

## A Site Description of the CARICOMP Mangrove, Seagrass and Coral Reef Sites in Bocas del Toro, Panama

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**ABSTRACT.**—Bocas del Toro is located in the western region of the Republic of Panama. It is part of a province of approximately 8917 km<sup>2</sup> with an estimated 68% of its area covered by tropical rainforest. The area receives 2870 mm/year of rainfall. The dry and rainy seasons are not clearly defined. There are two periods each of low and high rainfall, March and September-October, and July and December, respectively. Mangrove forests, seagrass meadows and coral reefs are vast, covering large areas in the shallow waters surrounding the islands of the archipelago and along the mainland coast. The CARICOMP sites were established in 1998-99 and are periodically monitored following Level I protocol. Herein we describe the sites in a regional context and present the baseline data for each site. This paper fulfills the requirements of the formal site description for CARICOMP monitoring sites.

**KEYWORDS.**—Environmental monitoring, CARICOMP, Bocas del Toro, Panama

### INTRODUCTION

Natural systems that help protect marine and coastal resources are rapidly being degraded by anthropogenic activities. Clearing of mangroves, which buffer the land from storm surges and the sea from land-based sources of pollution, and uncontrolled development schemes, over-exploitation of living resources, and impacts related to urbanization, tourism, and agriculture all contribute to decreased resilience of coastal and marine ecosystems. Consequently, the vulnerability of coastal resources to global warming is increasing, underscoring the urgent need for basic data on which to base an integrated framework for addressing these issues (Cicin-Sain and Knecht 1998). Development of such a framework is difficult due to the inadequacy of the data, the lack of long-term data, and the lack of institutional structures for managing coastal and marine resources in some countries.

Coral reef, mangrove and seagrass habitats are important resources for tropical islands and coastal areas. In addition to their economic and recreational value, coral reefs and seagrass meadows are sensitive indicators of the quality of coastal waters in tropical areas (Spurgeon 1992; English et al. 1997). If coastal resources are to be developed, managed or protected, scientific information about the impact of natural and man-made disturbances must be monitored. Consequently, looking at the long-term trends in the condition of these three ecosystems is vitally important. A monitoring program can provide information on species richness and abundance of the biota, the conservation condition of particular habitats, and seasonal and spatial variations in environmental conditions. It may enable scientists to understand natural perturbations within the systems and, therefore, to predict the effects of human activities on ecological processes (English et al. 1997).

The Caribbean-wide reef, mangrove and seagrass monitoring program, known as CARICOMP, represents an important step to providing long-term data that will be useful in this context. The CARICOMP sampling sites for Panama are located in Bocas del Toro, but the efforts of the Smithsonian's Environmental Science Program (ESP) extend beyond the CARICOMP sites located near Isla Colon, encompassing the entire archipelago (see <http://striweb.si.edu/esp/>). Here we describe the CARICOMP mangrove, seagrass and coral reef sites following the format used in the formal description for all sites within the network (Kjerfve 1998) and we provide a preliminary analysis of data from the first survey.

#### *Marine ecosystems in Bocas del Toro*

The inadequate management of the coastal zone and the deforestation of surrounding areas have accelerated the destruction of marine habitats in Panama. At the same time, the country is preparing to launch a massive international campaign to increase local tourism and the recreational use of coastal resources. The province of Bocas del Toro is considered a development priority zone at the national level, thus it is necessary to design a suitable territorial management plan of these resources for the long term, and considering local needs (Guzmán 2003). In 1997, the Smithsonian Tropical Research Institute (STRI) recognized the need to supply ecological information to the local authorities for management initiatives thus started an overall assessment of marine resources at population and ecosystem levels in the Bocas del Toro archipelago. STRI also implemented a monitoring program at diverse sites throughout the archipelago.

Research in the Bocas del Toro archipelago includes a study of 71 coral reefs that were described in a series of studies designed to evaluate the distribution, structure and current state of the coral reefs in the region (Guzmán and Guevara 1998a, 1998b, 1999, 2000). These authors reported

preliminary data on the diversity of 61 scleractinian coral species, 31 octocorals, and 63 sponges, with the Bocas taxa representing about 87%, 82%, and 72% of the country's total, respectively (Guzmán 2003). One important finding was that most of the reef habitats containing the highest diversity were outside the existing limits of the marine protected area, resulting in a proposal to change the existing limits of the protected area (Guzmán 1999). Later, Aronson et al. (2004) reported a shift in species composition at 5 m depth on the reefs. Within a few decades, the dominant coral genus changed from finger coral (*Porites* sp.) to one species, as yet unidentified, of lettuce coral (*Agaricia* sp.). This shift is comparable to that reported in Belize at similar depth. However, *Porites* continues to dominate all shallow reefs (<3 m) in Bocas del Toro (Guzmán and Guevara 1998a). Through analysis of coral skeletons and reef sediments, two studies revealed high-to-intermediate levels of metal pollution, including mercury and other 12 different metals, in different areas of the archipelago and from different sources including agriculture, land development, oil pollution, and port activities (Guzmán and Jimenez 1992; Guzmán and García 2002).

The seagrass meadows in Bocas del Toro are vast, covering large areas in the shallow waters surrounding the islands of the archipelago and along the mainland coast. Four species of seagrass are found in Bocas: *Thalassia testudinum*, *Syringodium filiforme*, *Halodule beaudettei* and *Halophila decipiens*. The seagrass meadows throughout the archipelago are dominated by *T. testudinum*. Sediment, water quality, and seagrass were surveyed at 32 *T. testudinum* sites and results, including seagrass tissue nutrients and  $\delta^{15}\text{N}$  values, are discussed in Caruthers et al. (this volume). Seagrass meadows within the Bocas del Toro archipelago are heavily influenced by their proximity to coral, mangroves and coastal rivers. The latter influence, in combination with abundant siliclastic sediments, makes the archipelago an interesting contrast to most Caribbean systems. The influences of coral, mangroves and rivers affect the sediment composition as well as the water clarity ex-

perienced by seagrass, two of the most important factors responsible for the occurrence and abundance of seagrass meadows. The large rivers deposit large volumes of siliciclastic sediment, the mangrove forests and associated wetlands yield organic matter, and the erosion of coral and calcareous macroalgae produces coarse carbonate sediment. The combination of proximities to these main influences results in seagrass habitats within the archipelago being defined as: wetland, river, mangrove and reef.

Mangrove forests within Almirante Bay in Bocas del Toro are extensive and comprise several forest types, including: 1) tall riverine forests alongside rivers that drain from the hinterland into the northwestern portion of the lagoon; 2) narrow fringing mangrove forests that flank the coasts of the mainland and islands; 3) broad fringe along the mainland; 4) large mangrove islands with fringing forests around the periphery and extensive scrub/dwarf mangrove stands in the interiors; 5) scrub/dwarf stands on coastal flatland adjacent to upland vegetation; 6) overwashed mangrove islands; 7) hammocks; 8) dieback areas. This vast network of islands and mainland peninsulas fringed by mangroves covers ~2885 km<sup>2</sup> (D'Croz 1993), approximately half the mangrove area on the Caribbean coast of Panama. These mangrove forests are overwhelmingly dominated by *Rhizophora mangle*, with other mangrove species being uncommon. The forests are utilized for timber, particularly the larger trees in landward settings, and for access for logging terrestrial forests, and are cleared to build houses at the water's edge. Most of the forests are intact, especially within the Bastimentos Marine National Park and away from the main settlements on Isla Colon and Bastimentos.

Much of the mangrove forest in Bocas consists of scrub or dwarf trees, which are a common feature throughout the Caribbean (Lugo 1997; Rivera-Monroy et al. 2004). The cause of the small stature of these forests (<1.5 m tall) has been a matter of debate (Lugo and Snedaker 1974; Cintrón et al. 1978; Lin and Sternberg, 1992; Feller, 1995). In areas dominated by *Avicennia germinans* or *Laguncularia racemosa*, high soil salinity is

often correlated with low stature (Cintrón et al. 1978). However, in Belize and Florida, experimental studies in *R. mangle* forests showed that phosphorus (P) and nitrogen (N) deficiencies limit the growth of trees (Feller 1995; Koch 1997; Feller et al. 1999; McKee et al. 2002; Feller et al. 2003a, b). Similarly, a fertilization experiment in a dwarf *R. mangle* forest in Almirante Bay showed that growth increased by 10-fold when trees were fertilized with P and two-fold when fertilized with N, indicating that the stunted growth of these mangroves was partially due to nutrient deficiency (Lovelock et al. 2004). In that study, the growth enhancements caused by N or P enrichment could not be attributed to increases in photosynthesis on a leaf area basis, although photosynthetic nutrient-use efficiency was improved. The most dramatic effect was on stem hydraulic conductance, which was increased six fold by P and 2.5-fold with N enrichment. These findings indicate that anthropogenic over-nutrient enrichment has the potential to alter ecological processes in the mangroves at Bocas del Toro.

We indicated above that the lack of effective protection for marine ecosystems is the main cause of indirect degradation in Panama. Land development has increased during the last decade with a concomitant increase in sedimentation and the impact on mangrove, seagrass beds and corals reefs. While habitat loss directly associated to coastal development is common in Bocas del Toro (Guzmán, personal observation), pressure from commercial and artisanal fisheries has also forced several stocks of economically important species into an imminent collapse. For example, populations of sea cucumbers were harvested and depleted within few months during 1997 (Guzmán and Guevara 2002; Guzmán et al. 2003). In addition, several species of conch (*Strombus* spp.) have been historically exploited to critical levels and population densities are now as low as 1.4 individual per ha (Tewfik and Guzmán 2003). Both studies supported new government regulations implemented in January 2004 that imposed a 5-yr ban on the conch fishery and a permanent ban on the sea cucumber fishery

throughout the Republic of Panama. A recent assessment of the lobster fishery in the archipelago indicates that this resource is also in critical conditions (Guzmán and Tewfik 2004).

Because of the extent of the coastal zone of Bocas del Toro (approximately 3500 km<sup>2</sup>), the monitoring efforts of the Smithsonian's Environmental Science Program (ESP) extend beyond the CARICOMP sites located near Isla Colón, encompassing the entire archipelago (see <http://striweb.si.edu/esp/>). Here we describe the CARICOMP mangrove, seagrass and coral reef sites following the format used in the formal description for all sites within the network (Kjerfve 1998) and we provide a preliminary analysis of data from the first survey.

#### *Climate and oceanography*

The province of Bocas del Toro is located in the western region of the Republic of Panama, between 8°30' and 9°40' N, and between 82°56' and 81°18' W (Fig. 1). Bocas del Toro is bordered by the Caribbean Sea to the north, the province of Chiriquí to the south, the province of Veraguas to the east, and the Republic of Costa Rica to the west. Bocas del Toro has a land area of approximately 8917 km<sup>5</sup> (Rodríguez et al. 1993); it is estimated that 68% of its land surface is currently covered by tropical rainforest (INRENARE 1995). The climate is one of high rainfall, ca. 287 cm/yr, with a higher rainfall towards the southeast of the Chiriquí Lagoon (Gordon 1982). Depending on the type of vegetation or life zone, the rainfall may be higher than 7000 mm/year (Rodríguez et al. 1993). The dry season and the rainy season are not clearly defined, but there are two periods of low rainfall (March and September-October) and two periods of high rainfall (July and December). Generally, heavy rains along the coast are accompanied by storms in the morning and night in response to the cooling of air masses related to local orography. A detailed description of environmental parameters and local patterns in sea surface temperature and rainfall is provided in Kaufman and Thompson (this issue).

The Bocas del Toro Basin includes large Neogene sequences that comprise the lower Miocene to the lower Pleistocene, with the most ancient sequence of about 20 Ma, identified as deep tropical marine bed, which existed before the formation of the isthmus (Coates and Jackson 1998). Igneous and sedimentary rocks, which at present form the rocky basement of many parts of the archipelago, indicate volcanic activity ranging between 16 and 10 Ma. When volcanic activity ceased, subsequent marine transgressions allowed for the deposition of a sedimentary sequence, between the late Miocene and the Pleistocene, near the coast and towards the external platform, which would have allowed for the settlement of a diverse and abundant marine fauna that would have included reef formations in the Miocene, Pliocene and Pleistocene (Coates and Jackson 1998). Mid-Miocene deposits found in the area suggest that during that period a faunistic change took place in the whole Caribbean region, which would have increased the speciation of reef-forming coral and benthic foraminifers (Collins et al. 1996). Changes in the sea level that took place during the last 9500 years notably modified the bathymetry and topography of the Bocas del Toro archipelago, causing episodes of separation and joining of the islands among themselves and between them and the mainland. It is estimated that the archipelago as it exists now was formed 6000 years B.P. (Summers et al. 1997).

The orography near the littoral zone is represented by a mountain chain with a variable altitude of 50-400 m that runs parallel to the coast, at a distance lower than 3.5 km in the area of Chiriquí Lagoon and 1 km in Bahía Almirante (IGNTG 1988). Several rivers and gullies drain towards both areas. Due to their short length and the narrow distance between the coast and the mountains, there is an increase in the flow of rivers and gullies as an immediate response to the rains, which causes a constant overland flow towards the coastal zone. The water from these rivers forms a superficial water lens approximately 0.5 m thick and rich in suspended organic material, which affects the bay and the lagoon, and it

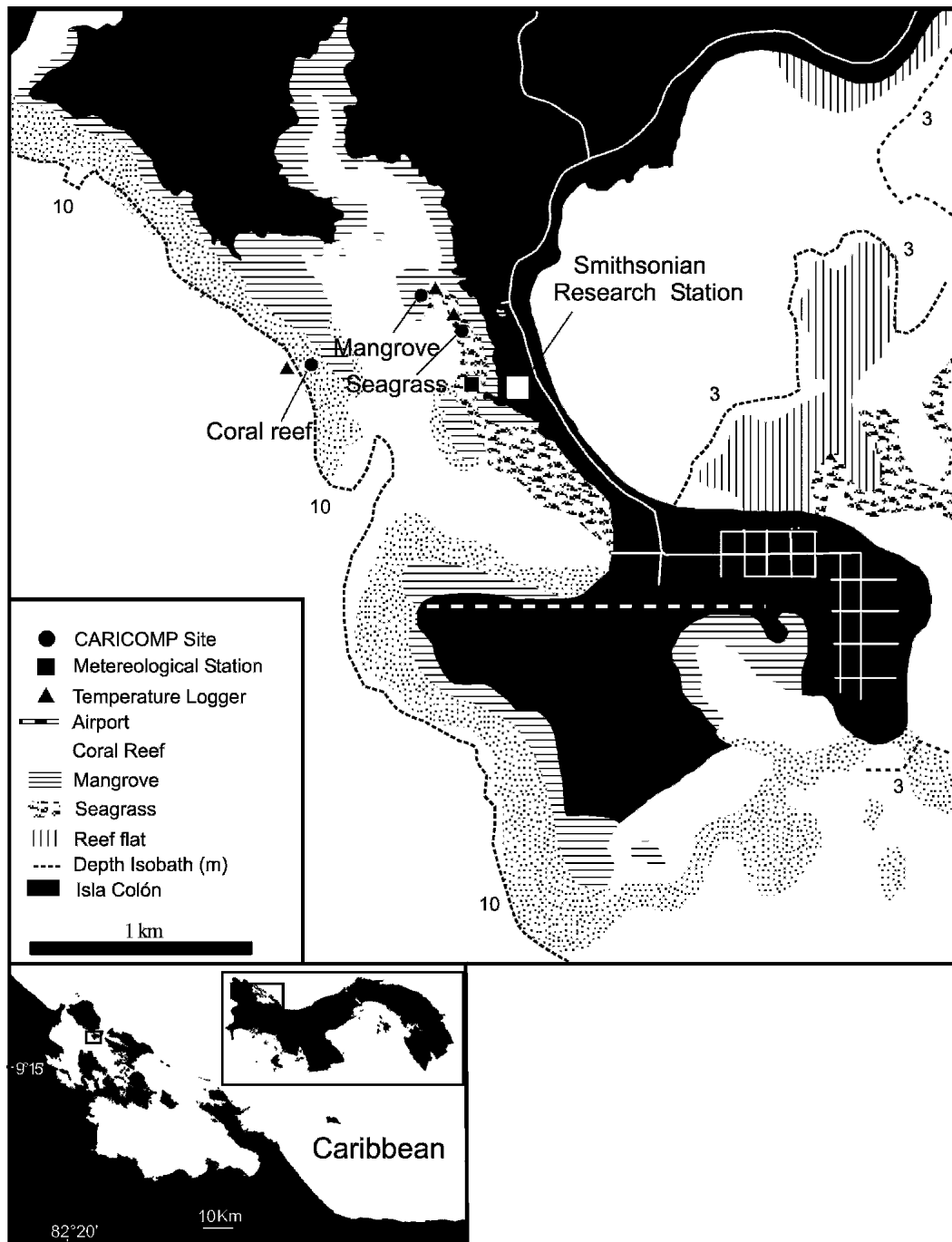


FIG. 1. Map of Matumbo Bay, Isla Colón, Bocas del Toro, Panama. The distribution of mangrove, seagrass and coral reef habitats in the coastal area near the Smithsonian Research Station and the CARICOMP sites are indicated. The approximate location for the Environmental Sciences Program (ESP) meteorological station and water temperature loggers are shown (see legend).

subsequently mixes with lower strata rather near the surface.

In the Bocas del Toro region, the continental shelf is rather narrow, and it is located near the coast. The coastal zone has maximum depths of 20-50 m, and it is formed by two large water bodies, Bahía Almirante and Chiriquí Lagoon, and an archipelago consisting of seven main islands and dozens of mangrove-covered keys (Rodríguez et al. 1993, see box in Fig. 1). Surf and tides have a greater effect outside the archipelago, where the conditions are more oceanic. The tides of Panama's Caribbean Sea may be semidiurnal or diurnal (mixed), not clearly predictable and with an amplitude below 0.5 m; tides are higher than usual during the dry season due to the influence of the Northeast winds (Glynn 1972). The main coastal current that affects Panama flows towards the east throughout the year, from the North of Nicaragua and Costa Rica, and it may have greater influence between the months of June and August, when it runs closer to the coast of Bocas del Toro (DMA 1988; Greb et al. 1996). The winds that have stronger influence and predominate throughout the year come from the North and Northeast (DMA 1988). The influence of winds, tides and surf within Bahía Almirante and Chiriquí Lagoon is notably reduced by the insular system and reef barriers located north of the archipelago, resulting in a semi-lagoonal system with marine currents variable in direction and ruled by the winds, which are also variable during daytime. The tidal range varies between 2 and 15 cm and the currents have a speed lower than 40 cm/sec (Ballou et al. 1985; Gundlach et al. 1985; Greb et al. 1996).

#### Mangrove site

The CARICOMP mangrove sites at Bocas del Toro were established in November 1998 using Level I protocol ([http://www.ccdc.org.jm/methods\\_manual.html](http://www.ccdc.org.jm/methods_manual.html)). We set up three 10 × 10 m plots in a stand of *R. mangle* in the fringe zone of a small peninsula adjacent to the Smithsonian Tropical Research Institute's Marine Laboratory on Matumbo Bay, Isla Colón (Fig. 1).

Tree in this zone are 3-5 m tall. The canopy height decreases along transects perpendicular to the shoreline with trees <1 m tall in the interior of the peninsula. Trees closer to the terrestrial boundary are taller (~5-10 m tall). The characteristics of the CARICOMP site are listed in Table 1. The basal area of the trees is low compared to many other CARICOMP sites (Kjerfve 1998). For example, the basal area of sites in Bermuda, Cayman, Barbados, Colombia and Venezuela exceed 30 m<sup>2</sup>/ha. The Bocas mangrove site has a somewhat lower basal area, comparable to sites in Belize, Bonaire and Curacao, and the Dominican Republic, possibly reflecting the similarity in the hydrological regime, nutrient availability, and the underlying limestone platform on which the forests grow (Koltes et al. 1998; Geraldles 1998). The basal area of the site at Bocas exceeds that of the Bahamas (3-4 m<sup>2</sup>/ha) and one dwarf site from Belize (1.17 m<sup>2</sup>/ha).

Litter fall, which is used as an indicator of primary production, was assessed for one year after the establishment of the Bocas site, from January through December 1999. Variation in leaf litter among the individual plots was low. Leaf litter fall was low in December to June, and high from July through November, peaking in November 1999, with average rates of 0.44 g/m<sup>2</sup>/day. Similar to measures of basal area and tree biomass, litter fall was similar in magnitude to sites in Belize (Koltes et al. 1998) and Curaçao (Pors and Nagelkerken 1998). The timing of litter fall also had a

TABLE 1. Characteristics of the CARICOMP site at Bocas del Toro, Panama. Means are from 3 plots.

	Mean	Standard deviation
Height (m)	4.13	0.89
No. trees/plot	59.30	3.20
Basal area (m <sup>2</sup> ha <sup>-1</sup> )	12.28	4.73
Total biomass <sup>a</sup> (kg m <sup>-2</sup> )	4.62	2.61
Total biomass <sup>b</sup> (kg m <sup>-2</sup> )	9.57	1.91
Saplings/m <sup>2</sup>	1.00	0.92
Total annual litter fall (g m <sup>-2</sup> y <sup>-1</sup> )	33.80	1.40
Standing litter (g m <sup>-2</sup> )	122.00	42.00

<sup>a</sup>Cintrón and Schaeffer-Novelli (1984)

<sup>b</sup>Golley et al. (1962)

similar pattern to other sites, with leaf litter production decreasing in December, after peak propagule production. Propagule production occurred April through November, with a small pulse in May, but peak propagule fall occurred in October and November. Annual variability in rainfall and/or levels of solar radiation is likely to influence the timing of primary production and reproduction, but this is yet to be tested.

#### Seagrass site

The two CARICOMP seagrass sites were selected in November 1998 and monitoring began in March 1999. The seagrass sites are located in Matumbo Bay, Isla Colón, in close proximity to the new marine research facility of the Smithsonian Tropical Research Institute (Fig. 1). The seagrass meadow within the Bay extends from the shoreline to a distance of approximately 150 meters; the CARICOMP seagrass sites are located approximately 12 and 18 meters from the shoreline of fringing mangrove and are 25 meters apart. Data were collected every 3 months in 1999 and 2000 (March, June, September and December) in order to assess seasonality. Because fine-scale seasonal trends were not apparent, subsequent sampling occurred biannually, at times representing maximum and minimum seagrass productivity.

Only one species of seagrass, *Thalassia testudinum*, was present at the CARICOMP sites and calcareous macroalgae accounted for a maximum of only 0.7% of the total plant biomass. Total biomass and productivity data for *T. testudinum* (mean  $\pm$  1 s.d.) for the four sampling periods, plus annual means ( $\pm$  1 s.d.), are summarized in Table 2. The annual mean *T. testudinum* total bio-

mass and standing crop for 1999 were  $560 \pm 105$  g/m<sup>2</sup> and  $47.1 \pm 6.9$  g/m<sup>2</sup>, respectively. Annual mean areal productivity and turnover rate at the Bocas seagrass sites, both measures of productivity, were  $1.82 \pm 0.54$  g/m<sup>2</sup>/day and  $2.54 \pm 0.06\%$ /day, respectively, in 1999. While productivity measures were comparable to those recorded at most other CARICOMP seagrass sites, both total biomass and standing crop for *T. testudinum* at Bocas were less than half those reported for most other CARICOMP seagrass sites (CARICOMP 1997).

Leaf data are summarized in Table 3. The mean shoot density in 1999 ( $17.6 \pm 3.05$ /quadrat) is higher or comparable to other CARICOMP sites. Annual mean leaf length at the Bocas site was  $15.0 \pm 1.25$ , while the annual mean leaf width was  $9.49 \pm 0.05$ . Shoot density, plus leaf length and width, are used to calculate Leaf Area Index (LAI). The mean LAI at the Bocas site in 1999 was  $3.72 \pm 0.06$ . LAI and leaf width decrease as a result of nutrient limitation and stress from sources such as increasing salinity or temperature (CARICOMP 1994). These variables are most useful in monitoring trends at one site over time but can also be used to compare sites. The LAI and leaf width data suggest that the Bocas seagrass communities, in 1999, are not markedly stressed in comparison with other CARICOMP sites (CARICOMP 1997).

#### Coral reef site

The CARICOMP's reef site in Panama was established between May-June 1999 following the Level I protocol ([http://www.ccdc.org.jm/methods\\_manual.html](http://www.ccdc.org.jm/methods_manual.html)). The site is part of a fringing reef located 50 m offshore that trends parallel to a man-

TABLE 2. 1999 CARICOMP *Thalassia testudinum* biomass and growth measurements, Bocas del Toro, Panama. Data from the two sites are pooled and summarized as mean  $\pm$  1 s.d. for each of the four sampling dates. The data are also summarized as annual means  $\pm$  1 s.d. Sample size (n) is given next to the data.

	March	June	September	December	1999 Mean
Biomass (g/m <sup>2</sup> )	704 $\pm$ 202 (8)	458 $\pm$ 193 (8)	515 $\pm$ 269 (8)	563 $\pm$ 175 (8)	560 $\pm$ 105 (4)
Standing crop (g/m <sup>2</sup> )	51.5 $\pm$ 17.8 (8)	54.3 $\pm$ 26.2 (8)	39.5 $\pm$ 20.8 (8)	43.0 $\pm$ 20.6 (8)	47.1 $\pm$ 6.9 (4)
Areal Productivity (g/m <sup>2</sup> /day)	2.45 $\pm$ 1.73 (10)	1.88 $\pm$ 0.71 (12)	1.81 $\pm$ 1.20 (11)	1.13 $\pm$ 0.34 (12)	1.82 $\pm$ 0.54 (4)
Turnover (% per day)	3.21 $\pm$ 2.26 (10)	2.22 $\pm$ 0.24 (12)	2.85 $\pm$ 1.12 (11)	1.90 $\pm$ 0.42 (12)	2.54 $\pm$ 0.06 (4)

TABLE 3. 1999 CARICOMP *Thalassia testudinum* leaf measurements, Bocas del Toro, Panama. Data from the two sites are pooled and summarized as mean  $\pm$  1 s.d. for each of the four sampling dates. The data are also summarized as annual means  $\pm$  1 s.d. Sample size (n) is given next to the data. Quadrat size is 0.02 m<sup>2</sup>.

	March	June	September	December	1999 Mean
Shoots/quadrat	21.8 $\pm$ 6.70 (10)	15.0 $\pm$ 5.59 (12)	15.7 $\pm$ 5.64 (11)	17.8 $\pm$ 3.96 (12)	17.6 $\pm$ 3.05 (4)
Leaf Length (cm)	14.8 $\pm$ 2.79 (10)	16.5 $\pm$ 5.84 (10)	13.5 $\pm$ 2.96 (10)	15.4 $\pm$ 2.82 (10)	15.0 $\pm$ 1.25 (4)
Leaf Width (mm)	9.70 $\pm$ 1.32 (10)	9.10 $\pm$ 1.29 (10)	9.14 $\pm$ 0.92 (10)	10.1 $\pm$ 1.12 (10)	9.49 $\pm$ 0.05 (4)
Leaf Area Index	4.18 $\pm$ 0.94 (10)	3.49 $\pm$ 1.32 (10)	2.94 $\pm$ 0.82 (10)	4.27 $\pm$ 1.94 (10)	3.72 $\pm$ 0.06 (4)

grove and a small seagrass bed. Reefs in this area do not develop deeper than 18 m. The site is not typical to most Caribbean reefs, instead of being dominated by the *Montastraea* complex, major reef-building coral species are *Porites furcata* in shallow water (0.5-2 m), *Agaricia tenuifolia* and *A. danae* along the upper slope (2-6 m), large stands of *Madracis mirabilis* mixed with large colonies of *Colpophyllia natans*, *Montastraea cavernosa*, *M. franski*, and few *M. faeolata* along lower slope (6-12 m), and *Siderastrea siderea*, *Solenastrea* spp. and *Stephanocoenia intersepta* at the base (down to 18 m). The site is located on relatively protected waters on the leeward side of Isla Colón compared to other more exposed CARICOMP sites. A total of 47, 22 and 37 species of scleractinian corals, octocorals and sponges are known for the area, respectively (not recorded in the transects; Guzmán 2003).

Here, we present the percentage cover data (n = 10 transects) for the first survey carried out for CARICOMP in Bocas del Toro, Panama. We do not include in this summary the percentages for all categories as mentioned for Level I (branching, massive, etc.), only general groups and coral species observed along the transects, which can provide a better picture of coral abundance and composition. Seventeen coral species were recorded along the transects. Coral and algae coverage were 26.9% and 21.4%, respectively (Table 4). Live coral cover in Bocas del Toro seems comparable with other CARICOMP sites reporting values between 20% and 30% (Bermuda, Bonaire, Cayman, Nicaragua, Trinidad & Tobago), or intermediate if compared to sites with >30% (Colombia, Curaçao, Puerto Rico, Venezuela) by the mid 1990's (see Kjerfve 1998).

TABLE 4. Percentage cover of major categories and coral species at CARICOMP site in Bocas del Toro, Panama.

Categories	Percent cover	Standard deviation
ALGAE (Encrusting, Turf, Fleshy)	21.4	8.6
HARD CORALS	26.9	5.7
<i>Agaricia tenuifolia</i>	14.6	5.1
<i>Agaricia danae</i>	0.2	0.3
<i>Agaricia lamarcki</i>	1.4	1.3
<i>Agaricia undata</i>	0.4	1.3
<i>Agaricia agaricites</i>	1.1	2.2
<i>Agaricia fragilis</i>	0.5	0.8
<i>Solenastrea hyades</i>	2.2	1.8
<i>Madracis decactis</i>	0.4	0.3
<i>Montastraea cavernosa</i>	0.2	0.5
<i>Montastraea franski</i>	4.3	4.2
<i>Porites astreoides</i>	0.3	0.3
<i>Siderastrea siderea</i>	0.9	1.1
<i>Leptoseris cucullata</i>	0.1	0.1
<i>Colpophyllia natans</i>	0.3	0.9
<i>Scolymia cubensis</i>	0.02	0.06
<i>Eusmilia fastigiata</i>	0.05	0.1
<i>Stephanocoenia intersepta</i>	0.2	0.3
SOFT CORALS		
<i>Erythropodium caribaeorum</i>	0.2	0.6
SPONGES (Encrusting)	4.1	1.8
ABIOTIC (Boulders, Rubble, Sand, etc.)	47.3	7.4
Total Chain Links	1451	93
RUGOSITY	1.451	0.09
% HARD CORAL & SOFT IN BIOTIC	52	10.9

*Background for coral reef monitoring in Panama under the Smithsonian Environmental Science Program (ESP)*

Coral reefs have been monitored in Panama since 1985. Initially, several reef



sites were monitored along the central Caribbean coast in association with the assessment of a major oil spill (Guzmán et al. 1991). In 1992, monitoring ended at these sites, and new sites were developed in the San Blas region, eastern Caribbean Panama. The program in San Blas started in 1993 and ended in 1997. In 1997, recognizing the need to establish a stable and unbroken series of observations, we established the Panama Coral Reef Monitoring Network (PCRMN) at the Smithsonian Tropical Research Institute (<http://striweb.si.edu/esp/>). The program aimed to unify methodologies, to re-establish former sites and to add new sites across the country, including the Pacific side.

The number of sites has increased within the last five years and we now consider the current spatial scale to be reliable and sufficiently comprehensive to detect short-term to long-term changes in reef community structure that are associated with both natural and anthropogenic disturbances and at both local and regional levels. PCRMN's program presently has 19 reefs, encompassing reefs located in different hydrographic regimes and falling within different categories of management on both sides of the Isthmus of Panama. Nine sites are located inside marine protected areas.

Several methods have been suggested for reef monitoring, with most methods favoring the use of either line/chain or quadrat transects (comprehensive reviews in Stoddart and Johannes 1978; Rogers 1994; English et al. 1997). STRI's method is a modified version of the model described in Loya (1978), where permanent line transects run along depth contours parallel to the shore and parallel to each other. Since 1985, we have used the quadrat transect approach which increases reef surface area and allows a better counting of new recruits (Guzmán and Cortes 2001). It is more reliable under current low coral cover conditions (<10 %). The chain transect procedure is used only for the survey of the CARICOMP site located in Bocas del Toro.

The conventional measurement for reef health is the percent cover of living stony (scleractinian) corals. However, the PCRMN program records sessile organ-

isms in far more detail. From the beginning, all stony corals have been identified to species and other sessile organisms—sponges, soft corals, macroalgae, and crustose algae—were recorded as categories and in some cases to species level. A standard annual survey includes cover, abundance, size, and diversity of scleractinian corals, and others. Each reef is surveyed at two to five depth levels (0.5–25 m), depending on the reef profile. At each level, three replicate 10-m transects are set permanently, parallel to the shore. Along each transect, 1 m<sup>2</sup> quadrats are placed contiguously (total 30 m<sup>2</sup> quadrats/depth). Each quadrat is divided by strings into one hundred 10 × 10 cm grids, which facilitates visual estimations of cover and abundance of sessile organisms.

#### CONCLUSIONS

The Bocas del Toro sites are an important addition to the CARICOMP network. Not only do these sites represent the extreme west of the Caribbean but also, in contrast to most CARICOMP sites, the Bocas del Toro site is highly influenced by river flow from the mainland (as a result of high annual rainfall and mountainous watershed), as well as having abundant siliclastic sediments. The CARICOMP research in Bocas del Toro, in conjunction with extensive monitoring conducted as part of the Smithsonian Environmental Science Program, has provided a comprehensive, robust, and extremely useful baseline data set. These ongoing programs, along with an increasing number of affiliated research programs aided by STRI's new research facility on Isla Colón, continue to provide valuable information on the status of mangrove, seagrass and coral ecosystems in Bocas del Toro. Research currently underway on these ecosystems will provide the much needed data for the development of a broad coastal management framework and the scientific basis for planning and policy.

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