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SEDIMENTATION AS AN IMPORTANT ENVIRONMENTAL INFLUENCE ON DOMINICAN REPUBLIC REEFS

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ABSTRACT

Reconnaissance surveys and benthic community mapping in Parque Nacional del Este, southeastern Dominican Republic, revealed that discontinuous and poorly developed fringing reefs are interspersed with vast areas of low-relief hard-bottom in coastal shelf areas of the mainland peninsula and Isla Saona. Predominant reef and hard-bottom (non-reefal) community types are patch reefs, shallow and deeper low-relief hard-bottom, reef crests, and deep fore reef slope communities represented by rocky outcrops and low-relief spur-and-groove. Coral cover is very low (<10%) in most sites and consists predominately of relatively sediment-tolerant species such as *Montastraea cavernosa* and *Siderastrea siderea*. *Acropora palmata* and *A. cervicornis* do not form extensive and well-developed shallow (reef crest or reef flat) or mid-depth (fore reef terrace) reefs. Spatial patterns of hard-bottom community structure suggest that wave energy and natural, episodic sedimentation events are important environmental factors to consider when evaluating the condition of reefs in this area. Qualitative observations and quantitative data collected from the eastern area of the Park near the Mona Passage to the more sheltered leeward peninsula indicate a gradient in the development of reef crests and fore reef slope communities. Biological patterns were corroborated by information on monthly sedimentation rates collected during 1996–97 in mid-depth (15–20 m), fore reef slope communities. Coral coverage is lower (<5%) and the abundance of octocorals is greater in more exposed, lower relief hard-bottom communities. These relationships suggest that reef and hard-bottom communities in the southeastern Dominican Republic are naturally stressed by sedimentation, and the paucity of reef frameworks likely reflects a long-term pattern of sedimentation and strong wave energy. Potential threats from increasing tourism development in the area could have dire consequences for the resilience and recovery of coral reefs, directly related to the protection of economically important beach resources.

Sedimentation is among the important factors determining coral reef distribution, community structure, growth, and recruitment (Stoddart, 1969; Hubbard, 1986; Yoshioka and Yoshioka, 1989). It is well known that coastlines subjected to heavy sedimentation, freshwater flooding, or excessive storm and wave action generally do not support structural reefs. Sediment characteristics in coral reef environments reflect a wide range of biological, physical, and chemical processes involved in formation and diagenesis (physical and chemical alteration of sediment after deposition) (Orme, 1977). Factors such as depth, circulation, the abundance of certain biota and reef geometry influence the distribution of sediment components (Clack and Mountjoy, 1977).

Sedimentation can result from natural processes or anthropogenic activities. Natural sources of sediment include river input, land-runoff after heavy rainfall, shoreline erosion, and sediment re-suspension during episodic events such as tropical storms (Loya, 1976; Rogers, 1983; Hubbard, 1986; Hands et al., 1993). Anthropogenic sources are dredging and coastal construction (Dodge and Vaisnys, 1977; Bak, 1978), terrestrial runoff from urbanization, and agricultural development (Maragos, 1972; Cortés and Risk, 1984). Land-based sources of total suspended solids are, in fact, one of the biggest potential sources of coral reef degradation (Rogers, 1990). In the wider Caribbean alone, land-based sources of sediments have increased 20% since 1960, reflecting significant changes in land use and lack of infrastructure development (UNEP, 1994). Chemical pollution (chlorine, heavy metals, and hydrocarbons) often accompanies sediment loading and the effects on coral reefs may be difficult to separate (Walker and Ormond, 1982). In addition, natural processes such as beach erosion, storms, and shoreline dynamics may mimic or act synergistically with human impacts (Hands et al., 1993).

An important consideration in evaluating sedimentation effects on coral reefs are whether sediment is delivered to the substratum or is simply advected through the system. Other important factors are the frequency of exposure, the organisms present, and the physical-chemical characteristics of the sediment (Hubbard and Pocock, 1972; Bak and Elgershuizen, 1976). In cases where sediments are advected through the system, the main negative effect is a reduction in light levels from increased turbidity (Bak, 1978). When sediment deposition occurs, the effects on coral reef organisms may include changes in coverage, species diversity, dominance patterns, growth rates and growth forms, mortality, and recruitment (Loya, 1976; Dodge and Vaisnys, 1977; Cortés and Risk, 1985). Sedimentation effects may be strongly species-specific, ranging from minimal to catastrophic (Brown and Howard, 1985; Pastorak and Bilyard, 1985; Rogers, 1990). Decreased calcification, photosynthetic and nutrient uptake rates, and increased production of mucus, zooxanthellae expulsion, and pathology are common responses of reef corals to sedimentation (Rogers, 1983; Brown and Howard, 1985).

This paper discusses a short-term evaluation of sedimentation and wave energy effects on coral reefs in the southeastern Dominican Republic. The study was undertaken in Parque Nacional del Este (PNE), a large coastal national park, to better understand natural and anthropogenic influences on this coastal ecosystem. Observations of coral reef and hard-bottom community structure and distribution are evaluated with respect to sedimentation patterns observed during a 1-yr period. These findings have implications for assessing the condition of coral reefs in the study area and potential increases in tourist visitation and coastal development pressures.

Study Area

Located in southeastern Hispaniola, Parque Nacional del Este (PNE) is the second largest coastal national park in the Dominican Republic. It comprises over 434 km^2 of terrestrial habitats and 120 km^2 of shallow-water (<30 m) marine habitats (not legally included to date) (Fig. 1). PNE is administered by the government and was designated a national park by the Dominican government in 1975. PNE is bordered by San Rafael de Yuma to the north, Bahía de Yuma to the east, and the Caribbean Sea to the south. Isla Saona is separated from the mainland by a large, mostly shallow (<10 m) lagoon (Canal de Catuano), with limited freshwater input and a deeper channel (Paso de Catuán) along the lagoon's southern boundary. To the south and east of Isla Saona are fringing reefs and a deep broad platform of low-relief hard-bottom and seagrass beds. The island shelf is very narrow, generally less than 1.5 to 2 km in width, and drops off precipitously into the Mona Passage.

Physical transport mechanisms near PNE are dominated by the North Equatorial Current. This current flows westward towards the Dominican Republic at 50–75 cm s^{-1} (Molinari et al., 1981) and divides into two currents north (Antilles Current) and south

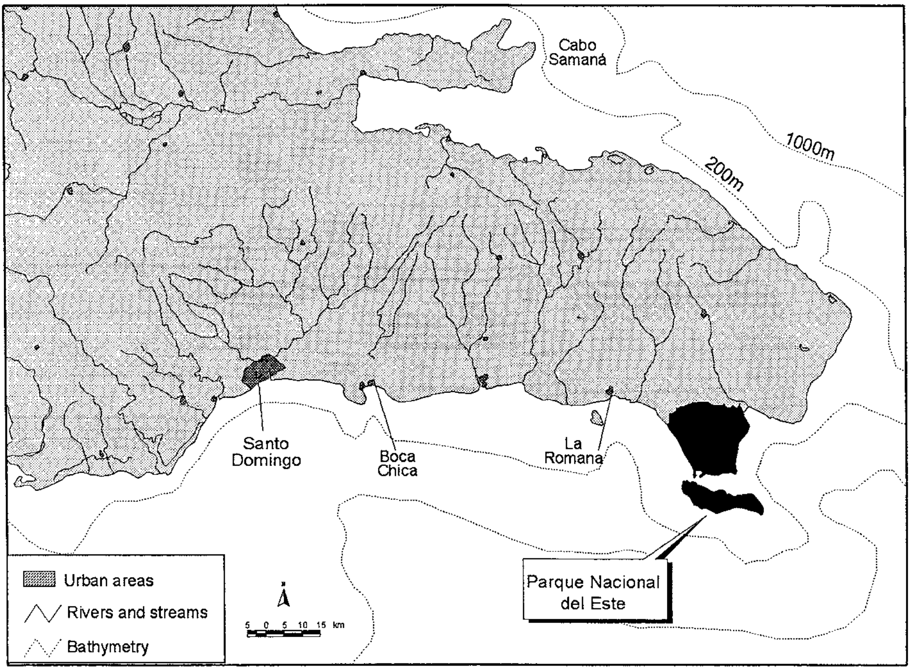

Figure 1. Location of Parque Nacional del Este, southeastern Dominican Republic.

(Caribbean Current) in the Mona Passage (Molinari et al., 1981). Averaging 300–400 m in depth, the Mona Passage is characterized by strong, complex tidal currents (Metcalf et al., 1977). Diurnal tides are present in the southeastern Dominican Republic, with a mean spring tidal range of 18–20 cm at La Romana, northwest of the PNE. Counter-currents (eastward flow) are common close to shore and are usually associated with tides. A major feature of PNE is the absence of surface freshwater resources; there are no lakes, few ponds, rivers, or large freshwater swamps. Annual rainfall is low (15–16 cm yr^{-1}), which collects in small basins and hollows during May–November, and soils are extremely thin. PNE and the southern Dominican coast are strongly affected by tropical storms (Fig. 2); these events can result in significant peaks in precipitation and sedimentation from re-suspension nearshore or coastal erosion. From 1945–96, sixteen tropical storms ranging in intensity from a tropical storm to a Category 5 hurricane have passed within 200 km of the southeastern coast. Of the 16 storms, 50% were hurricanes when they passed over PNE. Most tropical storms occur during August and September and have an average frequency of occurrence of one storm every 3 to 4 yrs.

Human impacts to PNE include fresh-water usage, clearing of coastal vegetation near tourist beaches, and fishing. There are no commercial developments within the park boundaries, but tourism infrastructure is increasing northwest of the park. Small wastewater treatment plants serve Bayahibe and the Dominicus resort, but these are not efficiently operated and the spatial extent of the discharge to coastal waters is unknown. Local communities obtain their fresh-water from wells, but also dispose of sewage through wells. An estimated 85,000 tourists visited the Park in 1993, compared to only 10,000 in 1989 (Vega et al., 1996). The population of three of the small towns within and near PNE totals 2156.

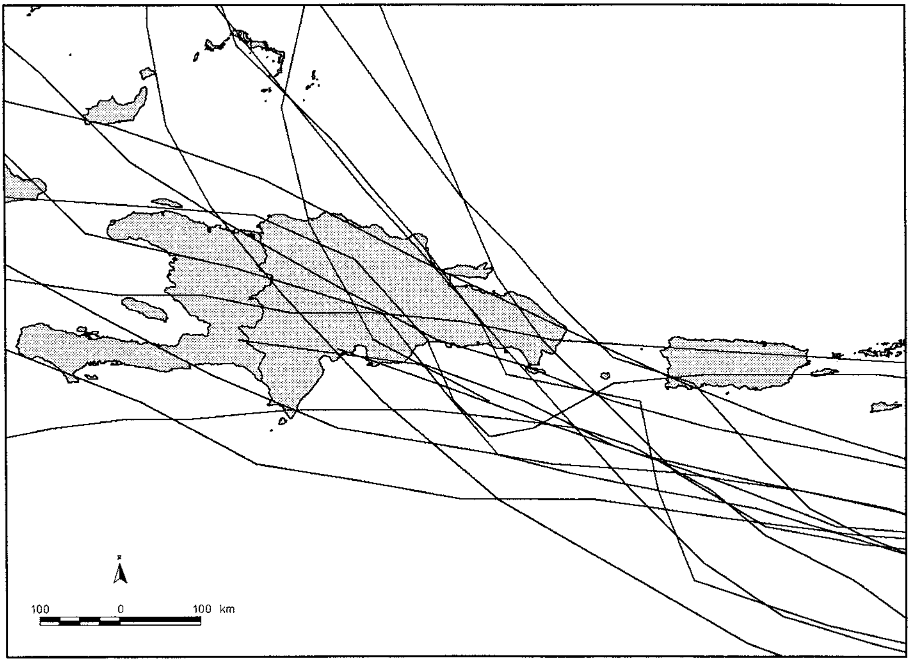

Figure 2. Tropical storm paths within 200 km of the southeastern Dominican Republic during 1944–1996 (data from http://wxp.atms.purdue.edu/hurricane/atlantic and http://www.nhc.noaa.gov/tracks.html).

Materials and Methods

Rapid Ecological Assessment.—The evaluation of sedimentation effects on coral reefs in the southeastern Dominican Republic was an iterative process beginning with a rapid ecological assessment (REA) in March 1994. An REA is a flexible process used to obtain biological and ecological baseline information for effective conservation and resource management decision-making. The REA integrates a hierarchy of methods to produce maps of natural communities and descriptions of flora and fauna. The synthesis of this information forms the basis for planning and implementing research and monitoring programs, but also strategic plans of protection, management, and information needs of a protected area. The objectives and rationale of REAs can vary, but typically include descriptions of natural communities, development of habitat or community maps, inventories of biota, and threats analysis (Vega et al., 1996).

The marine REA for PNE included 21 d of field sampling during March 1994 to map and reconnaissance sample mangrove, rocky intertidal and shallow-water benthic (<30 m) communities. Natural-color aerial photography of PNE was obtained at a 1:24,000 scale 1 mo prior to field surveys. Two sources of remote sensing data were acquired: Landsat Thematic Mapper (TM), which is digital satellite data, and aerial photography flown specifically for the REA. In February 1994, 80-color infrared, aerial photographs were taken for the terrestrial REA, while 70 natural-color aerial photos were captured for the marine REA. Fifteen hard-bottom sites from 0.5–22 m depth in PNE were surveyed using rapid assessment approaches during 1994–96 (Fig. 3). These sites represent seven hard-bottom or coral reef types distributed throughout the Park (Table 1). Rapid assessment surveys consisted of species presence-absence inventories and visual estimates of benthic coverage in quadrats using coverage classes (Bradbury et al., 1986). In coral reef and hard-bottom communities delineated on the photographs, replicate 25 m transects were oriented from inshore to offshore

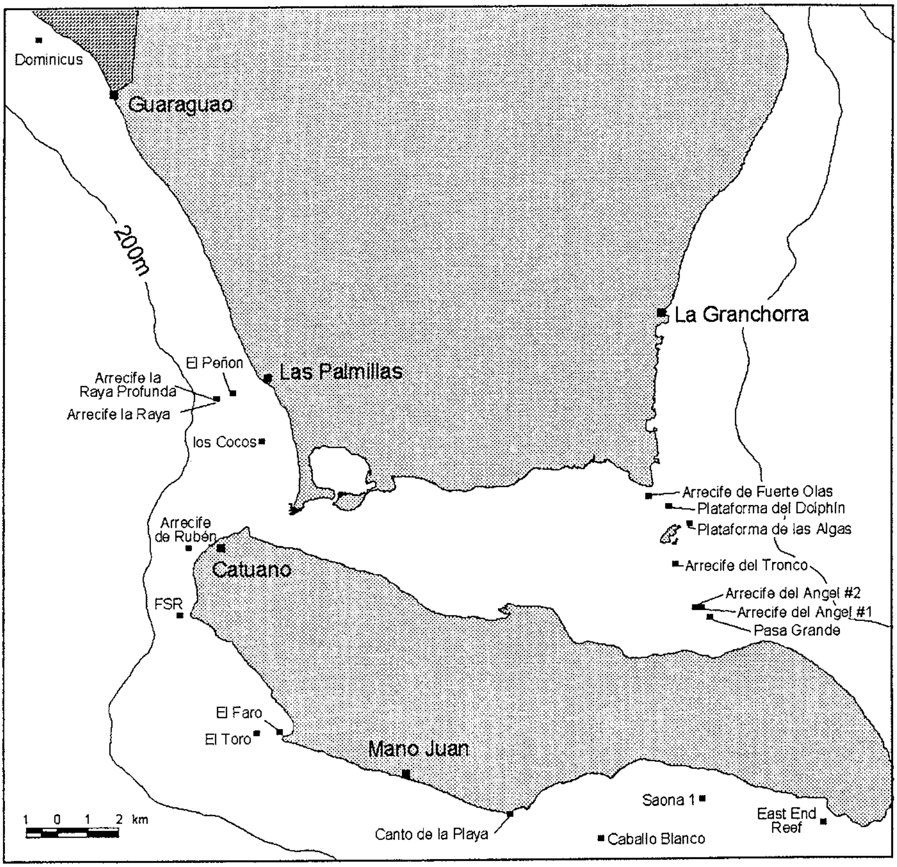

Figure 3. Reef and hard-bottom sampling sites in Parque Nacional del Este, southeastern Dominican Republic. Four sites (Dominicus, La Raya, Rubén and El Toro) were surveyed for sedimentation and benthic community structure.

and used as a guide for the placement of quadrats measuring 1 m^2. These were surveyed continuously along transects for visual estimations of substrate types (sand, rubble, algae, sponges, corals, octocorals) using the phytosociological method described in Van den Hoek et al. (1975).

Detailed Surveys of Reef Community Structure.—Upon completion of the marine REA, subsequent studies of coral reefs were undertaken in PNE during 1995–98 to obtain more detailed information on benthic community structure and important environmental factors like sedimentation. Four reefs in PNE were selected for periodic monitoring (every 4 mo) beginning in March 1996: Dominicus, La Raya, Rubén, and El Toro (Fig. 3). Within each reef, twenty 1 m^2 quadrats were permanently marked with stakes and benthic coverage was determined using point-intercept counts (Weinberg, 1981). A 1 m^2 quadrat was divided by string so that 25 intersection points were contained in the area of the quadrat. The type of bottom cover under each point was identified as sediment, bare hard-bottom, algae, sponges, hard corals, octocorals, and other benthic cnidarians. Because coverage by octocorals can be under-represented in point-intercept surveys, colony counts were made as well. Differences in mean coral cover and octocoral density were determined using one-way analysis of variance. Untransformed octocoral density data were used, but because of variance heterogeneity (Bartlett's test, $P < 0.05$), coral coverage data used in the Model I ANOVA was transformed (arcsine) prior to testing. Tukey's range simultaneous test procedure was used as the multiple comparison test (Zar, 1996).

SEDIMENTATION MONITORING.—Sedimentation was measured to evaluate monthly depositional rates (March 1996 to March 1997) among four mid-depth (17–20 m) fore reef areas with different degrees of exposure to the Canal de Catuano and oceanic processes on southern Isla Saona. The four sites, from northwest to southeast, were Dominicus, La Raya, Rubén, and El Toro. Sediment traps capture re-suspended sediments, which refers to material settling down onto the reef surface (Tomascik and Sander, 1985; Rogers et al., 1994). The flux of this material is a measure of gross sedimentation rate and is generally correlated with suspended particulate matter (Cortés and Risk, 1985). Sediment traps constructed of polyvinyl chloride (PVC) cylinders 3 in (7.62 cm) in diameter and 9 in (22.86 cm) in height (3:1 height to diameter ratio) were secured to permanent stakes so that the tops of the traps were 20 cm above the reef surface. Five traps were set in each reef and collected every 20–40 d. Sediment traps were transported to facilities in Santo Domingo for analysis after retrieval from the field. Trap contents were poured onto pre-weighed Whatman #2 filters fitted into a Buchner funnel and rinsed with distilled water to remove salts. Filters were placed in a drying oven at 70ºC until a constant filter weight was obtained. The sedimentation rate (mg dry weight cm^{-2} d^{-1}) was calculated as: [(sediment + filter weight) − (filter weight) ÷ (no. of days) ÷ (area of trap)]. The null hypothesis that sedimentation was independent of reef location and time of year was tested using two-factor ANOVA. Because sample variances were found to be heterogeneous ($P < 0.001$) and proportional to the mean according to Bartlett's test, a logarithmic transformation ($\log_{10}(x+1)$) was used on raw data (Zar, 1996).

RESULTS

DISTRIBUTION OF CORAL REEF AND HARD-BOTTOM COMMUNITY TYPES.—Surveys of marine benthic communities in PNE were used to develop a benthic community map; the 1996 version of the map is available in Vega et al. (1996). Hard-bottom communities, both reefal (constructional reefs, three-dimensional complexity) and non-reefal (low-relief hard-bottom), comprise 4383.1 ha, or 36.9% of the mapped subtidal area of PNE. Hard-bottom communities are represented by shallow (<10 m), low-relief hard-bottom, patch reefs, reef flats, reef rubble, reef crest or algal ridge, deep hard-bottom, deep reef outcrops, and low-relief spur-and-groove (Table 1). Low-relief hard-bottom comprises 50% of the total hard-bottom area (southern Isla Saona and bordering the Mona Passage), while patch reefs and fringing reefs (reef crest) together comprise 27%.

Reef crests are common on the southern coast of Isla Saona and near Isla Catalinita in the eastern Canal de Catuano, but are generally small and discontinuous on the southern coast of Isla Saona. Most are shallow (0.5–4 m depth) and dominated by brown frondose algae covering a dead elkhorn coral framework. Surveys of three reef crest sites along southern Isla Saona suggest that the size, three-dimensional complexity, and percentage live coral cover (particularly by *A. palmata*) increase from the eastern to western end of the island. This pattern reflects an exposure gradient from the highest wave energy conditions in the east to the more protected conditions in southwestern Isla Saona.

Fore reef slope communities (>15 m depth) consist of low-relief hard-bottom or relict reefs and were the focus of sedimentation monitoring. Low-relief hard-bottom dominates the platform along the southern coast of Isla Saona and the eastern area of PNE bordering the Mona Passage. In the western and more sheltered area of PNE, more structurally complex communities are present, represented by low-profile coralline spurs separated by coarse sediment. Large sponges are visually abundant and vertical relief may reach 1 m, but is generally less than 0.5 m. In addition to low-relief spur-and-groove, low-relief

Table 1. Location of reconnaissance surveys and monitoring sites in Parque Nacional del Este, Dominican Republic. Refer to Figure 1 for site locations.

Reef/hard-bottom type	Depth (m)	Sites surveyed
Low-relief hard-bottom		
Shallow, algal-dominated	2–3	Los Cocos
Windward, algal-dominated	4–10	Plataforma del Delfín, Plataforma de las Algas
Shallow, octocoral-dominated	3–8	FSR, El Faro #2 (Punta Faro)
Deep, octocoral-dominated	16–20	El Toro Reef
Reef crest/back reef	1–7	Fuerte Olas, Caballo Blanco, Canto de la Playa, Saona 1, East End Reef
Reef flat	0.5–4	Pasa Grande, Arrecife del Tronco
Patch reef	3–7	Arrecife del Angel #1, Arrecife del Angel #2
Reef ridge	6–10	El Peñón
Low-relief spur and groove	17–22	Dominicus Reef, Arrecife de Rubén
Deep reef outcrops	17–20	Arrecife la Raya
Deep fore reef slope	25–30	Arrecife la Raya Profunda

rocky outcrops also occur in the western area of PNE. Instead of coralline spurs, these sites consist of small patches of reef separated by greater expanses of sand.

Benthic Community Structure.—Fifteen sites representative of the types of hard-bottom and reef communities in PNE were sampled for percent coverage of major bottom types during rapid assessment surveys (Fig. 3). Survey sites were distributed over a wide depth range (0.5–30 m) and included true coral reefs (patch reefs, reef crests) and non-reefal hard-bottom. In all fifteen sites surveyed using rapid assessment approaches (visual estimates of coverage using cover classes), algae were the dominant bottom type, with mean coverage among sites ranging from 40% to nearly 90%. Algae were most abundant in low-relief hard-bottom and reef flat sites where structural reef development (i.e., relief and coral cover) was low. Sponges were most prevalent in deeper (>10 m) hard-bottom and reef sites, where mean percent coverage was as high as 20%. Live coral cover was generally below 10%, and was particularly low in many shallower sites such as shallow hard-bottom and reef flats. Octocoral coverage was typically greatest (up to 25%) in areas with low coral cover, such as shallow and deeper low-relief hard-bottom.

Periodic monitoring using point-intercept counts in marked 1 m^2 quadrats and counts of octocorals were undertaken four mid-depth sites where sedimentation was measured (Fig. 4). Mean live coral cover reflected differential exposure to the Canal de Catuano or oceanic processes on southern Isla Saona. Mean coral coverage was greatest (11–20%) at relatively protected sites (Dominicus, Rubén) and lowest (5–8%) and relatively exposed sites (La Raya, El Toro) ($P < 0.001$; F-test). Species comprising the majority of coral cover in most sites were *Montastraea annularis*, *M. cavernosa*, and *Agaricia agaricites* (Table 2). Measures of diversity and evenness revealed clear differences between the most sheltered and most exposed sites. Coral diversity was highly negatively correlated with monthly sedimentation rate ($r = 0.918$, $P = 0.082$) and the variability (variance) in sedimentation rate ($r = 0.933$, $P = 0.067$).

Octocoral density and diversity measures exhibited patterns potentially related to wave energy exposure and sedimentation (Fig. 4). Mean colony density was significantly greater at the most exposed site ($P < 0.05$; Tukey-test), as well as octocoral abundance, species richness, diversity, and evenness (Table 3). Correlation analyses indicated highly positive

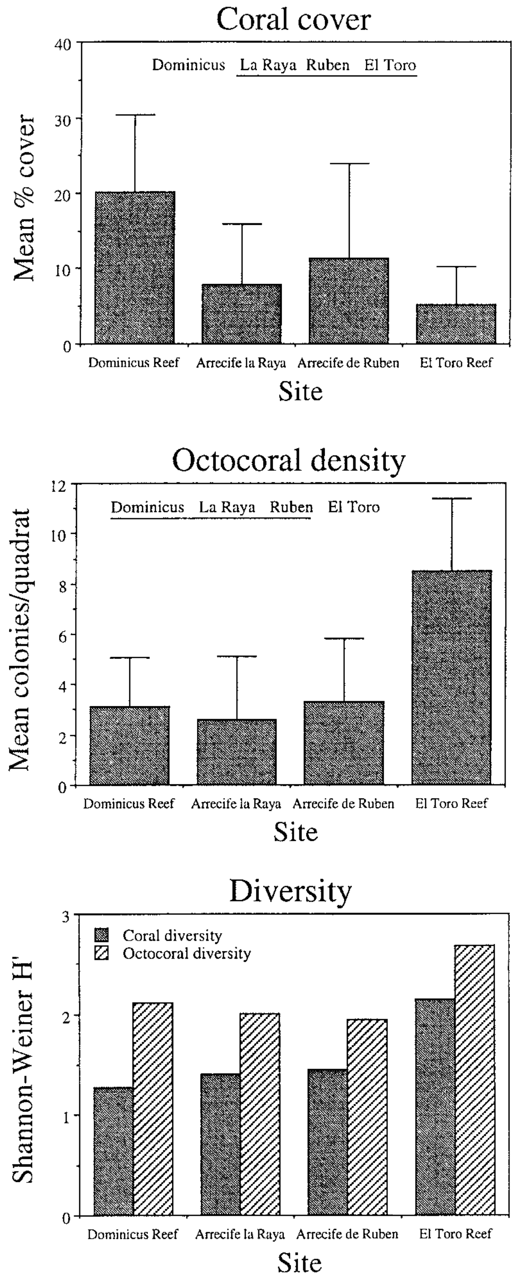

Figure 4. Mean percent coverage by corals, density of octocorals (no. colonies/m^2), and diversity (Shannon-Weaver, $\log_e$) of coral cover and octocoral density in mid-depth reef environments of the southeastern Dominican Republic. Error bars represent one standard deviation. Lines connecting sites are not significantly different ($P > 0.05$) as determined by parametric Tukey-type multiple comparisons.

Table 2. Mean percent cover (relative % cover) of reef-building corals in fore reef slope communities of Parque Nacional del Este. Data represent averages based upon surveys of 20 1-m^2 quadrats in each site during March 1996.

Species	Dominicus	La Raya	Rubén	El Toro
Agaricia agaricites	1.4 (6.9)	0.2 (2.6)	2.0 (17.5)	0.6 (11.5)
Dichocoenia stokesi		0.2 (2.6)		
Diploria clivosa		0.2 (2.6)	0.4 (3.5)	0.4 (7.7)
D. labyrinthiformis			1.0 (8.8)	0.6 (11.5)
Isophyllastrea rigida	0.2 (1.0)			
Leptoseris cucullata	0.4 (2.0)			
Madracis formosa		0.2 (1.8)		
Meandrina meandrites	0.6 (3.0)	0.2 (2.6)		0.2 (3.9)
Millepora alcicornis				0.4 (7.7)
Montastraea annularis	13.4 (66.3)	3.2 (41.0)	6.0 (52.6)	1.2 (23.1)
M. cavernosa	2.0 (9.9)	3.0 (38.5)	1.4 (12.3)	0.8 (15.4)
Mycetophyllia danaana			0.2 (1.8)	0.6 (11.5)
Porites astreoides	1.4 (6.9)			0.2 (3.9)
P. porites	0.4 (2.0)			0.2 (3.9)
Siderastrea siderea	0.2 (1.0)	0.6 (7.7)	0.2 (1.8)	
Stephanocoenia michelinii	0.2 (1.0)	0.2 (2.6)		
Total coral cover (%)	20.2	7.8	11.4	5.2
Total species in quadrats	10	8	8	10
Diversity (H' = Σ(pilnpi))	1.270	1.405	1.449	2.147
Evenness (J' = H'/ln S)	0.552	0.676	0.697	0.933

relationships between octocoral density ($r = 0.949$, $P < 0.05$), octocoral diversity ($r = 0.990$, $P = 0.10$) and monthly sedimentation rate, but also the variability in sedimentation rate for both density ($r = 0.950$, $P < 0.05$) and diversity ($r = 0.984$, $P < 0.02$). Several species-specific patterns in octocoral abundance may be related to differential wave exposure and sedimentation. *Briareum asbestinum* and *Erythropodium caribaeorum* were most abundant in relatively sheltered sites, while *Pseudopterogorgia americana* and several species of the family Plexauridae were most abundant in relatively exposed sites.

Spatial and Temporal Patterns in Sedimentation.—Monthly sedimentation rates were measured in four mid-depth (15–20 m) reefs in PNE from April 1996 to March 1997. Throughout the study period, the sedimentation rate in individual traps ranged from 0.03 to 45.97 mg cm^{-2} d^{-1}, while monthly site averages ranged from 0.33 to 37.15 mg cm^{-2} d^{-1}. During the 11-mo sampling period, sedimentation was generally within 1–10 mg cm^{-2} d^{-1} (Fig. 5). Two-factor analysis of variance indicated significant differences in mean sedimentation rate with respect to reef location ($P < 0.001$) and time of year ($P < 0.001$) (Table 4). While reef location accounted for approximately 10% of the variability in mean sedimentation rate, 47% of the variability was accounted for by time of year. Sedimentation in three of the four reefs sampled was greatest during November, with smaller peaks in September. Sedimentation at El Toro was exceptionally high (>37 mg cm^{-2} d^{-1}) during September of 1996, following the passage of Hurricane Hortense. Since other surveyed reefs are not in the immediate path of easterly winds, peaks in sedimentation rate were not as marked during the passage of the hurricane.

Table 3. Number of colonies and relative abundance (in parentheses) of octocoral species at mid-depth (15–20 m) reef and hard-bottom sites in Parque Nacional del Este. Sample size is twenty 1-m^2 quadrats per site.

Species	Dominicus	La Raya	Rubén	El Toro
Briareum asbestinum	15 (24.2)	7 (13.5)	6 (9.1)	7 (4.1)
Erythropodium caribaeorum	11 (17.7)	7 (13.5)		
Eunicea sp.			1 (1.5)	
E. calyculata				3 (1.8)
E. fusca				1 (0.6)
E. laciniata				3 (1.8)
E. laxispica			1 (1.5)	15 (8.8)
E. mammosa	2 (3.2)			16 (9.4)
E. palmeri	6 (9.7)	2 (3.9)	22 (33.3)	19 (11.2)
E. succinea		1 (1.9)	4 (6.1)	7 (4.1)
E. tourneforti	1 (1.6)			8 (4.7)
Gorgonia ventalina	8 (12.9)	1 (1.9)	7 (10.6)	12 (7.1)
Muricea atlantica	2 (3.2)	1 (1.9)	2 (3.0)	
Muriceopsis flavida	3 (4.8)	6 (11.5)	3 (4.6)	
Plexaura flexuosa	6 (9.7)	1 (1.9)		14 (8.2)
P. homomalla	1 (1.6)			10 (5.9)
Plexaurella dichotoma		1 (1.9)	1 (1.5)	11 (6.5)
P. grisea				3 (1.8)
P. nutans				3 (1.8)
Pseudoplexaura porosa	1 (1.6)			13 (7.7)
P. wagenaari				2 (1.2)
Pseudeopterogorgia acerosa		1 (1.9)		
P. americana		17 (32.7)	5 (7.6)	22 (12.9)
P. bipinnata	6 (9.7)	7 (13.5)	14 (21.2)	
Pterogorgia guadalupensis				1 (0.6)
Total colonies	62	52	66	170
Total species (S)	12	12	11	19
Diversity (H' = Σ(pilnpi))	2.109	2.005	1.954	2.683
Evenness (J' = H'/ln S)	0.849	0.807	0.815	0.911

Discussion

Benthic community mapping, rapid assessment techniques, and periodic monitoring were instrumental in evaluating the distribution and community structure of hard-bottom and coral reef types in the southeastern Dominican Republic (PNE). These approaches were also crucial for examining the relative importance of environmental factors such as sedimentation. There is a diversity of reef and hard-bottom types in PNE, reflecting a range in environmental conditions such as: influence of sediment transport from the Canal de Catuano; high wave exposure in the eastern and southeastern areas of the Park; and high wave energy conditions and sediment transport on the southern Isla Saona. Reefs in the western area of PNE lack a well-defined zonation pattern, while reefs and hard-bottom areas in the eastern area of the park are predominantly rubble, reef crest or algal ridge, and low-relief, algal-dominated hard-bottom. Mid-depth (15–20 m) reefs in PNE can be best described as shelf edge reefs (Adey and Burke, 1977). There are few ex-

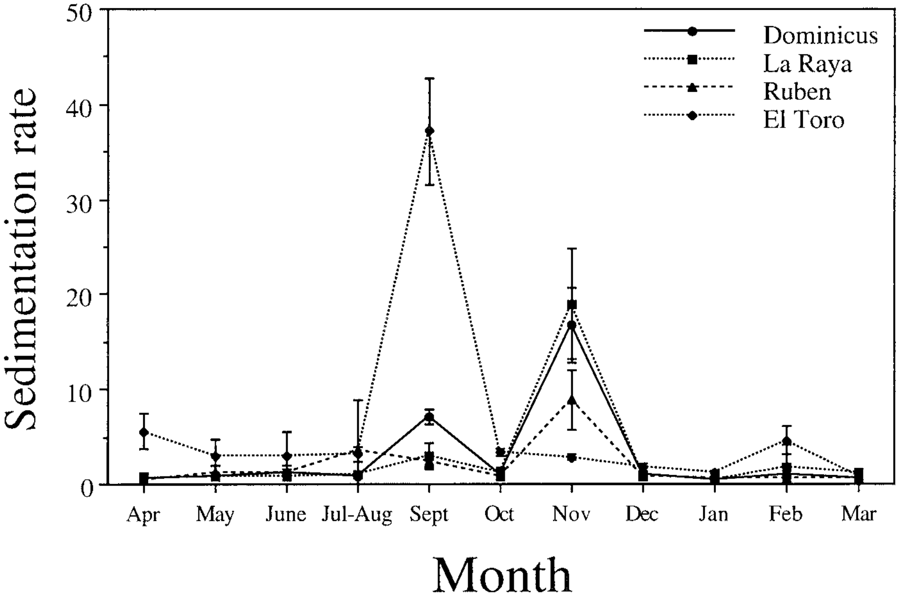

Figure 5. Average monthly sedimentation rates (mg cm^{-2} d^{-1}) in mid-depth fore reef environments of Parque Nacional del Este (April 1996–March 1997). Data based upon 5 sediment traps per station. Error bars represent one standard deviation. Note the high rate at El Toro during September 1996 during the passage of Hurricane Hortense.

amples where reef growth has met sea level in the Park; the exceptions are the offshore reef area at Caballo Blanco and the discontinuous and poorly developed reef crests on the southern coast of Isla Saona. Dominant reef-building corals in the Park are *M. annularis*, *M. cavernosa*, *S. siderea*, and *A. agaricites*. Shallow framework species common in other Caribbean locations, such as acroporids, were only locally abundant near Isla Saona and the eastern area of PNE.

Octocorals were most diverse and abundant where the degree of reef development and coverage by scleractinian corals was low such as the southern coast of Isla Saona. This pattern is similar to other areas of the Caribbean (Jordan, 1989; Yoshioka and Yoshioka, 1989). A variety of physical and biological factors are involved in the distribution and abundance of shallow-water octocorals: depth and habitat type (Kinzie, 1973; Opresko, 1973), substrate complexity (Sanchez et al., 1997), and episodic events (Yoshioka and Yoshioka, 1987). Sediment transport (more than water movement or topographic relief) may be directly related to octocoral distribution (Yoshioka and Yoshioka, 1989). This

Table 4. Effects of site location (4 sites) and time of year (11 months) on mean sedimentation rate (mg/cm^2/day) in Parque Nacional del Este, southeastern Dominican Republic. Model data were log transformed ($\log_{10}$ (X+1)). MS: mean square; df = degrees of freedom.

Source of variation	MS	df	F-value	Significance
Reef location	1.01	3	64.01	$P < 0.001$
Month	1.38	10	87.30	$P < 0.001$
Reef location × month	0.21	30	12.98	$P < 0.001$
Error	0.02	176	—	—

appears to be the case in PNE, as sites with the greatest rates of sediment re-suspension (El Toro) had high species diversity and density of octocorals. Because these organisms are flexible, they can counter drag and colonize turbulent habitats where hard coral growth may be impeded.

The prevalence of non-constructional hard-bottom communities in PNE suggests that the physical environment (wave energy, sedimentation) may impede the development of structurally complex reefs. Coral reefs relatively protected from the influence of the Canal de Catuano or high wave energy conditions on southern Isla Saona exhibit greater coral coverage. Sediment transport from the lagoon to the western margin was particularly prevalent at La Raya compared to Arrecife de Rubén. This finding is similar to other studies showing the influence of sediment transport from shallow lagoons or banks to adjacent reef areas in the Florida Keys (Chiappone and Sullivan, 1997), Bahamas (Chiappone et al., 1997), and eastern Caribbean (Hubbard, 1986). It thus appears that of the true coral reefs in PNE, some are keep-up reefs (reef crests on southern Saona), while the majority are give-up reefs (Neumann and Macintyre, 1985). The growth of these reefs may have been interrupted during rising seas, leaving them stranded in water depths generally below the limit of active reef-framework accumulation.

Although a myriad of factors potentially influence coral reef distribution and community structure, sedimentation may be among the more important influences in the southeastern Dominican Republic. Data collected in PNE during 1996–97 indicated a monthly sedimentation rate at 20 m depth ranging from 0.54 to 33.48 mg cm^{-2} day^{-1}. With the exception of episodic storms, however, average monthly sedimentation was generally less than 10 mg cm^{-2} d^{-1}. Ambient sedimentation rates in PNE are similar to other Caribbean coral reef environments, where anthropogenically induced fluxes of sediment are minimum or where river discharge is negligible (Dodge et al., 1974; Rogers, 1983; Cortés and Risk, 1984; Tomascik and Sander, 1985). Episodic events, such as hurricanes, appear to account for the majority of transport and re-suspension during the year (Rogers, 1983; Hubbard, 1986). In contrast to areas chronically stressed by high sedimentation, reefs in PNE appear to be only periodically disturbed by extreme sedimentation events, but these periodic disturbances appear to greatly influence community structure and diversity patterns.

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