



Coral reef health and management on the verge of a tourism boom: A case study from Miches, Dominican Republic



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ABSTRACT

The Miches Municipality lies in the second poorest province in the Dominican Republic, and its inhabitants rely heavily on nearby coral reefs for food and livelihoods. With the sudden influx of tourism from the completion of a new highway, now is a crucial time to ensure that future tourist development in this region is locally driven and environmentally responsible. As coral reefs are a foundation of Miches' identity, economy, and natural wealth, they play an integral role in the realization of this goal. This study employed global reef monitoring protocols to conduct the first-ever quantitative health assessment of Miches' reefs in order to guide future management practices. Surveys of multi-taxa indicator species were conducted alongside assessments of coral bleaching, disease prevalence, and evidence of anthropogenic impacts. Key findings include extremely low abundances of fishery-targeted species, high prevalence of diseased coral, anchor damage at nearly every site, and high abundances of indicator species for nutrient-based pollution such as fertilizers and raw sewage. Deeper, offshore reefs exhibited better health than shallow, inshore reefs, though they were still more degraded than comparable reefs in Dominican marine protected areas. Overall, Miches reefs are highly threatened by four main factors: overfishing, land-based pollution, human-related structural damage, and coral bleaching. To improve the well-being of the region's coral reefs and the communities that depend on them, an adaptive management plan is recommended that encompasses strong fisheries regulations, basic yet consistent monitoring efforts, and the integration of land-based and marine management practices.

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1. Introduction

Coral reefs are some of the planet's most complex and diverse ecosystems, and are essential to the well-being of human populations worldwide. In the Caribbean region alone, coral reefs provide up to \$5.8 billion annually through tourism, fisheries, and coastal protection (Burke et al., 2011). However, these ecosystems are also subject to numerous natural and anthropogenic stressors (Halpern et al., 2015), and over 75 percent of the reefs in the Caribbean are now under direct threat from human activities, with more than 30 percent classified under high threat (Burke et al., 2011).

Caribbean coral reef health has declined dramatically in the last 40 years, driven by human population growth, overfishing, coastal

pollution, climate change, and invasive species (Jackson et al., 2014). Coral cover has declined by more than 80% since 1970, while macroalgae cover has almost tripled within the same time period, marking a widespread and detrimental phase shift from coral-dominated to macroalgae-dominated ecosystems (Gardner et al., 2003; Hughes et al., 2007; Jackson et al., 2014). These phase shifts may reduce a reef's ability to provide essential ecosystem services, including coastal protection and tourism, while also negatively affecting many commercially valuable fisheries (Graham et al., 2014). Decades of overfishing have also reduced the size and abundance of the majority of targeted fish in the region (Ginsburg and Lang, 2003; Hodgson, 1999; Jackson et al., 2014), and invasive Indo-Pacific red lionfish (*Pterois volitans* and *P. miles*), capable of reducing small native fish biomass by greater than 50% one year after colonization of a new reef, are now widely established across the Caribbean (Green et al., 2014). Introduced pathogens responsible for *Acropora* coral die-offs (White Band Disease) and the massive 1983 *Diadema antillarum* die-off have also wreaked havoc on Caribbean reef ecosystems in recent decades (Aronson

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and Precht, 2001; Hughes et al., 1985). When compounded by the effects of climate change, all of these factors have major implications for economic and human well-being of the region (Hoegh-Guldberg et al., 2007; Hoegh-Guldberg and Bruno, 2010).

However, wide variability in the health of Caribbean reefs provides reason for hope. Some locations have fared considerably better than others, such as Bermuda, Grand Cayman, southwest Curaçao, and Flower Garden Banks in the Northern Gulf of Mexico (Jackson et al., 2014). Although the severity of threats at these locations varies, the main factor contributing to their relative health is the historical implementation of coral reef management strategies that address local threats – specifically, overfishing, overdevelopment, and coastal pollution (Hughes et al., 2010; Jackson et al., 2001; Knowlton and Jackson, 2008; Pandolfi et al., 2005). Strong fisheries regulations, basic yet consistent monitoring efforts, and the integration of land-based and marine management practices can have a significant effect on the well-being of coral reefs and the communities that depend on them (Jackson et al., 2014).

Located on the south side of the Samaná Bay of the Dominican Republic, the Municipality of Miches contains a population that relies heavily on nearby coral reefs for food and livelihoods (CODOPESCA 2010). The largest urban town that shares the name of the Municipality, Miches, has a population of 23,141, and is one of the poorest communities in the second poorest province in the Dominican Republic (CEES, 2007). The 15 fishing communities in the Municipality employ a diversity of fishing and harvesting techniques to intensively target marine organisms for food and income, and the local reefs are under intense fishing pressure (CEES, 2007, 2012). Additionally, there is no sewage treatment system, municipal water purification system, nor solid waste treatment system, and rivers and streams that flow directly onto reefs are widely used for waste disposal (Clary, 2008). Concern for the region's fisheries and other nature-based economies led to the development of this study, in collaboration with local community leaders and fishers. The economic and ecological well being of this region is inextricably linked, and so efforts to improve economic growth must address ecosystem health.

In tourism booms, undeveloped and rural coastal areas are often negatively affected by stressors such as discharge of sewage directly into rivers or coastal waters, accumulation of trash and waste in natural ecosystems, increased sedimentation and nutrient enrichment of coastal waters caused by unchecked run-off, clearing or degradation of mangroves and seagrass beds for development, physical damage to coral reefs caused by snorkelers, divers, and anchors, and in the most extreme cases, filling of lagoons and extracting limestone from coral reefs for development purposes (Gormsen, 1997; Cesar et al., 2003; Gil et al., 2015). Several marine management strategies have been used around the world to combat these pressures – many involve improved management of upstream and land-based practices like better wastewater treatment and agricultural methods, but commonly used marine management strategies include restrictions on anchoring and moorings, the establishment of zoned marine protected areas with designated spaces for tourism-related recreation, promotion of sustainable eco-tourism, development of education and public awareness programs, and improved fisheries management practices (Gormsen, 1997; Hall, 2001; Cesar et al., 2003).

The Dominican Republic is one of the most popular tourist destinations in the Caribbean, with coral reefs supporting substantial dive tourism and sport fishing industries (Wielgus et al., 2010). In December 2014, the Bavaro-Uvero Alto-Miches Highway connected Miches with the popular tourist hub of Punta Cana to the east, opening Miches itself as a tourist destination. This highway can either support further environmental and economic decline, or aid in restoration and growth. This will be determined directly by

local management decisions made in the next few years. Already the region has seen a sharp increase in tourism development, which was personally observed by the authors of this study and has resulted in concern and action by local councils to address pressures such as higher levels of beach pollution after the now-heightened tourism influx on weekends. Concurrent dialogue in favor of sustainable economic growth through alternative livelihoods like ecotourism has also arisen in local communities. Now is a crucial time to put measures in place that ensure future tourist development in this region is locally driven and environmentally responsible, retaining the integrity of ecosystems, culture, and local communities in Miches. As coral reefs are a foundation of Miches' identity, economy, and natural wealth, they play an integral role in the realization of this goal.

This study arose in response to local concerns expressed by Miches' fishing communities for their fisheries and nature-based economy during a previous qualitative investigation (CEES, 2016). Here, we employ global reef monitoring protocols to conduct the first quantitative health assessment of Miches-area reefs, identify specific threats, and propose feasible strategies for their future management and sustainable use by local communities.

2. Methods

2.1. Survey sites

Taking results from our previous study's interviews into consideration (CEES, 2016), reefs with various levels of fishing activity were identified along the Miches Municipality coast using Google Earth satellite imagery (Fig. 1), and visited by a dive team to determine suitability for surveys. Twelve sites were ultimately selected, and subdivided by mean transect depth into “shallower” ($\leq 5\text{m}$, patch reefs) and “deeper” ($> 5\text{m}$, fore-reef slope) reefs. The majority of sites were located within a sheltered portion of Samaná Bay, with the exception of four reefs to the east of this area. GPS points were taken and visualized on Google Earth, where distance from shore, distance from the nearest river, and distance to the nearest population source was calculated for each site. Dive teams also performed preliminary impacts assessments, with divers recording observations of anthropogenic threats such as siltation, blast fishing, poison fishing, aquarium fishing, invertebrate harvest, sewage pollution, industrial pollution, and commercial, artisanal, and recreational fishing. Input from local fishermen confirmed whether each site was used for tourism and/or natural resource extraction. All sites were likely visited throughout the study period by fishermen, one small-scale dive tourism operator, and other community members, with some inshore sites known by the study authors to be visited daily.

2.2. Survey protocol

Surveys were conducted every four months over a two-year period from December 2009 to December 2011, following Reef Check protocols (see Hodgson, 1999). These protocols were selected because there was an established Reef Check program in the Dominican Republic, the protocols were feasible with limited funding, they were employed globally which allows for useful cross-regional comparisons, and with the proper amount of training, they produce high-quality data while simultaneously providing educational and recreational value to volunteer divers (Lewandowski and Specht, 2015). Data collectors for this study were open-water certified at minimum, and completed several pool and open-water dive skill training sessions in addition to Reef Check's standard Eco Diver training course.

Three surveys were completed during every site visit: a fish

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