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Comparing monitoring data collected by volunteers and professionals shows that citizen scientists can detect long-term change on coral reefs

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ABSTRACT

Citizen science is increasing and can complement the work of professional scientists, but the value of citizen data is often untested. We therefore compared the long-term changes to coral reefs that were detected by a professional and volunteer monitoring program, operated by University of Rhode Island (URI) staff and Reef Check volunteers, respectively. Both groups monitored reefs in the British Virgin Islands from 1997 to 2012 but mostly monitored different sites (URI 8 sites and Reef Check 4 sites). When URI staff visited the Reef Check sites to perform a side-by-side to comparison, Reef Check fish density estimates were consistently higher than those made by URI observers but benthic indicators showed better agreement. When long-term trends were compared, the two programs detected qualitatively similar trends in the % cover of live coral and coral rubble, but temporal changes in the cover of other benthic indicators were less consistent. The URI program detected a widespread increase in parrotfish densities and a decline in snappers, whereas the Reef Check surveys detected no consistent changes in any fish density indicators. Overall, site-specific temporal trends revealed by the URI program were more often statistically significant than those from Reef Check (twice as often for benthic taxa, and five times as often for fish taxa), which implies greater precision of the scientists' counts. Nonetheless, volunteers were able to detect important changes in benthic communities and so have a valuable role to play in assessing change on coral reefs.

Introduction

Citizen science (defined by Kruger & Shannon, 2000) has been increasing, and has the potential to complement work done by professionals (e.g. Carr, 2004; Cohn, 2008; Conrad & Hilchey, 2011; Silvertown, 2009). Non-specialist volunteers participate in many conservation-orientated projects worldwide by monitoring species and environmental conditions in various habitats. Because financial, manpower and training resources for conservation monitoring are limited, involving volunteers can compensate for these constraints and greatly increase the overall amount of information available. Professional scientists have, however, sometimes questioned the accuracy and precision of volunteer data (Boudreau & Yan, 2004; Brandon et al., 2003; Crall et al., 2010; Fore et al., 2001; Hunter et al., 2013; Legg & Nagy, 2006; Nerbonne & Vondracek, 2003; Underwood & Chapman, 2002).

Arguably, citizen science monitoring is having the greatest influence on ecology by broadening the geographic scope of monitoring (Dickinson et al., 2010). These contributions are illustrated by recent marine examples, in which recreational divers helped to better define the geographic distributions of species of special significance in the Mediterranean (an endemic coral, *Corallium rubrum*, and sea horses, *Hippocampus* spp.) (Bramanti et al., 2011; Goffredo et al., 2004), and helped define the spatial extent of global coral bleaching events (Hodgson, 1999; Marshall et al., 2012). In fewer cases, citizen scientists have performed long-term monitoring to reveal longitudinal trends in population status (Carr, 2004; Conrad & Hilchey, 2011). Perhaps the best examples come from

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ornithology, beginning with the Audubon Society's annual Christmas bird counts, which started in 1900 and now engage 60–80,000 volunteers annually. Other major public bird monitoring surveys in the United States have developed since, including the U.S. Geological Survey Breeding Bird Survey, launched in 1966, and the Cornell Lab of Ornithology's nest record card scheme, begun in 1965 (Dickinson et al., 2010). The goal of biological monitoring is often to detect change over time (Boylen et al., 2004), but the inability to detect ecologically significant changes is a drawback of many programs (Legg & Nagy, 2006). Several studies have compared volunteer versus professional monitoring to assess their performance (e.g. Finn et al., 2010; Gillett et al., 2012; Gollan et al., 2012; Kremen et al., 2011; Lovell et al., 2009), but few studies have compared the ability of professional and volunteer monitoring programs to detect long-term trends (for exceptions see Kallimanis et al., 2012; Robbins et al., 1989; Royle, 2004).

Collecting reliable data on coral reefs is challenging because the technical demands of working underwater on SCUBA add to the usual difficulties of data collection in the field (Gillett et al., 2012). In addition, because coral reefs support complex species-rich communities, accurate data collection usually also requires learning to identify many species or functional groups that are used as indicators of reef status. Perhaps for this reason, previous comparisons between professionals and volunteers on coral reefs have usually focused on a single taxonomic group, such as fish (Darwall & Dulvy, 1996; Holt et al., 2013; Pattengill-Semmens & Semmens, 2003), sharks (Ward-Paige & Lotze, 2011), corals (Marshall et al., 2012), or sponges (Bell, 2007) (for an exception see Mumby et al., 1995).

Volunteer coral reef monitoring programs have been used to indicate the spatial extent of widespread impacts, such as coral bleaching events (Hodgson, 1999; Marshall et al., 2012). Temporal change has, instead, usually been examined using professional monitoring studies (e.g. De'ath et al., 2012; Gardner et al., 2003; Paddack et al., 2009), although volunteer data are included in some recent analyses (Schutte et al., 2010). These analyses of long-term change on coral reefs are often based on many short-term studies that are "stitched together" to create a region-wide picture of long-term changes, and there are relatively few extended time-series from individual sites (Bak et al., 2005; Hughes, 1994). For this reason, testing whether volunteer programs can detect long-term change is of interest. Our objective was thus to compare the ability of professional and volunteer monitoring to detect long-term temporal changes in coral reef communities.

Methods

Study design

We compared two monitoring programs in the British Virgin Islands (BVI). The first is part of popular global volunteer organization (Reef Check), whose volunteers collect a comprehensive array of measurements on fish, invertebrates and structural reef properties (Hodgson, 1999, 2001). One goal of Reef Check is "to create a global network of volunteer teams trained in Reef Check's scientific methods who regularly monitor and report on reef health". The BVI Reef Check group monitored 4 coral reef sites from 1997 to 2012 (Table 1, Fig. S1). We compared their results to the results of a professional monitoring program that was also based in the BVI. The professional program (hereafter referred to as the URI program) monitored 8 different BVI sites from 1992 to 2012 (Table 1, Fig. S1). The URI program was led by the first author and conducted by scientists with specialist training in coral reef ecology.

The two programs were designed and run independently, so our analysis involved only subsets of data from each program that were comparable. We compared sites similar in wave exposure (based on fetch distances), habitat (fringing reef slopes), and depth (10 m), and we limited the analysis to the period when the two programs ran concurrently (1997–2012). The 8 URI sites were each monitored annually from 1997 to 2012, but there were some early gaps in the Reef Check sampling as follows: Bronco Billy lacked data for 1997 and 2001, Diamond Reef lacked 2000, Pelican Island lacked 1998 and 2000, and Spyglass lacked 1997 and 2000.

Table 1
Sites monitored by the two programs (plus abbreviated site names) and their geographic coordinates.

Sites	Coordinates
Reef check program	
Bronco Billy (BB)	18.29.36N 64.27.37W
Diamond Reef (DR)	18.27.55N 64.31.50W
Pelican Island (PI)	18.19.51N 64.37.38W
Spyglass (Spy)	18.19.27N 64.36.9W
URI program	
Bigelow Beach (Big)	18.28.09N 64.33.44W
Crab Cove (Cra)	18.28.51N 64.34.45W
Grand Ghut (Gra)	18.28.48N 64.33.43W
Iguana Head (Igu)	18.28.23N 64.34.54W
Monkey Point (Mon)	18.27.46N 64.34.14W
Muskmelon Bay (Mus)	18.29.07N 64.34.53W
Pelican Ghut (Pel)	18.28.33N 64.33.27W
White Bay (Whi)	18.28.11N 64.34.28W

Our primary goal was to assess whether the two programs could detect widespread temporal changes in reef communities, rather than localized changes that might occur at only one site but not others. We defined widespread changes as those detectable at the majority of sites (50% or more), so our analysis was based on the premise that if one program detected a widespread trend then it was reasonable to expect the other program to reveal a similar trend. Because the two programs monitored different sites (Table 1), our ability to compare counts made at the same time and place is limited. There were, however, seven occasions when members of the URI group visited Reef Check sites (Diamond Reef in 1999, 2001, 2004 and 2006; Pelican Island in 2004; Spyglass in 2004, and Bronco Billy in 2004). These side-by-side measurements permitted direct comparison of URI and Reef Check counts.

Monitoring methods

Reef check methods have described by others previously (Hill & Wilkinson, 2004; Hodgson, 1999), so are outlined briefly here. At each site, two markers were placed permanently on the reef to define a fixed 100 m long transect. A tape was laid on the reef between the two markers, and divers swam along the transect to complete a fish survey, an invertebrate survey and a benthic survey. Fish were counted first using a belt transect, during which the diver swam slowly along the tape and counted fish within an area 100 m long × 5 m wide (400 m^2). After the fish count, invertebrates were counted within the same area 400 m^2 area. The benthic survey used the linear point-intercept method (Ohlhorst et al., 1988). A diver then swam along the tape and, at 0.5 m intervals, the substratum under the tape was assigned to one of ten categories (Table 2). The percent cover of each substratum category was estimated as the percentage of points under which that substratum was observed. A core group of 7 regular volunteers organized and participated in most surveys, joined by a larger number of less frequent participants.

For the URI program, each site was roughly 0.6 ha in area and was surveyed annually between June and August. To estimate the density of larger fishes (visually estimated to be >30 cm total body length), the entire site was first scanned by a single observer (the first author) as he swam slowly back and forth through the site.