Impacts of Coastal Development on the Resilience of Coral Reefs: Twenty Years of Monitoring from the Dominican Republic

Impactos del Desarrollo Costero en la Resiliencia de los Arrecifes de Coral: Veinte Años de Monitoreo en la Republica Dominicana

Impacts du Développement Côtier sur la Résilience des Récifs Coralliens: Vingt Ans de Suivi dans la République Dominicaine

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ABSTRACT

Coral reefs in the Dominican Republic currently face a number of threats that compromise their survival. Among the top ones, is the coastal development to support the ever-growing tourism industry, one of the main revenue source for the local economy. Coral reef health data collected from 1995 to 2018 was analyzed from three locations along the southeast portion of the island to assess how coastal development, or the lack of it, has affected these ecosystems over the past two decades. Data consisting of percent coverage of the bottom by live coral and macroalgae, as well as parrotfish densities were compared over time between locations developed or not for tourism, and their protection status was considered. The three locations selected vary greatly in both management approaches and socio-economic backgrounds. Results showed clear differences in reef health trends over time and between locations. Reefs located in areas of less coastal development proved to be more resilient as these recovered better after major impacts such as hurricanes and bleaching events. These results provide the first long-term local evidence on how coastal development can reduce coral resilience and negatively impact the health of coral reefs. This information is crucial for the development of better management strategies for the sustainable use of these resources and the environmental services they offer in tropical islands.

KEYWORDS: Coral reefs, coastal development, resilience, monitoring, Dominican Republic

INTRODUCTION

In recent decades, the coral reefs of the Dominican Republic have experienced a myriad of impacts, local, regional, and global, that have contributed to their degradation (Jackson et al. 2014). An increase in fishing pressure, ever-increasing coastal development, and climate change, that as of now, we shall consider it in the form of two coral bleaching events in 2005 and 2010 (Wilkinson and Souter 2008) (Alemu and Clement 2014), have caused a considerable impact in shallow and near to shore reefs around the country (Spalding et al. 2001).

Coral reefs hold an immeasurable value, both ecological and economical for the Dominican Republic. It is estimated that reefs represent a yearly income for the country of USD$4.5 trillion for the tourism industry alone, due to their ecological services of sand production and protection from beach erosion. Additionally, reefs serve as the main source of income for over 9,000 fishermen and their families around the country (Wielgus et al. 2010).

According to current legislation, most of the coral reefs around the country are protected by an extensive system of Marine Protected Areas that spans 56% of the territorial waters. However, many of these areas are "paper parks", lacking effective management or budget for vigilance and conservation. Some local NGO's have taken upon the task of co-managing small coastal marine areas, showing varying degrees of success. Local reef surveys led by several national and international organizations now provide a considerable amount of data spanning over two decades. However, there is little to none communication and/or collaboration between them, making long-term data comparison a challenge.

The goal of this investigation was to analyze the most usable of these data, collected between the years 1995 and 2018, in hopes to identify reef health trends in selected locations around the island and show how different management strategies and level of coastal development can influence coral reef resiliency.

METHODS

Three coastal locations from the southeastern portion of the country were selected for this study, chosen by their ecological and socioeconomic relevance. The selected locations were: La Caleta, Bayahibe, and Punta Cana. All three were chosen given their well-developed reef system, and available data from different time periods, making possible to compare reef health over time and between areas under different management scenarios.

La Caleta Underwater National Park is a small MPA near the country's capital of Santo Domingo and has been co-managed by Reef Check Dominican Republic for the past decade. Bayahibe is a town and a coastal area near the Cotubanamá MPA (formerly Del Este National Park), one of the largest and oldest MPA in the country. Despite little to no development along the coastline, there is intense boat traffic inside the MPA for tourism. Of the three locations, Punta Cana has experienced the most drastic coastal development over the past few decades, with the construction of over 40,000 hotel rooms, golf courses, and the second busiest airport in the Caribbean, and until recently, lacked any formal protection status.

For each location two reefs were selected, for their data availability and for being known for either scuba diving and/or research. A total of 30 datasets were utilized for all three locations, most of them previously unpublished. The reported values for percentage of coral cover, macroalgae cover, and parrotfish densities were compared over time and between

locations. These parameters were selected for both the intrinsic ecological correlation between them (Kramer 2003) and because all selected datasets contained values for these parameters.

RESULTS

Changes in Coral Cover

Mean coral cover showed great variation, ranging from 5% to 39% of live coral cover on some reefs over time period (Table 1), 23% being the average value for the Dominican Republic (Stenneck and Torres 2016). All three locations also showed marked and distinct trends, with coral cover either increasing or decreasing over time in response to both environmental and human impacts. For La Caleta, coral cover showed to be remarkably stable, recovering in a short period of time from damaging storms and bleaching events and maintaining an average cover of 28% (± 5%) over the past two decades. Bayahibe showed a significant increase in coral cover over time, from 8% to 38% over the studied time, and showed almost no perceived impact from major storms or bleaching events. In contrast, coral cover in Punta Cana decreased from 39% to 5% over time and averaging 10% in recent years (Figure 1).

Changes in Macroalgae Cover

Macroalgae cover decreased on all of the locations over the time period between 1995 and 2018 (Table 2). This parameter showed the greatest variation, with values ranging from 0% to 60%, 26% being the average macroalgal cover for the Dominican Republic. Even though all three locations showed a decrease of macroalgae over time, Punta Cana values were considerably higher over time when compared to other locations (Figure 2).

Changes in Parrotfish Density

Parrotfish densities consistently diminished on all three studied locations over the past two decades, from over 9 adult individuals per square meter, to less than one in some cases (Table 3). The average parrotfish density for the Dominican Republic is of 2 adult individuals per square meter, much lower than the average for Bonaire of 6 ind/m^2 (Stenneck and Torres, 2016). This decreasing trend was independent from management strategies and/or level of protection for any given location, with only one site in La Caleta showing a slight increasing trend (Figure 3).

Table 1: Reported values of coral cover for each studied location between the years 1995 and 2018.

Year	La Caleta		Bayahibe		Punta Cana	
	Paisanito	La Bomba	El Peñón	Dominicus	Coliseo	Restauración
1995	28%	28%	-	34%	39%	-
1996	-	-	13%	20%	-	-
1997	-	-	21%	-	-	-
1999	-	-	11%	-	-	-
2000	-	-	9%	-	-	-
2001	-	-	12%	-	-	-
2002	-	-	-	-	17%	17%
2003	-	-	8%	-	7.2%	7.3%
2004	-	-	-	22%	7%	-
2005	-	-	11%	31%	-	-
2006	-	-	-	33%	-	-
2007	20%	29%	-	19%	-	-
2008	22%	-	-	-	-	-
2009	-	-	-	30%	-	-
2010	35%	32%	-	31%	-	-
2011	29%	18%	30%	35%	-	-
2012	-	-	31%	35%	-	-
2013	-	-	31%	38%	-	-
2014	19%	37%	32%	-	-	-
2015	26%	-	27%	-	5%	10%
2016	25%	25%	27%	-	9%	9%
2017	35%	-	24%	-	11%	8%
2018	-	32%	-	-	-	-

Table 2: Reported values of macroalgae cover for each studied location between the years 1995 and 2018.

Year	La Caleta		Bayahibe		Punta Cana	
	Paisanito	La Bomba	El Peñón	Dominicus	Coliseo	Restauración
1995	41%	41%	-	34%	55%	-
1996	-	-	64%	20%	-	-
1997	-	-	30%	-	-	-
1999	-	-	60%	-	-	-
2000	-	-	19%	-	-	-
2001	-	-	44%	-	-	-
2002	-	-	-	-	79%	79%
2003	-	-	24%	-	71%	71%
2004	-	-	-	22%	67%	-
2005	-	-	16%	31%	-	-
2006	-	-	-	33%	-	-
2007	19%	32%	-	19%	-	-
2008	6%	-	-		-	-
2009	-	-	-	30%	-	-
2010	9%	1%	-	31%	-	-
2011	1%	1%	29%	35%	-	-
2012	-	-	21%	35%	-	-
2013	-	-	34%	38%	-	-
2014	17%	23%	37%	-	-	-
2015	21%	-	31%	-	35%	50%
2016	51%	51%	33%	-	62%	62%
2017	3%	-	33%	-	36%	39%
2018	-	11%	-	-	-	-

Table 3: Reported values of parrotfish densities (ind/m^2) for each studied location between the years 1995 and 2018.

Year	La Caleta		Bayahibe		Punta Cana	
	Paisanito	La Bomba	El Peñón	Dominicus	Coliseo	Restauración
1995	-	-	2.38	5.55	-	-
1996	-	-	-	-	-	-
1997	-	-	3.07	3.24	-	-
1999	-	-	-	-	-	-
2000	-	-	-	-	-	-
2001	-	-	-	-	-	-
2002	-	-	-	-	-	-
2003	-	-	-	-	9.8	7
2004	-	-	-	1	0.5	-
2005	-	-	1.75	5	-	-
2006	-	-	-	5.5	-	-
2007	4	2	-	0.75	-	-
2008	5	-	-	-	-	-
2009	-	-	-	6	-	-
2010	1	4	-	10	-	-
2011	2	1	1	2	-	-
2012	-	-	0.49	1	-	-
2013	-	-	2.04	0	-	-
2014	2.5	5	1.35	-	-	-
2015	2	-	1.19	-	3	2.5
2016	0.5	0.5	1.04	-	2.05	2.05
2017	3	-	4.6	-	1.3	0.75
2018	-	4	-	-	-	-

DISCUSSION

Reefs in the three studied locations showed marked difference in reef health trends over the time period (1995 to 2018). As an example, during the regional mass bleaching event of 2005, live coral cover in La Caleta and Bayahibe reefs decreased less and recovered faster than in Punta Cana, where the ecosystem never fully recovered after the bleaching event. During the second bleaching event that impacted Dominican reefs (in 2010), live coral cover for La Caleta decreased by 10%, yet it recovered at a steady rate of about 1% yearly afterward. Likewise, in Bayahibe this bleaching event had minimal impacts on both sites for that location. These results show the remarkable ability of the reef ecosystem to recover after major impacts, if provided with the adequate protection status and framework.

In contrast, by 2017, live coral cover in Punta Cana decreased by 29% from the reported levels at the beginning of the studied time period (1995). Even though conclusions cannot be made based on these results alone on the reason of this drastic decline, there is an important factor not present in the other locations, which is massive coastal development for tourism over the past 20 years. This brings several known impacts to reefs such as coastal modification, run-offs from hotels and golf courses operations, and sedimentation among other impacts. Major sedimentation on the reefs on the eastern shoreline of the country has been previously linked to beach dredging, a common practice in hotel areas, in the 2001 study "*Sedimentation as an important environmental influence on Dominican Republic reefs*" (Torres, Chiappone, Geraldes, Yira, and Vega). Ever since the mid-90s when the development of the tourism industry was just beginning in Punta Cana, it was perceived as a major threat to the reefs (Silva and Batlle 1995). The data clearly reflects that such degradation has continued to the present day with the ongoing coastal development of said location.

Macroalgae cover decreased across the different studied reefs, however showed high variation from year to year. Events like strong currents or increased runoff after storms could have caused major swings in macroalgae cover on the reefs, making it difficult to elaborate conclusions. Noteworthy is that current macroalgae coverage on the reefs of Punta Cana is three times higher than that of La Caleta, possibly indicating excessive nutrient input in the location and/or lack of herbivory.

Parrotfish densities showed a decreasing trend on most of the studied reefs over the past two decades. This is directly linked to a socioeconomic reality: The reefs of the Dominican Republic have been historically overfished. With large groupers and snappers virtually disappearing form near shore reefs, parrotfish has become the main target of the local fishery, representing up to 80% of the catch in some regions of the country. Formal protection for this fish family was only recently declared in 2017 with a complete ban on parrotfish fishing, but it has been weakly enforced. MPA's continue to be the most effective management strategy, reflected in the slight but rising trend of parrotfish populations in La Caleta.

Based on these identified trends over the past two decades we can affirm that in the Dominican Republic exist both highly degraded reefs and others that are highly resili-

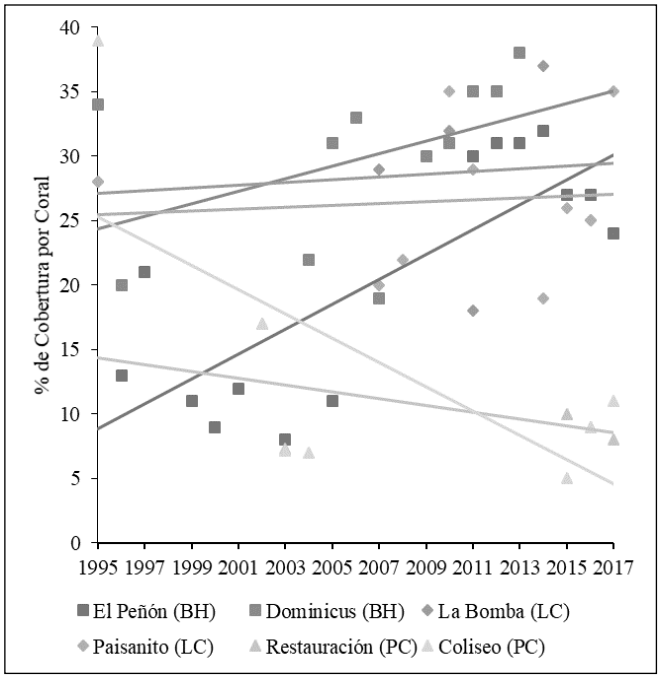

Figure 1. Changes in coral cover for each site of the three studied locations between the years 1995 and 2018.

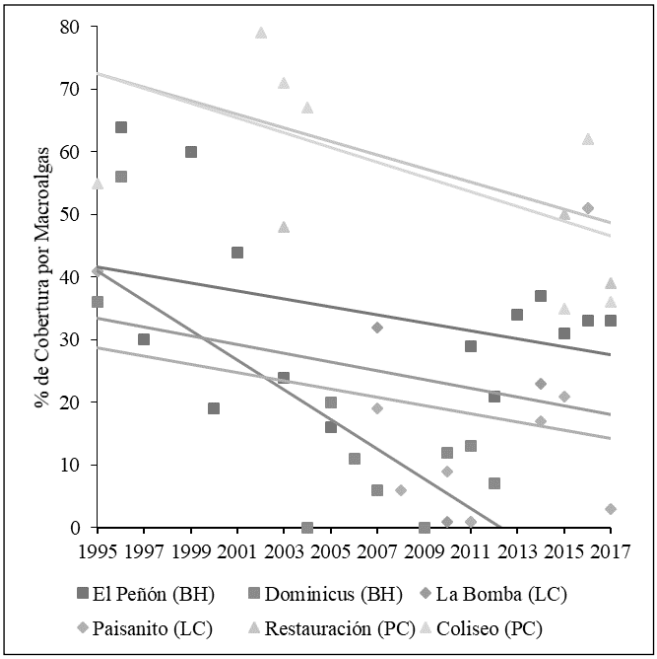

Figure 2. Changes in macroalgae cover for each site of the three studied locations between the years 1995 and 2018.

ent to environmental impacts. Also, these results provide the first long-term insight on how coastal development can negatively impact the health of coral reefs and their ability to recover in the face of damaging events by comparing the negative trends on the reef of a highly developed area with those from better managed locations. This study also shows that coral reefs can recover after considerable degradation, but it takes time and the right level of protection for them to do so. Such evidence should be implemented into the design of management plans for the sustainable use of these resources and the environmental services they offer to the Dominican Republic and other tropical nations.

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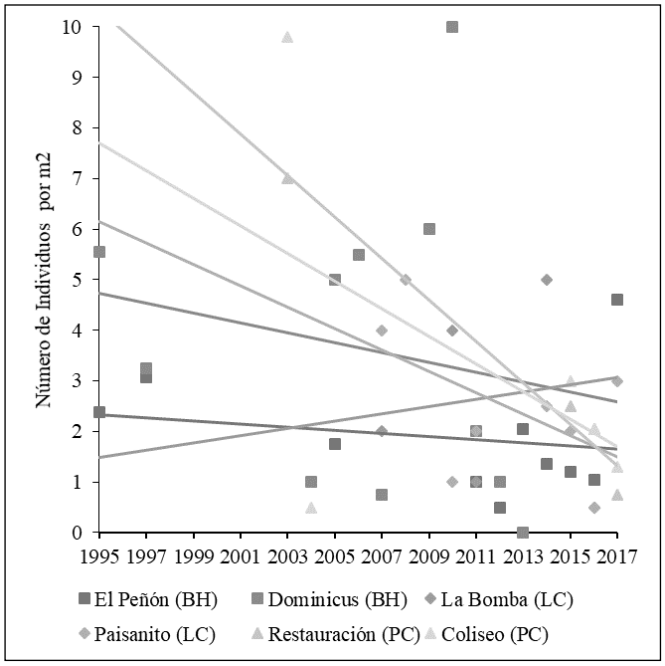

Figure 3. Changes in parrotfish densities for each site of the three studied locations between the years 1995 and 2018.