Long-term dynamics of coral reefs in St. John, US Virgin Islands

Abstract In this study, long-term (1987–1998) dynamics are described on a local scale (<20 km) for coral reefs in St. John, US Virgin Islands, which are located in a marine protected area (MPA). The study consists of two sites (Yawzi and Tektite) which were selected in 1987 based on relatively high coral cover (=32%), and six sites that were randomly selected in 1992. Over 12 years, mean coral cover at Yawzi (9 m depth) changed significantly, declining from 45 to 20% cover between 1987 and 1998 (a 56% reduction). Less than 1 km away at Tektite (14 m depth), coral cover also changed significantly, but here it increased 34% (from 32 to 43% cover). Over the same period, macroalgal cover showed a significant upward trend at both sites, increasing from 2 to 26% at Yawzi, and from 6 to 13% at Tektite. The random sites (7–9 m depth) differed from the initial sites in both community structure and dynamics. Mean coral cover at the random sites (~8%) was less than one third of that at Yawzi and Tektite, and varied significantly among sites and years in an idiosyncratic pattern. The percentage cover of macroalgae and the pooled coverage of crustose coralline algae, algal turf, and bare space showed a strong site × time interaction, illustrating that the sites differed in dynamics, but that the differences varied among times. Thus, as has been reported elsewhere in the Caribbean, serious reef degradation has occurred on at least one reef in St. John, but the patterns of change vary markedly on a kilometer-wide scale. In comparison with other long-term studies of Caribbean coral reefs, the degradation of a coral reef in an MPA around St. John is noteworthy since there are few local anthropogenic disturbances that can be held responsible for the decline. The strong possibility that large-scale events such as hurricanes and global warming have played a pivotal role in the decline of at least one reef in St. John emphasizes the need to embrace landscape- and regional-scale phenomena in order to understand and manage local coral reef dynamics. The occurrence of small patches of relatively healthy reef (i.e., at Tektite) appears trivial in comparison to region-wide reef decline, but such anomalies should be studied further because of their potential roles as refugia for corals and reef-associated taxa.

Keywords Corals · Dynamics · Virgin Islands · Ecology · Scleractinians

Introduction

Coral reefs consist of a spatio-temporal mosaic of patches at different stages of recovery depending on the magnitude and periodicity of disturbances (Grasse 1973; Done et al. 1991; Connell et al. 1997). Individual patches often follow disparate trajectories (Connell et al. 1997; Bythell et al. 2000) that are determined by the interwoven effects of local and regional processes (Done et al. 1991; Karlson and Cornell 1999), together with the history of individual patches (Witman 1992; Tanner et al. 1996). Turmoil in coral reef community structure plays an important role in maintaining diversity (Connell 1978), but can also result in alternative stable states (Knowlton 1992) where taxa other than corals – usually macroalgae (Hughes 1994) – dominate community structure. Intrinsic variability notwithstanding, changing modes and increasing tempos of coral mortality have created widespread agreement that a global loss of coral reefs has occurred (Knowlton 2001), and that further losses are inevitable (Hoegh-Guldberg 1999; Knowlton 2001).

Some of the best examples of reef degradation are found in the Caribbean (e.g., Hughes 1994; Aronson and Precht 2001), where data are available for multiple locations (e.g., Connell 1997; Smith et al. 1997). In the best known of these – Jamaica – more than two decades
of monitoring have recorded the widespread degradation of coral reefs along hundreds of kilometers of coast (Hughes 1994; Aronson and Precht 2001). Until recently there have been few signs of a reversal of these declines (Edmunds and Carpenter 2001; Knowlton 2001) and, instead, similar transitions from coral to macroalgae have occurred elsewhere (Ginsburg 1993). Analyses of coral reef community structure at multiple locations have enhanced the ability to generalize from local to regional scales (Ogden et al. 1994; Murdoch and Aronson 1999; Aronson et al. 1998), and have provided unequivocal evidence of ongoing Caribbean-wide reef decline. However, in addition to revealing the geographic extent of reef degradation, larger-scale studies often have identified areas of less degraded reef (Edmunds and Bruno 1996; Murdoch and Aronson 1999; Bythell et al. 2000). For example, Dairy Bull reef in Jamaica is ~2 km east of the degraded reefs of Discovery Bay, yet in 1995 coral cover was 11.5-fold higher at Dairy Bull (23%) compared to Discovery Bay (2%) (Edmunds and Bruno 1996). At Dairy Bull, both coral cover and three-dimensional reef structure are dominated by colonies of *M. annularis* (57% of the coral; Aronson and Precht 2001) that survived the destructive effects affecting adjacent reefs. In fact, many of the colonies of *M. annularis* are old enough (>50 years) to have been well established long before the damaging effects of Hurricane Allen initiated the demise of Jamaica reefs in 1980 (Aronson and Precht 2001). Anomalous patches of healthy coral appear trifling against the backdrop of region-wide reef decline, yet their potential significance must be gauged in the context of their overall abundance and ecological impact. Unfortunately, in both these regards the data currently available from the Caribbean are incomplete, notably because many reefs remain largely undescribed, and long-term data (i.e., >10 years) are relatively rare (Connell 1997). Thus, it is unknown whether patches of healthy reef amount to a biologically significant area within the region, or whether the patches differ in dynamics from adjacent areas, or simply are following the same declining trajectory at a slower rate.

The present study describes the dynamics of coral reefs in one relatively pristine location – St. John, US Virgin Islands – where patches of relatively high coral cover are common. The study reefs are on the south coast of the island, and first were described by John Randall in the late 1950s and 1960s (e.g., Randall 1961) and by scientists in the Tektite underwater laboratory (Collette and Earle 1972). Thereafter, few investigators have worked in this location [many are cited in Rogers and Teytaud (1988) and Rogers and Beets (2001)], with the most consistent efforts organized through the Virgin Islands National Park (VINP) (e.g., Rogers 1985, 1999). Despite this attention, there are published long-term data only describing coral reef community structure at one site on the south coast of St. John, beginning in 1989 (Rogers et al. 1991, 1997). The current project began in 1987 with the goal of quantifying long-term changes in coral reef communities following the effects of the first Caribbean-wide coral bleaching event of the same year (Roberts 1987). Over the last 15 years the study has been invaluable in providing the ecological context for the development of testable hypotheses concerning the mechanisms of change in coral populations. In this paper I first describe long-term changes on two reefs <1 km apart, which initially were selected because they had unusually high coral cover for St. John. Second, I ask to what extent the dynamics on these two reefs are representative of coral communities at a slightly larger scale (~4.5 km) along the same coastline. In the terminology of Mittelbach et al. (2001), the present study focuses on a single local scale (0–20 km), with the study reefs embedded in a landscape (20–200 km) that is part of the regional scale (200–4,000 km) represented by the entire Caribbean.

The longer-term analysis is generated from 12 years of data (1987–1998) at two sites that initially were selected to quantify the effects of coral bleaching on reefs with relatively high coral cover. The analysis at a larger spatial scale is generated from seven years of data (1992–1998) at six sites that were selected at random. This sampling regime was developed over several years in order to increase the spatial perspective of the original study by adding sites that were selected with no a priori criteria concerning coral cover. The goals of expanding the study were to obtain a more synoptic view of the coral communities along the south coast of St. John, and to provide a representative ecological context to subjectively interpret the changes in community structure at the initial two sites. Accordingly, the experimental design reflects the evolution of the project within the constraints of funding and accessible study sites, rather than the requirements for a statistical comparison of site selection procedures, which was not the goal of the study. In order to describe local patterns of variation in the coral reef community structure, I present a coarse-grained analysis of the percentage cover of four major components of the benthic community.

**Methods**

**Study sites**

This research is based on eight sites that are at intermediate depths (7–14 m), within the VINP and Biosphere Reserve, and between two rocky headlands – White Point and Cabritte Horn – enclosing Great Lameshur, Little Lameshur, and Europa Bays (Fig. 1). These bays are adjacent to an undeveloped watershed, protected from unregulated boating and fishing [although both occur (Garrison et al. 1998)], and are relatively free of anthropogenic disturbances (Rogers and Teytaud 1988). Coral reefs at <5 m depth are characterized by large amounts of crustose coralline algae, algal turf, vacant space, encrusting *Millepora*, low densities of small coral colonies, and a variety of sessile organisms adapted to wave-swept conditions (Witman 1992; Edmunds 1999, 2000). Between 5 and 15 m depth, coral cover generally is low (<10%), except for areas rich in *Montastraea annularis* and *Montastraea* spp. where coral cover can reach 20–40%.