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Rapid Assessment of a Coral Reef Community in a Marginal Habitat in the Southern Caribbean: A Simple Way to Know What's out There

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ABSTRACT
Reef monitoring programs can utilize simple effective techniques to collect abundance and distribution data which can be used to monitor long-term effects of human-environment interactions on reef benthos. Line and point intercept and quadrat methods were used to collect data at 2 sites located on the northeastern coast of Trinidad, West Indies, in the southern Caribbean. The diversity and abundance of reef-building corals were assessed annually from 2006-2008 for three intertidal reef flat areas at Toco Bay. Horizontal zones were divided into upper, intermediate and lower intertidal from the shore and were assessed at Toco Bay. An additional fourth zone was surveyed at Salybia Bay. Annual live cnidarian abundance along four randomly selected transects at Toco Bay averaged 55.6% (2006-2008); Zoanthid sp. comprised 40% abundance and the hydrocoral *Millepora alcicornis* and the scleractinian corals, *Siderastrea radians* and *Porites porites* the remaining 13.3%. Live abundance at Salybia Bay was 9.4% and included only *P. porites* (4.4%) and *Z. sociatus*. Quadrat data collected at both sites showed cnidarian abundance at Toco Bay (n = 11) and Salybia Bay (n = 15) to be 47.9% (8.7% scleractinian and 39.2% zoanthids) and 10.3% (4.5% scleractinian and 5.8% zoanthids), respectively. Coral species diversity at Toco Bay (Simpson's index, D = 0.68) was higher than at Salybia Bay throughout the inner reef flat. This study provides the first quantitative coral abundance and distribution data effectively using rapid reef-monitoring assessment methods for Trinidad and provided a quick and simple way to estimate coral and benthic coverage in both intertidal reef systems.

Key words: Intertidal zone, reef system, species diversity, coral abundance

INTRODUCTION
While the world's oceans cover two-thirds of the planet, coral reefs cover a little less than 1% of the ocean floor and it is this minuscule portion that provides resources and services such as fisheries and tourism (Moberg and Folke, 1999; Lamb and Willis, 2011; Hoegh-Guldberg, 2011). Most reefs lie between the Tropic of Cancer (30°N latitude) and the Tropic of Capricorn (30°S latitude) (Souter and Linden, 2000). Both hermatypic and a hermatypic corals that contain dinoflagellate algae (genus *Symbiodinium*) grow in tropical waters that are clear and warm, generally between 18-29°C. However, some species can tolerate higher water temperatures between 30-35°C (Garrison, 2004; Van Oppen and Gates, 2006). These species are currently

affected by coral bleaching due to a persistent abnormal rise in sea surface temperature which causes the release of an abnormal amount of zooxanthellae (genus *Symbiodinium*) from coral tissue, thereby giving corals a pale white color (Douglas, 2003). Other culprits of coral mortality are ocean acidification resulting from increased carbon dioxide released from combustion (Hoegh-Guldberg *et al.*, 2007) and coral diseases which are global problems that are causing severe decline in coral reef abundance (Mumby and Steneck, 2008). Overall, the aforementioned factors contribute to a 1-2% decline in coral reefs per year (Bruno and Selig, 2007).

In the Caribbean, natural variations such as river discharge, low salinity, turbidity, increased sediment discharge after storms and rising temperatures have decreased normal coral growth (Hoegh-Guldberg, 1999; Douglas, 2003; Mallela and Perry, 2007). Anthropogenic effects such as pollution and the use of pesticides have also indirectly caused an influx of nutrients added to intertidal reef flat zones causing increased algal growth that compete with coral for space and thus altering interactions between corals and their mutualists, pathogens and predators (Knowlton, 2001). Additionally, coral disease was shown to be the culprit in the Caribbean-wide depletion of the two dominant reef-building corals in the Caribbean (*Acropora cervicornis* and *A. palmata*), thus adding another dilemma for the continuing global decrease in coral reef habitat (Lamb and Willis, 2011).

The severe decline in Caribbean coral reefs during the last 25 years has produced dynamic shifts in the coral communities and has increased the development of Marine Protected Areas (MPA) to counteract an estimated 34% loss in reef habitat (Hargreaves-Allen *et al.*, 2011). Diseases that affect marine organisms are predicted to become more prevalent and severe in the future as a result of current climate trends (Harvell *et al.*, 2004) and Caribbean reefs are no strangers to frequent disease attack. For example, in the early 1980s, white-band disease decimated Elkhorn and Staghorn (acroporid corals) populations throughout the Caribbean (Aronson and Precht, 2006). Additionally, another disease decimated more than 90% of the dominant Caribbean reef grazer population; *Diadema antillarum* resulting in an increase in algal growth on Caribbean reefs (Hughes, 1994). Most research has been done on corals within the optimal range of their survival. However, there is a need for research on coral communities occupying sub-optimal conditions. An example of this criterion is found in reefs located on the northeastern coasts of Trinidad that are on the margins of the distribution range where conditions are not optimal (Belford, 2007). The reef systems studied here are the closest Caribbean coral communities to the mouth of the Amazon River. The coastal waters of Trinidad are heavily influenced by freshwater discharge from the Amazon and Orinoco Rivers which cause seasonal fluctuations of salinity and turbidity through riverine discharges from the South American mainland (Nansingh and Jurawan, 1999; Mallela and Harrod, 2008).

Consequently, the objectives of this study was to collect baseline data on abundance and distribution of reef benthos using 2 commonly used inexpensive methods so that data on reef benthos can be presented to the local environmental agency, as well as community stakeholders. This study will add valuable information to serve as material for a community citizen science reef-monitoring initiative to form partnerships between citizen volunteers and scientists of the Institute of Marine Affairs of Trinidad and Tobago.

MATERIALS AND METHODS

Study Area: Trinidad is the closest Caribbean island to South America. It lies between 10-11° north latitude and 61-62° west longitude (Fig. 1a). Its coastlines are surrounded by the Caribbean

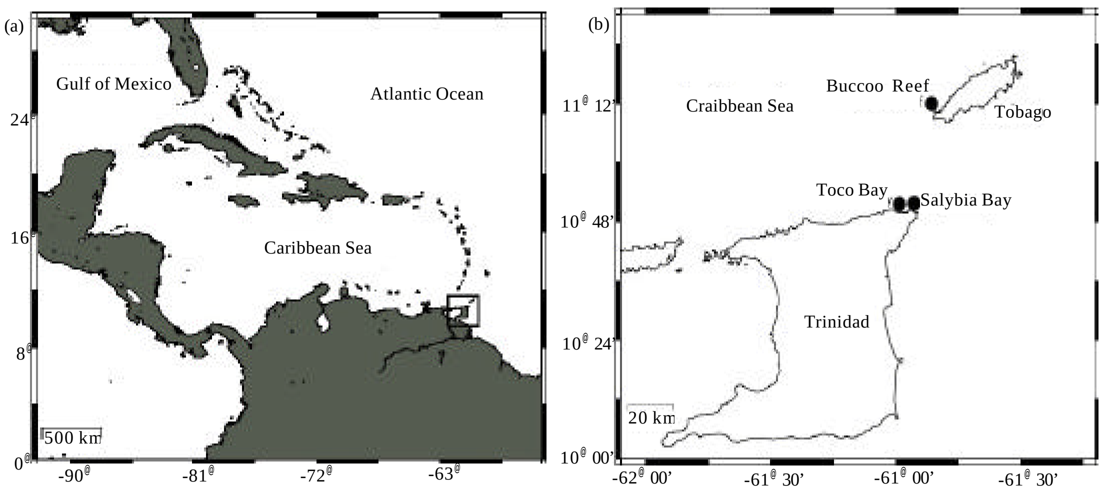

Fig. 1(a-b): Surveys were conducted on coral reefs in the southern Caribbean. (a) The island of Trinidad. (b) The location of reefs on the northeastern coast of Trinidad, Toco Bay and Salybia Bay (survey sites) with respect to Buccoo Reef which is the only marine protected reserve in Trinidad and Tobago

Sea, Gulf of Paria and the Atlantic Ocean. Both field sites are open to the Caribbean Sea and to some extent, the northern Atlantic Ocean. Sites experience semi-diurnal tides during the dry season (January-May) and wet season (June-December). Toco Bay (TB) is on the northeastern coast of Trinidad (Fig. 1b), approximately 4 km west of the Galeota Point which is northeastern extremity of the island. Salybia Bay (SB) lies about 1 km west of Galeria Point (Fig. 1b).

Similar characteristics of both TB and SB bays are low vegetated cliffs, man-made drains that empty their contents into the bays and infrastructures related to human activities (residential dwellings, fishing depot (TB), tourist rest area, camping sites (SB). TB has a 1 km crenulated beach along the bay with a narrow strip of sand and shingle compared to ~0.5 km of sandy beach running from east to west, followed by 0.5 km mixture of stone, coral rubble, exposed bedrock and mostly stone towards the extreme end of SB bay.

Field surveys: Coral distribution data were collected out to 30 m at TB (Fig. 2a-b) and 40 m at SB (Fig. 2c-d) from the shoreline during low tide along transects and inside quadrats. Eight transects were marked at 50 m intervals along the beach at TB and 10 transects were similarly marked at SB. A global positioning system (GPS) was used to record the location of each transects for future reference (Table 1). Distance along the transects lines from the vegetation to the water's edge at low tide was recorded with a measuring tape.

Photographs of corals and other marine biota were taken along transects with an underwater digital camera (Sea and Sea DX-860G, Salinas, CA.) during initial surveys and photographs were used to identify coral species in conjunction with taxonomic guides. Photographs of bleaching on corals and other marine biota also were taken during 7-10 August 2006 and 13-15 August 2007, to document bleaching events.

A brightly colored yellow polypropylene line (40 m) with florescent surveyor tape at 1 m intervals along the line was extended perpendicularly to the shoreline at randomly marked GPS points during exceptionally low tides (Fig. 2b, d). Both ends of the 40 m line were secured to ensure

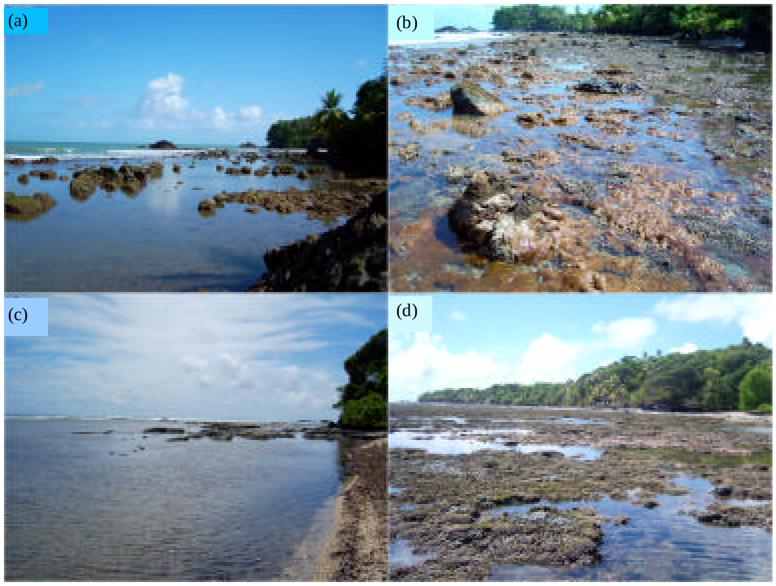

Fig. 2(a-d): Survey sites on the northeastern coast of Trinidad illustrating various low tide conditions. (a) Normal high tide at Toco Bay, (b) exceptionally low tides (spring tides) at Toco Bay, (c) normal high tide at Salybia Bay and (d) exceptionally low tide at Salybia Bay

Table 1: Global positioning system (GPS) coordinates of transect points at Toco and Salybia bays

Transect #	Latitude	Longitude
Toco Bay		
TB T1	10°50.107'N	60°56.772'W
TB T2	10°50.134'N	60°56.764'W
TB T3	10°50.156'N	60°56.747'W
TB T4	10°50.180'N	60°56.736'W
TB T5	10°50.205'N	60°56.730'W
TB T6	10°50.223'N	60°56.708'W
TB T7	10°50.242'N	60°56.691'W
TB T8	10°50.266'N	60°56.674'W
Salybia Bay		
SB T1	10°50.097'N	60°55.208'W
SB T2	10°50.099'N	60°55.108'W
SB T3	10°50.100'N	60°55.157'W
SB T4	10°50.111'N	60°55.129'W
SB T5	10°50.123'N	60°55.101'W
SB T6	10°50.124'N	60°55.073'W
SB T7	10°50.121'N	60°55.058'W
SB T8	10°50.106'N	60°55.036'W
SB T9	10°50.102'N	60°55.008'W
SB T10	10°50.097'N	60°54.975'W

tautness. All identities of reef components such as live coral, algae, dead coral (rubble), rock substratum at each point were recorded along the transect line. Rock substratum consisted of: bedrock (continuous with the coastline), rock (boulders that are >30.1 cm in length, stone (5-30 cm) and rubble (0.5-1 cm). Distances from the shoreline were divided into four zones: (1) 0-10 m, (2) 11-20 m, (3) 21-30 m and (4) 31-40 m. Simpson's index of diversity (1-D), where Simpson's index, D = S n (n-1)/N (N-1) was used to determine species diversity at both sites, as well as within zones 1-4 (N = total number of all coral species; n = total number of a particular coral species).

RESULTS

The sub-tidal reef flat at Toco Bay (TB) and Salybia Bay (SB) measured an average depth of 0.17 and 0.15 m, respectively during low tides observed from 17th-19th December 2005, 4th-7th March and 6th -11th August 2006, 11th-18th August 2007 and March 2008. Water temperature ranged from 26.0-27.5°C at TB and 29.5-30.5°C at SB.

In 2006, the line and point method revealed average estimated live cnidarian (excludes sea anemones) abundance from along four randomly selected GPS transects at TB to be 53.3% (Table 2). Hermatypic corals such as *Porites porites* averaged 11.7% total cover, with twice as much coverage in zone 3 (22.5%) compared to zone 2 (12.5%).

Other "reef-builders" such as *Siderastrea radians* and the hydrocoral *Millepora alcicornis* each had 0.8% coverage. Non reef-building cnidarian species like *Palythoa caribaeorum* and *Zoanthus sociatus* showed coverage at 18.3 and 21.7%, respectively. *Z. sociatus* showed a decrease in coverage from zones 1-3, whereas *P. caribaeorum* steadily increased in zones 1-3 (Table 2). Other notable reef components were algae (12.5%), rock (24.2%), coral rubble (5%) and sand (4.2%).

In 2007, the line and point method showed average cnidarian cover at TB to be 58.3% (Table 3). Hermatypic cover included 10.8% (*P. porites*), 1.7% (*S. radians*) and 0.8% (*M. alcicornis*). Zones 2 and 3 had equal coverage of *P. porites* in 2007 compared to 2006. Non reef builders like

Table 2: Line and Point Intercept estimated percentage cover of various coral species and other substrate types at Toco Bay, during 7-10 August 2006

	Percentage cover in each zone			
Reef component	Zone 1	Zone 2	Zone 3	Avg.% cover (120 points/zone)
Biota				
Porites porites	00.0	12.5	22.5	11.7
Siderastrea radians	00.0	02.5	00.0	00.8
Palythoa caribaeorum	07.5	15.0	32.5	18.3
Zoanthus sociatus	25.0	25.0	15.0	21.7
*Millepora alcicornis**	00.0	00.0	02.5	00.8
Total	32.5	55.0	72.5	53.3
Algae	10.0	22.5	5.0	12.5
Snail	00.0	00.0	2.5	00.8
Exposed substrate				
Bedrock	00.0	00.0	00.0	00.0
Rock	42.5	12.5	17.5	24.2
Stone	00.0	00.0	00.0	00.0
Coral rubble	07.5	05.0	02.5	05.0
Sand	07.5	05.0	00.0	04.2
Total	57.5	22.5	20.0	33.4
Physical				
Mean depth (cm)	15.5	17.8	18.5	-
Mean temperature (°C)	27.5	26.5	26.0	-

Zones 1, 2, 3 represent distances of 0-10, 11- 20 and 21-30 m, respectively from the shoreline, **Millepora alcicornis* is often thought to be a scleractinian but the resemblance is superficial (Humann and Deloach, 2002)

Table 3: Line and Point Intercept estimated percentage cover of various coral species and other substrate types at Toco Bay, during August 2007

	Percentage cover in each zone			
Reef component	Zone 1	Zone 2	Zone 3	Avg.% cover (120 points/zone)
Biota				
Porites porites	07.5	12.5	12.5	10.8
Siderastrea radians	05.0	00.0	00.0	01.7
Palythoa caribaeorum	05.0	20.0	42.5	22.5
Zoanthus sociatus	20.0	25.0	22.5	22.5
*Millepora alcicornis**	00.0	02.5	00.0	00.8
Total	37.5	60.0	77.5	58.3
Algae	15.0	07.5	10.0	10.8
Anemone	00.0	07.5	00.0	02.5
Exposed substrate				
Bedrock	00.0	00.0	00.0	00.0
Rock	07.5	12.5	12.5	10.8
Stone	25.0	02.5	00.0	09.2
Coral rubble	00.0	00.0	00.0	00.0
Sand	15.0	10.0	00.0	08.4
Total	47.5	25.0	12.5	28.4
Physical				
Mean depth (cm)	15.5	17.8	33.0	22.1
Mean temperature (°C)	27.5	26.5	26.0	26.7

Zones 1, 2, 3 represent distances of 0-10, 11-20 and 21-30 m, respectively from the shoreline, **Millepora alcicornis* is often thought to be a scleractinian but the resemblance is superficial (Kaplan, 1982; Humann and Deloach, 2002)

P. caribaeorum and *Z. sociatus* showed similar total average coverage of 22.5%. Interestingly, *P. caribaeorum* increased in coverage from zones 1-3 (Table 3). Algae made up 10.8% while other reef components were 10.8% (rock), stone (9.2%) and sand (8.4%).

In 2008, the line and point method recorded the average cnidarian cover at TB to be 55.2% (Table 4). Reef building coral cover was 14% (*P. porites*), 0.9% (*S. radians)* and 1.9% (*M. alcicornis*). Nonreef builders made up 24.3% (*P. caribaeorum*) and 12.5% (*Z. sociatus*). *P. porites* has the most coverage in zone 3 (21.3%), as do *P. caribaeorum* in zones 3 (30.0%) and 4 (43.3%). Similar increase in coverage was seen for *P. caribaeorum* and decrease in *Z. sociatus* in zones 1-3/4 during visits from 2006-2008. Additionally, algae made up 13.2% while rock (11.7%), coral rubble (5.5%) and sand (8.2%) were the other notable reef components (Table 4). The brown color morphs made up the majority of *P. porites* at TB throughout 2006-2008, with the lesser green morph present in a few areas while only the common brown *P. porites* morph was seen, with the green morph totally absent at SB. Additionally, *Z. sociatus*' green morphotype was more abundant than the orange, purple and blue morphs seen at TB, whereas only the green morphotype was seen at SB throughout the study.

Line and point measurements of hermatypic and ahermatypic coverage at SB totaled 9.4% in 2006 with *P. porites* and *Z. sociatus* making up 4.4 and 5%, respectively (Table 5). Both of these cnidarian species were observed only in zones 3 and 4. *P. porites*, *Z. sociatus* and *S. radians* were rare in zones 1-3. The highest percentage of coral coverage during these annual surveys was recorded in zone 4 (27.5%). *P. porites* and *Z. sociatus* occurred infrequently in zone 3 and corals were absent from zones 1 and 2. Overall, the major reef components other than live cnidaria at

Table 4: Line and Point Intercept estimated percentage cover of various coral species and other substrate types at Toco Bay, during August 2008

	Percentage cover in each zone				
Reef component	Zone 1	Zone 2	Zone 3	Zone 4	Avg.% cover (320 points/zone)
Biota					
Porites porites	13.8	12.5	21.3	08.3	14.0
Siderastrea radians	02.5	01.3	00.0	00.0	00.90
Palythoa caribaeorum	05.0	18.8	30.0	43.3	24.3
Zoanthus sociatus	20.0	12.5	07.5	10.0	12.5
*Millepora alcicornis**	00.0	01.3	01.3	05.0	01.9
Erythropodium caribaeorum	00.0	03.8	02.5	00.0	01.6
Total	41.3	50.2	62.6	66.6	55.2
Algae	07.5	16.3	08.8	20.0	13.2
Anemone	02.5	03.8	00.0	03.3	02.4
Exposed substrate					
Bedrock	00.0	00.0	00.0	00.0	00.0
Rock	20.0	10.0	10.0	06.7	11.7
Stone	07.6	05.0	02.6	00.0	03.8
Coral rubble	02.5	06.3	11.3	01.7	05.5
Sand	18.8	08.8	05.0	00.0	08.2
Total	48.9	30.1	28.9	08.4	29.2
Physical					
Mean depth (cm)					32.0
Mean temperature (°C)					28.1

Zones 1, 2, 3 represent distances of 0-10, 11-20 and 21-30 m, respectively from the shoreline, **Millepora alcicornis* is often thought to be a scleractinian but the resemblance is superficial (Kaplan, 1982; Humann and Deloach, 2002)

Table 5: Line and Point Intercept estimated percentage cover of various coral species and other substrate types at Salybia Bay, during 7-10 August 2006

	Percentage cover in each zone				
Reef component	Zone 1	Zone 2	Zone 3	Zone 4	Avg.% cover (160 points/zone)
Biota					
Porites porites	00.0	00.0	05.0	12.5	04.4
Palythoa caribaeorum	00.0	00.0	00.0	00.0	00.0
Zoanthus sociatus	00.0	00.0	05.0	15.0	05.0
Total	00.0	00.0	10.0	27.5	09.4
Algae	30.0	50.0	35.0	02.5	29.4
Exposed substrate					
Bedrock	00.0	00.0	12.5	00.0	03.1
Rock	15.0	15.0	07.5	20.0	14.4
Stone	12.5	00.0	00.0	12.5	06.2
Coral rubble	30.0	32.5	32.5	35.0	32.5
Sand	12.5	02.5	02.5	02.5	05.0
Total	70.0	50.0	55.0	70.0	61.2
Physical					
Mean depth (cm)	16.0	10.5	17.3	17.0	-
Mean temperature (°C)	30.5	30.5	30.0	29.5	-

Zones 1, 2, 3 and 4 represent distances of 0-10 , 11-20 , 21-30 and 31-40 m, respectively from the shoreline

SB consisted of algae (29.4%), rock (14.4%) and coral rubble (32.5%). Consequently, algae were common in zones 1-3 but dramatically decreased in zone 4. There was a noticeable consistency in the coral rubble coverage throughout zones 1-4 and rubble averaged 32.5% in all zones at SB (Table 5).

The quadrat method used at TB in 2006 indicated an average of 47.9% cnidarian (excluding sea anemones) cover (N = 11 quadrats) (Table 6). Reef building corals such as *P. porites* and *S. radians* constituted an average of 8.4 and 0.3% total coverage respectively. Non reef builders like *P. caribaeorum* and *Z. sociatus* averaged 15.4% and 23.8% respectively. Both *P. porites* and *P. caribaeorum* showed steady increased coverage from zones 1-3. Other notable reef components were rock (32.1%) and sand (8.7%).

At SB, quadrats (N = 15) showed the average cnidarian coverage to be 10.3% in 2006 (Table 7). This constituted *P. porites* (4.5%), *P. caribaeorum* and *Z. sociatus*, the remainder 1 and 4.8%, respectively. Rock (12.8%), stone (11.2%) and coral rubble (47.7%) were the other common reef components present in 2006 (Table 7).

Overall, the cnidarian assemblage at TB was more diverse (1-D = 0.68) than at SB (1-D = 0.54). Cnidarian species richness at TB was 7 compared to 4 at SB. Cnidarian species at TB were scleractinian corals: *P. porites*, *S. radians* and, *Favia fragum*, the zoanthids: *P. caribaeorum*, *Z. sociatus*, an unidentified octocoral and the hydrocoral: *M. alcicornis*. At TB, both *P. porites* and *Z. sociatus* had multiple color morphs present during all years of data collection.

Bleaching was observed in *P. porites* in 18-20 December 2005, 7-10 August 2006 and 13-15 August 2007 at both sites. Bleaching was observed in *M. alcicornis* and *Z. sociatus* in August 2006 and August 2007 at TB. Fishes observed throughout both sites were the damselfish (*Stegastes adustus*), schoolmaster (*Lutjanus apodus*), sergeant major (*Abudefduf saxatilis*), grey snapper (*Lutjanus griseus*) and grunts (*Haemulidae* sp.). Other invertebrates were crabs, snails, beaded anemones (*Epicystis crucifer*), sea slugs (*Elysia crispata*) and reef urchins (*Echinometra viridis*).

Table 6: Quadrat percentage cover of coral species and other substrates of Toco Bay, during 7-10 August 2006

	Percentage cover in each zone			
Reef component	Zone 1	Zone 2	Zone 3	Avg.% cover
Biota				
Porites porites	02.3	05.5	17.5	08.4
Siderastrea radians	01.0	00.0	00.0	00.3
Palythoa caribaeorum	02.3	10.0	34.0	15.4
Zoanthus sociatus	31.6	07.3	32.5	23.8
Total	37.2	22.8	84.0	47.9
Algae	03.0	06.0	02.5	03.8
Crab	01.3	01.0	00.0	00.7
Anemone	06.6	02.0	01.2	03.2
Exposed substrate				
Rock	40.6	46.2	09.5	32.1
Stone	00.4	00.0	00.0	00.4
Coral rubble	01.6	07.0	01.2	03.2
Sand	09.3	15.0	01.8	08.7
Total	51.9	68.2	12.5	44.4

Crabs and anemones were recorded as percentage cover of their surface area within quadrats, Individual counts were recorded but not used in the above table. A total of 11 quadrats were used

Table 7: Quadrat percentage cover of coral species and other substrates of Salybia Bay, during 7-10 August 2006

	Percentage cover in each zone				
Reef component	Zone 1	Zone 2	Zone 3	Zone 4	Avg.% cover
Biota					
Porites porites	00.0	14.4	04.0	03.2	04.5
Palythoa caribaeorum	00.0	00.0	04.0	00.0	01.0
Zoanthus sociatus	01.5	00.0	06.0	12.0	04.8
Total	01.5	14.4	14.0	15.2	10.3
Algae	02.5	10.4	03.0	06.2	05.5
Exposed substrate					
Rock	20.0	22.0	03.0	06.2	12.8
Stone	45.0	00.0	00.0	00.0	11.2
Coral rubble	30.0	37.4	63.0	60.5	47.7
Sand	01.0	14.6	10.0	12.5	9.5
Total	96.0	74.0	76.0	79.2	81.3

Snails, crabs and anemones were recorded as percentage cover of their surface area within the quadrat, Individual counts were recorded but not used in the above table. A total of 15 quadrats were used

Data from quadrats were used in conjunction with line and point intercept information to form a comprehensive description of transects at both sites in 2006. Random quadrat data taken along transects included observations of other reef organisms. At TB, beaded anemones (*E. crucifer*) of many different colors and small crabs were recorded in about half the quadrats. Sea slugs (*E. crispata*) also were recorded for the first time during the August 2006 visit and were abundant at both sites.

DISCUSSION

The results of this study add the first quantitative view of abundance and diversity of reef benthos at Toco and Salybia Bays. Currently, only anecdotal observations have been recorded for these sites and this study provided actual methods which can be used by stakeholders to begin long-term reef monitoring in this region. At first view, the cnidarian distribution at TB was dominated by soft corals like *Palythoa caribaeorum* and *Zoanthus sociatus* which were distributed more abundantly than the dominant reef building coral, *Porites porites* during 3 years of annual data collection using the line and point transect method. There was a noticeable increase in *P. caribaeorum* from zones 1-3/4, compared to a steady decline in *Z. sociatus* for 2006-2008. Furthermore, both survey techniques used in 2006 revealed closely similar percentage cover for reef components, with the most important values for average percentage cnidarian cover at 53.3% (line and point transect method) and 47.9% (quadrat survey method) being most noticeably similar.

The surrounding waters of Trinidad and Tobago acquire their complex coastal marine systems via the Atlantic Ocean, the Caribbean Sea, the Gulf of Paria and the Columbus channel (Mallela and Harrod, 2008). However, a lack of long-term quantitative reef monitoring in local areas alienates the community and the local marine agency from discovering patterns in these marine systems. For instance, effects such as the South Equatorial current brings nutrients and sediment from South America to the islands' coastlines, thereby adding major changes to additives from local runoff. Additionally, human-environment interactions affect the sustainability of resources acquired from the reef habitat, therefore, it is imperative that stakeholders monitor an important source of revenue.

The affects on local reef habitat can be monitored using the quadrat and line and point intercept transect methods which are frequently used to provide standardized and accurate descriptions of coral reef communities (Dodge *et al*., 1982). These methods are used in conjunction with benthic video transect surveys in many reef monitoring programs (Houk and Van Woesik, 2006).

Reef characteristics and zonation differed between Toco and Salybia Bays. Zones had different rock, sand, coral rubble, algae and coral species compositions. Temperatures of each zone varied at TB and were approximately 2.5°C higher at SB because of upwelling to the west along the north coast of these bays has a greater influence on TB. Coral species diversity was slightly higher at TB than SB but indicated a general feature of reef flats which are known for having low coral species richness (Spalding, 2004). Coral densities increased with distance from the shoreline at TB which might be an indication of close vicinity to the reef slope which has the highest concentration of coral density. The reef crest at SB was ~200 m from the shoreline and this study only focused on the first 40 m perpendicular to the shoreline. A future indobt study of SB's true upper intertidal zone (150-200 m from the shoreline) may reveal a higher coral abundance and diversity.

An unidentified octocoral purple morph was seen in the sub-tidal zone at Toco in March 2006 but drastically decreased in abundance in August 2007. It is not known what caused this morph to significantly decrease from the sub-tidal reef flat but it is possibly related to the abnormally high quantity of rainfall that the area received towards the end of rainy season in August for the last two years (Winston Montano, geologist and owner of Almond Park Estate, pers. com.). Low salinity from terrestrial runoff affects coral growth (Pandolfi *et al*., 2003) and salinity levels may have been too variable to support this octocoral's survival. Competition for space with "hardy" dominant species such as *P. caribaeorum* and *Z. sociatus* may also have caused its low distribution.

P. porites coral colonies were seen at SB during December 2005 and March 2006 visits and spring tides in August 2006 revealed large *P. porites* colonies close to the reef crest. The extensive coral rubble (32% of substrate) seen in the inner reef flat may be a result of intense wave action in the outer reef flat. Continuous pounding by waves could break off top parts of *P. porites* colonies that eventually settle on the inner reef flat and shores of the beach. Continual toppling and fragmentation of corals by turbulence at the reef crest has been shown to cause the formation of loose hard substrata in shallow waters (Liddell and Ohlhorst, 1987).

Low stability of coral rubble present in the inner reef flat may limit corel colonization in this area. Low corel diversity was seen in all zones at SB, together with low corel species density. Coral rubble at SB is very loose and water currents move coral rubble in different directions. Wave action is very strong during high tide seemingly making the coral rubble substrate physically stressful to coral colonies. Also, corals were rarely seen growing in coral rubble close to the mouth of Salybia River (Hubbard, 1997) indicated that low salinity limits reef development close to a river mouth. There were small living *P. porites* fragments seen in close proximity to the river mouth's outflow.

Both coral communities possess many similar coral species; however both intertidal coral systems are different. Wave action at TB is rougher than SB hence the reason why *Millepora alcicornis* and *Favia fragum* were found. Both growth forms can withstand continuous pounding by waves. TB seems to be more diverse because it gets deeper faster than SB and you would expect to see a change in species diversity as depth increases. However, the full extent of SB was not assessed in this study. SB is affected by algae cover which can be an indication of the fading 'health' of the reef system at SB. Soft corals such as, *Z. sociatus* and *P. caribaeorum* out competes reef-building corals for space at SB.

Coral rubble and algae cover at SB might be increasing at a faster rate than currently observed and this may decrease cnidarian growth in this already fragile system in the near future. Coral communities at TB may also be decreasing in species diversity since the sub-tidal octocoral species decreased in August 2007. Continual monitoring of this system in the future may only result in observing a general decline in this system due to worsening conditions but more robust monitoring is required for this determination. TB, unlike SB is much more dynamic due to continuous upwelling which provides an influx of nutrients from deeper waters (T. Goreau, pers. comm.).

Future analyses on reef benthic distribution will be conducted and used to educate personnel at the Stakeholders Against Destruction (SAD) for Toco, whom can share this information with the local villages and students of Toco Composite High school. SAD can also use this outreach process to actively collaborate with governmental agencies to initiate a proposal to protect the Toco region from future development that will decrease or damage reefs in this region. At the conclusion of this research, local board members of SAD for Toco discussed the student-reef monitoring issue and if implemented, this study will serve as the foundation research for a pilot project that will develop student, teacher and scientist partnerships.

CONCLUSION

This study will evidently provide knowledge that can be applied to a growing interest in monitoring reef systems and their valuable communities in the Toco region and hopefully see the initial phases to a conservation protection plan for the area. Continual collaboration with the University of the West Indies, Trinidad and the Institute of Marine Affairs conducting research in marine ecology and environmental impacts on local reefs also will assist with the development of protection plans for these coastal areas. Additionally, partnerships between citizens and scientist can develop a way to involve the community in public participation in scientific research which increases awareness, as well as concern to protect the environment.

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