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Coastal Capital: Dominican Republic

Case studies on the economic value of coastal ecosystems in the Dominican Republic

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Executive Summary

Coastal and marine ecosystems provide many valuable services to the people and economy of the Dominican Republic. At first glance, these benefits can be difficult to see. Reefs and mangroves help to build beaches and slow erosion, draw local and international tourists to the coast, and provide habitat for valuable recreational commercial fish. Unfortunately, these services are often overlooked in key development and policy decisions. As a result, coastal ecosystems are threatened by unsustainable coastal development, pollution, overfishing, and other local and global pressures.

One of the key barriers to better decision-making is lack of information and understanding of the scope and value of benefits provided by these ecosystems. Little work has been done on this topic in the Dominican Republic, and data gaps make it difficult to assess the economic impact of ecosystem services provided by coral reefs at the national level.

The studies presented here look at a small sample of the benefits that coastal ecosystems provide to the Dominican Republic. These ecosystems (a) protect white sand beaches in vital tourism areas; (b) provide habitat for commercial fisheries; (c) provide the engine for potential tourism growth in a small marine protected area; and (d) generate local tourism dollars in the southwestern part of the country. The studies highlight the contribution of coastal ecosystems to the economy and the need for greater investment in protecting coastal and marine ecosystems, including better management of marine fisheries, protection of existing reserves, and enforcement of coastal development guidelines.

The Coastal Capital Project

These studies are part of the World Resources Institute's (WRI) Coastal Capital project in the Caribbean. The project was launched in 2005, and aims to provide decision-makers with information and tools that link the health of coastal ecosystems with the attainment of economic and social goals. WRI and its local partners have conducted economic valuation studies of coral reefs and mangroves at national and subnational levels in five countries, using the results to identify and build support for policies that help to ensure healthy coastal ecosystems and sustainable economies. More on the project is available online at http://www.wri.org/coastal-capital.

1. Coralline beaches

The first two studies in this paper look at the importance of coralline beaches in the Dominican Republic. The first study makes the case for the economic importance of beaches by assessing the losses that could ensue from continuing beach erosion. The second study argues that coral reefs play an important role in reducing wave energy and thus protecting coastal beaches from erosion. Together, these studies make the case for investing in protection of beaches in the Dominican Republic, including renewed efforts to protect coral reefs.

Potential economic impacts of beach erosion. This study assesses potential losses to the hotel industry alone if beach erosion continues at the current pace. We use a hedonic price technique to estimate the relationship between the price of a hotel room and the width of the beach (perpendicular to the shoreline) in front of the resort. Our results suggest that current rates of beach erosion would result in revenue losses to the resorts of $52–$100 million[1] over the next 10 years.

Modeling the potential impacts of coral reef decline on beach erosion. In their natural state, beaches are in a dynamic equilibrium between the sources that supply their sand and the forces that erode it. Corals and other organisms that inhabit coral reefs supply sand to adjacent beaches and control the rates of beach erosion by reducing the energy of incoming waves. The Dominican Republic has suffered from increased rates of beach erosion in recent years. This study uses an Excel-based model to examine the role of coral reefs in reducing wave energy and to estimate the potential increase in beach erosion that could result from further degradation of the reefs. We find that 10 years after the disappearance of live corals, erosion rates could increase by more than 100 percent on eastern beaches and by more than 65 percent in the south.

Slowing the pace of beach erosion in the Dominican Republic will require protecting the ecosystems that help to protect the coastline, including coral reefs, mangroves, and sand dunes. Regulations for coastal development should be strengthened and enforced, including limiting construction in sensitive areas. The protection of coral reefs will require curbing overfishing, reducing pollution (both from the hotel industry and from agricultural runoff), and reducing deforestation.

2. Marine fisheries

Marine fisheries in the Dominican Republic support an estimated 9,000 fishermen. It is a small-scale industry, with 99 percent of landings sold domestically. In this study, we identify the major commercial species in the Dominican Republic that depend on mangroves or coral reefs at some point in their life cycle, and examine the changes in landings and associated revenues for these groups over the past few decades. Using FAO landing data for three periods (1982–86, 1992–96, and 2002–06), we find that landings for many key commercial species—including spiny lobster, king mackerel, southern red snapper, and yellowtail snapper—grew significantly between the first two periods and then dropped sharply in the third, with recent landings for most species falling well below levels during the 1980s. This pattern typically suggests that fish populations have been overexploited, and unless steps are taken to protect remaining stocks, fisheries will continue to decline. For local fishermen, gross income from reef-dependent fisheries has decreased by nearly 60 percent over the past decade.

These results demonstrate that the protection of coral reefs and mangroves is vital to the welfare of the fishing communities that depend on these resources for their livelihoods. It is essential for the Dominican Republic to improve its capacity to enforce regulations protecting mangroves and fisheries (Silva 2003). Existing regulations include Decree 303 of 1987, which bans activities that destroy mangroves, and Law 307 of 2004, which regulates fishing and aquaculture.

3. The potential for dive tourism in La Caleta National Marine Park

La Caleta National Marine Park is located 15 miles from Santo Domingo and just two miles from the airport. Due to its healthy reefs and multiple shipwrecks, the park has become a popular SCUBA diving site for people living in the city. The area around the park is also important for fishing, traditionally providing a source of food and income for people living in the town of La Caleta and its vicinity. In recent years, the park has suffered from overfishing, threatening the livelihoods of local fishermen. In response, the fishermen have begun exploring the potential for the tourism industry, and are working to establish an aquatic center to offer recreational activities in the park. This study assesses the willingness to pay (WTP) of dive tourists for a dive trip in the park. We find that the revenue maximizing fee would be $53 per two-dive trip for local visitors and $59 per two-dive trip for international visitors. Assuming a gradual increase in visitation, we estimate that fishermen could earn 90 percent of their current income over the short term through dive tourism alone. Additional income from snorkeling, kayaking, and other business opportunities associated with the reserve should enable fishermen to earn more from tourism than from fishing over the coming years.

4. Economic benefits of the Jaragua-Bahoruco-Enriquillo Biosphere Reserve

The three national parks that make up the UNESCO Biosphere Reserve in the Dominican Republic provide habitat for many rare and threatened plant and animal species. In Parque Jaragua, the beach at Bahía de las Águilas is considered one of the most beautiful and best preserved beaches in the country. Each year, the reserve receives over 24,000 visitors, mostly Dominican citizens. Visitors travel to the reserve by land from all over the country, stopping at different locations along the way to purchase gasoline and food. These travel expenses provide important economic benefits to the small communities on the way to the reserve. Visitors spend approximately $523,000 during stopovers between their cities of origin and the reserve, and $511,000 in lodging (hotel rooms and food) each year. Visitors pay an additional $136,000 in park fees, which help cover the management activities of the reserve.

Areas in and around the reserve in the southwest, however, are currently being considered for mining and mass-tourism developments that could have significant impacts on the ecologically fragile areas in the reserve (ACRD 2004). If this area follows the established tourism-development model, which focuses on attracting foreign visitors, it is likely that its value as a center for recreation and enjoyment for Dominicans will be diminished, impacting the economic benefits for towns in the surrounding areas as well as the ecological value of the park itself. Maintaining the region's low-intensity, ecologically friendly tourism model and discouraging large-scale, intensive tourism and mining in and around the reserve would be a benefit to the Dominican people and the nation's biodiversity.

Conclusion

These studies provide insight into the value of some of the key ecosystem services provided by coastal ecosystems in the Dominican Republic. We examined the value of coralline beaches, reef- and mangrove-dependent fisheries, and ecotourism. This is a critical first step in a country where ecosystem services are typically given very little consideration in decision-making, both in the public and the private sector. Some of the main findings include:

- Current rates of beach erosion could result in revenue losses of $52–$100 million over the next 10 years to the hotel industry alone.
- If corals continue to die off, beach erosion—and thus tourism revenue loss—will be exacerbated. Ten years after the disappearance of live corals, erosion rates could increase by more than 100 percent on eastern beaches and by more than 65 percent in the south.
- Countrywide, gross income from reef-dependent fisheries has decreased by nearly 60 percent over the past decade—from over $41 million to under $17 million—almost certainly as a result of overfishing.
- Overfishing is also threatening fish populations in La Caleta Marine Park. However, tourists in the park are willing to pay about $60 for a two-dive trip. At this price, fishermen in the park could earn nearly as much in the short term if they become dive tourism operators, and more in the longer term as tourist activities expand—solving the overfishing problem and benefiting fishermen at the same time.
- Dominican tourists spend over $1 million yearly in roadside communities while traveling to the biosphere reserve in the southwest.

Protecting coastal ecosystems will provide the longest-term, most cost-effective solution to problems of beach erosion, while also sustaining fisheries, improving biodiversity, and enhancing other ecosystem services. It is in the long-term economic interest of the Dominican Republic to:

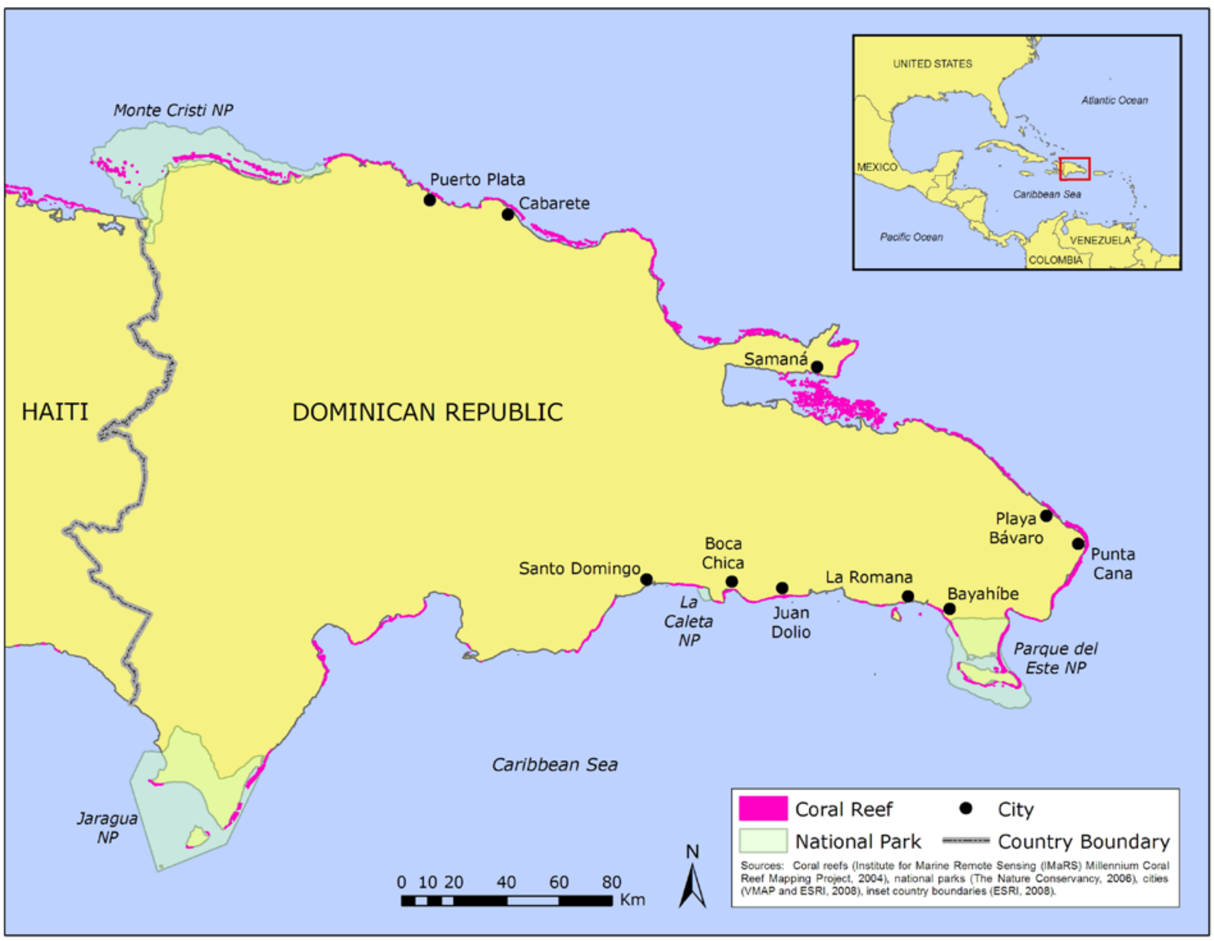
- Strengthen and enforce coastal development regulations, including those protecting mangroves.
- Enforce fisheries regulations and reduce overfishing pressure.
- Curb pollution—both from the hotel industry and from agricultural runoff—and deforestation.
- Protect and restore sand dunes and their native vegetation.
- Increase public awareness about marine and coastal ecosystems, the benefits they provide to society, and threats to their existence.

1. Coralline Beaches in the Dominican Republic: Two Studies

The economy of the Caribbean region is strongly dependent on tourism, which accounts for approximately 15 percent of the area's gross domestic product, 13 percent of its jobs, and 18 percent of its export earnings (WTTC 2009a). Among the principal features that have made Caribbean islands popular destinations for tourists are the tropical climate and the wide, sandy beaches (Beekhuis 1981; Uyarra et al. 2005; Cambers 2009), whose white sand originates in adjacent coral reefs (Thorp 1935; UNEP/GPA 2003).

This section contains two analyses of coralline beaches in the Dominican Republic. The first study makes the case for the economic importance of beaches by assessing the losses that could ensue from continuing beach erosion. The second study argues that coral reefs play an important role in reducing wave energy and thus protecting coastal beaches from erosion. Together, these studies make the case for investing in protection of beaches in the Dominican Republic, including through renewed efforts to protect coral reefs.

Figure 1. Location of coral reefs and selected tourist destinations



1a) Potential Economic Impacts of Beach Erosion in the Dominican Republic

Summary. The Dominican Republic is the most visited island in the Caribbean, receiving four million visitors annually, excluding cruise passengers (CTO 2009). Its beaches play a major role in attracting international visitors. Tourism is concentrated in coastal regions that contain wide beaches and numerous all-inclusive resorts. We used hedonic functions to investigate the relationship between the price of accommodation and various accommodation attributes, and found a significant relationship between accommodation price and the width of beaches in front of the hotels. The implicit price of beach width (perpendicular to the shoreline) was $1.57 per meter per person per night. Our results suggest that current rates of beach erosion can result in revenue losses to the resorts of $52–$100 million over the next 10 years. Beach erosion in the Dominican Republic has until now been managed through programs of sand replenishment and coastal engineering, but a long-term strategy should involve protecting coral reefs, which produce sand and protect coastlines from further erosion.

<u>Introduction</u>

International tourism in the Dominican Republic generates 37 percent of the country's total export earnings (WTTC 2009b). Tourism is concentrated in two main regions: the southeastern region, which includes the towns of Playa Bávaro, Punta Cana, Bayahíbe, and La Romana, and the northern region, which includes Puerto Plata and Cabarete (Figure 1). In addition, the towns of Boca Chica and Juan Dolio, located to the east of the capital (Santo Domingo), and the Samaná Peninsula in the northeast, are expanding as tourism centers. Nearly half of the hotel rooms in the coastal regions belong to all-inclusive resorts (Coles 2004). These resorts are usually located seaside and contain a large number of guest amenities that include sports activities, cultural events, and a variety of restaurants. The guests of all-inclusive resorts in the Dominican Republic spend most of their travel (averaging 1–2 weeks) on beach-and-sun activities within the grounds of their resorts (Coles 2004).

Beach quality plays an important role in the selection of the Dominican Republic as a travel destination for a large number of international tourists (Mercado and Lassoie 2002; Coles 2004). In a survey conducted in 1999 (BCRD 2000) at the country's international airports, "beach quality" was given as the main reason for visiting the Dominican Republic by 25 percent of the respondents (international visitors); second only to "climate" (37 percent).

In recent years, beaches in the Dominican Republic and other Caribbean countries have experienced accelerated erosion (UNEP/GPA 2003). This long-term loss of beaches is distinct from the naturally occurring cycles of sand erosion and deposition. Beach loss is related to human impacts, such as interference with natural coastal processes by excessive construction in coastal areas; activities that contribute to coral reef degradation; and production of greenhouse gas emissions, which contribute to global warming and sea-level rise (Cambers 1999). To maintain the quality of popular beaches, beach enhancement projects have been implemented throughout the region, including (a) the placement of artificial structures in shallow water to mitigate wave impact, and (b) depositing sand obtained from other sites on beaches that have been severely eroded (UNEP/GPA 2003). However, beach enhancement remains a costly and temporary measure that does not address the root causes of erosion.

This study sought to estimate the long-term costs of reductions in beach width through beach erosion in the main tourism regions of the Dominican Republic. We investigated the contribution of beach width to the prices of hotel accommodations in the country. Previous studies have illustrated the economic importance of beach width as a characteristic of coastal properties (see Whitehead et al. 2008 for a recent review). For example, Pompe and Rinehart (1995) found that the prices of beachfront properties in South Carolina in the southeastern United States were positively associated to beach width.

Methods

The hedonic-price valuation technique is based on the premise that the price of a housing unit is determined by the components—such as total size or number of rooms—of the unit (Rosen 1974). Although originally developed to study house prices, the method has also been applied to assessing the determinants of hotel-room prices (White and Mulligan 2002; Fleischer and Tchetchik 2005; Hamilton 2007). By estimating a "hedonic function"—with room prices as the dependent variable and accommodation amenities as independent variables—we can estimate the contribution of each amenity to room prices. We included beach width as an amenity to study its contribution to room prices.

To estimate a hedonic function, we gathered information on room prices and accommodation amenities, including location of the resort (latitude and longitude), size of the resort (number of rooms), beach width (meters), distance to the closest airport (kilometers), star rating (an objective system based on number of amenities, offered by the travel site Expedia®), value rating, and cleanliness rating. We estimated average beach width in front of each resort in the sample using Google™ Earth. Please see Appendix 1 for a full discussion of our data sources and methodology.

Results

From a total of 87 all-inclusive seaside resorts in the Dominican Republic, we found information on hedonic variables for 30 resorts with a combined total of more than 31,000 rooms. Our sample represents 34 percent of all-inclusive seaside resorts and 95 percent of all-inclusive hotel rooms in the country.[2] The mean number of rooms (±SD) for the resorts in our sample was 480 (±222), and the mean width of their beaches (±SD) was 47m (±26m). The mean room number of our sample was 17 percent larger than the mean number of rooms in the Dominican Republic overall (411; CTO 2009). The mean price (±SD) of accommodation for one person per night was $263 (±$75). Table 1 summarizes the results of the linear regression, including the coefficients, standard error (SE), and P-values, which can be used to evaluate the significance of a variable. Beach width and high star rating were significant predictors of room prices at the 1 percent significance level ($P\text{-value} < 0.05$), and value was a significant predictor at the 10 percent significance level (P-value < 0.10). Please see Appendix 1 for a more complete discussion of the results.

Table 1. Results of a linear regression with daily per person room price as the dependent variable and the following independent variables: location of the resort (dummy variables), size of the resort (number of rooms), beach width (m), distance to the closest airport (km), star rating (dummy variables), value rating, and cleanliness rating.[3]

Parameter	Coefficient	SE	T	P (>|t|)
Intercept	243.700	122.200	1.993	0.060
Southeast	30.570	32.923	0.929	0.364
North	36.300	37.280	0.973	0.342
Resort size	0.001	0.059	0.012	0.990
Beach width	1.571	0.496	3.166	0.005
Distance to airport	2.414	1.560	1.548	0.137
High star rating	109.700	35.360	3.102	0.006
Medium star rating	29.060	25.600	1.135	0.270
Value	-84.990	42.720	-1.989	0.060
Cleanliness	40.520	33.480	1.210	0.240

Our results indicate that the implicit price of beach width is $1.57 per meter. Based on a 72 percent mean annual room occupancy rate for the Dominican Republic (CTO 2009), the mean price of accommodation for one person per night ($263), and assuming an average occupancy of two people per room, the mean annual gross revenue for our sample of resorts is approximately $57 million. Using an estimated mean of 411 rooms per resort across all 87 resorts in the country, the total annual gross revenue for the Dominican Republic's resorts is approximately $4.5 billion. Assuming a beach erosion (shoreline retreat) rate of 0.5 m per year (Cambers 2009), the potential annual loss of revenue to these resorts due to erosion would be approximately $13.4 million. Applying discount rates (*d*) between 3 percent and 10 percent, the net present value of potential revenue losses is estimated to be $52–$100 million over the next 10 years (Table 2).

Table 2. Potential revenue losses to resorts in the Dominican Republic accruing from beach erosion over 10 years using three discount rates (*d*)

Year	Cumulative beach loss (m)	Cumulative revenue losses ($US million) *d=0.03*	Cumulative revenue losses ($US million) *d=0.05*	Cumulative revenue losses ($US million) *d=0.10*
1	0.5	13,006,388	12,758,647	12,178,709
2	1.0	25,255,122	24,302,185	22,143,107
3	1.5	36,779,304	34,717,407	30,195,145
4	2.0	47,610,750	44,085,597	36,600,176
5	2.5	57,780,036	52,482,853	41,591,109
6	3.0	67,316,547	59,980,403	45,372,119
7	3.5	76,248,516	66,644,893	48,121,945
8	4.0	84,603,069	72,538,659	49,996,826
9	4.5	92,406,264	77,719,991	51,133,117
10	5.0	99,683,133	82,243,377	51,649,613

Discussion

This analysis shows that beach erosion has a high potential negative impact on the gross revenue of seaside resorts in the Dominican Republic. Using a hedonic function, we found a statistically significant and positive relationship between beach width and accommodation prices in all-inclusive resorts. Although the effect that beach width had on prices was relatively small compared to that of other predictors of room prices (for example, star rating and perceived satisfaction per dollar spent), a loss of 0.5 meters in beach width would nevertheless potentially result in annual gross-revenue losses of approximately $160,000 for an average-size resort.

This analysis concurs with other evidence that beach erosion has affected tourism. For example, facing pressure from the hotel lobby, the Dominican government spent $18 million in 2007 in a widely publicized program to restore the beaches of Puerto Plata and Juan Dolio. These funds came from an entry fee that international tourists pay when arriving in the country; hence, tourists ultimately bore the costs of beach erosion. The restoration project consisted of importing sand to the eroded areas from neighboring beaches that lack resorts. Two years later, beach losses are again evident in these areas, and there is debate on whether similar "beach nourishment" programs should be pursued.

Our study illustrates the financial costs that resorts would face if the government stops financing beach nourishment programs. Beach erosion also has had a noticeable effect on the price of condominium apartments. In Juan Dolio, the average pre-construction price in beachfront properties before beach enhancement was approximately $\$500/m^2$; after beach enhancement, the average price rose to approximately $\$800/m^2$.[4]

Coastal areas facing erosion have traditionally used three different strategies to confront beach losses: (1) beach nourishment, (2) engineering solutions, and (3) beach retreat (Parsons and Powell 2001). Beach nourishment programs, as discussed above, offer short-term solutions. The same processes that caused erosion to occur in the first place will likewise affect the nourished beaches, which will need to be replenished eventually (Bird 2008). Engineering structures, such as jetties and breakwaters, are designed to trap sand offshore and direct it to areas that have been eroded. In some cases, jetties have been useful in restoring sand that has been depleted through erosion, but their effective design and placement face large uncertainties due to the complexity of the oceanographic processes responsible for sand dynamics (Silvester and Hsu 1997). In addition, jetties can exacerbate erosion in beaches located downstream (Hanson and Kraus 2001). A breakwater that was deployed in an eroded beach in the Puerto Plata area in 2007 has not helped restore sand to the beach; the sand that accumulates at the structure is taken offshore by currents.[5] The effectiveness of engineering structures is also contingent on the state of the coral reef. In the U.S. Virgin Islands, engineering structures that were placed to control sand erosion were ineffective at sites where the sand supplied by degraded coral reefs was low (Hayden et al. 1978).

When beaches retreat due to erosion, marine and wind processes establish a beach profile in which the original beach width is maintained if there are no inland barriers to the movement of sand (Komar 1998). Some coastal communities can adopt a strategy of retreat, which involves dismantling infrastructure and rebuilding inland. If there are no inland barriers, coastal dwellers can resettle at distances from the sea that allows the beach to provide protection from storms. For example, some coastal communities in North Carolina in the United States historically have coped with beach erosion by routinely moving their houses inland (Pilkey et al. 1998). However, in the Dominican Republic, the volume of large infrastructure constructed along the coastline impedes the adoption of a strategy of retreat.

Conclusion

Ultimately, the long-term solution to beach erosion in the Dominican Republic will be contingent on policies protecting coastal ecosystems at the national and international levels. Nationally, this would entail curbing overfishing and pollution, as well as reducing deforestation, which increases sediment loads that affect coral health. Local strategies should also include the restoration of once-existing sand dunes and their native vegetation, which act as a barrier to wind erosion, and which in many cases were removed to give tourists easier access to beaches. Even though the effects of sand dune restoration efforts will only be observed in the medium to long term, the ability to recreate natural beach components that are aesthetically compatible with tourism can represent a cost-effective and visually appealing solution to beach erosion. These measures to protect coastal ecosystems will also provide other benefits, such as improving fisheries and creating better conditions for dive tourism. At the international level, stringent policies on the emission of greenhouse gases that contribute to global warming could help reduce the current rate of sea-level rise, which contributes to erosion and imperils coastal communities worldwide.

1b) Coral Reef Decline and Beach Erosion in the Dominican Republic

Summary. In their natural state, beaches are in a dynamic equilibrium between the sources that supply their sand and the forces that erode it. Corals and other organisms that inhabit coral reefs supply sand to adjacent beaches and control the rates of beach erosion by reducing the energy of incoming oceanic waves. The Dominican Republic has suffered from increased rates of beach erosion in recent years. This study uses an Excel-based model to examine the role of coral reefs in reducing wave energy and to estimate the potential increase in beach erosion from further degradation of the reefs. We find that ten years after the disappearance of live corals, erosion rates could increase by more than 100 percent on eastern beaches and by more than 65 percent in the south.

Introduction

Small "patch" coral reefs are numerous in the shallow waters of the Dominican Republic. Other coral reefs form continuous structures that protect the Dominican coastline from incoming oceanic waves. These reefs also contain corals between the reef edge and the beach. The largest of these continuous reefs is located off the northern coast, in waters belonging to Montecristi National Park. Another continuous reef, in the east, protects the beaches of the resort towns of Playa Bávaro and Punta Cana, and a smaller one, off the southern coast, protects the beaches of the resort towns of Boca Chica and Juan Dolio. Both reefs have an average depth of approximately 2 m. The average width (from the beach to the reef rim) of the eastern reef is approximately 1,000 m, while the southern reef is approximately 400 m wide. The goal of this study was to investigate the role of these two coral reefs in protecting beaches that are located in front of the tourism resorts at the important tourism destinations of Playa Bávaro, Punta Cana, Boca Chica, and Juan Dolio.

In their natural state, beaches are in a dynamic equilibrium between the sources that supply their sand and the forces that erode it. Corals and other organisms that inhabit coral reefs in the Dominican Republic supply sand to the adjacent beaches, and waves and wind hitting the beaches transport this sand to other locations offshore or inshore.

In addition to providing a source of sand, coral reefs control the rates of beach erosion by reducing the energy of incoming oceanic waves. Other natural features of the coast also play important protective roles. Sand dunes and their associated vegetation control the erosive impact of wind, while mangroves stabilize the shoreline and provide additional protection from waves. The energy carried by waves is related to the water depth, so rising sea levels, a consequence of climate change, also contribute to beach erosion by increasing the energy of waves reaching the shoreline. If the ability of coral reefs or sand dunes to control erosion is impaired, beaches will suffer a net loss of sand.

Coral reefs in the Dominican Republic have suffered from coral mortality in recent decades, probably due to a combination of direct factors such as disease, pollution, and sedimentation, and indirect factors such as overfishing and warming ocean temperatures. Live corals currently represent only 9.4 percent of the total cover of the eastern reef and 11.0 percent of the southern reef.[6] The percent cover of corals that have recently died (the skeletons have not yet eroded) is 0.4 percent and 3.0 percent, respectively. Living corals, and remains of corals that have recently died, produce calcium carbonate, and they make an important contribution to the formation of beach sand. When corals die, the supply of sand to beaches is reduced, and the erosion of beaches by waves increases. The complex structure of coral colonies also contributes to bottom friction, which is an important factor in the dissipation of wave energy. In addition, once living corals no longer cover the surface, the substrate of old coral skeletons that make up a reef becomes exposed to waves and begins to erode. This increases the relative depth of the water, leading to an increase in wave energy.

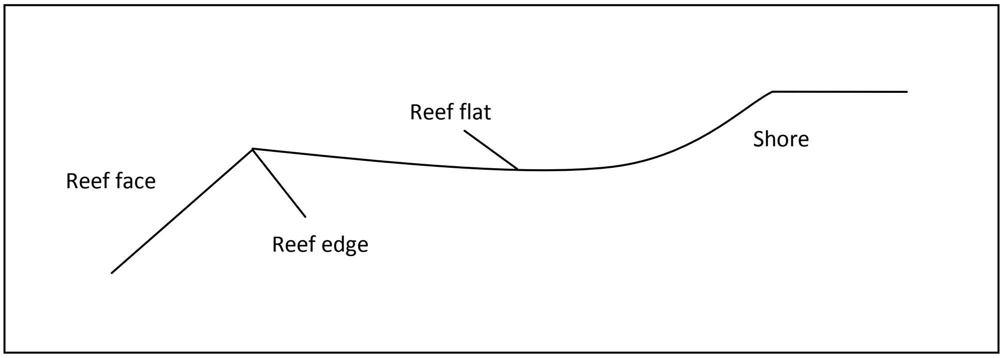
The Dominican Republic has suffered from increased rates of beach erosion in recent years. In 2007, the government conducted a program to restore the sand that was lost in various beaches throughout the country. These programs are only short-term solutions because the same forces that caused erosion will be at play in the restored beaches.

Methods

To estimate the potential increase in beach erosion due to coral reef degradation, we used a model developed by Sheppard et al. (2005) that relates the condition of coral reefs that are adjacent to the coastline with the wave energy dissipated by the reefs. The model requires information for the following parameters (Figure 2; see Sheppard et al. 2005 for details):

1) slope of the edge of the reef where the waves break (reef face);
2) depth of the reef edge;
3) average depth of the reef (multiple points);
4) average width of the reef from the edge to the beach;
5) slope of the beach;
6) root mean square (RMS) of offshore wave height;
7) mean offshore wave period; and
8) the coefficient of bottom friction of the reef flat.

Figure 2. Diagram of reef structure used in model



Appendix 2 summarizes the data sources and input values used in our application of the model in the Dominican Republic.

We studied the effects on beach erosion of the death of the remaining corals in the reef flat and the subsequent erosion of the dead coral colonies. To do this, we used the Excel spreadsheet to look at the changes in wave height that would result in a reduction of the reef flat's bottom friction coefficient from 0.14 to 0.10, which is the category in Sheppard et al. (2005) corresponding to 75 percent to 100 percent smooth (eroded) coral rock. We also studied the effects of a deepening of the reef flat caused by the erosion of the dead coral substrate, which, like a reduction in bottom friction, leads to higher waves reaching the beach. We assumed that the reef edge will not suffer further "rounding"—that is, a decrease in its slope—because the edge is a turbulent area where, if live coral cover is low, most coral skeletons have already been eroded (Sheppard et al. 2005).

The proportional increase in net offshore transport of sand from a beach (erosion) is assumed to be roughly equivalent to the proportional increase in wave height to the 2.5 power (Dean and Galvin 1976; CETS 1987). We used this relationship to study the effects of increasing wave height (obtained from the Excel spreadsheet) on beach erosion.

<u>Results</u>

Table 3 shows the percent increase in beach erosion over 10 years if live coral cover is completely eliminated and assuming that the dead reef will erode at a rate of 6 mm per year. It should be noted that these estimates should be taken only as gross approximations. Erosion rates such as these have been measured at other sites (Scoffin et al. 1980; Eakin 1992), but have been shown to vary greatly between reefs (Hutchings 1996) and within different sites of reefs (Eakin 1996).[7]

Table 3. Model results predicting the impact of reef degradation (indicated by increasing wave height over the reef) on beach erosion

Eastern reef	**Wave height (m)** H_o is the initial wave height, and H is the wave height for each period after all corals die.	**% increase in erosion relative to current** $\left[\left(\frac{H}{H_o}\right)^{2.5} - 1\right] * 100$
Current (live and recently dead coral cover = 9.8%)	H_o =0.204	-
No live coral (bottom friction is reduced)	H= 0.260	83.4
Year 1 (erosion of the reef substrate begins)	H= 0.261	85.2
Year 2	H= 0.262	86.9
Year 3	H= 0.263	88.7
Year 4	H= 0.264	90.5
Year 5	H= 0.266	94.1
Year 6	H= 0.267	96.0
Year 7	H= 0.268	97.8
Year 8	H= 0.269	99.7
Year 9	H= 0.271	103.4
Year 10	H= 0.272	105.3

Southern reef	Wave height (m)	% increase in erosion
Current (live and recently dead coral cover= 14.0%)	H_o = 0.379	-
No live coral (bottom friction is reduced)	H= 0.448	51.9
Year 1 (erosion of the reef substrate begins)	H= 0.450	53.6
Year 2	H= 0.452	55.3
Year 3	H= 0.454	57.1
Year 4	H= 0.456	58.8
Year 5	H= 0.457	59.7
Year 6	H= 0.459	61.4
Year 7	H= 0.461	63.2
Year 8	H= 0.463	65.0
Year 9	H= 0.465	66.7
Year 10	H= 0.466	67.6

This first stage of analysis does not consider additional increases in erosion that can be expected as a result of sea-level rise, which will increase the relative depth of the areas where waves break and thus increase the energy of waves. Table 4 considers a relative rate of sea-level rise of 2 mm/yr, assumed from the time in which all corals have died, based on the Caribbean-wide average of 1 mm/yr in the past 100 years and a projected doubling of this rate (a conservative estimate) over the next 100 years (USGCRP 2003).

Table 4. Model results predicting the impact of reef degradation on beach erosion, taking into account projected sea-level rise

Eastern reef	**Wave height (m)** H_o is the initial wave height, and H is the wave height for each period after all corals die	**% increase in erosion relative to current** $\left[\left(\frac{H}{H_o}\right)^{2.5} - 1\right] * 100$
Current (live and recently dead coral cover = 9.8%)	H_o = 0.204	-
No live coral (bottom friction is reduced)	H= 0.260	83.4
Year 1 (erosion of the reef substrate begins)	H= 0.261	85.2
Year 2	H= 0.263	88.7
Year 3	H= 0.264	90.5
Year 4	H= 0.266	94.1
Year 5	H= 0.268	97.8
Year 6	H= 0.269	99.7
Year 7	H= 0.271	103.4
Year 8	H= 0.273	107.2
Year 9	H= 0.274	109.1
Year 10	H= 0.276	112.9
Southern reef	**Wave height (m)**	**% increase in erosion**
Current (live and recently dead coral cover=	H_o = 0.379	-

14.0%)		
No live coral (bottom friction is reduced)	*H*= 0.448	51.9
Year 1 (erosion of the reef substrate begins)	*H*= 0.451	54.5
Year 2	*H*= 0.453	56.2
Year 3	*H*= 0.456	58.8
Year 4	*H*= 0.458	60.5
Year 5	*H*= 0.460	62.3
Year 6	*H*= 0.463	65.0
Year 7	*H*= 0.465	66.7
Year 8	*H*= 0.468	69.4
Year 9	*H*= 0.470	71.3
Year 10	*H*= 0.472	73.1

Discussion

The results show that if the remaining live coral disappears from the reefs, beach erosion rates could increase by more than 80 percent in the eastern area and by more than 50 percent in the southern area relative to current rates. Ten years after the disappearance of live corals, erosion rates could increase by more than 100 percent in the east and by more than 65 percent in the south relative to current rates. The study of the economic consequences of beach erosion in the Dominican Republic included in this assessment suggests that, under current erosion rates, seaside resorts stand to lose $52–$100 million in gross revenues over the next 10 years due to reductions in room prices associated with decreases in beach width. Considering the potential increases in beach erosion due to coral degradation and sea-level rise illustrated above, the economic losses could be much larger than those resulting from current erosion rates.

Conclusion

These two studies make the case for investing in protection of beaches in the Dominican Republic, including through renewed efforts to protect coral reefs. Policies to protect coastal ecosystems—instead of stop-gap measures such as beach nourishment—will provide a longer-term and more cost-effective solution to problems of beach erosion, while also improving biodiversity and enhancing ecosystem services. Furthermore, because white sand beaches are so important to the tourism industry, hotels and private landowners should have a vested interest in supporting public policies that target reef and coastal degradation.

Regulations for coastal development should be strengthened and enforced in the Dominican Republic, including limiting construction in sensitive areas. The protection of coral reefs will require curbing overfishing, reducing pollution (both from the hotel industry and from agricultural runoff), and reducing deforestation, which increases sediment loads that affect coral health. It is also critical that Decree 303 of 1987, which bans activities that destroy mangroves, be enforced.

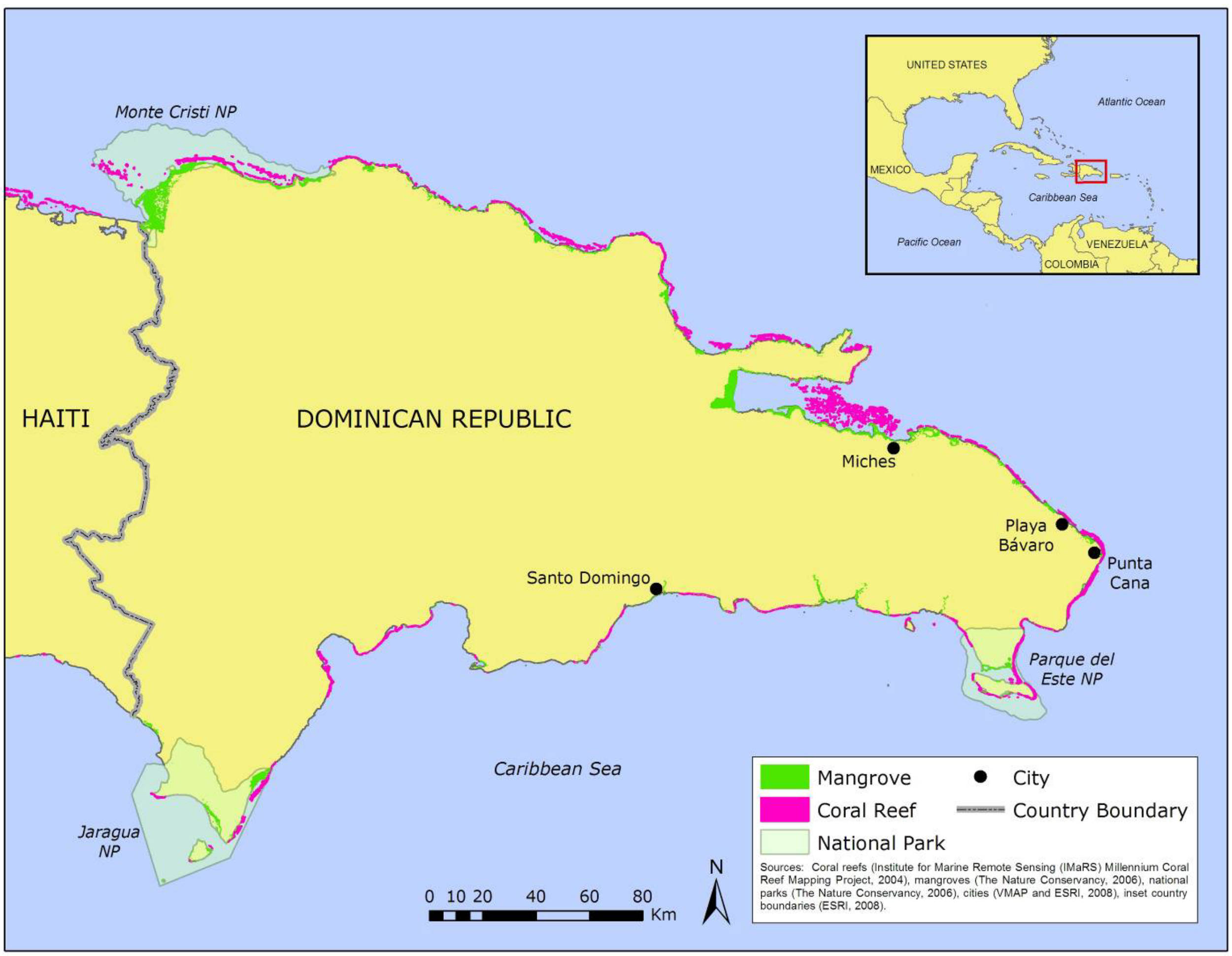
Finally, local strategies to slow beach erosion should also include retention and restoration of sand dunes and their native vegetation, which act as barriers to wind erosion.

2. A Worrying Trend: Declines in Coral Reef- and Mangrove-Associated Fisheries in the Dominican Republic[8]

with Jeannette Mateo

Summary. Marine fisheries in the Dominican Republic support an estimated 9,000 fishermen. It is a small-scale industry, with 99 percent of landings sold domestically. In this study, we identify the major commercial species in the Dominican Republic that depend upon mangroves or coral reefs at some point in their life cycle, and examine the changes in landings and associated revenues for these groups over the past few decades. Using FAO landings data for three periods (1982–86; 1992–96; 2002–06), we find that landings for many key commercial species—including spiny lobster, king mackerel, southern red snapper, and yellowtail snapper—grew significantly between the first two periods and then dropped sharply in the third, with recent landings for most species falling well below levels from the 1980s. This pattern typically suggests that fish populations have been overexploited. Unless steps are taken to protect remaining stocks, fisheries will continue to decline. For local fishermen, this has meant that despite putting in the same level of effort, gross income from reef-dependent fisheries has decreased by nearly 60 percent over the past decade.

Figure 3. Location of coral reefs and mangroves



Introduction

The Dominican Republic has a coastline extending nearly 1,600 km and an exclusive economic zone covering 238,000 km^2. Most of the country's fisheries are small-scale, but there are some semi-industrial and industrial operations that target fishing banks off the northern coast. Mangroves and coral reefs provide critical habitat for many of the Dominican Republic's most economically important fish species.

Nearly 99 percent of the marine resources caught in Dominican waters are sold domestically, and 60 percent of the seafood consumed in the country is imported (FAO 2006). Although diverse, the country's marine resources have historically been considered sparse because of the narrow continental shelf that supports them (Silva 2003).[9]

Coastal fishing is practiced by around 9,000 fishers, mostly men. Women and children also work in the wider fisheries industry, typically helping with processing and sale of fish once they are caught. Fishing takes place mainly in inshore waters around approximately 200 coastal landing sites in the Dominican Republic. A typical fishing boat is a small wooden or fiberglass dinghy with an outboard engine and a crew of two fishermen (Silva 2003). The socioeconomic conditions of fishers varies by village, but most are located in some of the poorest regions in the country, where fishing is the most important or even the only source of income (for example, Parque Nacional Jaragua, Miches).

Coral reefs and mangroves provide critical habitat for most of the commercially caught fish in the Dominican Republic. Degradation of reefs and mangroves, in combination with high fishing pressure, poses a serious threat to the country's fisheries. This study looks explicitly at changes in landings over time of fish that depend on these two habitats. In addition to focusing on the challenges of managing fishing pressure, protection of these critical habitats will be essential to sustaining local fisheries.

Methods

To estimate the contribution of coral reefs and mangroves to fishery production (measured as landings) in the Dominican Republic, we selected the groups that rely on coral reefs or mangroves at some point in their life cycle. To identify fish families that use mangroves as habitats, we used the information on habitat use by different fish families available in Rönnbäck (1999). Species or families that are dependent on coral reefs for habitat were identified in the databases FishBase (available at www.fishbase.org) and SeaLifeBase (available at www.sealifebase.org).

We included species and families that depend on both ecosystems in the mangrove category only. Although somewhat arbitrary, we selected this allocation of fish groups because mangroves are generally the habitat required by the early life stages of these groups, and mangrove health is critical for the survival of these stages. In contrast, some fish groups utilize coral reef habitat primarily as shelter, and can live in degraded coral reefs (Bell and Galzin 1984). Although this method of separating species likely affected how economic value estimates were distributed between ecosystems, the calculation of the combined value of the two ecosystems was not affected.

We classified 15 fishery groups in the coral reef category and 14 groups in the mangrove category (Table 5), and calculated mean annual landings during the periods 1982–86, 1992–96, and 2002–06. For fishery groups representing a single species, we compared mean annual landings from different periods using ANOVA and Tukey's HSD test for significant differences at the 0.05 significance level. We also calculated the mean annual gross revenues obtained by fishermen by multiplying ex-vessel prices (prices at landing of fisheries products) by mean annual landings.

Results

We found significant differences between time periods in the landings of the common octopus (*Octopus vulgaris*), king mackerel (*Scomberomorus cavalla*), red grouper (*Epinephelus morio*), spiny lobster (*Panulirus argus*), southern red snapper (*Lutjanus purpureus*), and yellowtail snapper (*Ocyurus chrysurus*) (Table 5). For fisheries dependent on coral reefs, mean annual revenues were 2.5 times higher during 1992–96 than during 2002–06 (Table 6a). For fisheries dependent on mangroves, mean annual revenues were similar during the different time periods that were studied (Table 6b).

Table 5. Mean annual landings (in metric tons) of fishery groups associated with (a) coral reefs and (b) mangroves during three time periods: 1982–86, 1992–96, and 2002–06

(a) Coral reef groups	1982–86	1992–96	2002–06
Amberjacks	87.2	69.6	69.8
Blue runner	278.6	294.8	124.8
Cero	81.4	61.0	29.0
Common octopus	52.4	34.4	70.8
Goatfishes	217.2	348.2	79.0
King mackerel	829.6	1,318.6	336.6
Needlefishes	78.6	76.0	32.0
Parrotfishes	187.2	202.8	68.8
Porgies	473.2	521.0	107.8
Red grouper	166.4	365.6	77.0
Squirrelfishes	152.0	90.8	89.2
Spiny lobster	438.8	615.0	1,221.0
Stromboid conchs	1,458.8	2,803.8	1,603.0
Triggerfishes	292.0	469.0	114.2
Wrasses	368.4	834.0	160.8
Total (metric tons)	**5,161.8**	**8,104.6**	**4,183.8**

(b) Mangrove groups	1982-1986	1992-1996	2002-2006
Barracudas	155.0	30.0	82.0
Grunts	491.4	406.6	216.4
Mojarras	98.8	37.8	58.8
Mullets	167	214	89.2
Penaeid shrimps	256.6	207.6	78.8
Southern red snapper	579.8	483.4	177.4
Scaled sardine	105.4	86.6	87.2
Other groupers	733.2	1108.2	546.4
Other jacks	300.8	360.6	289.0
Other snappers	128.2	109.8	1,302.4
Snooks	102.4	52.8	54.8
Tarpon	198.8	145.0	41.4
Yellowtail snapper	219.4	450.4	132.6
Total (metric tons)	**3,536.8**	**3,662.8**	**3,074.4**

Table 6. Ex-vessel prices of fisheries groups dependent on coral reefs and mangroves in the Dominican Republic, and mean annual gross revenues obtained by fishermen during three time periods: 1982–86, 1992–96, and 2002–06 (Prices in 2009 $)

(a) Coral reef groups	US$/kg	1982–86	1992–96	2002–06
Amberjacks	2.20	191,840	153,120	153,560
Blue runner	2.20	612,920	648,560	274,560
Cero	3.28	266,992	200,080	95,120
Common octopus	2.53	132,572	87,032	179,124
Goatfishes	2.20	477,840	766,040	173,800
King mackerel	3.28	2,721,088	4,325,008	1,104,048
Needlefishes	1.52	119,472	115,520	48,640
Parrotfishes	2.20	411,840	446,160	151,360
Porgies	2.20	1,041,040	1,146,200	237,160
Red grouper	3.28	545,792	1,199,168	252,560
Squirrelfishes	1.52	231,040	138,016	135,584
Spiny lobster	7.59	3,330,492	4,667,850	9,267,390
Stromboid conchs	2.53[10]	13,129,200	25,234,200	4,055,590
Triggerfishes	2.20	642,400	1,031,800	251,240
Wrasses	1.52	559,968	1,267,680	244,416
Total ($)	-	**24,414,496**	**41,426,434**	**16,624,152**

(b) Mangrove groups	US$/kg	1982–86	1992–96	2002–06
Barracudas	2.20	341,000	66,000	180,400
Grunts	1.52	746,928	618,032	328,928
Mojarras	1.52	150,176	57,456	89,376
Mullets	2.20	367,400	470,800	196,240
Penaeid shrimps	6.31	1,619,146	1,309,956	497,228
Southern red snapper	3.28	1,901,744	1,585,552	581,872
Scaled sardine	1.52	160,208	131,632	132,544
Other groupers	3.28	2,404,896	3,634,896	1,792,192
Other jacks	1.52	457,216	548,112	439,280

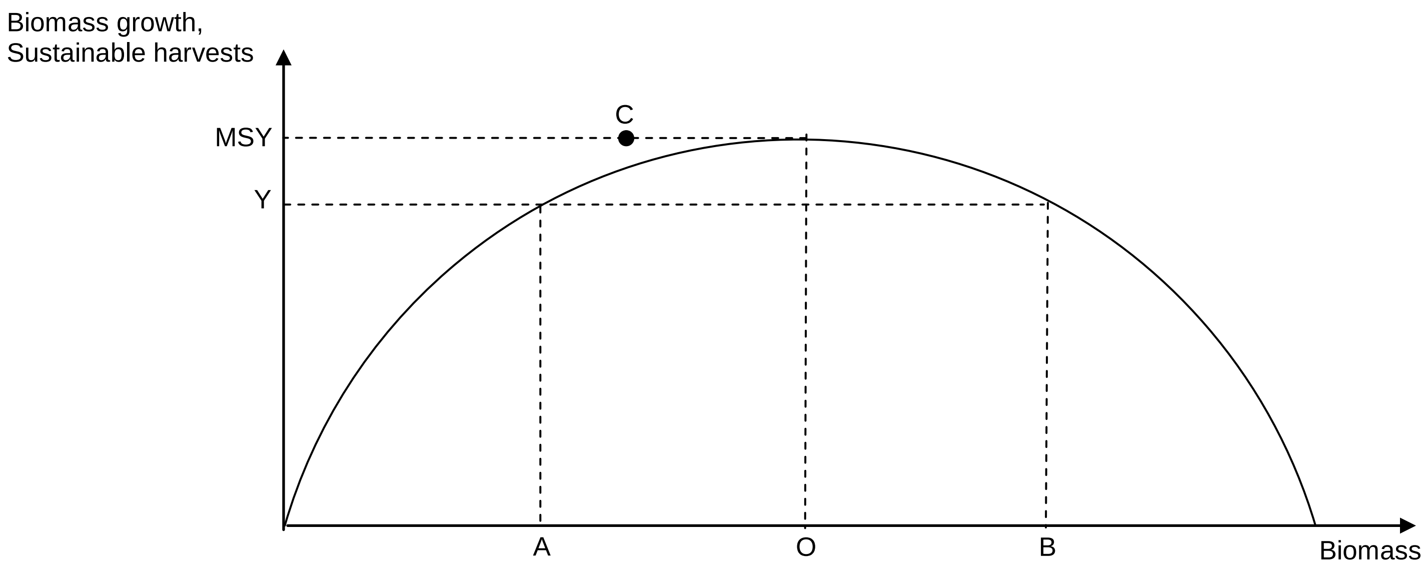
Other snappers	3.28	420,496	360,144	4,271,872
Snooks	1.52	155,648	80,256	83,296
Tarpon	1.52	302,176	220,400	62,928
Yellowtail snapper	3.28	719,632	1,477,312	434,928
Total ($)	-	**9,746,666**	**10,560,548**	**9,091,084**

Discussion

In a fishery, there is a bell-shaped relationship between the biomass of the harvested population and its sustainable harvest levels (Figure 4). In order to harvest the resource sustainably, the maximum amount of biomass that is extracted annually should be less than or equal to the biomass growth. When a fishery begins operating, the biomass of the fished population is high. At this stage, the population is at a high density (near the carrying capacity of the ecosystem), and there is high competition for habitat and food, which results in low levels of biomass increases per year. As the fishery increases its effort (such as additional boats entering the fishery, or boats spending more time fishing), more biomass is removed, habitat and food availability increase, and biomass growth also increases. The maximum sustainable yield (MSY) of the fishery will take place when biomass is reduced to half the carrying capacity (level O in Figure 4). If biomass is reduced below this point, sustainable harvests will begin to decrease. Note that biomass levels on either side of the biomass midpoint (levels A and B in Figure 4) can have the same corresponding biomass growth and sustainable harvests (level Y), but different levels of effort associated with harvesting them. Point B is considered biologically and economically superior to point A because the fish population is at a higher biomass level, and the profits to fishermen are greater.

If the fishery is driven below biomass level O but continues to be harvested at the levels that corresponded to MSY (point C in Figure 4), biomass growth will not be able to keep up with harvests, and the fishery may collapse. A well-known example of this type of overfishing is the Peruvian anchoveta fishery, which was the largest fishery in the world. In the early 1970s, unexpected climatic events reduced the biomass of the anchoveta population, but fishing was not reduced and the fishery collapsed.

Figure 4. Relationship between biomass and biomass growth in a fishery



Note: The maximum sustainable harvest (yield) is the level MSY. At biomass levels A and B, biomass growth—and sustainable harvest—is the same. At point C, the harvest level is not sustainable.

Key reef-dependent fish on the decline in the Dominican Republic

Recent landings of five fisheries (common octopus, king mackerel, red grouper, southern red snapper, yellowtail snapper) in the Dominican Republic are statistically lower than the landings in previous periods (Table 5). Landings data for the common octopus are likely to be poor indicators of real catches because this species is a common by-catch that is used as bait. (Most of the octopus sold in the Dominican Republic is actually imported.) Fishing effort has likely increased in recent decades. Although the number of fishermen and boats has remained stable, fishing boats spend more time fishing because many are now powered by engines. Consequently, a plausible explanation for the observed differences in landings is that, at some point previous to 1992–96, harvesting rates surpassed sustainable rates, and these fisheries are being depleted. This is supported by a study of total landings in the southwestern town of Trudillé for the period 1987–93, which showed a decrease of 49 percent, from 185 tons to 94 tons (PROPESCAR-SUR 1995).

To compensate for decreasing catches of southern red and yellowtail snappers, fishermen seem to be targeting other snapper species, which is seen in the increased landings of other snappers (Table 5). While southern red and yellowtail snappers are caught mainly with fishing lines, other snapper species are fished with traps. As motorized boats have become more abundant, the traps have been placed across larger coastal areas.

Although mean annual landings of spiny lobster in 2002–06 were twice those of 1992–96, the difference is not statistically significant (Table 5a). Studies conducted in Parque Nacional Jaragua (Herrera and Colom 1995) and neighboring areas (Beck et al. 1994) found that more than 70 percent of the landed lobsters were below the legal size limits; in Parque Jaragua, most lobster fishing occurred on or near nursery habitats. An external supply of larvae from the South

American Caribbean may have prevented the collapse of the spiny lobster fishery in the Dominican Republic. If the source populations collapse, the Dominican fishery may suffer the same fate.

Implications for local fishermen

The last comprehensive census of marine fisheries in the Dominican Republic was conducted in 1990–91 (Colom et al. 1994). It indicated that there were approximately 8,600 marine fishermen in the country. Although more recent estimates of fishermen numbers are not available, it is estimated that they are similar to 1990–91 because the growth of coastal populations has been offset by the relocation of employment from fisheries to tourism-related activities. Assuming an equal number of marine fishermen during the periods 1992–96 and 2002–06, the per-capita gross income proceeding from coral-reef dependent fisheries decreased by nearly 60 percent between these periods (Table 6a), whereas the per-capita gross income proceeding from mangrove-dependent fisheries decreased by almost 14 percent (Table 6b).

Conclusion

These results demonstrate that reef- and mangrove-related fisheries in the Dominican Republic have declined in recent years, almost certainly due to overfishing. If these fisheries are to be sustained, then it will be important for the Dominican Republic to improve its capacity to enforce regulations protecting mangroves and fisheries (Silva 2003). Existing regulations include Decree 303 of 1987, which bans activities that destroy mangroves, and Law 307 of 2004, which regulates fishing and aquaculture.

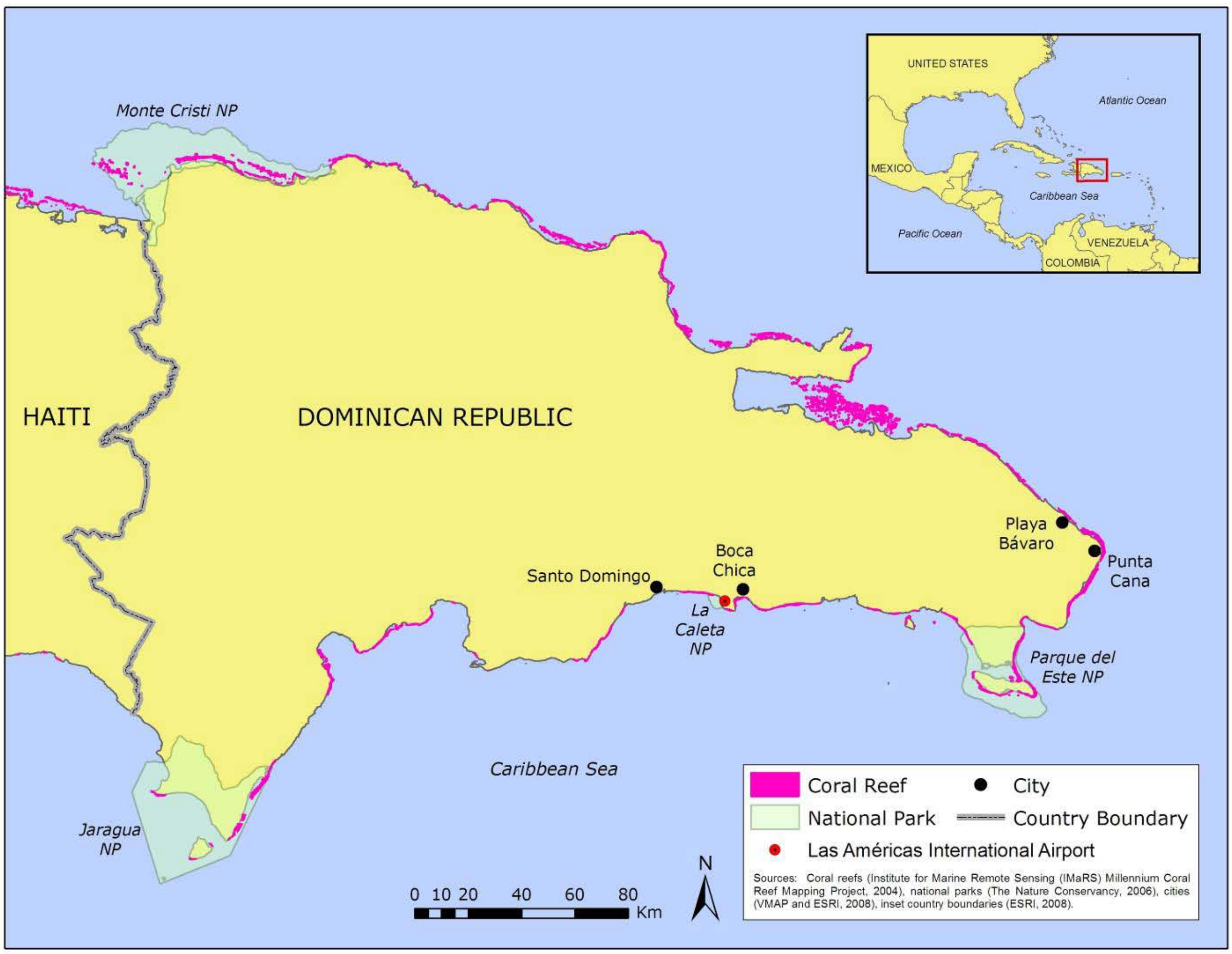
In addition to the need for better management of fishing pressure, a focus on protecting the habitats themselves is needed at the national level. Further losses of mangrove cover and degradation of the country’s reefs threaten the sustainability of these fisheries over the long term.

The Dominican Republic Fisheries and Aquaculture Council (CODOPESCA) is currently conducting a fisheries census throughout the country. By providing an updated description of the number of people that currently depend on fishing and on the levels of fishing effort, the census will help to fill important gaps in current knowledge. Information on levels of by-catch for different fisheries and the relationship between reported landings and actual catches will be crucial for developing a more complete understanding of the status of coastal fisheries, including those that depend on habitat supplied by mangroves and coral reefs. The census will also provide information on the costs of fishing for the different fisheries—information that was not available for this analysis. This will be useful in estimating net fishing revenues and bioeconomically optimal harvest levels.

3. Dive Tourism in La Caleta Marine Park: A Win-Win Opportunity for Fish and Fishermen

***Summary*.** La Caleta National Marine Park is located 15 miles from Santo Domingo and just two miles from the airport. Due to its healthy reefs and multiple shipwrecks, the park has become a popular SCUBA diving site for people living in the city. The area around the park is also important for fishing, traditionally providing a source of food and income for people living in the town of La Caleta and its vicinity. In recent years, the park has suffered from overfishing, threatening the livelihoods of local fishermen. In response, the fishermen have begun exploring the potential for enlarging the tourism industry, and are working to establish an aquatic center to offer recreational activities in the park. This study assesses the willingness to pay (WTP) of dive tourists for a dive trip in the park. We found that the revenue maximizing fee would be $53 per two-dive trip for local visitors and $59 per two-dive trip for international visitors. Assuming a gradual increase in visitation, we estimate that fishermen could earn 90 percent of their current income in the short term through dive tourism alone. Additional income from reef-related tourism should enable fishermen to earn more from tourism than from fishing over the coming years.

Figure 5. Location of La Caleta National Marine Park



Introduction

La Caleta National Marine Park is located 15 miles from Santo Domingo and less than two miles from Santo Domingo airport (Figure 5). The waters in this part of the Dominican Republic are rich in coral reefs, and reef fish have traditionally been a source of food and income for the people living in the town of La Caleta and its vicinity. In order to protect this resource, the Dominican government established a 10 km^2 national marine park in La Caleta in 1986. The park has since become a popular recreational site for people living in Santo Domingo. In particular, SCUBA divers enjoy the park's clear waters and healthy coral reefs, as well as several shipwrecks that are now teeming with marine life.

In recent years, the neighboring city of Boca Chica has seen a surge in North American and European tourists, and the demand for seafood from the city's hotels and restaurants has increased greatly. Due to this increased demand, there has been a growth in illegal fishing in the protected waters of La Caleta Park. This has negatively affected the legal fisheries outside of the park by lowering fish populations. As a result, the fishermen of La Caleta have seen a decline in fish catches in recent years, putting their livelihoods in peril.

Fishermen are aware of the importance of La Caleta as a tourist destination, and they have begun to supplement their incomes by providing services such as boat transport for divers in the park. Although the diving sites at La Caleta are accessible by land, traveling by boat instead of swimming out from land access points means that divers have more time to spend diving at the sites. In order to increase the community's capacity to offer services to tourists, the park's co-manager, Reef Check-Dominican Republic, is helping the fishermen to establish an aquatic center that will rent diving and kayaking equipment, a restaurant, and a gift shop.

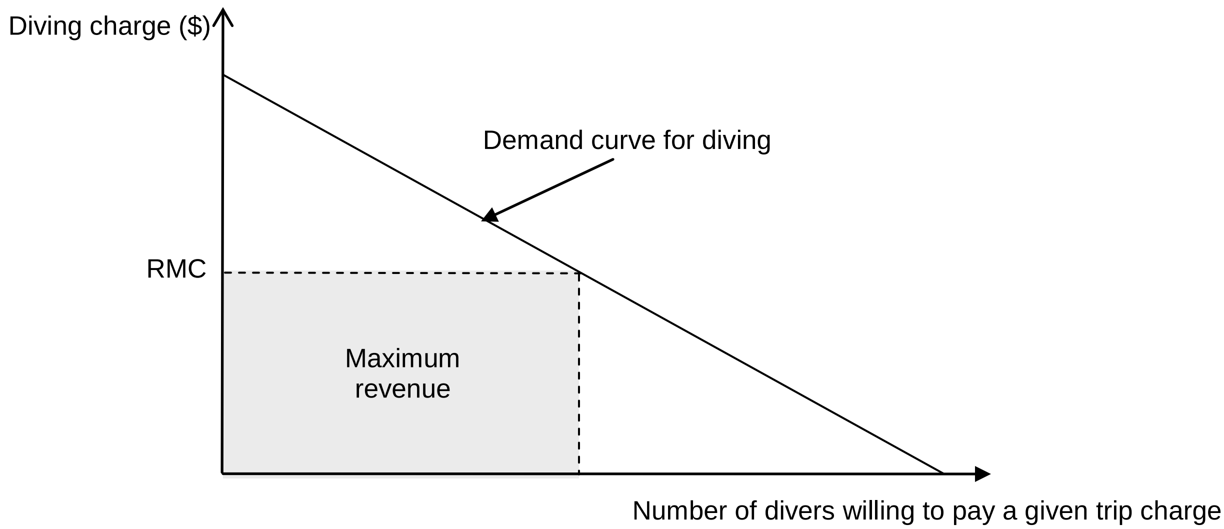
Recently, the leaders of the La Caleta fishing and tourism services cooperative (COOPRESCA) have expressed interest in learning if tourism could be a sustainable, full-time activity that could replace fishing and improve their livelihoods. To help address this question, WRI and Reef Check conducted a study to estimate the potential revenue that could be obtained by providing diving services—part of the portfolio of recreational activities that would ultimately be offered by the aquatic center at the park.

Methods

In many areas around the world, the willingness to pay of recreational users of coral reefs is substantially higher than what the users actually pay (Peters and Hawkins 2009). To assess the willingness to pay of current or potential divers in La Caleta, divers in the Santo Domingo area were presented with a survey (see Appendix 3) that explained the current situation in the park and asked their willingness to pay for diving at two sites in the park.[11] Participants were also told that fishermen were interested in becoming full-time providers of tourism services in the park. If fishing activities around La Caleta decreased as a result, divers would be able to enjoy more abundant and larger fish during their dives. To illustrate a typical diving site, divers were presented with two photographs depicting a coral reef with abundant coral and fish life.

The purpose of the willingness to pay survey was to collect the information necessary to estimate a demand function for diving (Figure 6).

Figure 6. Demonstration of a demand curve



The demand curve slopes downward because the higher the diving charge, the lower the number of divers who are willing to pay it. With a linear demand function, one-half of the highest willingness to pay value is called the "revenue-maximizing charge" (RMC in Figure 6).[12] This charge will maximize the total income that fishermen could make by providing diving services in La Caleta, which is represented by the shaded rectangle above.

Results

The results of this survey indicate that the revenue-maximizing charge for local divers is $52.70 per two-dive trip, and for international divers it is $58.80 per two-dive trip.[13] One possible reason for the difference in willingness to pay between domestic and international divers is that international visitors see the diving experience as part of a wider vacation package for which they have a high willingness to pay. In addition, international divers are less likely to have dived in the local sites previously, so they will be enjoying a new experience. Because willingness to pay depends partly on a person's income level, visitors from countries with relatively high income levels may also have a higher willingness to pay for recreational activities in general.

Conclusion

Based on the results of our survey, we suggest establishing diving charges of $60 per two-dive trip for international visitors and $50 per two-dive trip for local divers. Differentiated charges have a precedent; many national parks worldwide charge different fees to domestic and international visitors (Ceballos-Lascuráin 1996).

The switch to a tourism focus should be accompanied by higher levels of enforcement of fishing regulations in the park as well as a commitment to self-enforcement among members of the small fishing community. Reef Check and other local experts estimate that the current number of divers per year (850) could be doubled in a short period of time after the fish populations in the park recover.[14] We believe this is a conservative figure. Because diving operators in Santo Domingo cater mostly to local divers, many tourists are not aware of the existence of La Caleta. Advertising for the evolving aquatic center and the availability of transportation services to the park will likely make the park known and accessible to a larger number of tourists. An increase to 1,700 divers annually due to both increased fish populations and increased promotion of the park is therefore a reasonable estimate.

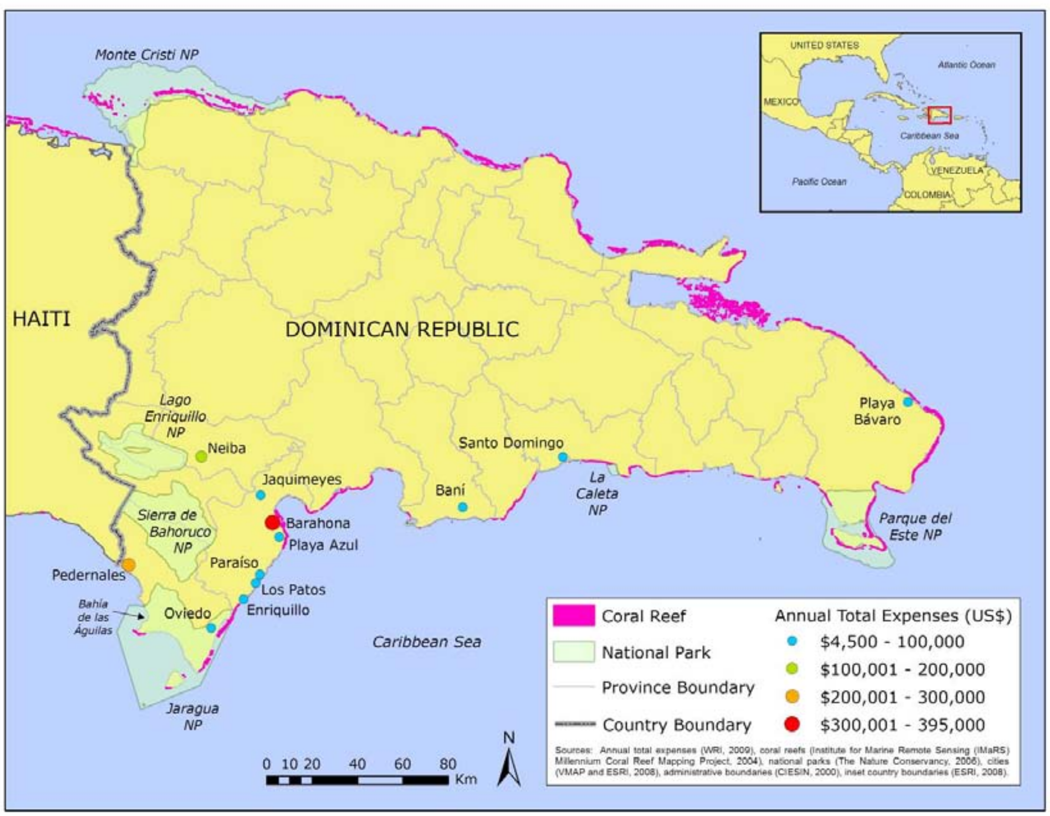
Assuming an equal proportion of domestic and international divers (850 domestic, 850 international), and operational costs of approximately $10 per diver, the annual net revenue for the aquatic center from diving operations would be approximately $76,500 once fish populations have recovered. The annual net income of the 27 fishermen of La Caleta is currently $84,240, so fishermen who become tourism operators can expect net revenues equivalent to 90 percent of their current net revenues. Studies in marine protected areas have shown that populations of fish species that are attractive to divers, such as groupers and snappers, can recover in approximately 4–6 years (Polunin and Roberts 1993; Roberts et al. 2001; Russ and Alcala 2003). This means that if fishing around La Caleta Park is reduced, and if fishing regulations that ban fishing inside of the park are respected, fishermen who become tourism operators can expect short-term net revenues equivalent to 90 percent of their current earnings. In the longer term, the aquatic center should generate additional revenues from other recreational activities—such as snorkeling and kayaking—making it likely that fishermen will earn more from tourism than from current fishing activities, creating a win-win situation for La Caleta’s fish and human populations.

4. Economic Benefits of the Jaragua-Bahoruca-Enriquillo Biosphere Reserve

Summary. The three national parks that make up the UNESCO Biosphere Reserve in the Dominican Republic provide habitat for many rare and threatened plant and animal species. The beach at Bahía de las Águilas, in Parque Jaragua, is considered one of the most beautiful and best preserved beaches in the country. Each year, the reserve receives over 24,000 visitors, mostly Dominican citizens. Dominican visitors travel to the reserve by land from all over the country, stopping at different locations along the way to purchase gasoline and food (Figure 7). These travel expenses are important economic benefits to the small communities where stopovers are made on the way to the reserve. Visitors spend approximately $523,000 during stopovers between their cities of origin and the reserve, and $511,000 in lodging (hotel rooms and food) each year. Visitors pay an additional $136,000 in park fees, which help to cover the management activities of the reserve.

Areas in and around the reserve in the southwest, however, are currently being considered for mining and mass-tourism developments that could have significant impacts on the ecologically fragile areas in the reserve (ACRD 2004). If this area follows the established tourism-development model, which focuses on attracting foreign visitors, it is likely that its value as a center for recreation and enjoyment for Dominicans will be diminished, impacting the economic benefits for towns in the surrounding areas as well as the ecological value of the park itself. Maintaining the region's low-intensity, ecologically friendly tourism model and discouraging large-scale, intensive tourism and mining in and around the reserve would be a benefit to the Dominican people and the nation's biodiversity.

Figure 7. Location of Jaragua-Bahoruca-Enriquillo Biosphere Reserve and roadside communities



Introduction

Three national parks in the western Dominican Republic—Jaragua, Sierra de Bahoruco, and Lago Enriquillo—were designed as a UNESCO Biosphere Reserve in 2002. These parks provide habitat for a large variety of plant and animal species, several of which are endemic to the area. Parque Jaragua harbors coral reefs, mangroves, and sea-grass beds, and its beaches are used as nesting grounds by the hawksbill (*Eretmochelys imbricata*), loggerhead (*Caretta caretta*), green (*Chelonia mydas*), and leatherback (*Dermochelys coriacea*) turtles (SEMARENA 2004). In Parque Jaragua, the beach at Bahía de las Águilas contains white sand produced in a coral reef that fringes the shoreline (Grupo Jaragua 2005). It is considered one of the most beautiful and best preserved beaches in the country (Ramírez-Tejeda 2002). The mountains of Sierra de Bahoruco contain some of the last remaining primary forests in Hispaniola, ranging from dry forest in the lowlands to broadleaf rainforests and pine forests at higher elevations. Lago Enriquillo is the largest lake in the insular Caribbean. It is home to the two endemic iguana species in Hispaniola (*Cyclura cornuta*, *C. ricordi*) and to a critically endangered population of the American crocodile (*Crocodylus acutus*) (SEMARENA 2007).

In addition to its ecological importance, the reserve provides a wide array of recreational opportunities. Most visitors to the reserve are Dominican citizens. This contrasts with other tourism destinations in the country, such as Punta Cana, Playa Bávaro, and Puerto Plata, where international visitors predominate. While international visitors usually travel with an organized tour to the reserve, Dominican visitors travel by car from throughout the country. Visitors to the reserve stop at different locations during their road trips to purchase gasoline and food, contributing to the local economy of the communities along the way. This study examines the economic impact of spending by domestic visitors to the biosphere reserve as they pass through and stay in towns along the route to the reserve.

Visitor survey

To estimate the economic benefits to local communities, we calculated the expenses in gasoline and food made at different locations throughout the Dominican Republic by people traveling by car to the reserve. We conducted a survey of 55 visitors to Parque Nacional Jaragua during two national holidays, in April and October 2009 (see Appendix 4). Only one traveler per group (a party arriving by car or bus tour) was interviewed.

The mean household income reported by the Dominican citizens in the sample ($20,067) was more than three times higher than the national mean of $6,179 (ONE 2005). Most respondents (51 respondents, 94 percent of the total) included marine-related recreation (beach going, swimming, snorkeling, and fishing) as part of their activities during their visit to the park.

Table 7. Socioeconomic characteristics of survey participants

Gender	**12 female (22%), 43 male (78%)**
Mean age (± standard deviation)	38 (±12)
Nationality	Dominican Republic: 47 (85%), Argentina or Colombia: 4 (7%) Other: 4 (7%)
Number belonging or donating to a conservation	23 (42%)

organization	
Number with university degrees (including technical degrees)	53 (96%)
Mean annual household income (US$), Dominican citizens (± standard deviation)	$20,067 (±$19,032)
Mean annual household income(US$), foreign citizens (± standard deviation)	$59,000 (±$66,182)

Travel and lodging costs

Table 8 shows the number of gasoline and food stopovers made in different locations, based on the 41 respondents who provided information on gasoline stopover locations and the 44 respondents who provided information on food stopover locations. Each respondent in the survey belonged to a separate group of visitors.

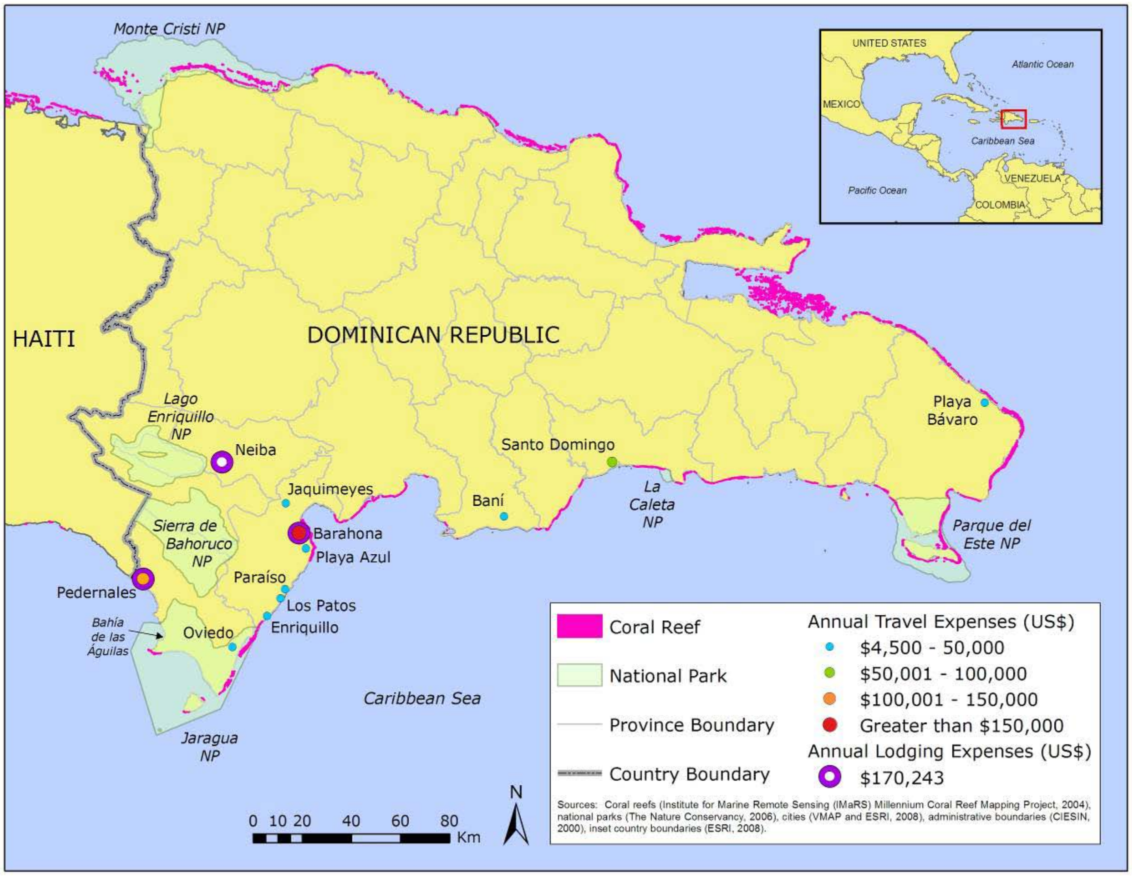
Table 8. Gasoline and food stopovers by visitors to the Biosphere Reserve

Stopover location	Number of gasoline stopovers (and % of total)	Number of food stopovers (and % of total)
Baní	1 (2.4%)	2 (4.5%)
Barahona	19 (46.3%)	18 (40.9%)
Enriquillo	2 (4.8%)	2 (4.5%)
Jaquimeyes	0 (0.0%)	1 (2.3%)
Los Patos	2 (4.8%)	2 (4.5%)
Oviedo	0 (0.0%)	2 (4.5%)
Paraíso	1 (2.4%)	0 (0.0%)
Pedernales	7 (17.1%)	9 (20.5%)
Playa Azul	1 (2.4%)	1 (2.3%)
Playa Bávaro	1 (2.4%)	1 (2.3%)
Santo Domingo	7 (17.1%)	6 (13.6%)
Total number of respondents	**41**	**44**

The mean gasoline expenses of a vehicle (party) per stopover were $32.52 (±$10.37). Assuming an average of four people per vehicle, mean gasoline expenses per person (and stopover) were $8.13. The mean food expenses per person and stopover were $13.43 (±$39.31).

The reserve receives an estimated 24,300 annual visitors (SEMARENA 2004). To estimate the expenses made at each location annually by Dominican visitors traveling by car, we multiplied 24,300 by the corresponding percent participation of each location (see Table 8), and the result was multiplied by the mean per-person expenses in gasoline and food. Figure 8 illustrates the annual estimated expenses in gasoline and food made at each location.

Figure 8. Estimated spending on food, fuel, and accommodation by visitors to the reserve



Each year, Dominican visitors spend approximately $523,000 on food and gas in their stopovers between their cities of origin and the reserve. The majority of the Dominican respondents (28, or 60 percent) camped during their stay in the reserve. The remaining 40 percent rented accommodation for an average cost of $39.81 (±$14.25) per room. Assuming four people per room and a one-night stay, accommodation expenses associated with the reserve were an estimated $9.95 per person, or approximately $193,428 per year. Most hotels are located in the towns of Barahona, Neiva, and Pedernales. People staying in these towns had mean food expenses of $32.64 (±$28.99) per person, which is approximately $317,300 per year. Figure 8 also illustrates expenses in accommodation and food for people staying in hotels, assuming an equal number of people stay at hotels in Barahona, Neiva, and Pedernales. We did not have information on the overall distribution of accommodation, so we conservatively assume an equal breakdown among the three towns.[15]

The entrance fee to the reserve is $2.80 per day, and our survey indicated that Dominican visitors spend two days on average in the parks. Therefore, the payments paid in park entrance fees by the 24,300 annual visitors is approximately $136,000. The minimum willingness to pay of visitors to the reserve is the sum of travel, accommodation, and on-site expenses, which is approximately $1,170,000 per year.

This figure does not include expenses incurred by international visitors to the reserve, which are a small proportion of the total.[16] In addition, expenses incurred at different locations in the country are circulated in the local economies through the multiplier effects of re-spending, amplifying the economic impact of tourism spending. A visitor survey extending through the entire year would be useful to attain a sample size large enough to calculate the recreational benefits above and beyond those that are manifested as current spending (consumer surplus). Finally, the survey could also be expanded to include other types of tourism revenue, such as for tour guides and curios. Therefore, our estimates of the economic benefits of the reserve, while significant, are conservative.

Conclusion

The Jaragua-Sierra de Bahoruco-Lago Enriquillo Biosphere Reserve is a unique destination in the Dominican Republic. An unspoiled area with both terrestrial and marine habitat, it draws thousands of Dominican visitors from across the country every year. We have shown that the economic benefits to the Dominican Republic of the reserve clearly extend beyond the reserve's boundaries. While visitors to the reserve benefit from the extraordinary marine and terrestrial biodiversity of the three parks, numerous communities throughout the country profit from the goods and services they sell to people on their way to the reserve—over $1 million per year in food, gas, and lodging expenses alone. Many of these communities are in rural districts, which include some of the poorest areas in the country (León 2004). Before undertaking any economic activity that may have an impact on the condition of the reserve, including its buffer areas, it is critical to consider the potential effects on the economic benefits currently accruing to these communities.

There is currently a debate in the Dominican Republic between proponents of developing the country's southwest for mass tourism and mining, and supporters of maintaining ecologically friendly (low-intensity) tourism as the mainstay of the region (ACRD 2004). The first group argues that significantly increasing the scale of national and international tourism and allowing the expansion of bauxite and limestone mining is the best way to enhance the economy of the region. Conservation organizations view this scheme as a replication of the mass-tourism model that has damaged coastal ecosystems, including coral reefs and mangroves, in the country's main tourism centers (León 2004). Contributing to this debate are two recent and conflicting laws: Law 64 of 2000 (Law of the Environment and Natural Resources) reinforces previous legislation designed to conserve the region's protected areas, while Law 158 of 2001 (Law for the Support of Tourism Development) names the southwestern portion of the country a "tourism development center" and calls for a rapid expansion of tourism in the region (Ramírez-Tejada 2002).

Experts on the country's natural resources have stated that ecologically fragile areas in the region, such as Bahía de las Águilas, would be unable to support intensive tourism (ACRD 2004). Any ecological damage would also diminish the site's unique recreational value. Moreover, if the southwest region follows the previous tourism development model, which focuses on attracting foreign visitors, it is likely that the value of the area as a center for recreation and enjoyment for Dominicans will be degraded, which will also cause a negative economic impact to communities along the route.

Conclusion

These studies demonstrate how valuable the Dominican Republic's coastal ecosystems are at both the local and national levels. Coralline beaches attract millions of tourists yearly and depend on the existence of healthy coral reefs. Overfishing has already had devastating consequences for the country's fisheries, as well as the incomes of fishermen in recent years. We have seen how fishermen in La Caleta Marine Park could find alternative livelihoods as dive tourism operators, allowing fish populations to recover. Finally, we have seen how the Jaragua-Bahoruco-Enriquillo Biosphere Reserve's current low-intensity pattern of tourism provides benefits to Dominican tourists, sustains local ecosystems, and brings economic benefits to low-income communities throughout the country.

These studies also point to actions that both public and private sector actors in the Dominican Republic can take to protect their coastal ecosystems, allowing for economic benefits to be sustained in the long term. Public awareness about marine and coastal ecosystems—as well as the benefits they provide to society, and threats to their existence—is currently low in the Dominican Republic. An effort to improve public awareness, both through the educational system and more broadly, is needed. Just as important, a critical first step for the government will be to enforce existing laws regulating coastal development and protecting mangroves. This includes Decree 303 of 1987, which bans activities that destroy mangroves. Protection and restoration of sand dunes and their native vegetation would further help to preserve the Dominican Republic's beaches. In addition, managing land-based sources of sediment and pollution—from agriculture, deforestation, and coastal development—will be important to improving coastal water quality and reducing threats to coral reefs. Finally, enforcement of fishing regulations would help to improve the sustainability of fisheries as well as reduce pressures on coral reefs.

A major challenge in conducting these studies was a lack of existing data. The beach protection and fisheries analyses, in particular, were hampered by data gaps, and point to the critical need for improved data collection in the fisheries sector and a better understanding of the physical processes that shape the country's coastlines. Advances in techniques for modeling the protective role of coral reefs against wave damage are also needed, and should ultimately serve as a critical tool for planning development and mitigation efforts in the face of sea-level rise and increases in storm damage associated with climate change.

We hope that local authorities will expand and improve upon these and other economic valuation studies, and move toward integrating ecosystem services into their decision-making. As these studies demonstrate, economic valuation can be a useful tool for framing important decisions, and provides information that can have far-reaching economic consequences. Improving the management of coastal and marine ecosystems—including maintaining existing reserves and enforcing existing regulations—will be to the long-term economic benefit of the Dominican Republic and its people.

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Appendix 1.

Data sources, methodology, and detailed results for Study 1a: Potential Economic Impacts of Beach Erosion in the Dominican Republic

Methods and data sources

To estimate a hedonic function, we used information on room prices and accommodation amenities from the TripAdvisor® website (www.tripadvisor.com). This website publishes hotel reviews and ratings submitted by Internet users. It also provides electronic links for some of the hotels to the travel site Expedia® (www.expedia.com), which uses an objective system ("Star Ratings," given from one to five stars in ½ star intervals) based on the types of amenities available in the hotel installations and rooms. We obtained a complete list of all-inclusive, seaside resorts in the Dominican Republic from a travel agency (Desde el Medio Tours, Santo Domingo). There are currently 87 such resorts, situated in the areas of Playa Bávaro, Punta Cana, Bayahíbe, La Romana, Puerto Plata, Cabarete, Boca Chica, Juan Dolio, and the Samaná Peninsula (Figure 1). The names of the resorts were used as a search term in Google™ Earth to locate the resorts, and the "zooming tool" was used to obtain an eye altitude of 500–700 m. An identical eye altitude could not be achieved with all of the images, so we used the lowest eye altitude possible in this range. This altitude range was found to provide optimal resolution to distinguish areas where the beach and ocean intersected. The main building of a resort was identified (the largest building, usually in the center of the resort, and containing a balloon-shaped marker—a Google™ Earth "placemark"—and a label with the resort name). A line was drawn from the center of the building marker to the point where the surf reached the shore. We used the "ruler tool" to measure the distance between the beginning and end of the beach. Three parallel lines were drawn at intervals of 10 m to each side; this provided a total of 7 measurements to estimate mean beach width. The interval of 10 m was chosen to obtain a horizontal distance of 30 m at each side of the original line. This is the maximum distance that tourists are observed to walk when choosing a site on the beach.[17]

To assess the accuracy of measurements using Google™ Earth, we conducted twelve *in-situ* measurements of various objects using a measuring tape and compared the results with those obtained in Google™ Earth (Table A1). Because beach width changes throughout the day because of the effect of tides (discussed below), and because the time of day at which photographs were taken was not available in Google™ Earth, it was not possible to compare measurements of beach width obtained from Google™ Earth to *in-situ* measurements, and thus comparisons of beach measurements were avoided. Google™ Earth underestimated the measurements in 10 of the 12 occasions, and the mean ratio of real to Google™ Earth measurements was 1.02 (SD=0.04). Consequently, we corrected our Google™ Earth measurements of beach width by multiplying by 1.02. Google™ Earth provides the year in which its photographs were taken, and for the sites that we studied in the Dominican Republic, the year of photograph acquisition ranged from 2003 to 2008. Because we wanted to compare current (2009) room prices to current beach width, we corrected the beach width of photographs for past beach erosion. Beach erosion rates for the Dominican Republic were not available, so we assumed a constant annual erosion rate of 0.5 m/yr, which was the mean reduction in beach width measured at 113 beaches on eight Caribbean islands between 1985 and 2000 (Cambers 2009).

Table A1. Comparison of 12 measurements taken on the ground and using the "ruler tool" in Google™ Earth

Object	A. *In situ* (m)	B. Google Earth (m)	A/B
Bridge length	27.0	28.8	0.94
Building 1 side	18.0	18.4	0.98
Building 2 side	35.0	34.7	1.01
Building 3 side	17.2	16.5	1.04
Building 4 side	37.0	36.1	1.02
Park diameter	55.5	53.8	1.03
Parking lot 1 side	17.5	15.5	1.13
Parking lot 2 side	44.0	41.8	1.05
Parking lot 3 side	47.5	47.4	1.00
Parking lot 4 side	48.4	45.1	1.07
Pond side	43.5	42.6	1.02
Pool side	50.0	48.6	1.03
Mean	**-**	**-**	**1.02**

In our analysis we assumed that the beach measurements conducted in Google™ Earth reflected mean tide levels.[18] During high tide, a section of each beach becomes unusable to beach-goers, and we studied if the width of the portion of beaches that remains dry throughout the entire day is a better predictor of room prices than the tide-dependent beach width. To do this, we used mean spring tide ranges for Hispaniola (NOAA 2009). Half of this value (0.31 m; SD=0.12 m) is the mean water elevation above mean tide level during spring tides. From Geraldes et al. (2004) we obtained information on mean beach slopes (±SD) for the Punta Cana area (5.6°±0.72°), Samaná Peninsula (6.3°±1.95°), and the Puerto Plata/Cabarete areas (5.6°±0.37°). Data on beach slopes was not found for Bayahíbe, La Romana, Boca Chica, Juan Dolio, or Playa Bávaro, and these slopes were assumed to be the same as in Punta Cana, which is in the same general location (Figure 1). Using tide and slope information, we calculated the reduction of beach width in the different areas of the Dominican Republic during spring tides: 3.2 m in Punta Cana, Bayahíbe, La Romana, Boca Chica, Juan Dolio and Playa Bávaro; 2.8 m in Samaná; and 3.2 m in Puerto Plata and Cabarete.

The resorts that were located in Google™ Earth were then searched by name in TripAdvisor's webpage for the Dominican Republic (http://www.tripadvisor.com/Hotels-g147288-Dominican_Republic-Hotels.html). Information was collected on hotel size (number of rooms), per person room price (annual average of daily price per person), and the number of guests who reviewed each resort. The guest ratings for value and cleanliness on TripAdvisor were also recorded, since they are not explicitly included in the computation of Expedia's Star Ratings. Value measures how much satisfaction guests believe they obtain for each dollar spent. Because it is an indicator of overall satisfaction, we tested if value was correlated to the other hedonic variables. Finally, information on the distance of the resort to the nearest airport was recorded. The mean number of TripAdvisor guest reviews (±SD) of the resorts in our sample was 575 (±507).

Each tourism area was assigned to one of three regions: southeast (Punta Cana, Bayahíbe, La Romana, Playa Bávaro), north (Puerto Plata, Cabarete), and other (Boca Chica, Juan Dolio, Samaná). Two dummy variables were used to assign resorts to a region (Table 1). For each dummy variable, a value of 1 was assigned to resorts located in that region, and a value of 0 to resorts not located in that region. Resorts in the other category were assigned zeros for both variables. Star ratings were also divided into three categories and classified with two dummy variables (Table 1). For the first variable (medium star rating), resorts with a rating of 3.5 stars (43 percent of the samples) were coded with 1, and all other resorts were coded with 0. For the second variable (high star rating), resorts with a rating of 4.0 and higher were coded with 1, and all other resorts were coded with 0. The remaining hotels had ratings below 3.5 and were assigned zeros for both variables.

Results

We estimated three regression models that are commonly used in hedonic analysis (Freeman 2003): linear, log-log, and log-linear. The linear form of the hedonic function using the entire beach length had a higher goodness of fit (R^2=0.6534) than the log-log (R^2=0.5639) and log-linear (R^2=0.5405) specifications. In addition, this model had a somewhat higher goodness of fit than the linear model that considered reductions in beach width at high tide (R^2=0.6531), and the coefficient estimates for both models were very similar, so we used the linear model to estimate the hedonic coefficients. The linear model also complied with the assumptions of normal regressions according to the global validation test of Peña & Slate (2006) (Table A2).

Table A2. Results of the test for compliance with the assumptions of normal regressions

Assumption tested	Parameter and p-values
1. Skewness	S_1 = 1.011, p = 0.315
2. Kurtosis	S_2 = 2.506, p = 0.113
3. Linearity	S_3 = 2.566, p = 0.109
4. Homoscedasticity	S_4 = 0.006, p = 0.938

Source: Peña and Slate 2006.

The mean price (±SD) of accommodation for one person per night was $263 (±$75). The location of the resort did not have a significant effect on room prices. Beach width and high star rating were significant predictors of room prices at the 1 percent significance level, and value was a significant predictor at the 10 percent significance level. The absolute magnitude of the value and high star rating coefficients were 1 and 2 orders of magnitude higher, respectively, than the magnitude of the beach width coefficient (Table 1). The overall model was significant at the 1 percent significance level.

Larger resorts may offer a larger variety of amenities to their guests, but their beaches may also be more congested. However, there was no evidence that resort size was a positive or negative attribute because the coefficient was not significant. Unexpectedly, the coefficient of distance to airport was positive (Table 1). The variance inflation factor (VIF) of this variable (1.578) is considerably lower than the threshold for consequential collinearity (VIF=10) proposed by Hair et al. (2006), so collinearity does not appear to explain the unexpected sign of this variable. However, the average distance to an airport was relatively low (24 km), and distances were relatively uniform (SD=7.6 km), which may explain the variable's lack of statistical significance. We had no theoretical grounds for predicting the sign of the value coefficient. We found no indication of collinearity for this variable (VIF=2.512), and the negative sign of its coefficient suggests that the amenities offered by highly priced resorts, on average, do not compensate for their high prices in terms of the relative satisfaction obtained by their guests.

Appendix 2.

Parameter values and data sources for Study 1b: Coral Reef Decline and Beach Erosion in the Dominican Republic

The model requires information for the following parameters (see Sheppard et al. 2005 for details):

1) slope of the edge of the reef where the waves break (reef face);
2) depth of the reef edge;
3) average depth of the reef (multiple points);
4) average width of the reef from the edge to the beach;
5) slope of the beach;
6) root mean square (RMS) of offshore wave height;
7) mean offshore wave period; and
8) the coefficient of bottom friction of the reef flat.

We estimated parameters 1–3 using field observations contributed by Reef Check; we used the "ruler tool" of Google™ Earth 5.0 to obtain 10 measurements of reef width at regular intervals for calculating the average reef width (we measured the length of the line perpendicular to the coastline drawn from the edge of the beach to the edge of the reef, where breaking waves were observed). We obtained beach-slope data for the eastern reef from Geraldes et al. (2004), and assumed the same slope for the southern reef. RMS estimates of significant wave height (the mean of the highest 1/3 of waves) and mean wave period for the Caribbean were found in Calverley et al. (2001). We converted significant wave height (SWH) to RMS wave height by using the equation SWH = 1.4•RMS (Gourlay 1997). Sheppard et al. (2005) provided values for the friction coefficient that correspond to different levels of live coral cover. A value of 0.14 corresponds to reefs containing 10 percent or more cover of living or recently dead corals, which is the situation for the eastern and southern reefs.

Table A3. Input values for parameters used in the estimation of changes in wave height

Parameter	Eastern reef	Southern reef
Reef profile shape factor	0.78	0.67
Tangent reef-rim angle	1.0	0.60
Offshore wave height (RMS)	1.2 m	1.2 m
Offshore wave period	5.2 sec	5.2 sec
Reef flat depth	2 m	2 m
Depth of reef edge	17 m	15 m
Tangent of beach slope gradient angle	0.10	0.10
Reef width	1,028 m	388 m
Frictional coefficient	0.14, 0.10	0.14, 0.10

Source: See Gourlay (1997) and Sheppard et al. (2005) for details.

Appendix 3.

SCUBA DIVING STUDY
LA CALETA NATIONAL MARINE PARK

Reef Check Dominican Republic
World Resources Institute

La Caleta National Marine Park was established in 1986 to protect the area's coral reefs. SCUBA divers enjoy the park's clear waters, the abundant fauna and flora of its reefs, and its wrecks. Diving sites with abundant fish such as groupers, snappers, parrotfish, and moray eels can be found at depths between 10 and 90 feet. The park is located 15 miles from Santo Domingo and less than two miles from Santo Domingo airport.

La Caleta Marine Park currently faces a serious challenge: the number of fishermen who fish for a living in areas near the park has increased in recent years, and fishing activities are affecting the fish populations inside the park. The goal of this study is to find incentives for fishermen to become involved in the tourism sector instead of continuing to rely on fishing.

For fishing to stop, fishermen would have to earn at least the same income as diving operators as they currently earn in their fishing activities. For this to occur, each SCUBA diver would have to pay a fee of $60 for two dives, which includes transportation to and from Santo Domingo or Santo Domingo airport, transportation to the diving sites, and rental of SCUBA equipment.

Previous scientific studies have shown that if fishing stops, fish populations in La Caleta Marine Park will be able to recover. Previous studies have shown that it takes between three and five years for reef-fish populations to recover. The following photographs show how a typical diving site in the park may look like after the fish populations have recovered.

Photographs by José Alejandro Álvarez

Please answer the following questions regarding La Caleta Marine Park

1. Considering your other expenses during your current visit to the Dominican Republic, would you be willing to pay at least US$60 for two dives in La Caleta Marine Park after the fish populations have recovered? Yes__ No__

2a. If you answered **Yes**, how much is the maximum amount that you would be willing to pay for two dives in La Caleta Marine Park? US$ ______

2b. If you answered **No**, how much is the maximum amount that you would be willing to pay for two dives in La Caleta Marine Park? US$ ______

3. What is the main purpose of your current visit to Santo Domingo?

Tourism	Business	Other (please specify which)

4. From what city and country did you travel to Santo Domingo? __________________________

5. Is Santo Domingo the sole destination of your current trip? Yes__ No__

6. What mode of transportation did you use to get to Santo Domingo? Air__ Sea__

7. Is this your first visit to Santo Domingo? Yes__ No__

8. How many days do you intend to spend in Santo Domingo during your current trip? ______

9. Have you ever dived in La Caleta Marine Park? ______

10. If you answered yes to question 7, how would you rank La Caleta Marine Park as a diving spot among the other places that you have dived in?

Exceptional	Very Good	Good	Average	Below Average

11. What is your age? _____

12. Sex: M__ F__

13. The average gross annual income per **household** in the United States is $61,000. Is your household income:

___ Considerably higher than the average
___ Approximately average
___ Considerably lower than the average

If you are not a U.S. citizen, please classify your household into the categories above based on your estimate of your country's average gross annual income level.

14. For how many years have you been a SCUBA diver? ______

15. Do you belong to a nature conservation organization? Yes__ No__

16. What is the highest level of education that you completed?

Sixth grade	High school	Technical school	College undergraduate	College graduate

Thank you for your participation!

Appendix 4.

Socioeconomic Study- Jaragua Nacional Park
Reef Check-República Dominicana
World Resources Institute

Jaragua Nacional Park occupies an area of 1,374 km^2, and includes Beata and Alto Velo islands, as well as Los Frailes and Piedra Negra keys. The park was established in 1983 to protect the diverse fauna and flora of the region, and it is one of the most important recreation areas for Dominicans. The goal of the present study is to estimate the social and economic benefits that the park provides to its visitors and to people who depend on the park for a livelihood. We would be grateful for answering the following short questionnaire regarding your visit.

1. What is your nationality? ________________________

2. From what city and province did you travel to the park? ________________________

3. On average, how many visits do you make to the park during the year, and how many days do you spend on each visit?
   Number of visits: ________ Number of days per visit: ________

4. If you traveled by car, how many people traveled with you in your vehicle? ________

5. How many days will you be spending in the park, and where will you be staying?
   Number of days: ________ Name and location of accommodation: ____

6. What are your approximate expenses in food and lodging during your stay? Please also include expenses for other members of your party. Please **do not** include expenses incurred during the road trip from your city of origin to the park.
   Lodging _________ Food (Own expenses) ________ Food (Others in party) ____________

7. Please indicate in which towns you stopped for gasoline (if you traveled by car) and food on your way to the park:

Name of town	Approximate gasoline expenses (if traveling by car)	Approximate food expenses	
		Own	**Others in party**

8. If you traveled in a bus tour, please provide the cost of your ticket. If you traveled with your family, please also provide the cost of tickets for the other members of your family.
   Own_______ Others ________

9. What is your age? __ ¿What are the ages of the other members of your family who are traveling with you? _________

10. Sex: M ____ F____ (please indicate with an X)

11. Please provide the approximate monthly income of all members in your household: ________________

12. What recreational activities do you like to do in the park? ____

13. What level of education have you completed? (please indicate with an X):

Primary school	High school	Technical college	Undergraduate degree	Graduate degree

14. Do you belong, or have recently donated money, to a nature-conservation organization? Yes ___ No ___ (please indicate with an X)

Thank you very much for your participation

Notes

[1] Unless otherwise noted, all dollars are U.S. dollars.
[2] A recent publication (CTO 2009) estimated that there are approximately 65,000 hotel rooms in the Dominican Republic, of which approximately one-half are in all-inclusive, seaside resorts (Coles 2004).
[3] Model statistics:
Multiple R^2=0.653
$F_{(9, 20)}$=4.188
P(>|F|)=0.004
[4] R. Alfonso, pers. comm., October 20, 2009.
[5] K. Strum, Wyndham Tangerine, pers. comm., October 8, 2009.
[6] Coral reef data obtained from Reef Check-Dominican Republic for four sampling sites in the east and three sampling sites in the south.
[7] In addition, a hard, fossilized reef structure may lie at a certain depth below the recently deposited reef structure, and the erodibility of this fossilized structure may be very low (for example, see Grigg 1998). For precise measurements of erosion, field studies on the stratigraphic structure of specific reefs are required.
[8] This chapter was written with the help of Jeannette Mateo, Dominican Council for Fisheries and Aquaculture (CODOPESCA), Edificio Secretaría de Agricultura, Km. 6.5 Avenida Duarte, Santo Domingo.
[9] The Dominican Republic has reported its official fisheries landings to FAO since 1950; this information is available from FAO's fisheries databases (available at http://www.fao.org/fishery/statistics/software/en). The country reports landings on 32 fishery groups. Each group corresponds to a species (e.g., Caribbean spiny lobster) or a family (e.g., grunts).
[10] Most of the landed conch was exported until 2003. Since 2003, exports have been banned following recommendations by the Convention on International Trade in Endangered Species (CITES). The export price of queen conch was approximately $9.00/kg. The local price is currently $2.53. Revenue calculations for 1982–86 and 1992–96 used the pre-2003 price, and revenue calculations for 2002–06 used the current price.
[11] In order to provide a reference value for the willingness to pay questions, we estimated a realistic figure based on current diving expenses. Fishermen that currently offer boat-transportation services to divers charge 1,200 Dominican pesos ($33) for transporting 1–4 divers to a dive site. There are usually 4 divers per boat, so the average cost per diver is $8.25. Divers currently pay between $33 and $45 for the rental of diving equipment, which is currently done in Santo Domingo or Boca Chica. Therefore, total current diving expenses are approximately $47, and we used a reference value of $60 in the surveys to account for a possible higher willingness to pay due to the expected recovery of the fish populations in the park.
[12] Linear demand functions for domestic and international divers were assumed for simplicity. Assuming a linear demand function, the revenue maximizing fee is one-half the maximum WTP. Variables were log (X+1) transformed to improve linearity, and R-squared values with transformed values were 0.827 and 0.850 for domestic and foreign divers, respectively. Estimated regression parameters were back-transformed to calculate revenue maximizing fees.
[13] In this study, 67 tourist divers and 35 domestic divers completed the survey during June 2009. The number of tourists was higher because the surveys were administered at the Santo Domingo airport and at diving centers, and the number of respondents at the airport (where more tourist divers than domestic divers were encountered) was larger.
[14] A. L. Franco, pers. comm., February 6, 2009.
[15] The survey only provided information on where visitors to La Jaragua stayed during their visit; this was not enough information to scale up with confidence for visitors to the wider reserve. As a result, the accommodation figures here are a rough estimate that could readily be improved with a local survey at entrances to the reserve.
[16] P. Feliz, INTEC, pers. comm., October 23, 2009.
[17] K. Strum, Wyndham Tangerine, pers. comm., May 5, 2009.
[18] As noted above, images in Google Earth are taken at different points in the day and thus at different tides. In making this decision, we took into consideration the fact that the effects of tides on beach width in the Dominican Republic are fairly small. The average width of the beaches in the DR is 47 m and the daily changes in width average approximately 3 m, which is about 6 percent of total width.

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