

# **STATUS OF MARINE ECOSYSTEMS AT TURNEFFE ATOLL**

## **RESULTS OF 2010 MBRS SYNOPTIC MONITORING**



**Environmental Research  
Institute**

**UNIVERSITY OF  
BELIZE**

**AUGUST 2011**

## ACKNOWLEDGEMENTS

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We extend our most sincere appreciation to all the University of Belize student volunteers who assisted with the data collection process: Victor Alamina, Tanya Barona, Allen Romero, Allan Romero, Vanessa Figueroa, Karina Mahung, Akeem Williams, Rudolph Williams, and Jani Salazar.

We also thank Mr. Eduardo Barrientos from the University of Belize's Natural Resources Management Program, who volunteered his time and skills to participate in the field data collection.

We thank the Calabash Caye Field Station staff for assisting us with equipment, facilities and transportation.

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## INTRODUCTION

Turneffe atoll is one of three atolls in Belize and the largest of four atolls in the western hemisphere. It is located between Belize's main barrier reef and the Lighthouse Reef Atoll, about 50 km east of Belize City. Turneffe is characterized by its large and numerous mangrove cayes and lagoon areas. The atoll spans about 50 km in lengths and 16 km in width.

Turneffe Atoll forms part of the Mesoamerican Barrier Reef System which spans from northern Yucatan in Mexico, down to the Bay Islands of Honduras, stretching approximately 1,000 km in length (Figure 1). Turneffe Atoll functions as fishing grounds to the national conch, lobster and fin fish industry. The atoll also serves as a tourism destination for overnight tourists who look for diving, sport fishing activities and outdoor activities. Over the past decades the Atoll has also been utilized for scientific studies on the marine environment.

Over the years the atoll has been witness to numerous natural and anthropogenic events such as hurricanes, bleaching, development, and increased fishing. All these events impact the health of the marine environment and ultimately users who depend on the resources. Given the nature of the marine environment and its complexity, changes are better observed over long periods of time. Identifying the changes in the marine ecosystems require long-term monitoring of them. Given that the Turneffe Atoll is located in the Mesoamerican region of which Belize is a part of, **the MBRS Synoptic Monitoring Program 2003** was implemented for long term monitoring of ecosystem health at Turneffe Atoll in 2010.

In 2010 the biological component of the MBRS SMP Program was implemented for; Coral Reef Ecology and Associated Ecosystems. The chemical/pollution component and physical oceanography components are expected to follow in the coming years.

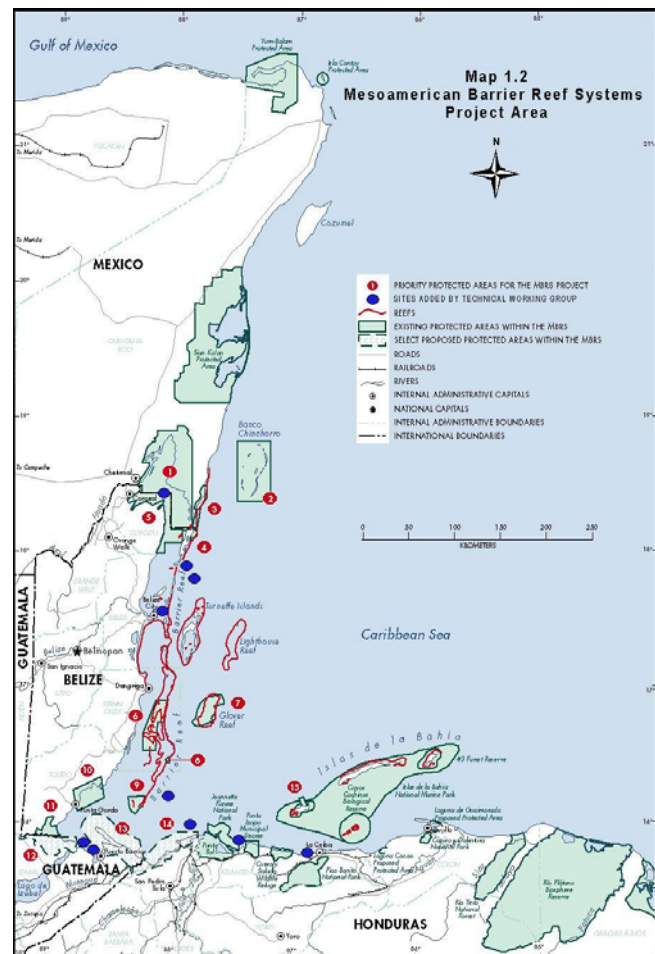


FIGURE 1: MBRS REGION. (MBRS TECHNICAL DOCUMENT NO. 4, 2003)

## METHODS

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The methodology used for the monitoring of the coral reefs and associated ecosystems at Turneffe Atoll was the biological component of the MBRS Synoptic Monitoring Program 2003, Category 1. Analysis of field data for mangroves and seagrass ecosystems was carried out using instructions in the MBRS 2003 Program. Coral reef field data was analyzed using parameters common in the region and those stated in the Report Card for the Mesoamerican Reef 2008 and 2010 by The Healthy Reefs Initiative, (2008, 2010). Reef fish data was analyzed through biomass measurements. Coefficient values obtained from fishbase.org were applied to a biomass function obtained from Marks and Klomp (Lang 2003) and also described in the MBRS Technical Document No. 18, (2006).

## SITES

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A total of ten sites at Turneffe Atoll were selected for long-term monitoring: six coral reefs, two mangrove and two seagrass. Mangrove and seagrass sites were selected based on accessibility and representation of the atoll. **All coordinates provided in this report are in the WGS 84 Central Datum and hddd<sup>0</sup>mm.mmm' format.**

Most of the sites were identified from past studies, others like the seagrass and mangrove sites were strategically identified through GIS software. Based on the 2004 Ecosystem Map, two mangrove sites and two seagrass sites were identified. These were strategically selected to be located nearby a reef site for the purpose of accessibility. For this reason a site visit was made to the sites to confirm their suitability for long-term monitoring. During April 15-18 2010, all 10 sites were visited and GPS coordinates were validated based on the presence of the ecosystem being targeted.

## MANGROVES

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Historically there was an established site at Calabash Caye for long-term monitoring using the CARICOMP methodology, (pers.com, Garcia). This site now serves an education function for courses from the University of Belize.

One MBRS mangrove site was established at Calabash Caye about 200m from the previous CARICOMP site. The site was established in a more remote and less accessible area to diminish impacts from student groups. The Calabash Caye mangrove site was located in the Central Eastern part of the atoll (windward). The second mangrove site was established in the south western area of the atoll (leeward).

**Calabash Mangrove: N 17<sup>0</sup> 17.060'    W 087<sup>0</sup> 48.778'**

**West Mangrove: N 17<sup>0</sup> 13.302'    W 087<sup>0</sup> 56.195'**

During the site visit, the permanent plots and salinity wells were established and marked and the habitat was characterized.

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## SEAGRASS

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The seagrass sites were strategically established with a focus to coordinate field data collection between mangrove and seagrass ecosystem monitoring. The seagrass sites were established within the vicinity of the mangrove sites. Therefore one site was established nearby Calabash Caye and the other was established nearby the west mangrove site on the south western area of the atoll.

**Calabash Seagrass: N 17° 17.177' W 087° 48.345'**

**West Seagrass: N 17° 13.328' W 087° 56.259'**

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## CORAL REEFS

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In the selection of the six coral reef sites, a list of previously studied sites was obtained from past reef assessments such as the AGRRA 2000 assessment and the 2006 Rapid Reef Assessment. A total of 30 sites were obtained from which six sites were randomly selected through the use of the Microsoft Excel 2007 random function. The six selected sites are aimed at representing six distinct areas of the atoll: North East, Central East, South East, North West, Central West and South West, (Figure 2).

**North East, WP6: N 17° 35.625' W 087° 44.643'**

**Central East, 1213: N 17° 21.949' W 087° 47.820'**

**South East, Caye Bokel: N 17° 09.460' W 087° 54.493'**

**North West, WP5: N 17° 32.903' W 087° 49.366'**

**Central West, WP4: N 17° 23.150' W 087° 56.339'**

**South West, 1062: N 17° 15.702' W 087° 57.624'**

Based on the site visit during the 15-18 of April 2010 one change was made. Site 1213 was observed to have very little to no coral cover on the fore reef areas and the back reef area was characterized as sand and algal beds. This made site 1213 unsuitable for long-term monitoring and thus site 1206 was selected to represent the Central East area of the atoll.

**Central East, 1206: N 17° 15.058' W 087° 50.316'**



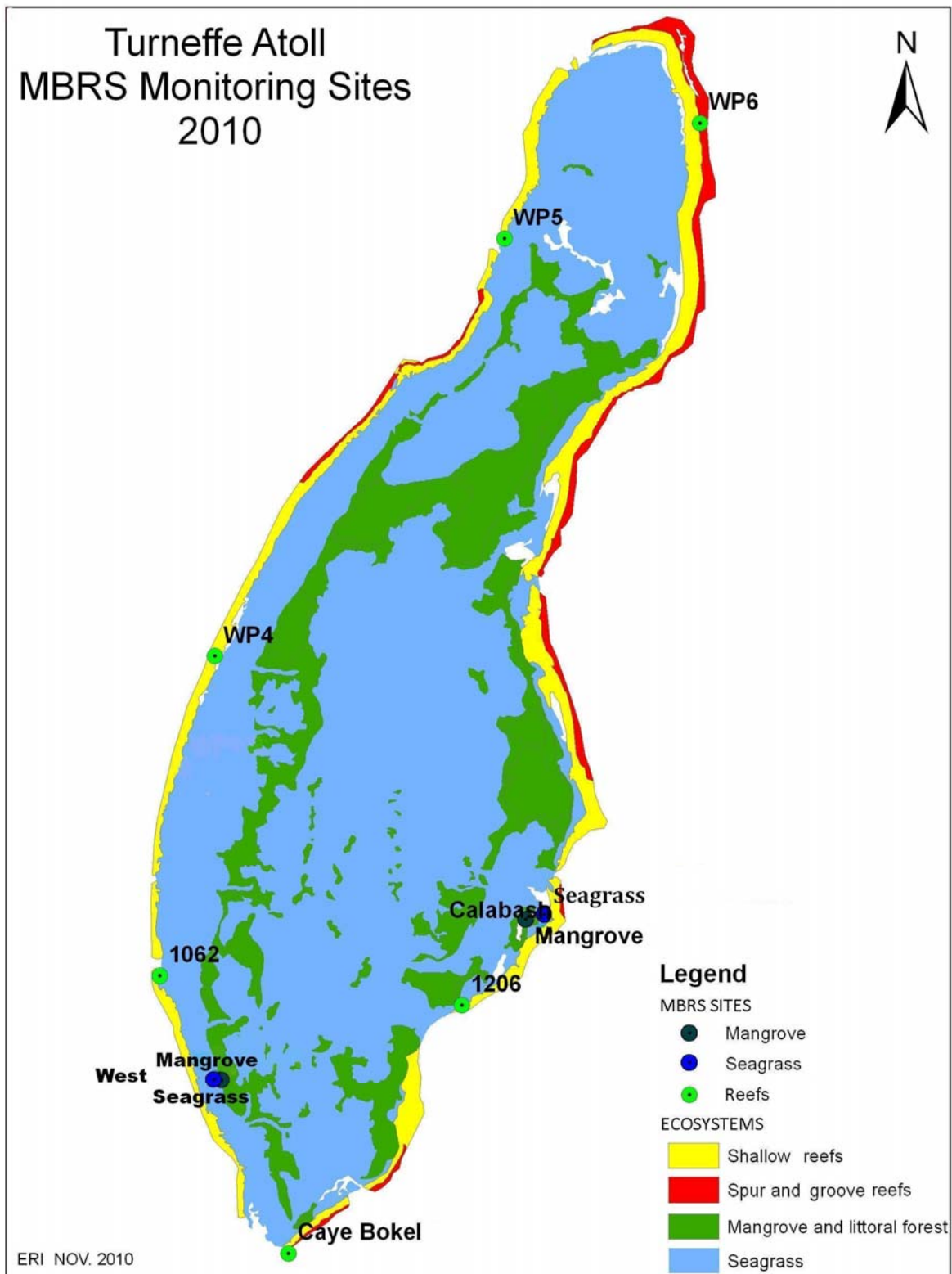


FIGURE 2: TURNEFFE ATOLL MBRS SITES 2010

The criterion used to analyze the reef monitoring results was the Integrated Reef Health Index described in the 2008 Report Card for the Mesoamerican Reef (Healthy Reefs Initiative, 2008) and described below. The index is obtained from two sub indices: coral index and reef biota index. These are further obtained by specific indicators highlighted in Table 1.

TABLE 1: INTEGRATED REEF HEALTH INDEX, (HEALTHY REEFS, 2008)

<b>Coral Index Indicators</b>	<b>Reef Biota Index Indicators</b>
Coral %cover (stony corals)	Fleshy macroalgae index
Coral disease prevalence %	Herbivorous fish abundance, measure of biomass g per 100m <sup>2</sup>
Coral recruitment m <sup>2</sup>	Commercial fish abundance, measure of biomass g per 100m <sup>2</sup>
	<i>Diadema</i> abundance m <sup>2</sup>

Since data collected using MBRS monitoring methodology does not allow for the calculation of the fleshy macroalgae index, the fleshy macroalgae % cover was used instead. The criterion for fleshy macroalgae cover is obtained from the 2010 Report Card for the Mesoamerican Reef (Healthy Reefs Initiative, 2010). The various indices are highlighted in Table 2.

TABLE 2: THRESHOLD VALUES USED TO DETERMINE RANKING FOR EACH INDICATOR, (HEALTHY REEFS, 2008 & 2010)

Index	Very good (5)	Good (4)	Fair (3)	Poor (2)	Critical (1)
Coral cover	≥ 40	20-39.9	10-19.9	5.0-9.9	<5
Coral disease prevalence	>1	1.1-1.9	2.0-3.9	4.0-6.0	>6
Coral recruitment	≥10	5.0-9.9	3.0-4.9	2-2.9	<2
Fleshy macroalgae % cover	0-0.9	1.0-5.0	5.5-12.0	12.1-25	>25.0
Commercial fish abundance	≥2800	2100-2799	1400-2099	700-1399	<700
Herbivorous fish abundance	≥4800	3600-4799	2400-3599	1200-2399	<1200
<i>Diadema</i> abundance	>2.5 ( and <~7)	1.1-2.5	0.5-1.0	0.25-0.49	<0.25

Note: All the indicator threshold values presented in Table 2, (except fleshy macroalgae cover) were obtained from the Health Reefs 2008 Report Card. The fleshy macroalgae % cover threshold values presented in Table 2 were obtained from the Healthy Reefs 2010 Report Card.



## RESULTS

Analysis of data for mangroves and seagrass ecosystems was carried out as described in the MBRS Synoptic Monitoring Program. Coral reef field data was analyzed using parameters common in the region and those stated in the Report Card for the Mesoamerican Reef 2008 by the Healthy Reefs Initiative Program. All field data and results are being housed at ERI.

### MANGROVES

#### DENSITY

Characterization of the habitats obtained through the Point Centre Quarter Method indicated that in general the Calabash Mangrove site had more than four times the density of the West Mangrove site. Densities at both sites were very similar at the water's edge and at the end of the transect approximately 85 meters from the water edge (Figure 3).

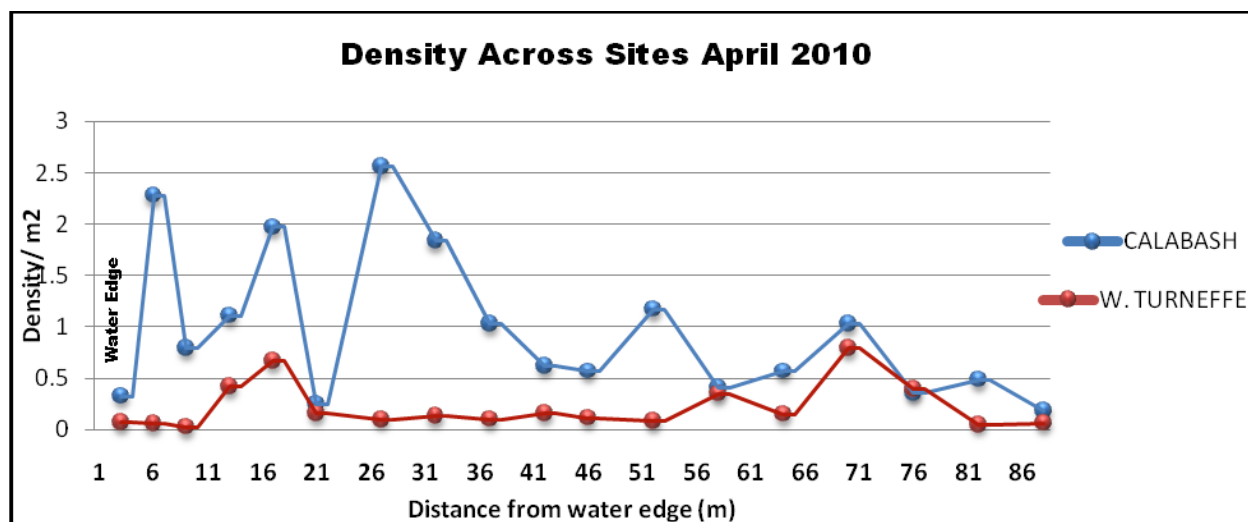


Figure 3: Mangrove density/ -m<sup>2</sup>

TABLE 3: AVERAGE MANGROVE DENSITY/HECTARE

	Calabash Mangrove	West Turneffe
Mean density/hectare	9736.06	2142.50
Median	7026.35	1204.85
Std.Dev	7283.47	2208.89
Min	1890.35	256
Max	25600	7901.23

For comparison with other sites in the region, the density of the sites was calculated per hectare. When compared to results of the MBRS 2006 report (Technical Document No. 18 2006) for seven sites in the MBRS region, the Calabash mangrove site has the highest density, (9736/ hectare). Xcalak Mexico, identified as having the highest density in the MBRS 2006 report, had the second highest density with 8380/hectare when compared to the Calabash Mangrove site. Thus Calabash Caye possessed the highest mangrove density across the MBRS region with 9736/ ha. The West Turneffe mangrove site ranked as the fourth highest in density when compared with other sites in the MBRS region.

### HEIGHT

The height difference between the two sites was very large. Mean mangrove height at Calabash Caye was approximately 3m and ranged between 1.2 m and 6 m. At West Turneffe, mean height was approximately 8 m, and ranged between 1.7 m and 12 m in height.

At Calabash Caye the mangrove canopy height steadily increased with increased distance from the shoreline. Canopy height at West Turneffe generally decreased as distance from the shoreline increased, (**Figure 4**).

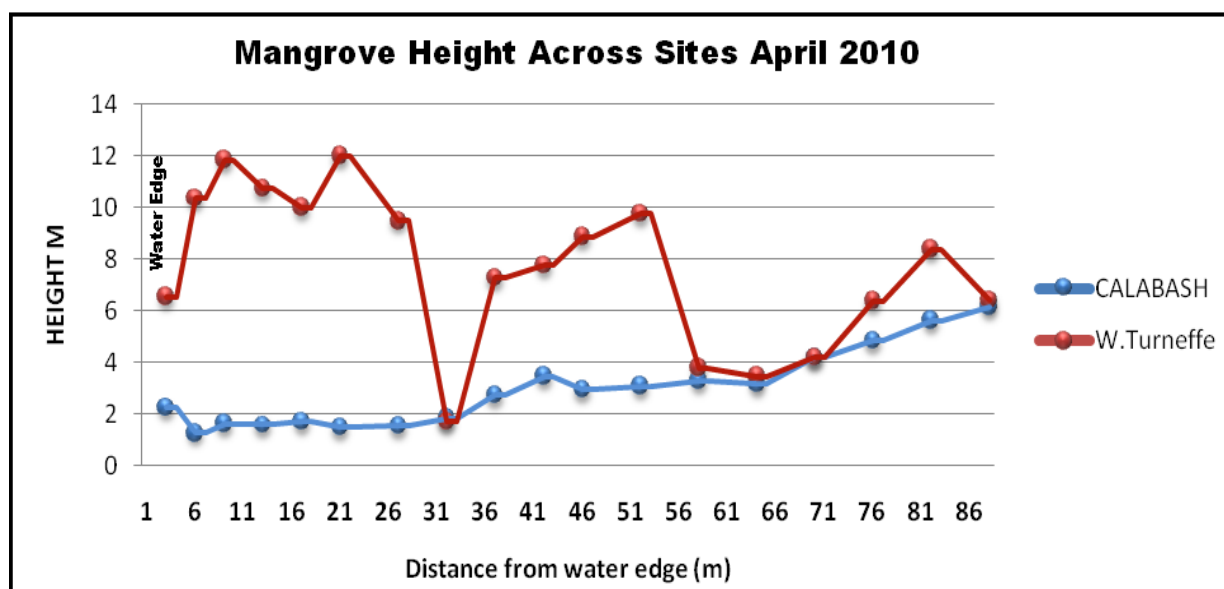


FIGURE 4: MANGROVE HEIGHT ACROSS TRANSECT

**TABLE 4: AVERAGE MANGROVE HEIGHT BY LOCATION**

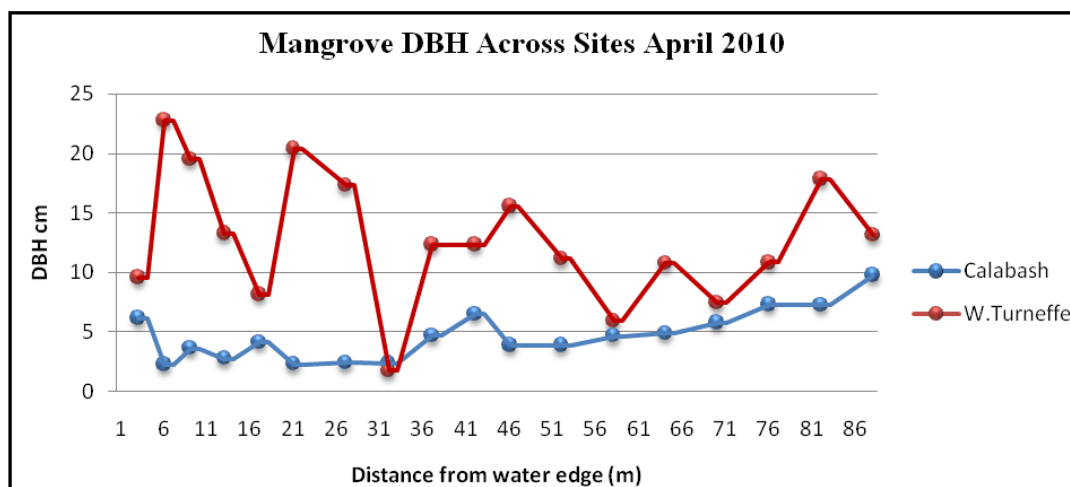
When compared to the MBRs region (2006), West Turneffe had the third highest canopy height with a mean of 7.7 m; Cayos Cochinos was identified with the tallest canopy height with 11.69 m followed by Sarstoon River with 9.86 m (MBRS Technical Document No. 18, 2006). Calabash Caye had the lowest canopy height (2.92 m) in the region.

Units = m	Calabash Mangrove (2010)	West Turneffe (2010)	Cayos Cochinos (2006)	Banco Chinchorro (2006)
AVR. HEIGHT	2.9	7.71	11.69	5.91
Median	2.83	8.06	6.29	6
Std.Dev	1.47	3.00	9.56	1.62
Min	1.27	1.7	.91	2
Max	6.16	12	29.6	10

The lowest mean canopy height presented in the MBRs report 2006, was 5.91m at Banco Chinchorro (**Table 4**).

#### DBH

As with height, diameter at breast height was highest at the West Turneffe site. The average DBH at West Turneffe was 12.7 cm, while at Calabash, the average DBH was 4.6 cm. DBH at the Calabash Caye site was observed to increase with increased distance from the shoreline, this same pattern was not observed at West Turneffe, (**Figure 5**)



**FIGURE 5: MANGROVE DBH ACROSS SITES**

TABLE 5: AVERAGE DBH BY SITE

	Calabash	W. Turneffe
Avr. DBH	4.68	12.7
Median	4.38	12.3
Std.Dev	2.09	5.41
Min	2.25	1.7
Max	9.75	17.82

DBH at Calabash ranged between 2.25 cm and 9.75 cm while at West Turneffe DBH ranged between 1.7cm and 17.8 cm (Table 5).

When compared to the MBRS region (2006), West Turneffe ranked fourth in DBH and Calabash Caye had the lowest DBH in the region. According to the MBRS Technical Document 18, 2006, the largest DBH was 18.48 cm and the smallest was 5.02 cm.

Mean DBH for Turneffe Atoll, (mean of both sites) was 8.72 cm. Out of eight locations; this ranked as fifth in the MBRS region when compared to the results of 2006.

### COMMUNITY COMPOSITION

Community composition was determined using the permanent plots established at each site (Figure 2). Community composition at both sites was very similar. Both sites mostly consisted of red mangroves but also contained black and white mangroves.

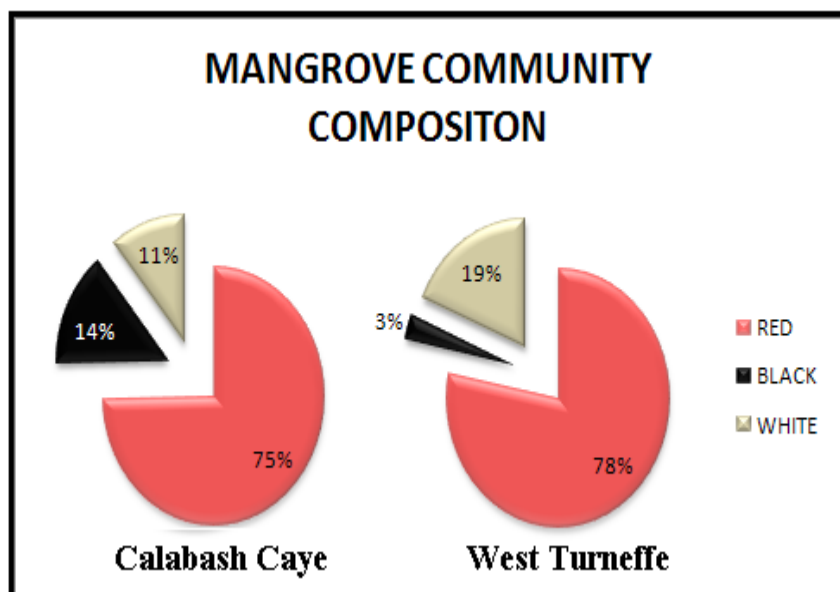


FIGURE 6: MANGROVE COMMUNITY COMPOSITION JULY 2010

Red mangrove made up 75% to 78% of mangroves at both sites. Therefore both sites were red mangrove dominated habitats (Figure 6).

White and black mangroves composed almost similar percentages at Calabash Caye, 11% and 14%. At the West Turneffe site, black mangrove was very uncommon, representing only 3% of the mangroves characterized.

## BASAL AREA

Basal area is a measure of ground space covered by trees, expressed as per unit area ( $\text{m}^2 \text{ha}^{-1}$ ). It takes into account the number of trees and diameter at breast height (DBH). Basal area was calculated for each individual tree in the plot and summed. The average basal area for both sites at Turneffe Atoll are presented below (**Figure 7**). The highest basal area was observed at Calabash Caye with  $25.4 \text{ m}^2 \text{ha}^{-1}$ . West Turneffe had a basal area of  $19.6 \text{ m}^2 \text{ha}^{-1}$  (Table 6).

The mean basal area for Turneffe Atoll (mean of both sites) was calculated at  $22.5 \text{ m}^2 \text{ha}^{-1}$ . When compared to the results of the MBRS region (2006), this value ranks as fourth out of eight sites in the MBRS region.

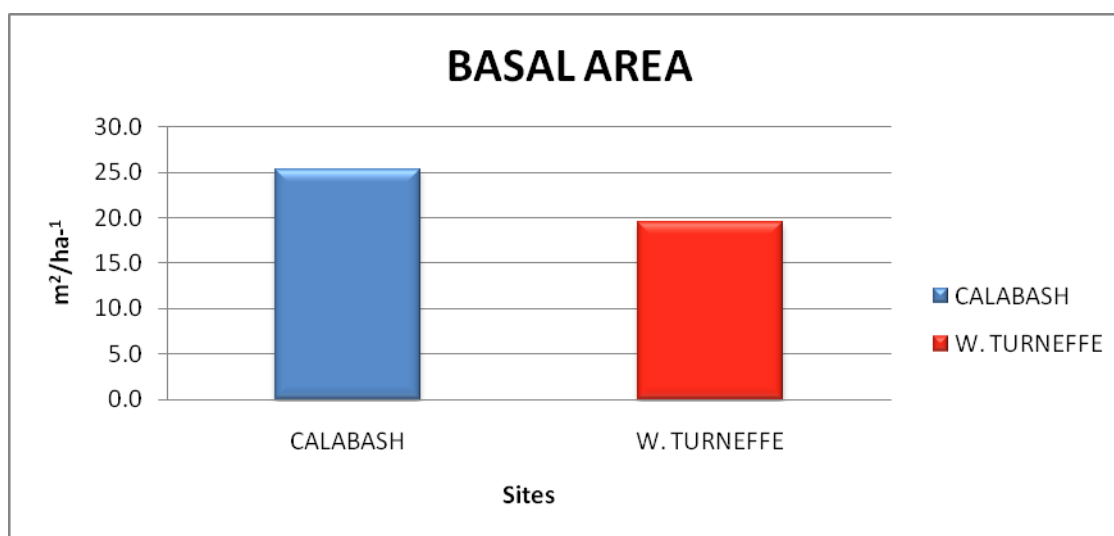


FIGURE 7: BASAL AREA OF MANGROVE SITES AT TURNEFFE ATOLL

TABLE 6: AVERAGE MANGROVE BASAL AREA PER SITE

	CALABASH	W. TURNEFFE
AVR.	25.4	19.6
MEDIAN	26.4	18.5
STD. DEV	5.1	8.2
MIN	19.8	12.0
MAX	29.9	28.2

The highest basal area recorded in the MBRS region (2006) was  $46.99 \text{ m}^2 \text{ha}^{-1}$  at Cayos Cochinos in Honduras. The lowest was  $7.71 \text{ m}^2/\text{ha}$  recorded at Bacalar Chico.

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## SEAGRASS

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Two seagrass species were present in the samples collected at both sites: *Thalassia testudinum* and *Syringodium filiforme*. The sea grass sites were dominated by *Thalassia testudinum*, as in the Mesoamerican Barrier Reef System (MBRS 2006).

Biomass estimates from both sites indicate little difference. Calabash Seagrass site had a mean biomass of 895.35 g/m<sup>2</sup>. West Turneffe Seagrass site had a mean biomass of 886.85 g/m<sup>2</sup>. The distribution of biomass among the components of the seagrass plant differed across sites. The Calabash Caye seagrass site had a larger biomass for the above ground sections of the plants. The West Turneffe Seagrass site had a slightly higher biomass for the below ground plant section (Figure 8). The mean biomass for both sites was 891 g/m<sup>2</sup>.

When compared to the results of the MBRS region (2006), the mean biomass values of both sites ranked as fourth out of eight sites in the region.

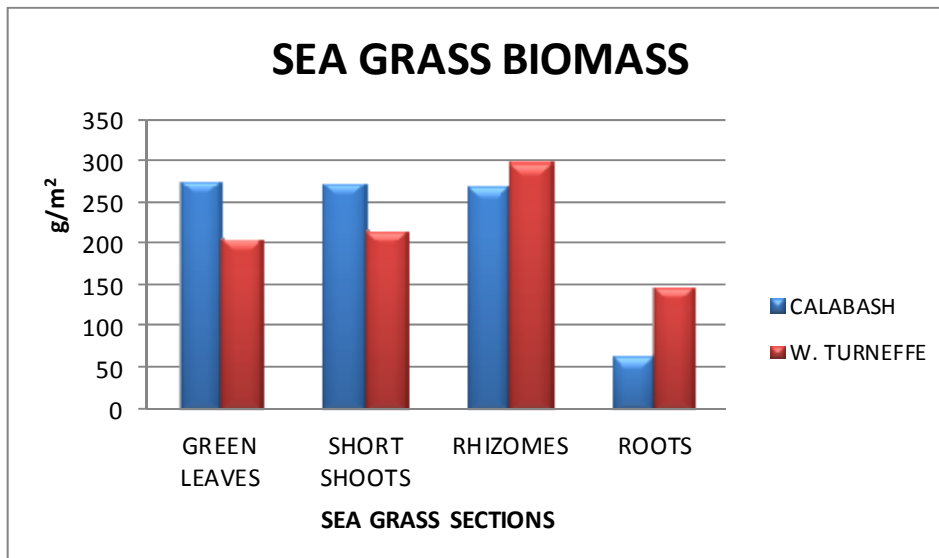


FIGURE 8: SEAGRASS BIOMASS PER PLANT SECTION

## CORAL REEFS

Six reef sites (Figure 9), each representing three distinct reef habitats: back reef, shallow fore reef and deep fore reef were monitored.

- BR= Back-Reef , (leeward) habitats at 1-5m depth
- SFR= Shallow fore-reef (windward) habitats at 1-5m depth
- DFR= Deep fore-reef habitats at 8-15m depth

In total, 18 sub-sites were monitored to identify critical factors such as coral and algal cover, commercial fish species abundance and herbivorous fish species abundance.

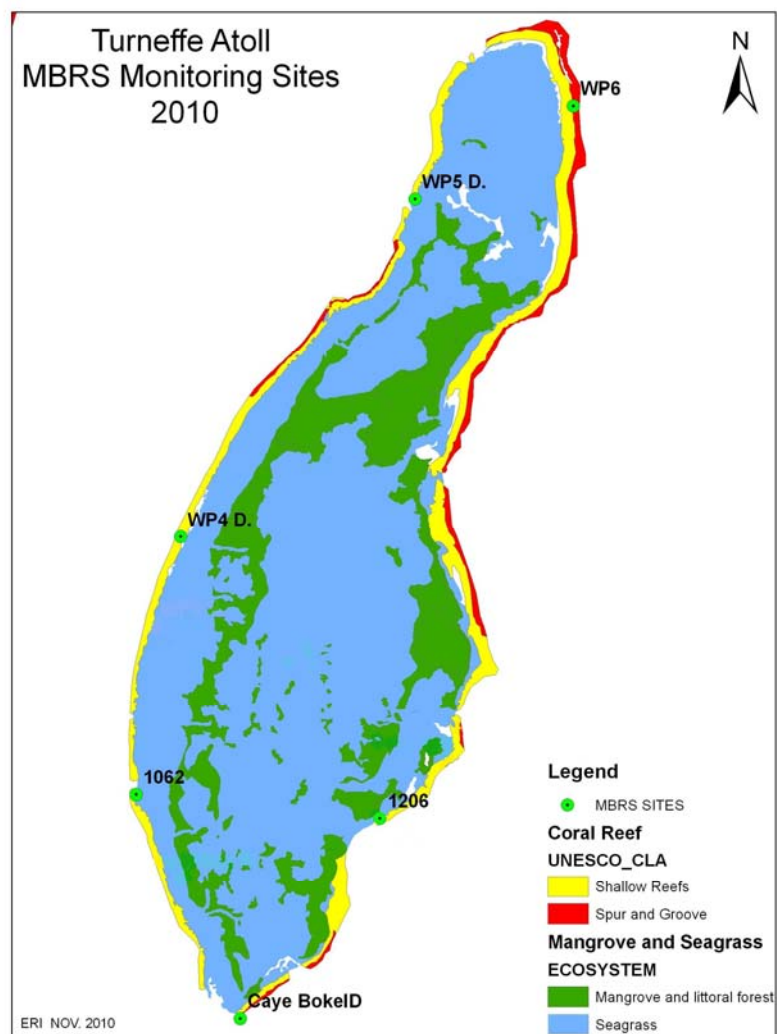


FIGURE 9: MAP OF TURNEFFE ATOLL MBRS REEF SITES



## CORAL COVER AND FLESHY MACROALGAE COVER

Coral % cover is a measurement of the end result of all reef processes such as recruitment, mortality and competition. This measurement has been widely used to assess the condition of reef-building corals, (Mc Field and Kramer 2007). Another major component of the reef benthic community is macroalgae. Over the years, macroalgae cover has become more abundant, and in some locations much more abundant than stony corals, (MBRS Technical Document No 18).

The % cover for corals and macroalgae at the sites is presented below in Figure 10. Macroalgae % cover includes the following species: *Dictyota*, *Lobophora*, *Halimeda* and other macroalgae species with a height greater than 1 cm.

Coral cover across sites and habitats monitored within Turneffe Atoll ranged from 2.6% to 23.1% with a **mean cover of 9.59%**. Fleshy macro algae cover ranged from 0.2 % to 48% with a **mean cover of 16.5%**. The most recent estimates of coral and macroalgae cover for the Mesoamerican Region are documented in the 2010 Report for the Mesoamerican Reef (Healthy Reefs, 2010). Based on results presented in this report, the mean coral cover and macroalgae cover for Belize in 2009 was 18.7% and 17.3% respectively. The 2010 results obtained for Turneffe Atoll is well below the 2009 nationwide mean and the macroalgae cover slightly below the nationwide mean.

The highest coral cover of 23% was observed on the north western side of the atoll at the back reef area of site WP5. The lowest coral cover, 2.6% was observed on the north eastern side of the atoll at back reef area of site WP6. The two highest fleshy macro algae cover were observed at the shallow fore reef and deep fore reef areas of site WP6 ( **Figure 10**).

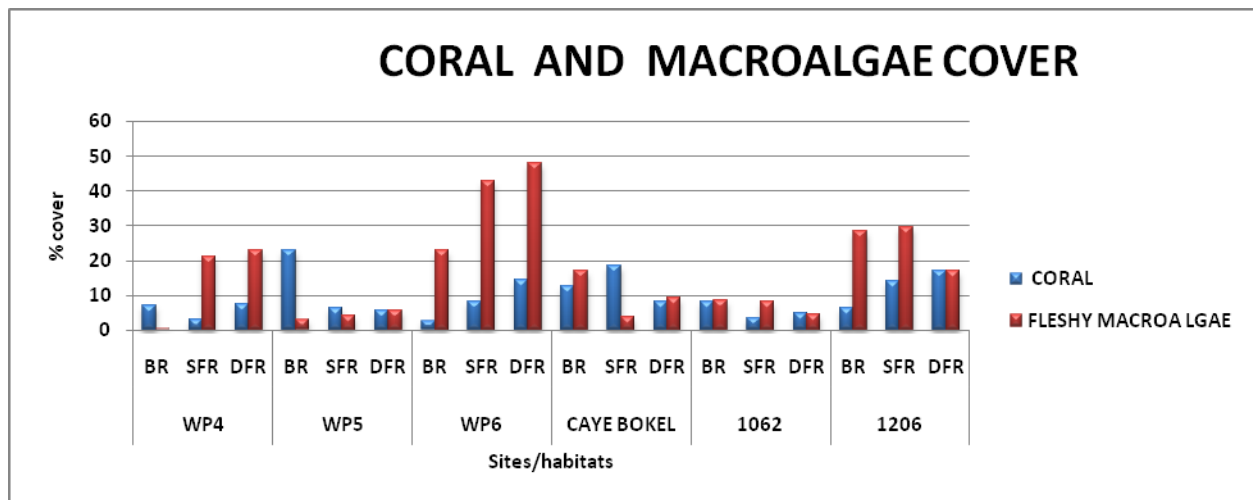


FIGURE 10: MEAN CORAL AND FLESHY MACROALGAE % COVER

Mean coral cover was similar across the three different habitats: back reef, shallow fore reef and deep fore reef. It ranged between 9% to 10% cover. The highest cover of 10.05% was observed in back reef habitats. The lowest cover was observed on shallow fore reef habitats of 9.02%, (**Figure 11**). Fleshy macroalgae cover was observed in similar percentages in the shallow fore reef and deep fore reef habitats with 18.3% and 17.8% respectively. The lowest percentage cover of macroalgae was observed on the back reef areas, 13.4%, (**Figure 11**).

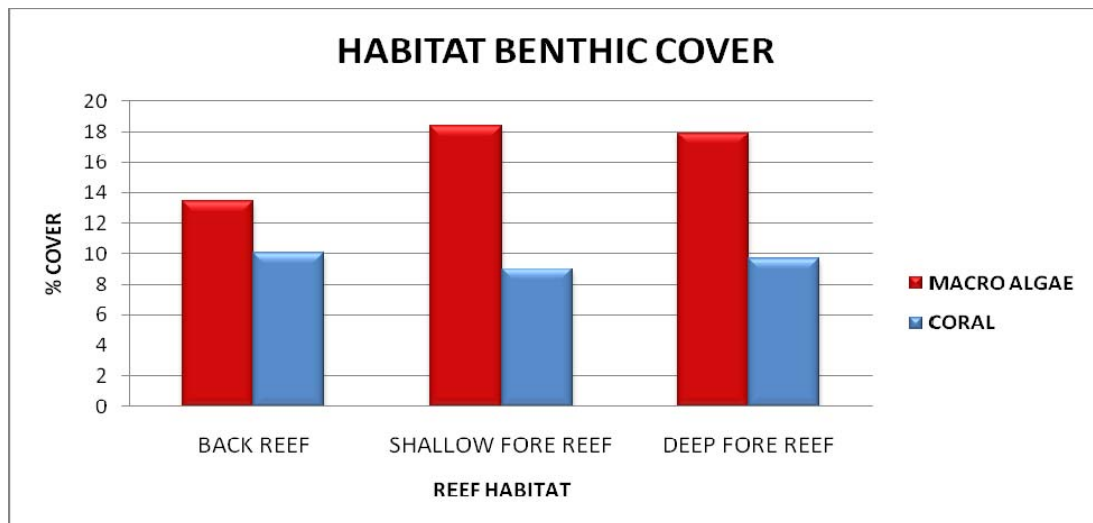


FIGURE 11: CORAL AND FLESHY MACROALGAE COVER BY HABITAT

Mean coral and macro algae cover per site is presented in **Figure 12**. The highest mean macro algae % cover was observed at site WP6 (38%) and the lowest was observed at site WP5 (2.3%). Coral cover was highest at site Caye Bokel (13.2%) and lowest at site 1062 (5.5%).

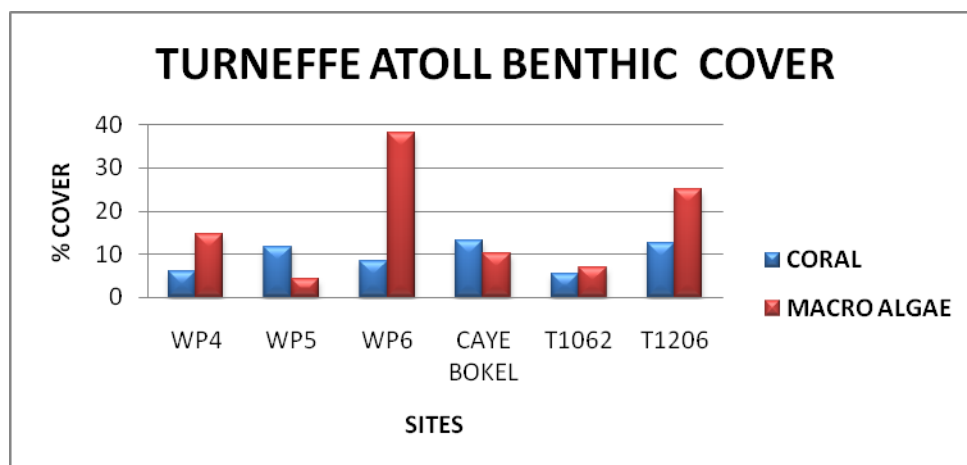


FIGURE 12: CORAL AND MACROALGAE COVER PER SITE

Analysis of the major reef benthic types encountered during the field monitoring at all the sites, resulted in **Figure 13**. The most common benthic type encountered was sand, with mean cover of 39%. Fleishy macroalgae was the second most common benthic type with 16.5% cover. This was followed by turf algae with 11% cover. Stony corals had a mean cover of 9.55%. This was very similar to bare substrate, which covered 9.38%. The lowest benthic type was gorgonians with 2.43%.

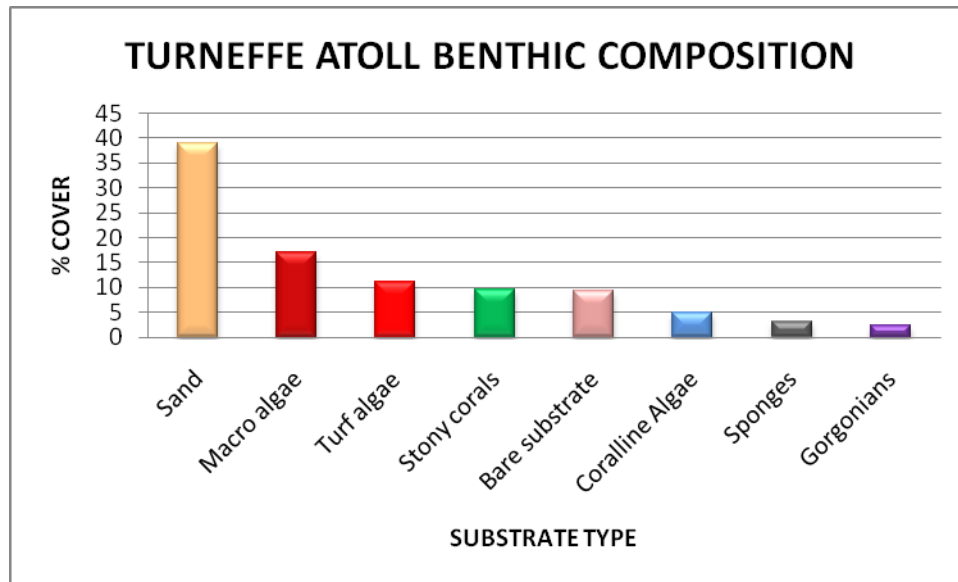


FIGURE 13 REEF BENTHIC COMPOSITION

The most abundant coral species present was *Millepora alcicornis* with a mean cover of 2% followed by *Porites asteroides*, *Agaricia tenuifolia* and *Montastrea annularis*, with mean cover of just over 1% (**Figure 14**).

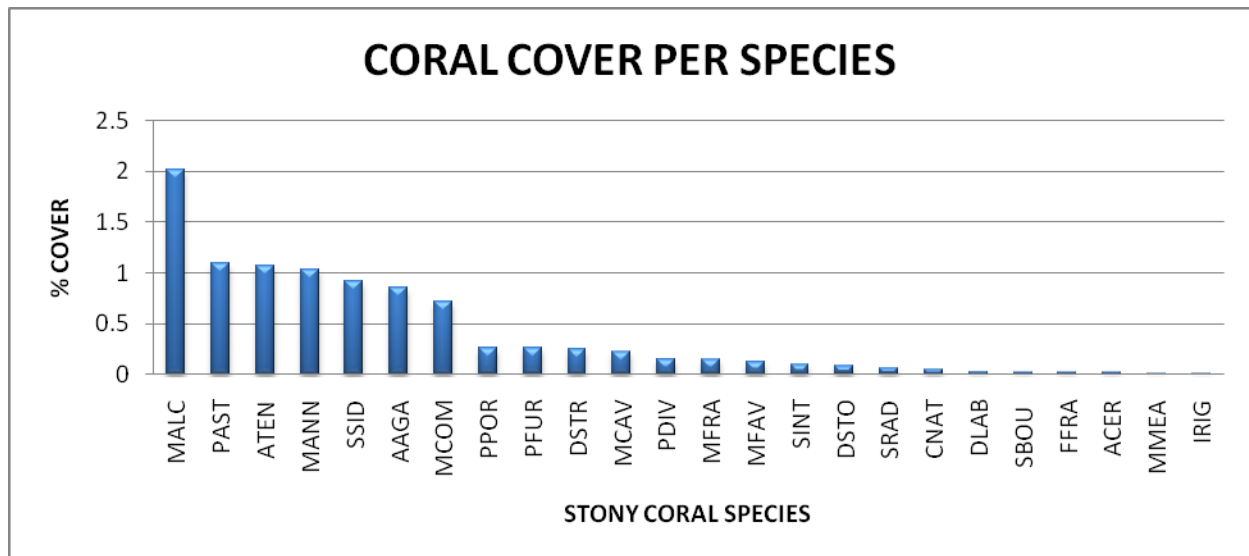


FIGURE 14: TURNEFFE ATOLL CORAL SPECIES COMPOSITION

A total of 26 species of corals were recorded in the reef surveys (Table 7). Several other species of stony corals not documented during the surveys were observed in other areas around the atoll.

Species richness and distribution is presented in **Figure 15**. The most widely distributed species was *Siderastrea siderea* present at 17 sub-sites. This was followed by *Millepora alcicornis* present at 16 sub-sites which was the species with the highest coral cover (2%). *Agaricia agaricites* was present at 15 sub-sites, followed by *Porites asteroides*, present at 14 sites.

Other more commonly encountered species included *Porites furcata*, *Montastrea annularis*, *Agaricia tenuifolia* and *Montastrea cavernosa*, present at more than 10 sub-sites.

The mean number of species observed was 10. The sites with the highest number of coral species were WP5 back reef habitat and Caye Bokel back reef habitat with 15 and 14 species respectively. Species richness ranged from 5 to 15. The sites with the lowest species present were WP6 back reef and WP6 shallow fore reef habitat, both with 5 species.

TABLE 7: STONY CORAL SPECIES ENCOUNTERED AT TURNEFFE REEF SITES

	Scientific name	Species Code	Common name
1	<i>Millepora alcicornis</i>	MALC	branching fire coral
2	<i>Porites astreoides</i>	PAST	mustard hill coral
3	<i>Agaricia tenuifolia</i>	ATEN	thin leaf lettuce coral
4	<i>Montastraea annularis</i>	MANN	lobed star coral
5	<i>Siderastrea siderea</i>	SSID	massive starlet coral
6	<i>Agaricia agaricites</i>	AAGA	lettuce coral
7	<i>Millepora complanata</i>	MCOM	blade fire coral
8	<i>Porites porites</i>	PPOR	club-tip finger coral
9	<i>Porites furcata</i>	PFUR	branched finger coral
10	<i>Diploria strigosa</i>	DSTR	symmetrical brain coral
11	<i>Montastraea cavernosa</i>	MCAV	great star coral
12	<i>Porites divaricata</i>	PDIV	thin finger coral
13	<i>Montastraea franksi</i>	MFRA	boulder star coral
14	<i>Montastraea faveolata</i>	MFAV	mountainous star coral
15	<i>Stephanocoenia intersepta</i>	SINT	blushing star coral
16	<i>Dichocoenia stokesi</i>	DSTO	elliptical star coral
17	<i>Siderastrea radians</i>	SRAD	lesser starlet coral
18	<i>Colpophyllia natans</i>	CNAT	boulder brain coral
19	<i>Diploria labyrinthiformis</i>	DLAB	grooved brain coral
20	<i>Solenastrea bournoni</i>	SBOU	smooth star coral
21	<i>Favia fragum</i>	FFRA	golfball coral
22	<i>Acropora cervicornis</i>	ACER	staghorn coral
23	<i>Meandrina meandrites</i>	MMEA	maze coral
24	<i>Isophyllastrea rigida</i>	IRIG	rough star coral

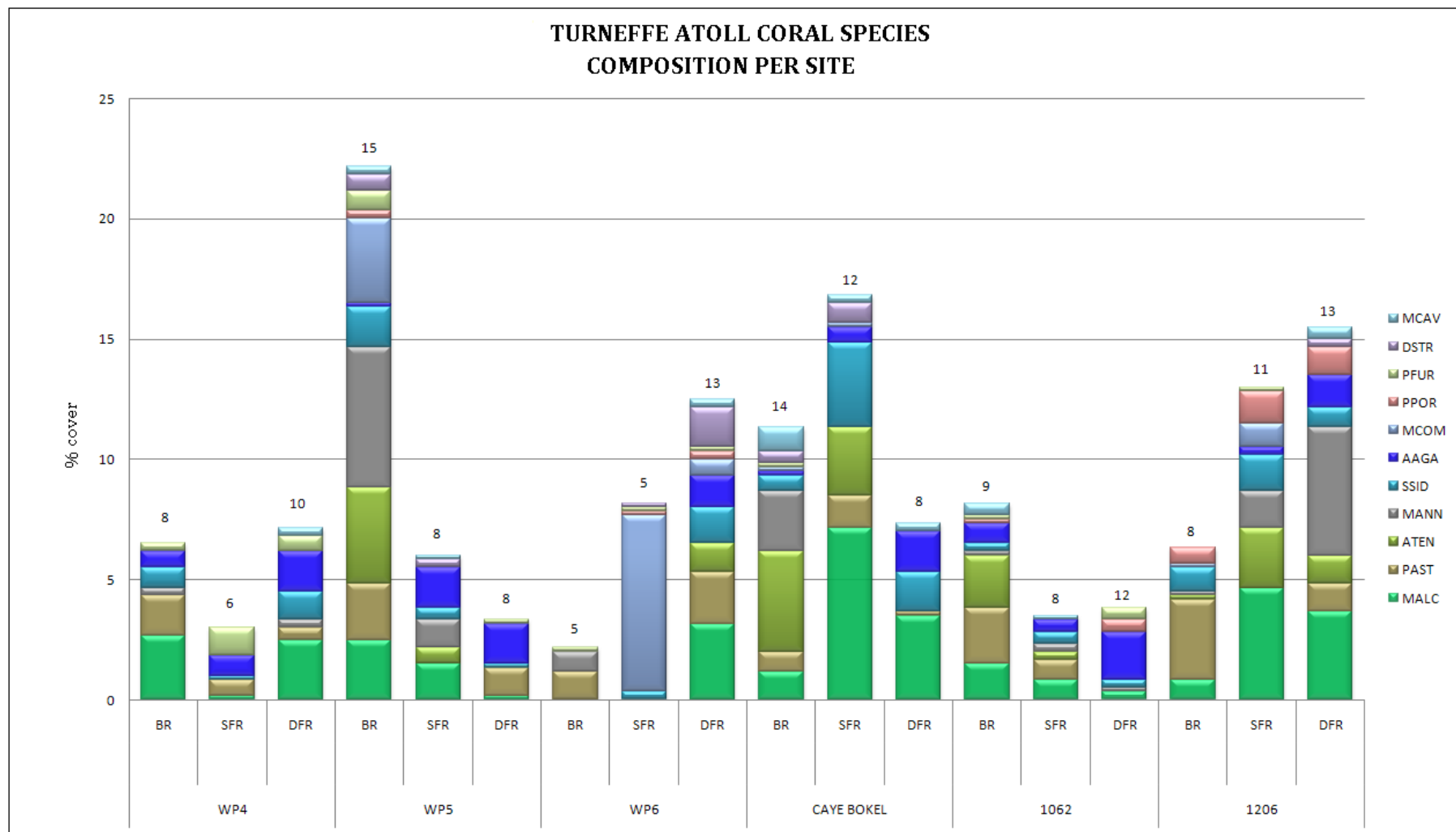


FIGURE 15: STONY CORALS SPECIES RICHNESS AND DISTRIBUTION ACROSS SITES

## REEF FISH

The biomass of commercial and herbivorous reef fish species was estimated using the biomass function obtained from Marks and Klomp (Lang 2003). Based on calculations the commercial species biomass ranged between 0 g per 100m<sup>2</sup> and 4963.8 g per 100m<sup>2</sup> and with a **mean of 1143.4 g per 100m<sup>2</sup>**. The highest biomass for commercial species was observed in the shallow fore reef habitat of site 1062 (Figure 16).

Herbivore species biomass ranged between 129.8 g per 100m<sup>2</sup> and 1955.8 g per 100m<sup>2</sup> with a **mean of 781.0 g per 100m<sup>2</sup>**. The highest herbivore biomass was observed on the deep fore reef at site 1206. Anecdotal observations have been made of a small school of about 7 Rainbow parrot fish from frequent visits at this site.

Based on the Healthy Reefs 2010 Report Card, the mean commercial fish biomass for the Belize was **609 g per 100m<sup>2</sup>** and the mean herbivorous fish biomass was **1144 g per 100m<sup>2</sup>**. When compared to these results, (Healthy Reefs 2010), Turneffe Atoll has almost twice the commercial fish biomass estimated for 2009. As per herbivorous fish biomass, Turneffe Atoll has just over half the mean value obtained in 2009.

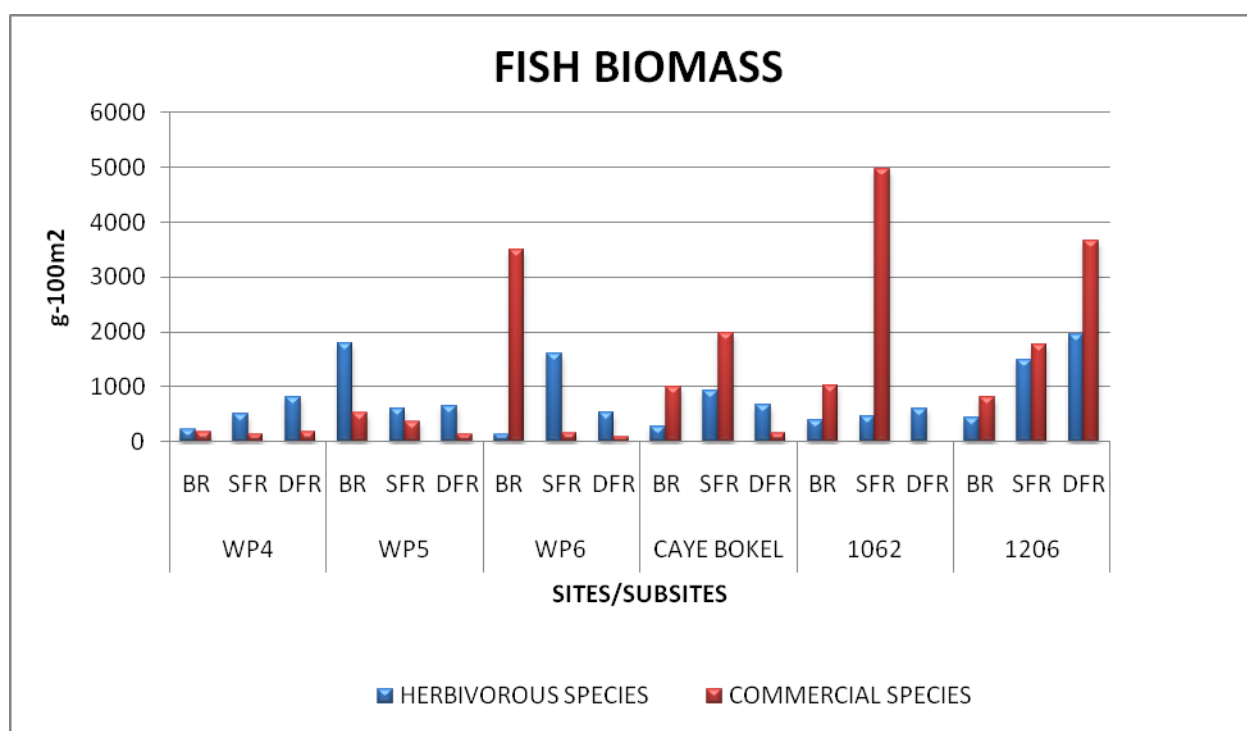


FIGURE 16: COMMERCIAL AND HERBIVOROUS REEF FISH MEAN BIOMASS g/100<sup>2</sup>

Analyses of fish biomass by habitat indicated that commercial species were more abundant in shallow fore reef habitats (mean biomass of 1560 g per 100m<sup>2</sup>) and less common in deep fore reef habitats, with a mean biomass of 700.2 g per 100m<sup>2</sup>. Herbivore species were also more common in shallow fore reef habitats, with a mean biomass of 930.7 g per 100m<sup>2</sup> and much less in back reef habitats, with a mean biomass of 541 g per 100m<sup>2</sup> (**Figure 17**).

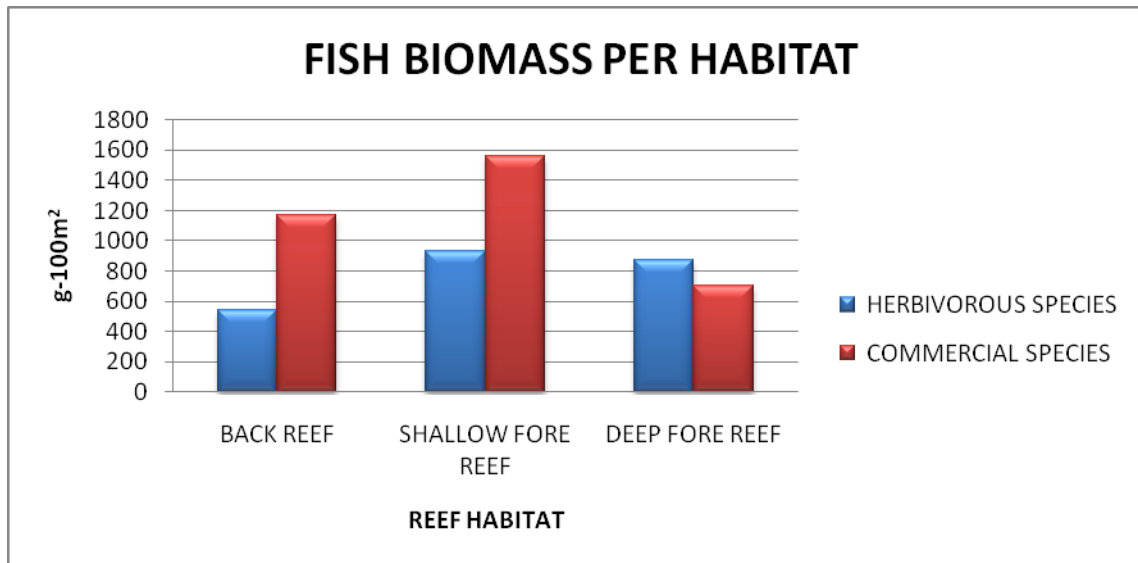


FIGURE 17: COMMERCIAL AND HERBIVOROUS REEF FISH MEAN BIOMASS PER HABITAT g/100m<sup>2</sup>

Mean fish biomass per site is presented in **Figure 18**. Site 1206 was noted to have the highest biomass of both commercial and herbivorous species with 1296 g per 100m<sup>2</sup> and 2073.5 g per 100m<sup>2</sup>, respectively.

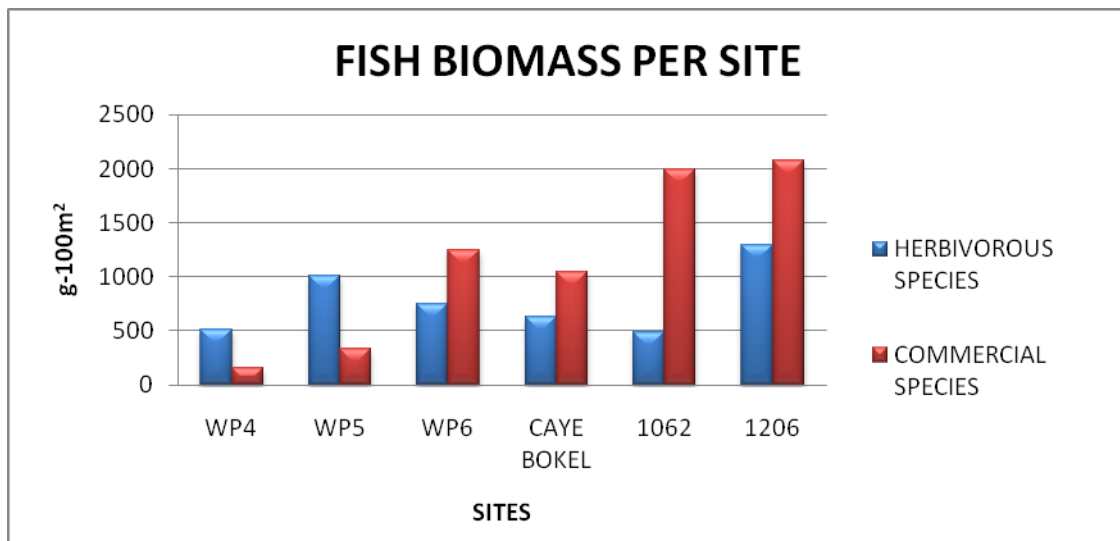


FIGURE 18: MEAN COMMERCIAL AND HERBIVORE FISH BIOMASS PER SITE g/100m<sup>2</sup>



## INTEGRATED REEF HEALTH INDEX

With six out of seven core reef health indicators, each site by habitat was assigned an Integrated Reef Health Index (IRHI). This quantitative analysis allows for comparison with other locations within the Mesoamerican Barrier Reef System and gives an overall measure of reef health. The values obtained per indicator and also as the Integrated Reef Health Index are presented in **Table 8**.

Based on the Integrated Reef Health Index results, ten (55.5%) of the eighteen sub-sites were categorized as being in **POOR** health, seven sites (39%) were categorized as **FAIR** and only one site (5.5%) was categorized as **GOOD**. The mean IRHI value for all eighteen sub-sites was 2.55, categorizing the coral reefs of Turneffe Atoll as being in overall **POOR** health. Since the Integrated Reef Health Index was used to determine the health of the sites monitored at Turneffe Atoll, the results were compared with the 2008 Report Card for the Mesoamerican Reef, (Healthy Reefs, 2008). This comparison, (despite a two years time difference) showed very similar results **Figure 19**.

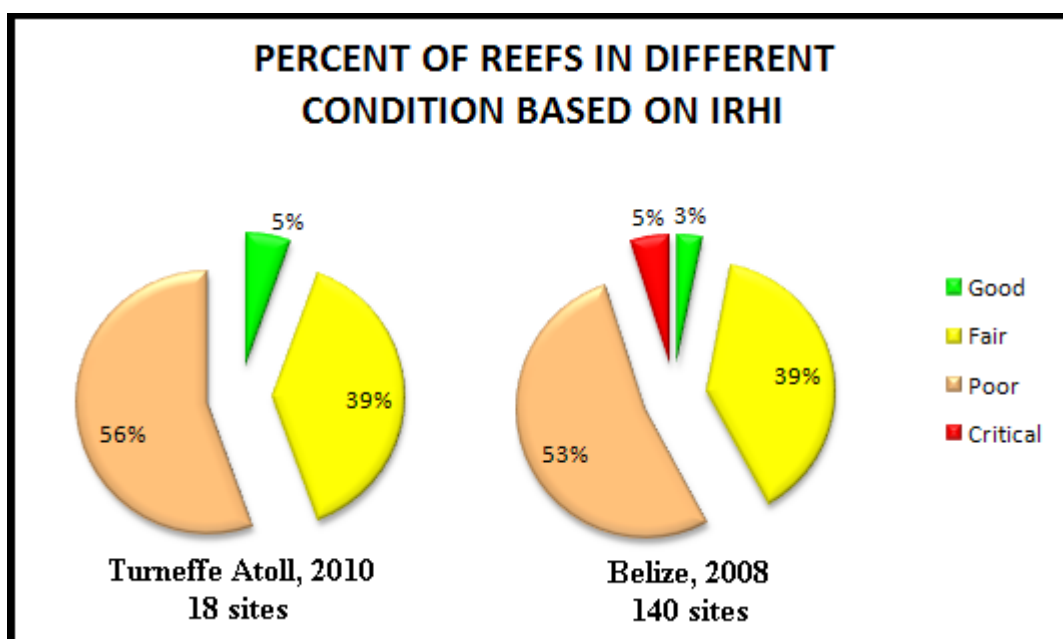


FIGURE 19: REEF HEALTH BASED ON IRHI 2008

In terms of habitat health, back reefs were categorized as being in **FAIR** health with a mean IRHI of 2.75. Shallow fore reef habitats were categorized as being in **POOR** health with mean IRHI of 2.55 IRHI. Deep fore reef habitat were categorized as being in **POOR** health with mean IRHI of 2.36, (**Figure 20**).

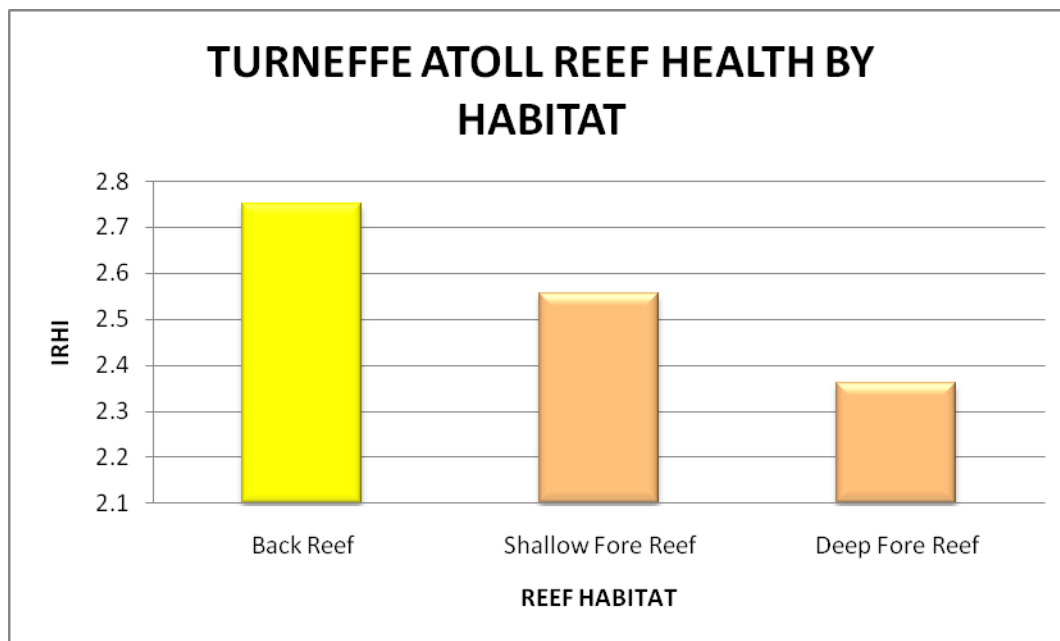


FIGURE 20: TURNEFFE ATOLL REEF HEALTH BY HABITAT

The IRHI indicator with the lowest value was *Diadema* abundance with a value of 1IRHI and categorized as **CRITICAL**. The second lowest indicator was herbivorous fish biomass with a value of 1.27 IRHI and categorized between **CRITICAL** and **POOR**. The third lowest indicator was **CORAL % COVER** with 2.1 IRHI and categorized as **POOR**. The indicators with the highest values categorized as **GOOD** were coral disease prevalence and % macroalgae cover; both obtained a value of about 4 IRHI, (**Table 8**).

By averaging the IRHI of all three different habitats per site, it was noted that three sites were in **POOR** health and three sites were in the **FAIR** health. The sites noted in **FAIR** health were located towards the southern part of the atoll, while those in **POOR** health were located in the central to the northern part of the atoll (**Figure 9**).

Table 8: Integrated Reef Health Index per habitat and per site

Sites Name	WP4			WP5			WP6			CAYE BOKEL			1062			1206			Mean IRHI
	BR	SFR	DFR	BR	SFR	DFR	BR	SFR	DFR	BR	SFR	DFR	BR	SFR	DFR	BR	SFR	DFR	
Mean coral cover	2	1	2	4	2	2	1	2	3	3	3	2	2	1	1	2	3	3	2.16
Mean macroalgae cover	5	3	3	5	5	5	3	2	2	4	5	5	5	5	5	3	3	4	4
Diadema abundance m <sup>2</sup>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Coral disease prevalence	5	5	3	5	3	3	5	5	3	5	2	5	5	5	5	5	5	5	4.3
Herbivorous fish g-100m <sup>2</sup>	1	1	1	2	1	1	1	2	1	1	1	1	1	1	1	1	2	3	1.2
Commercial fish g-100m <sup>2</sup>	1	1	1	2	1	1	5	1	1	3	5	1	3	5	1	3	5	5	2.5
IRHI value per habitat per site	2.5	2	1.83	3.2	2	2.2	3	2.16	1.83	2.83	2.83	2.5	2.83	3	2.3	2.5	3.16	3.5	2.55
Health	POOR	POOR	POOR	FAIR	POOR	POOR	FAIR	POOR	POOR	FAIR	FAIR	POOR	FAIR	FAIR	POOR	POOR	FAIR	GOOD	
IRHI			2.1			2.5			2.2			2.7			2.7			3.1	2.55
Reef Health per site			POOR			POOR			POOR			FAIR			FAIR			FAIR	POOR

## DISCUSSION

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Turneffe Atoll is widely known for its extensive mangrove cover which represents approximately 12% of the Belize's national mangrove cover (Meerman, 2005). The mangrove site located on the leeward side (West Mangrove) of the atoll presented larger DBH, taller canopy height and lower density than the site on the windward side of the atoll (Calabash Caye). These differences in measurements may indicate that conditions on the leeward side of the atoll have been more conducive to development of the mangrove forest structure as indicated by the tall mangrove canopies and large DBH measurements. A more mature forest structure (based on measurement of DBH and height) may not necessarily indicate a healthy habitat, since this may be compromised by very low densities of plants that could affect the life cycle of plants, particularly at the early stage. Low density forests usually tend to have large gaps of terrain, giving opportunistic plant species (grass) the chance to become established and out compete seedlings and saplings. On the other hand, high density habitats may be unhealthy due to short height and small DBH (MBRS, 2006). In order to track the health of mangrove habitats, long term monitoring of the forest structure and habitat is recommended. These differences between the windward and leeward side of the atoll may indicate differences in mangrove habitat type. Based on the extensive mangrove cover at Turneffe Atoll it is recommended that at least two more permanent sites be established across the atoll to be representative of the different regions. The results generated will allow for comparison across spatial and temporal scales.

The most extensive ecosystem in the Turneffe Atoll is seagrass beds. Seagrass represents approximately 67% of Turneffe Atoll (Meerman, 2005). Seagrass is crucial as the primary food source for species such as sea turtles and manatees and also as habitat for juvenile reef fish, invertebrates and commercial species such as conch and lobsters (MBRS 2006). After mangroves, seagrass serve as a secondary barrier to stabilize coastal seabottoms, absorb nutrient runoff from coastal development and stabilize sediments. In Belize five species have been documented *Thalassia testudinum*, *Syringodium filiforme*, *Halodule wrightii*, *Halophila decipiens* and *Halophila bailloni* (SeagrassNet 2004). Three of the five species of seagrass are present at Turneffe Atoll; two were documented at the established sites: *Thalassia testudinum*, *Syringodium filiforme*.

The seagrass sites were very alike in terms of biomass; this is despite the difference in location within the atoll (windward and leeward). The distribution of biomass across the different sections of the plant differs however. In the results obtained for Calabash Caye site, the biomass ratio of above ground: below ground appear to indicate that the site is not a healthy one. An above ground biomass larger than the below ground biomass suggests that the plant does not have the necessary components (roots and rhizomes) to uptake sufficient nutrients and store starch. This may be as a result of poor water quality and can affect stability during storms and asexual reproduction (MBRS 2006). It is important to note that this result is based on one monitoring session and thus further regular monitoring is recommended to support or confirm this assessment.

Coral reefs support two major industries in Belize: tourism and fisheries. Reefs also provide shoreline protection that is crucial for the development and settlement along the coast. In 2008, the World Resource Institute estimated that the economic contribution of the reef to Belize is between USD 268 and 370 million dollars (WRI 2008). Turneffe Atoll represents 15% of Belize's coral reefs, (Meerman, 2005) and like the Caribbean and Mesoamerican region, over the past decades it has experienced numerous impacts both natural and anthropogenic, such as storms, coral bleaching, ship groundings and coastal development.

In general the reefs at Turneffe Atoll were identified as being in **POOR** health. The major contributing factors were lowered abundance of herbivores (urchins and fish) and poor coral cover. Healthy Reefs 2010 reported a fleshy macroalgae cover of 17.3% for 2009. The 2010 MBRS assessment show a macroalgae cover of 16.5%. This cover of macroalgae may not yet reflect the large absence of herbivores, which was reported to be twice as abundant in 2009 with a mean biomass of 1144 g/100m<sup>2</sup> (Healthy Reefs 2010). The 2010 MBRS assessment show a mean biomass of 781 g/100m<sup>2</sup>. This impact of a decline in herbivore fish abundance may not yet be reflected and will require long term monitoring to detect changes.

The dominant benthic component was sand, with 40% cover ( **Figure 13**). The abundance of sand however is not factored into determining the reef health and therefore may often be underrepresented. A large abundance of sand may be indicative of large scale sand production through processes such as the break-down of calcareous algae, erosion, and consumption of calcareous algae by herbivorous species.

Stony coral only comprised 9.55% of the benthic community. Most of these stony corals were made up of branching and plate corals such as *Millepora* and *Agaricia*. Due to their structural formation, these corals provide critical habitat to reef fish, however this feature also limits the size of fish that can inhabit the crevices. These corals are also very prone to storm impacts which often results in fragmentation and loss of habitat. Therefore these corals may be limited in their capacity as habitat for juvenile and sub-adult fish. The major reef building or reef framework species such as *Montastraea* and *Diploria* were uncommon. These species creates more ideal and three-dimensionally complex habitats than the smaller plate or branching species. Also *Acropora* abundance is severely limited, indicating their continued endangered status.

The healthiest coral reef habitat observed across Turneffe Atoll was back reefs (**Figure 20**) with a health ranking of **FAIR**. The largest biomass of herbivorous and commercial fish species were observed in these habitats along with low percentages of macroalgae cover and in some instances good coral cover, 20%-39%. These back reef habitats were located near to channels and thus the constant exchange and circulation of water along with protection from wave action and access to reef fish may contribute to the health of the back reef habitats.

Another pattern noted was that the three sites identified in the best health condition (**FAIR**), were located on the southern part of the atoll. Three factors were noted to greatly influence this result. Macroalgae cover was much less on the southern part of the atoll. Coral diseases were almost absent at the sites monitored. And commercial fish biomass was usually between the FAIR and VERY GOOD categories. Based on this information, a difference in reef health is noted between the northern and southern parts of Turneffe Atoll. This trend has also been

highlighted by fishermen of Turneffe Atoll. This information needs to be incorporated into any further assessments or considerations for management of the Turneffe Atoll.

## CONCLUSION

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The 2010 MBRS monitoring of Turneffe Atoll marked the beginning of long-term marine ecosystems monitoring for the atoll and the establishment of baseline data. A total of 18 reef sites, two mangrove sites and two seagrass sites were monitored in 2010.

The results of the 2010 MBRS monitoring described the mangrove ecosystems to be dominated by red mangroves with mean composition of 75%. Mangrove habitat on the leeward side was more mature and developed as it had the highest mean height (8 m) and DBH (12.7cm), while mangrove habitat on the windward side was characterized by young, short mangrove plants with mean height of 3 m and mean DBH of 4.6cm.

Seagrass sites were dominated by *Thalassia testudinum* with mean biomass of 891 g/m<sup>2</sup>. Biomass estimates indicated little difference between sites; however the distribution of biomass within the plants was not representative of a healthy habitat and as such makes these sites more vulnerable to loss due to threats such as storms and coastal development.

Reefs at Turneffe Atoll were similar in condition to those in other parts of the Mesoamerican Region. Most of the reefs were in poor health, while a few sites were in fair condition. Little change was observed in reef health between 2008 and 2010. The 2008 Healthy Reefs Report Card reported Belize as having 53% of sites surveyed in poor health. The results of the 2010 MBRS monitoring report showed that 55.5% of sites assessed in the Turneffe Atoll were in poor health. The poor health of the reefs at Turneffe Atoll was attributed to very low abundance of herbivorous species (*Diadema* and reef fish) and the low coral cover (<10%).

A difference in health was noted between north and south Turneffe Atoll. The healthiest reefs were located in the southern area. This status was attributed to high abundance of commercial fish species and low presence of coral diseases.

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