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Temporal dynamic of reef benthic communities in two marine protected areas in the Caribbean

Susana Perera-Valderrama[a,*], Héctor Hernández-Arana[b,*], Miguel-Ángel Ruiz-Zárate[b], Pedro M. Alcolado[c], Hansel Caballero-Aragón[d], Jaime González-Cano[e], Alejandro Vega-Zepeda[b], Isael Victoria-Salazar[b,f], Dorka Cobián-Rojas[g], Juliett González-Méndez[h], Zaimiuri Hernández-González[i], Elena de la Guardia-Llansó[j]

[a] *Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Subcoordinación de Monitoreo Marino, Laboratorio de Sistemas Arrecifales, UABCS, Carretera al Sur Km 5.5. Col. El Mezquitito, 23080, La Paz, B.C.S., Mexico*
[b] *Departamento de Sistemática y Ecología Acuática, El Colegio de la Frontera Sur, Avenida del Centenario, Km 5.5, 77014 Chetumal, Quintana Roo, Mexico*
[c] *Instituto de Oceanología, Calle 1ra. No. 18406 e/184 y 186, Reparto Flores, 11300 Playa, La Habana, Cuba*
[d] *Acuario Nacional de Cuba, Avenida 1ra y 60, Miramar, 11300 Playa, La Habana, Cuba*
[e] *Comisión Nacional de Áreas Naturales Protegidas, Boulevard Kukulcán Km 4.8, Zona Hotelera, Benito Juárez, 77500 Cancún, Quintana Roo, Mexico*
[f] *Departamento de Ecología y Recursos Naturales, Facultad de Ciencias, Universidad Nacional Autónoma de México, Cd. Universitaria, México 04510, Ciudad de México, Mexico*
[g] *Parque Nacional Guanahacabibes, Centro de Investigaciones y Servicios Ambientales (ECOVIDA), La Bajada, 24150 Sandino, Pinar del Río, Cuba*
[h] *Centro Nacional de Áreas Protegidas, Calle 18A, No. 4114, Miramar, 11300 Playa, La Habana, Cuba*
[i] *Parque Nacional Cayos de San Felipe, La Coloma 20100, Pinar del Río, Cuba*
[j] *Laboratorio de Ecología de Ecosistemas de Arrecifes Coralinos, Dep. de Recursos del Mar, CINVESTAV IPN-Unidad Mérida, Ant. Carr. a Progreso Km. 6, A.P. 73 Cordemex, Yucatán 97310, Mexico*

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A B S T R A C T

This study assessed the coral reef condition of two marine protected areas in the Caribbean: Guanahacabibes National Park, Cuba, and Costa Occidental de Isla Mujeres-Punta Cancun-Punta Nizuc National Park, Mexico, in a two-year period. The analyzed indicators for corals were live coral cover, diameter and height of the colonies, ancient and recent mortalities and abundance of recruits, which were evaluated in quadrats of 1 m^2. In addition, it was estimated the coverage by morphofunctional groups of macroalgae in 25 × 25 cm quadrats and the density of the *Diadema antillarum* urchin in 1 m^2 quadrats. The results showed differences between countries at broad spatial scales (hundreds of kilometers). Reefs of both MPAs seem to be in different stages of changes, which have been associated with deterioration of Caribbean reefs, toward the dominance of more resistant, non-tridimensional coral species, causing a decrease of the reef complexity that may leads to the reefs to collapse. At scales of kilometers (within MPAs), a similar pattern was found in reefs of GNP-Cuba and different trends were observed in reefs of CNP-Mexico. The observed differences between CNP-Mexico sites appear to be associated with the current tourism use patterns.

1. Introduction

Caribbean coral reefs account for only 7% of the world's total coral reef area but play a vital role in the economy of the region and in the livelihoods of millions of people who depend on the reefs for income and employment (Jackson et al., 2014). However, because of the impact of human and natural disturbances, coral reefs' both biodiversity and ecosystem functioning have suffered significant impacts over recent years (Díaz-Pérez et al., 2016). In comparison to the 1970s, live coral cover across the Caribbean has been reduced by half (Gardner et al., 2003; Schutte et al., 2010). Consequently, the structural complexity of the reef has been reduced and quickly flattened (Álvarez-Filip et al., 2009), and rates of sexual recruitment and survival of recruits have declined (Edmunds et al., 2015).

Coral reef decline is a result of interactions of multiple factors of local and global scope (Knowlton and Jackson, 2008). Global factors, such as increased sea temperature and ocean acidification, combined with each other and local environmental stresses such as fishing, have altered the state of coral reefs by disrupting the physiology, gene expression, and behavior of corals and other organisms within this system

* Corresponding authors.
E-mail addresses: sperera@conabio.gob.mx (S. Perera-Valderrama), hhernand@ecosur.mx (H. Hernández-Arana).

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(Mora et al., 2016). Thus, the threats to reef functioning have multiple and conflicting effects on functionally similar groups of species and their interactions (Pendleton et al., 2016).

Unsurprisingly, the cover of most benthic organisms on coral reefs shows considerable variation across the Caribbean region (Mumby et al., 2014). Accordingly, knowledge of the dynamics and current condition of individual reef communities is essential for the implementation of strategies for conservation and restoration.

Marine protected areas (MPAs) are a commonly used management tool that has proved to be effective in conserving coral reef biodiversity, restoring coral reef food webs, and replenishing the fishing stocks in neighboring areas through ‘spillover’, among other benefits (Mellin et al., 2016). However, a 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 (Selig and Bruno, 2010). Thus, it is necessary to evaluate the effectiveness of these conservation strategies to effectively implement them, ensuring where possible, the increase in the resilience of individual reefs, to deal with global stressors.

We planned this work to determine the reef condition in two marine protected areas in the Caribbean (in Cuba and in Mexico) by evaluating possible temporary short-term changes in variables of reef benthic groups (corals, macroalgae, and *Diadema antillarum*).

2. Materials and methods

2.1. Study areas

We chose two Caribbean MPAs, one in Mexico and the other one in Cuba. Guanahacabibes National Park in Cuba was established in 2001 and Costa Occidental de Isla Mujeres – Punta Cancun – Punta Nizuc National Park in Mexico was established in 1996. Both MPAs are administered based on a management plan (Márquez et al., 2013; CONANP, 2008).

The Guanahacabibes National Park (GNP-Cuba) is located in the Pinar del Rio province at the western end of Cuba. The Ministry of Science, Technology and Environment of Cuba manages this area, which includes 39,830 ha, of which 15,950 are marine on the south of the Guanahacabibes Peninsula (Fig. 1). The main use of this marine area is recreational diving in coral reefs, conducted by the International Diving Center Maria La Gorda. The average diving intensity per point is 6000 divers a year, according to the database of this center (Márquez et al., 2013). In GNP, the reefs are fringing or coastal ones, with a unique terrace extending down to a deep escarpment (deep fore reef), sometimes presenting a cursory escarpment or a first shallower fore reef.

The Costa Occidental de Isla Mujeres-Punta Cancun-Punta Nizuc National Park (CNP-Mexico) is located northeast of the state of Quintana Roo, Mexico. It comprises a fully marine area of 8,673 ha distributed in three separate polygons. Polygon 1 covers the western coast of Isla Mujeres; polygon 2 is located in Punta Cancun, and polygon 3, in Punta Nizuc (Fig. 1). Due to its proximity to the tourist resort of Cancun, the park receives a heavy influx of visitors, especially for nautical activities such as scenic tours, sailing, yachting and diving. The record number of visitors overall, since 1996, has remained stable, with around 750,000 tourists a year (CONANP, 2014). The reefs are fringing and constitute the northern part of the Mesoamerican Barrier Reef System.

2.2. Data collection

In GNP, Cuba, the selected study reefs were Laberinto and Yemaya. At these reefs, SCUBA diving intensity is low (15 divers/day) (Márquez et al., 2013). Data were collected every four months during a two-year period (seven times at each site). Samplings were done during February and October of 2014 and 2015.

In CNP-Mexico, field trips were accomplished in April and November 2014 and April and August 2015. In this area, the studied reefs were Cuevones and Manchones. Cuevones has remained closed to any tourist activity since 1997, because of the impact of a ship grounding (CONANP, 2008). Manchones receives more than 100 visitors every day for diving or snorkelling (CONANP, 2014).

In every reef, eight 1 m × 10 m belt transects were permanently marked, as guidelines for locating the ten sampling units of 1 m^2 (Fig. 2). The belt transects were placed always keeping a distance of 5 m or greater between each other.

At each belt transect (Fig. 2), five 1 m^2 quadrats were randomly selected, for a total of 40 sampling units per reef, in each sampling date. At each quadrat, we identified all stony coral colonies at the species level. For adult corals (≥ 5 cm diameter), we registered maximum and perpendicular diameter, height, and percentages of surface with ancient mortality and recent mortality as well as the presence of microbial diseases and bleaching (Lang et al., 2010). For juvenile corals (≤ 4 cm in diameter) only the maximum diameter was recorded (Moulding, 2005). At each selected 1 m^2 quadrat, sea urchins *D. antillarum* were counted (Santiago and Soto, 2013).

To assess macroalgae coverage, we divided each sampled quadrat of 1 m^2 into 16 quadrats of 25 × 25 cm (Fig. 2). One 25 × 25 cm quadrat was randomly selected to visually determine the cover data of five morpho-functional groups: fleshy macroalgae, peyssonnelid algae, crustose coralline algae, calcareous macroalgae and turf algae (Lang et al., 2010).

2.3. Data analysis

Overall averages of coral colonies density, live coral cover and percentages of the area affected by both ancient and recent mortalities were estimated. The density of juvenile corals, as well as the density of *D. antillarum* in 1 m^2, were determined. The averages of coral colonies density and live coral cover of the most abundant species of adults and juveniles were also estimated. The bottom cover percentage by morpho-functional groups of macroalgae was also determined. To evaluate the differences between the mean values of colonies density, live coral cover, and juvenile density, mixed model ANOVAs (factorial/nested) were performed. The factors were MPA-Country (fixed), Site nested in MPA-Country (random) and Date (fixed). Community structure of adults' coral referring to colonies density and live coral cover, as well as coral juveniles densities and the cover of macroalgae groups were analyzed using Permutational Multivariate Analysis of Variance (PERMANOVA) (Anderson et al., 2008). The factors considered were the same used for the mixed model ANOVAs.

To assess how distinct the reefs of the studied MPAs were from one another in the multivariate space, we performed a Discriminant Canonical Analysis of Principal Coordinates (CAP). Constrained multivariate methods based on a cross-validation procedure, such as CAP use an *a priori* hypothesis to produce ordination plots. The plots allow us to detect patterns masked by overall dispersion in unconstrained methods such as the multidimensional scaling (Anderson and Willis, 2003).

3. Results

We identified 38 coral species in GNP-Cuba, and 26 species in CNP-Mexico. In GNP-Cuba 36 and 35 species were detected in Laberinto and Yemaya, respectively, while in CNP-Mexico 23 and 20 species were observed in Cuevones and Manchones correspondingly (Appendix C).

The average values of colonies density and live coral cover showed very similar behavior among sites of GNP-Cuba (Fig. 3). The average values of coral colonies' density in this MPA ranged from 16.92 ± 4.73 cols/m^2 in Laberinto, October/14 and 12.55 ± 6.33 cols/m^2 in Yemaya in October/15. The detected values of live coral cover were among 16.88 ± 9.20 cm^2 × m^2 in Laberinto in February/14 and 24.80 ± 20.40 cm^2 × m^2 in Yemaya in October/14.