Spatio-temporal Variability in the Benthic Composition of the Coral Reefs of Barbados between 1997 and 2012

Variabilidad Espacio-temporal en la Composición Bentónica de los Arrecifes Coralinos de Barbados entre 1997 y 2012

Variabilité Spatio-temporelle dans la Composition Benthique des Récifs Coralliens de la Barbade entre 1997 et 2012

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EXTENDED ABSTRACT

Coral reefs are one of the most threatened ecosystems globally (Gardner et al. 2003, Hughes et al. 2018), which has prompted initiatives at regional and local scales in the Caribbean aimed at monitoring the state of these important ecosystems (Jackson et al. 2014). In Barbados, a long-term reef survey programme was officially launched in 1982 with the establishment of permanent monitoring reef plots at multiple sites representative of the three different reef types found off the island's south and west coasts: the shallow leeward fringing reefs of the west coast (hereafter fringing reefs; average depth: 4.4 m), the shallow semi-windward patch reefs of the south coast (hereafter patch reefs; average depth: 6.2 m), and the deep bank reefs on both coasts (hereafter bank reefs; average depth: 20.5 m). On-going monitoring at these sites has since taken place every five years. Here, we describe spatial and temporal trends in reef benthic composition between 1997 and 2012 across 43 sites spanning 30 km of coastline and including these three main reef types (Figure 1). Our specific goals are to:

i) Assess and summarize differences in benthic composition among the different reef types,
ii) To describe changes in benthic composition over time for each reef type, and
iii) To identify environmental correlates of variability in coral reef benthic composition.

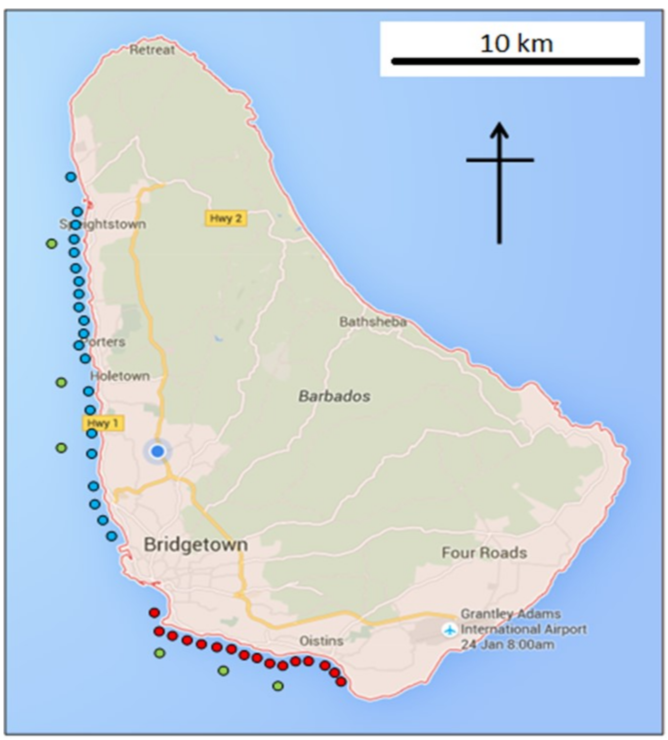

Figure 1. Location of the 43 monitoring sites with permanent reef plots along the west and south coasts of Barbados (W.I.) as part of the Barbados Reef Survey Programme (BRSP). Red dots indicate the location of shallow patch reefs on the south coast (n = 16); blue dots indicate the location of shallow fringing reefs on the west coast (n = 21); green dots indicate the location of deep bank reefs on both coasts (n = 6).

At each site, one 20 m x 10 m permanent monitoring plot was established and divided into ten 10 m transversal sections (each 2 m wide). Data collection involved using a point-contact method; a chain was laid along the contour of the mid-line of each transversal section and the substrate under the chain was identified (to the highest taxonomic level possible) and recorded at 10 cm intervals. For the analyses, data across the ten sections of each plot were combined to yield a single aggregate value per benthic component per permanent plot. Data were also pooled within nine broad functional / taxonomic groups:

i) Large massive corals,
ii) Small weedy corals,
iii) Fire corals,
iv) Macro-algae,
v) Turf algae,
vi) Crustose coralline algae (CCA),
vii) Clionid (excavating) sponges,
viii) Erect sponges and
ix) Encrusting sponges.

Thus, our final dataset involved 172 observations (n = 43 sites x 4 survey periods) for each of the nine aforementioned benthic groups.

We used Non-Metric Multidimensional Scaling (NMDS) to visually assess variability in benthic composition among reef types and over time. We used Permutational Multivariate Analyses of Variance (PERMANOVA) to test for significant differences in benthic composition among reef types and over time.

The NMDS and PERMANOVA jointly confirmed strong differences in benthic cover composition among the three reef types (Pseudo-F = 16.82; d.f. = 2,40; *p*-value = 0.001). These differences mainly reflected an increasing contribution of large-sized massive corals (versus fire and small weedy corals) to overall coral cover as we moved from the west coast fringing reefs, through the south coast patch reefs, to the bank reefs of both coasts (Figure 2a; note mainly the variability along the NMDS1 axis). This gradient positively correlated with increases in depth and overall coral cover (from an average 16% coral cover on the west coast fringing reefs, through 21% on the south coast patch reefs, to 27% on the bank reefs).

The data also support that all three reef types were significantly affected by the 2005 mass-bleaching event, which had a measurable effect on Barbados' corals (Oxenford et al. 2007, Oxenford et al. 2008). Indeed, the PERMANOVA identified significant differences in benthic composition between 2002 and 2007, the only interval between monitoring periods in which this was simultaneously the case for all reef types ($p \leq 0.009$; Figure 2b).

Furthermore, the NMDS indicated that temporal trends in benthic composition between 1997 and 2012 differed among reef types, with notable increases over time in macro-algae and excavating sponges on both the fringing reefs of the west coast and the bank reefs, but not on the patch reefs of the south coast (Figure 2b). Thus, the data suggested divergent temporal trajectories in benthic composition among reef types.

In summary, there are strong differences in benthic composition among the fringing, patch and bank reefs of

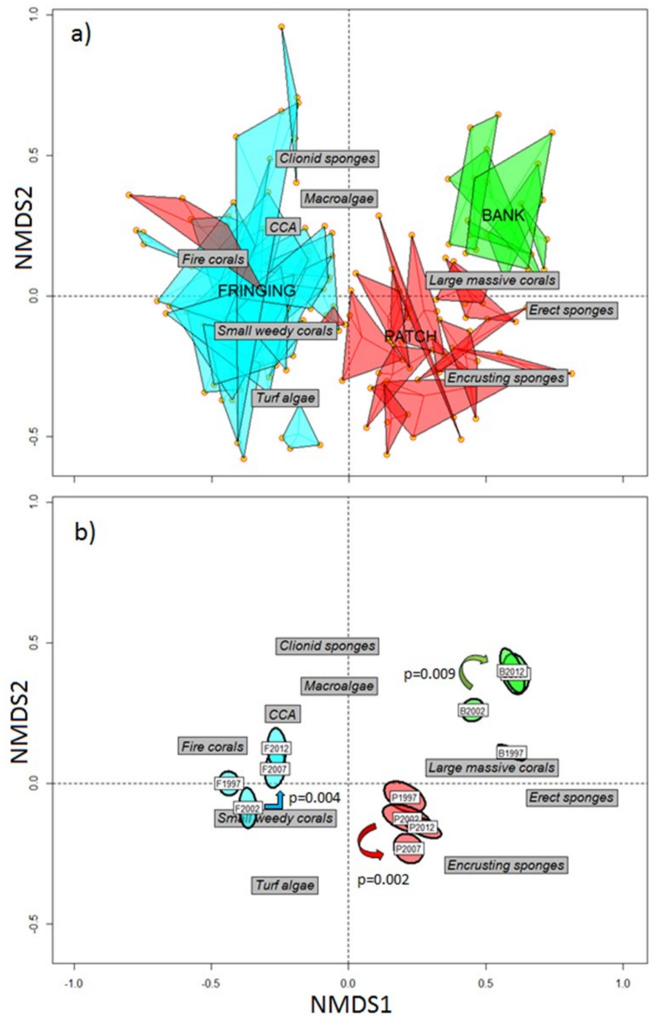

Figure 2. Non-Metric Multidimensional Scaling (NMDS) biplots showing the scores of 43 sites measured four times between 1997 and 2012 (N=172). Coloured polygons in (a) delineate the four repeated measurements (1997, 2002, 2007, 2012) for each of 43 sites; blue polygons represent the fringing reefs of the west coast; red polygons represent the patch reefs of the south coast; green polygons represent the deep bank reefs of the both coasts. Coloured circles in (b) represent the standard error around the centroid for a given reef type during a given monitoring year (i.e. 1997, 2002, 2007, 2012); blue circles represent the fringing reefs of the west coast; red circles represent the patch reefs of the south coast; green circles represent the deep bank reefs of the both coasts; the year corresponding to each circle is indicated in white labels. Grey labels in (a) and (b) indicate the loadings of the nine substrates on the ordination plot. The p-values shown in (b) were obtained after testing for differences in benthic composition between 2002 and 2007 for a given reef type.

Barbados, driven by total coral cover and relative abundance of large-massive corals and associated with depth. The three reef types also exhibit different trajectories over time, with fringing and bank reefs showing signs of more rapid degradation. Importantly, most of the variability in benthic composition over time manifests itself among reef types (rather than within reef types). The latter suggests that environmental drivers of reef change over time along Barbados' coastlines operate over broad spatial scales (i.e. distances ≥10 km), which is an important consideration for management.

KEYWORDS: Barbados, long-term monitoring, coral reef

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