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Reliability and utility of citizen science reef monitoring data collected by Reef Check Australia, 2002–2015

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A B S T R A C T

Reef Check Australia (RCA) has collected data on benthic composition and cover at >70 sites along >1000 km of Australia's Queensland coast from 2002 to 2015. This paper quantifies the accuracy, precision and power of RCA benthic composition data, to guide its application and interpretation. A simulation study established that the inherent accuracy of the Reef Check point sampling protocol is high (<±7% error absolute), in the range of estimates of benthic cover from 1% to 50%. A field study at three reef sites indicated that, despite minor observer- and deployment-related biases, the protocol does reliably document moderate ecological changes in coral communities. The error analyses were then used to guide the interpretation of inter-annual variability and long term trends at three study sites in RCA's major 2002–2015 data series for the Queensland coast.

1. Introduction

Long-term ecological monitoring makes important contributions to the science, adaptive management and public perception of the state of coral reefs. 'Citizen scientists' have long been notable contributors to long-term reef monitoring (Hodgson, 1999, Hodgson, 2001; Beeden et al. 2014; Loder et al., 2015). Along the Queensland coastline, including the Great Barrier Reef (GBR), major citizen science initiatives include Eye on the Reef (Beeden et al. 2014), Coralwatch (Marshall et al., 2012) and Reef Check Australia (RCA) (Loder et al. 2015), all with a major focus on recreational dive sites.

RCA (established in 2001) is a not-for-profit, registered charity with a small staff, a large volunteer membership base and an established governance framework. Program objectives are organized into three main streams; conservation; education and citizen science (Reef Check Australia 2013). In its citizen science stream (the focus of this paper), RCA trains and coordinates SCUBA and snorkel volunteers to contribute data sets on benthos, substratum, invertebrates, fish and human impacts on reefs. At >70 sites along the Queensland coast, volunteers annually visit long-term monitoring sites to record data. Critical to the success and sustainability of citizen science projects such as this are opportunities for the meaningful engagement of volunteers and the collection of data of suitable quality for the research question (Dickinson et al. 2010). RCA has a strong record of engagement. Since 2002, 218 RCA volunteers have monitored >60 sites in the GBR and, since 2009, an additional 15 in South East Queensland (SEQ) (Fig. 1). Volunteers also work with staff to share data through multiple formats, including scientific journals (e.g. Roelfsema et al. 2016), reports for program stakeholders and community members (e.g. Welch et al. 2016), social media, community talks, infographics, and community events. In relation to data quality, RCA's objective is to produce benthic data that complements formal government monitoring programs in the provision of indicators of ecological conditions at a spatial scale appropriate for site management and condition reporting.

RCA's methods are derived from those of Reef Check (RC), the international volunteer, community-based reef monitoring program (Hodgson 1999) that aspires to 'provide a valuable method to detect broad-brush changes on a local, regional and global scale, as well as increasing public support for coral reef conservation' (Hodgson 1999, p 345). RC affiliates around the world use a standard point intercept

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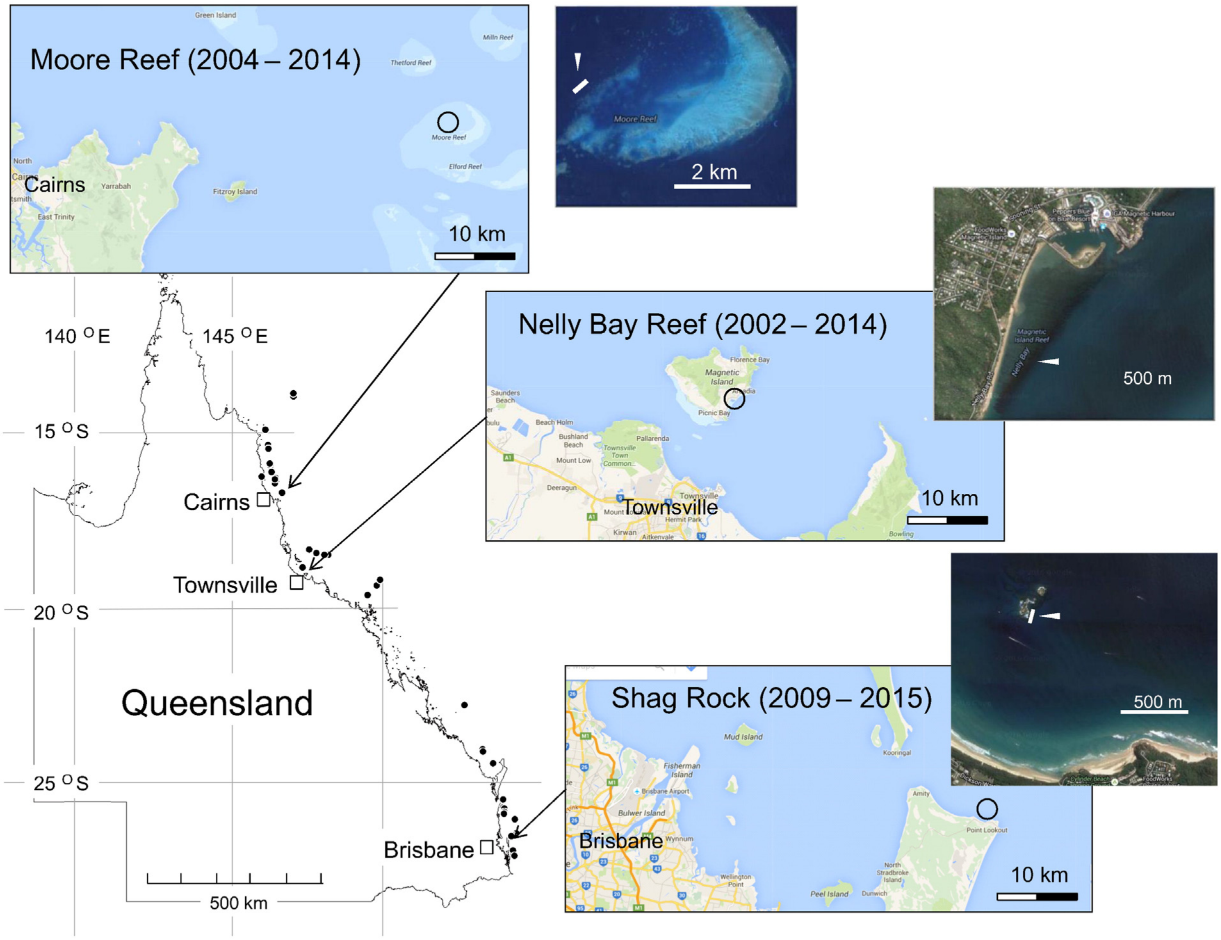

Fig. 1. RCA monitoring sites Queensland. Black dots indicate locations of reefs with one or more RCA monitoring sites. Location detail and years of monitoring at Moore Reef, Nelly Bay and Shag Rock, sites of the precision study reported here are indicated. Standard study site used in routine monitoring is a narrow band within which a 100 m tape measure is haphazardly deployed. For Shag Rock, a non-standard length of 75 m was used due to space and logistic constraints. Within each 25 m section of the site, a 20 m section of the 100 m tape measure is sampled at 0.5 m intervals of each deployment.

transect (PIT) sampling protocol and report on percent cover of 10 standard benthic categories: live hard coral, recently dead hard coral, soft coral, fleshy seaweed, sponge, other benthos, rock, rubble, sand, and silt/clay. A principal focus of most reef monitoring is live hard coral, because of its functional roles as key builder of reef structure and key provider of complex, rigid habitat for much other reef biodiversity (McClanahan et al. 2002). Marine pollution, particularly in the form of agricultural runoff, can be a key driver of phase-shifts from coral to non-coral benthic dominance (Done 1992), so it is important that RC's protocols should reliably document both catastrophic change and long-term trends in live hard coral cover, and transformation to alternate states such as soft corals, fleshy algae or sponges. If RCA's field estimates of benthic cover are to constitute a useful basis for such scientific inference or management decision making, the degree of uncertainty associated with RCA estimates needs to be known. On the GBR, episodic losses in live hard coral generally range from 12 to 43% (caused by storms, coral predators, diseases and bleaching events; Osborne et al. 2011), and incremental hard coral gains over 5–10 years in recovering shallow slope sites have been reported at around 4% per year (Done et al. 2010; Osborne et al. 2011). Therefore, monitoring to track changes in cover must be able to document changes of these magnitudes.

Accordingly, this paper investigates the reliability and utility of the RCA benthic monitoring data. As with many citizen science projects, this is especially important given that surveyors may change from one year to the next, and that, while study sites are well defined, transect lines within study sites are not permanently marked. Here, we quantify these effects statistically through replicated field studies at representative sites. Our statistical null hypothesis is that there is no difference in estimates of percent cover among observers using the same transect line, or using different placements of the transect line (henceforth referred to as 'deployments') within the delineated study area. We consider that, despite any such observer or deployment effects, an effective citizen-based long-term monitoring program still needs to be able to reliably distinguish real change from sampling noise in key indicators such as the percentage cover of macro algae and hard coral.

2. Methods

2.1. Routine benthic monitoring

RCA benthic monitoring is carried out only by volunteers who have undertaken standardised training and demonstrated competency in identification of benthic categories through both a photographic identification exam (85% pass rate) and *in-situ* identification skills (95% pass rate). In routine monitoring, RCA volunteers record corals, algae and sponges down to the level of specific growth forms (25 categories) but for the purposes of the present study records are grouped into the10 standard RC categories. Data may be accessed through the RCA web site http://www.reefcheckaustralia.org.

The term 'site' refers here to a narrow long strip of reef along which 100 m of transect tape is laid along the reef edge along a designated tide-corrected depth contour (<1 m variation), typically at 3–6 m, but ranging from 1 to 12 m. A system of detailed maps and tide times is used to ensure consistent transect placement from year to year,

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