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Simple family-level parrotfish indicators are robust to survey method

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ABSTRACT

Given the current degradation of Caribbean coral reefs, considerable regional emphasis has been put into monitoring the state of key exploited reef fish herbivores, namely surgeonfishes and parrotfishes, through underwater visual fish surveys (UVFS). However, like all survey methods, UVFS suffer from sampling errors that could mask *real* spatio-temporal trends in fish metrics. Here, we compare trends in simple reef fish herbivore metrics, i.e. average individual fish weight, fish abundance and fish biomass, between UVFS and fish trap surveys, an alternative survey method. Because both methods fundamentally differ in the underlying nature of their sampling errors, we argue that fish metrics exhibiting high consistency between methods will more likely reflect *real* environmentally-induced trends and should thus be emphasized in monitoring programs. We conducted repeated surveys using both methods concurrently at six sites along a fishing pressure gradient in a Caribbean island. We then examined between-method consistency in fish metric trends across sites and precision in fish metric estimates for each method using surgeonfish and parrotfish data at different levels of aggregation, i.e. species-, family- and functional-level (both herbivorous families combined). We found high and robust between-method consistency only for parrotfish data aggregated at the family level, which also exhibited the highest overall precision in metric estimates. All other fish groups exhibited poorer between-method consistency and poorer precision in their metrics, indicating comparatively higher sensitivity to method-specific sampling errors. Overall, our study supports that family-level parrotfish metrics are particularly robust to survey method, which considerably increases their value as indicators for Caribbean reef monitoring programs.

1. Introduction

The poor state of many Caribbean coral reefs and the fisheries they support (for details, see Jackson et al., 2014; Newton et al., 2007), together with the dependence of many Caribbean communities on these reef systems (Burke et al., 2011) has highlighted an urgent need to improve coral reef and fisheries management in this region. This, together with an increasing interest in ecosystem-based fishery management (EBFM), has resulted in a recent focus on the role of exploited surgeonfishes and parrotfishes as keystone herbivores or reef health engineers (Adam et al., 2015), and justified their inclusion as function-based indicators for coral reef health (McField and Kramer, 2007). This has also prompted a number of important management responses that recognise their ecosystem function, including adoption of a recommendation to better protect reef fish herbivores in the Caribbean (ICRI, 2013), the implementation of fishing regulations which ban fishing for these species in a few territories (e.g. Belize, Bonaire, Turks and Caicos Islands) as well as implementation, or consideration of, other measures to more effectively protect the reef whilst still utilizing a fishable herbivore stock (Bozec et al., 2016; Mumby, 2016).

Such measures require on-going monitoring to assess the current status of reef fish herbivore assemblages and management effectiveness and, within the Caribbean, a number of regional and sub-regional reef monitoring programmes involve the collection of data on reef fishes that include surgeonfishes and parrotfishes, such as the Caribbean Coastal Marine Productivity Program (CARICOMP; https://www.mona.uwi.edu/cms/caricomp.htm) and the Atlantic and Gulf Rapid Reef Assessment (AGRRA; http://www.agrra.org/), among others. The recognition of the importance of the aforementioned reef fish herbivores is best illustrated by The Healthy Reefs Initiative (http://www.healthyreefs.org/cms/), which uses surgeonfish and parrotfish biomass combined as one of four key indicators in their coral reef health report cards.

A limitation of all the aforementioned monitoring programs is that they rely exclusively on underwater visual fish surveys (UVFS) to obtain reef fish data. A widely recognized problem with the use of UVFS is that they are unavoidably subject to both random and systematic (bias) sampling errors (Usseglio, 2015 and references therein). Frequently

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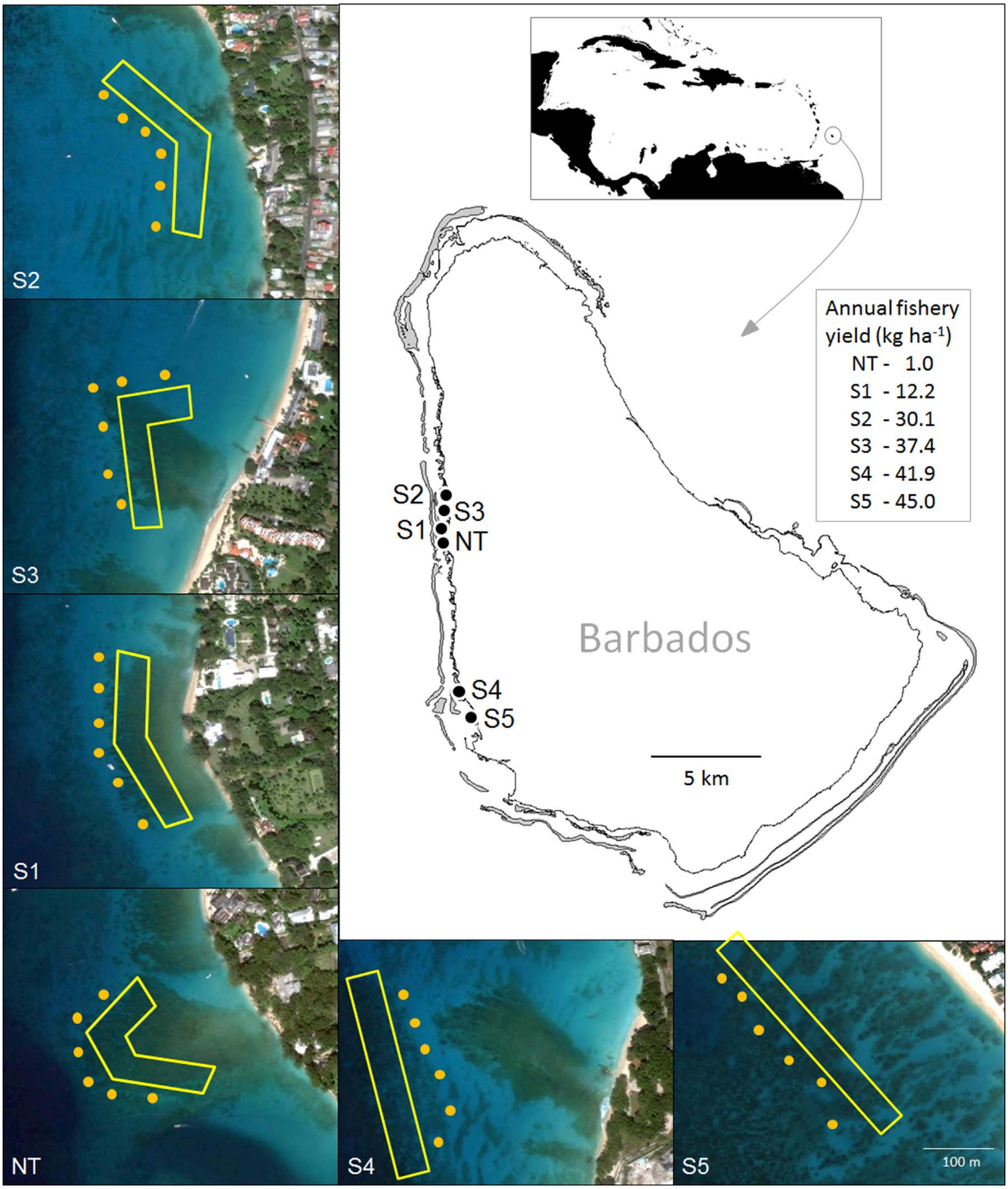

Fig. 1. Map showing the location of the six study sites along the west coast of Barbados. Satellite images from Google Earth (Image@2016DigitalGlobe) show the geo-referenced locations of the six fish traps (yellow circles) and approximate area (yellow polygon) where the underwater visual fish surveys were conducted. NT indicates no-take site, whereas other sites are numbered by increasing fishing pressure, which is shown as approximate annual fishery yield in inset legend. All sites are at least 600 m apart. Insert map shows location of Barbados (13.14N, 59.55W) within the Caribbean. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

highlighted sources of error include fish behaviour, whether in relation to fish life history (e.g. cryptic versus conspicuous) or in response to observer presence (e.g. attraction versus avoidance), observer error, and sampling technique (e.g. belt transect versus stationary survey) among others (Usseglio, 2015). Some of these errors can be minimized through appropriate training (e.g. observer error), but others are inherently difficult to deal with. For example, in the moderately-to-heavily fished systems of the Caribbean, the magnitude of diver avoidance by target species is likely to differ in space and time (e.g.; Gotanda et al. (2009); Januchowski-Hartley et al. (2011)), potentially undermining relative comparisons of the state of exploited fish assemblages among sites and/or over time (Bozec et al., 2011; Kulbicki, 1998). Furthermore, UVFS require trained divers and are inherently expensive, perhaps placing it beyond the reach of managers in many developing countries.

Alternatives to UVFS do exist. Fish trap surveys have long been used to assess the state of exploited Caribbean reef fish assemblages (Munro, 1983). Both surgeonfishes and parrotfishes are commonly caught in traps in the Caribbean (Hawkins et al., 2007), making this gear particularly well suited to sampling these two fish groups. The use of trap surveys to monitor reef fish herbivore populations offers many benefits compared to UVFS (Miller, 1988). However, like any sampling methodology, they are also subject to sampling errors. In this regard, even with a standardized trap design and a fixed soak time, habitat