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Condition assessment of coral reefs of two marine protected areas under different regimes of use in the north-western Caribbean

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ABSTRACT

Knowledge of the current condition of reef communities is essential for the implementation of marine protected areas (MPAs). In 2014, we assessed the conditions of reefs of two MPAs in the Caribbean: Guanahacabibes National Park (Guanahacabibes), Cuba and Costa Occidental de Isla Mujeres - Punta Cancun - Punta Nizuc National Park (Cancun), Mexico. Within each of the two MPAs studied, we examined two reefs. We took data from fifteen 10-m long transect lines. Indicators included coral cover, diameter of coral colonies, old and recent coral mortalities and coral diseases. The abundance of coral recruits and the density of *Diadema antillarum* were assessed in 1 m^2 quadrats. The cover of groups of macroalgae was obtained from 25 × 25 cm quadrats. Our data illuminated distinct stages in the loss of reef structure similar to what has been seen by other investigators, particularly the change in the dominance of coral species and the deterioration of the three-dimensional structure of reefs. The Cuevones site (in Cancun), which has been closed to tourism for fifteen years, remains dominated by corals, with a high coral cover (33.36%), but with a species dominance (principally *Porites astreoides*), different from the lead species observed in the Caribbean a few decades ago. The reefs of Guanahacabibes (Laberinto and Yemaya) subject to a low diving intensity appear to be at an earlier stage of changes than the Cancun reefs. The coral indicators remains similar to previous reports, so perhaps this can be slowed or reversed. Meanwhile, Manchones in Cancun showed the lowest coral cover (11.49%) and the lowest recruit density (0.6 recruits/m^2), probably due to the joint action of the natural pressures and to the heavy influx of visitors these reefs receive.

1. Introduction

Coral reefs are the most diverse marine ecosystem with millions of plant and animal species across the globe (Hoegh-Guldberg, 2004). Coral ecosystems around the world sustain roughly 850 million people living within 100 km of coral reefs, who derive benefit from reef productivity such as food, employment, coastal protection, and tourism (Burke et al., 2011). Such benefits may be compromised as coral reefs are increasingly threatened and destroyed (Hoegh-Guldberg, 2014).

The 26,000 km^2 of coral reefs in the Caribbean region, approximately 7% of the shallow reefs of the world, is at a crossroads (Burke et al., 2011). The coral cover has fallen sharply, from about 50% in the 1970s to 10% in the first decade of the 2000s (Gardner et al., 2003). At the same time, the dominant species have changed, favoring smaller weedy coral species like *Porites astreoides* and *Agaricia agaricites* that are more resilient and have more

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effective reproductive strategies (Perry et al., 2015). The main species responsible for the three-dimensional structure of the reefs, have been seriously affected (Newman et al., 2015). Mass mortalities of species of the genus *Acropora* have been reported since the 1980s (Aronson et al., 2008). Similarly, species of the *Orbicella* complex have declined dramatically in abundance and live coverage (Porto-Hannes et al., 2015). As a result, the architectural complexity of Caribbean reefs has been compromised, resulting in a continued flattening of reefs throughout the region (Alvarez-Filip et al., 2009). Furthermore, the rates of sexual recruitment and survival of coral recruits and juveniles have decreased (Quinn and Kojis, 2005; Edmunds et al., 2015).

At present, the Caribbean is regarded worldwide as the reef region with the lowest resilience (Roff and Mumby, 2012). This situation has serious consequences for reef biodiversity, ecosystem functioning and related environmental services (Alcolado et al., 2009; Micheli et al., 2014; Pratchett et al., 2014). Despite widespread recognition that coral reefs in the Caribbean are extremely vulnerable, information regarding the mechanisms by which reefs decline is still limited, thus hampering conservation efforts (Jackson et al., 2014).

The principal known causes of deterioration of the Caribbean reefs include those of local anthropogenic origin such as land-based sedimentation, pollution, overfishing, mechanical damage and massive tourism (Kennedy et al., 2013). This last activity is of particular concern for the Caribbean nations due to the high tourism dependence of local economies (Schuhmann and Mahon, 2015); healthy reefs are essential to healthy tourism in many of the islands. Damage to reefs caused by tourism includes pollution, direct contact of tourists and anchor damage (Diedrich, 2007). In addition, global climate change is now seen to be a major long-term threat to coral reefs (McClanahan et al., 2014). Increasing sea temperatures leads to mass coral bleaching events (Kemp et al., 2014). Physical damage to coral reefs is increasing as a result of higher frequency and intensity of hurricanes (Marciano et al., 2015). Ocean acidification is thought to affect the reproductive success and recruitment of corals, and compromises the construction and integrity of their calcium carbonate skeletons (Andersson and Gledhill, 2013). The combination of anthropogenic stressors and severe climatic disturbance events can generate cycles of decline and recovery, and in some extreme cases, community-level phase shifts (Williamson et al., 2014).

The implementation of Marine Protected Areas (MPAs) arose to enhance conservation of coral reefs (Keller et al., 2009). These areas can help restore ecosystem structure and functioning and protect marine biodiversity and associated ecosystem services (Selig and Bruno, 2010). A key economic argument for setting aside MPAs is their attraction to tourists seeking a high quality diving experience. (Green and Donnelly, 2003). For MPAs to maintain biological integrity of coral reefs while still providing economic benefits for tourism, management plans that provide long term sustainable use of reef communities need to be applied (Hammerton and Bucher, 2015).

MPAs are thought to be able to increase resilience of coral reefs by directly mitigating local stressors like massive tourism, overfishing and nutrient inputs (Grimsditch and Salm, 2006). Unfortunately, coral loss that is driven by regional or global stressors like climate change and coral disease outbreaks seems unlikely to be mitigated by MPAs or other local management actions (Graham et al., 2008).

The aim of this study was to determine the coral communities condition in reefs within two MPAs of the Caribbean (Mexico and Cuba), with different use intensity. Based on the actual condition of the studied reefs we contrasted them with other studied reefs in order to assess their status within the regional context of overall changing path of Caribbean reefs.

2. Materials and methods

2.1. Site description

The work was carried out in two Caribbean MPAs that have been established for more than 10 years: 1) Guanahacabibes National Park (2001) in Cuba and 2) Costa Occidental de Isla Mujeres – Punta Cancun – Punta Nizuc National Park (1996) in Mexico (Fig. 1). Guanahacabibes is managed by the Ministry of Science, Technology and Environment of Cuba. Inside the park, there is an International Diving Center with more than 50 diving spots, managed by Gaviota Tours SA. In 2012, the park's administration established a carrying capacity limit of between 4380 and 6570 visitors per year per diving spot (12–18 divers/day per diving spot). Nevertheless, the number of visits to the diving spots all together has never exceeded 5000 divers in a year.

In contrast, the Mexican MPA has a high influx of tourists due to its close proximity to the Cancun city and tourist facilities. This area is managed by the National Commission of Natural Protected Areas of Mexico. The park authorities have set a limit on the number of boats that can remain inside the area (over 600 for the 3 polygons of the park). So far, however, there are no carrying capacity limits established by diving spot. The park staff monitors the tourism activities to establish appropriate carrying capacity limits under its management program (CONANP, 2014), including restricting access to certain reefs.

In both MPAs, fishing, anchorage, disposal of solid waste and bilge are prohibited, to enhance the conservation of their coral reefs. In Guanahacabibes there are other important conservation targets, but coral reefs is one of the most important.

Data were collected at two sites in Guanahacabibes: Laberinto and Yemaya, and two sites in Cancun: Cuevones and Manchones (Fig. 1, Table 1). At the Guanahacabibes sites, scuba diving intensity is low (15 divers/day). In Cancun, Cuevones has been closed to any tourist activity since 1997, following the impact of a ship grounding. The other site in Cancun, Manchones, receives more than 100 visitors every day for diving or snorkeling (CONANP, 2014). In both sites of Cancun a reef restoration project is underway, although samples were not taken in the area where restoration measures are being implemented. The area affected by the ship grounding in Cuevones was not included in this study.

In both MPAs previous studies have been undertaken in the studied sites. In Guanahacabibes, Yemaya, one of the most visited dive spots, has been one of the most studied. In 2004, Caballero et al. (2007) found 13% live coral cover, as well as a density of six colonies/10 m. The old mortality reported by these authors reached 23%. In the same year González-Ferrer et al. (2007) reported 17 species for Yemaya. Perera et al. (2013) found in 2010, 14% of coral cover in Yemaya and 16% in Laberinto. All these studies detected *A. agaricites* as the dominant species in Yemaya and Perera et al. (2013) detected the complex *Orbicella faveolata* as the dominant in Laberinto. In Cancun, Carriquiry et al. (2013) detected 10 species of corals in Cuevones with 26% of coral cover and 13 species in Manchones with 27% of coral cover.

2.2. Field data collection

Data were gathered in February 2014 in Guanahacabibes and in April 2014 in Cancun. Reef sites were evaluated for hard coral community composition, live coral cover, dead coral cover, macroalgae functional groups cover and height, recruits composition and abundance and *Diadema antillarum* density. To