that visit a site. In general, travel to a site takes a long time and can be affected by environmental conditions such as water depth, wind, waves and currents, all of which can reduce ease of access.

Volunteers participating in underwater research need to be relatively fit and often need to be trained and experienced divers or snorkellers, which can limit the number of eligible volunteers. Additionally, divers and snorkellers are limited to a certain depth and dive time in order to conduct surveys safely, and environmental conditions such as wind, waves, swell and temperature, also greatly impact data collection activities, as was experienced during the FREA surveys (30). Annual sea temperatures in the MBMP vary from 15–27°C, and underwater visibility varies from centimetres to tens of metres.

Collecting data underwater often requires specialised and costly equipment, such as dive gear, waterproof paper forms, slates and underwater camera gear. As GPS signals don’t penetrate the water, positioning relies on towing a GPS directly above the diver. This assures that the recorded location is within GPS error, and it is a well-documented method for determining survey location (26).

Summary of how citizen science is helping to monitor and understand the reef areas of the MBMP

Reef citizen science data in the MBMP has provided additional ecological information about these areas that complements and augments data collected by government agencies, consultants and academic researchers. In some locations, these are the only available datasets. The information gathered has proven to be useful and it has been integrated into government and non-government programs to provide additional temporal and spatial information, as well as novel types of data (13, 28-32, 34, 37).

The range of citizen science programs, from casual observations to in-depth bio-inventories, opens up opportunities for wide-scale participation for a range of interests and at many levels of experience. Increasingly there are chances for volunteers to get
involved in other activities that don’t involve fieldwork, through identification, validation, reporting and outreach. The opportunities will continue to grow as increased access to survey methodologies that can be transferred to citizen science teams, along with ease of access to online repositories of manuals, tools and publicly accessible data, amplify data sharing and validation. This will continue to boost citizen science reef data collection and integration.

The citizen science programs presented here, build science literacy and capacity in the community by training and including volunteers, and through increased communication about the condition and/or location of these reef areas. Citizen science brings together multiple stakeholders to discuss how the scientific and broader community can improve partnerships that can help generate positive science and management outcomes.