Port Honduras Marine Reserve

Annual Monitoring Report

2009

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Abstract

The Port Honduras Marine Reserve (PHMR) lies off the coast of southern Belize, covering an area of 414 km^2. The 2009 monitoring program for PHMR included many aspects, from water quality, benthic habitats and coral health to population assessments of Queen Conch and Spiny Lobster. Over 16 sites throughout the reserve (in both the General Use and no-take zones) were included in the monitoring program. The results presented here demonstrate that PHMR is relatively healthy in terms of its coral reefs; however, more can be done to improve the protection provided for many key species within the reserve. A marginal decline in coral cover and an increase in macroalgal cover, combined with the associated decline in reef fish abundance during 2009 are a cause for concern and will be closely monitored throughout 2010. Conch and lobster populations have shown only minimal recovery throughout 2009, with highly variable numbers observed among sites within the general use zone and no-take zones. While some of the results collected during monitoring activities in 2009 indicate an improvement of ecosystems and populations within PHMR, it is evident that the reserve is not functioning as effectively as it could in preserving population numbers and benthic habitats. An increase in the no-take zones from 5% to 20% is recommended in order to protect and enhance the diversity and functioning of the ecosystems and populations within PHMR.

Introduction

The Port Honduras Marine Reserve (PHMR) lies off the coast of southern Belize, starting from 8km north of Punta Gorda Town; the reserve extends north to the mouth of Monkey River and 25 km eastward to encompass the Snake Cayes (Figure 1). The Marine Reserve covers an area of 414 km^2 and is composed of three zones (Figure 1). The general use zone covers 95% of the reserve and regulated extractive activities (commercial, sport, subsistence and recreational fishing) are permitted within this area. The Conservation Zone covers 4% of the reserve and no-take recreational activities (snorkelling, diving, swimming, kayaking) are allowed within this area. The Preservation Zone makes up the final 1% of the reserve where entrance is restricted to researchers only (with a permit), or those in an emergency. As such, a total of 5% of the seascape of PHMR is enclosed within a no-take area. The no-take zones were established to provide a refuge to commercially important species, such as the spiny lobster and queen conch, to help minimize human impacts on coral reefs, seagrass beds and mangroves, to enhance the value of the area for recreational and tourism activities and to provide areas that are preserved in their natural state.

PHMR is primarily estuarine in character which is the result of the seven major watersheds that flow into it; Deep River, Golden Stream, Indian Hill Lagoon, Middle River, Monkey River, Punta Ycacos Lagoon, and the Rio Grande (Heyman and Kjerfve 1999). During the rainy season, the water column becomes highly stratified, with fresh, often very turbid water at the surface, and freshwater plumes frequently extending as far as the Snake Cayes. The Marine Reserve incorporates four distinct ecosystems; coastal and tidal wetlands, marine lagoonal habitats comprised of mangroves and seagrass beds, mangrove islands with associated shallow banks, and the Snake Cayes fringing reef system (Sullivan et al. 1995). These ecosystems are home to many species, such as the Caribbean Spiny Lobster (*Panulirus argus*) and the Queen Conch (*Strombus gigas*), that have considerable commercial benefit to the buffer communities (Punta Gorda, Punta Negra, Monkey River and the Cayes) and the economy of Belize. PHMR also provides an important nursery habitat for a great diversity of marine and coastal fishes, many of commercial benefit (Heyman and Kjerfve 1999). Essentially two different finfish populations exist in PHMR, near-shore estuarine and reef-associated (Sullivan et al. 1995). Extensive surveys of these

habitats have revealed over 118 finfish species, six of which were observed only at sites around the Snake Cayes (Sullivan et al. 1995; Harborne 2000; Robinson et al. 2004). PHMR also contains 138 mangrove cayes, arranged in three, nearly shore-parallel lines and resting on shallow carbonate banks, separated by deep channels paralleling the cayes (Heyman and Kjerfve 1999). A total of 61 stony coral species have been observed in the waters of Belize, with eight unusual coral sightings on the reefs of the Snake Cayes (Fenner 1999).

The Biological Monitoring Program for the Port Honduras Marine Reserve, established in 2004, has continued to grow and expand, and it now provides an ecosystem-based approach to the management and conservation of the natural resources within PHMR. At present, the monitoring program incorporates the following activities. Water quality (temperature, salinity, dissolved oxygen, conductivity and turbidity) is measured at 17 sites across PHMR on a monthly basis. *Strombus gigas* and *Panulirus argus* populations are surveyed at 16 and 12 sites, respectively, at the start and end of the closed seasons. Benthic cover, coral health and reef fish populations are assessed twice a year at eight sites. Seagrass beds (species percent cover, density, grass height, grazing evidence) are assessed at two sites on a quarterly basis and mangrove community structure and productivity are surveyed at one site on an annual basis. Since January 2009, a fisheries stock assessment has been implemented for all finfish species, *S. gigas* and *P. Argus* populations, utilising catch landings at local markets in Punta Gorda and Monkey River and the Rio Grande Fisheries Cooperative in Punta Gorda. In addition, bleaching surveys are conducted when necessary in conjunction with the Belize Coral Reef Monitoring Network.

Moreover, as of 2008, an adaptive management approach has been adopted for PHMR and the data collected during past and current surveys are being analysed and fed back into the management of the reserve in order to assist in prioritising monitoring and research programs. The analysis of the data and incorporation of the information into management has led to a more integrated approach to the conservation of PHMR, and is greatly assisting in the revision of the Management Plan for the reserve. Furthermore, with intermittent data sets extending as far back as 1995, when (Sullivan et al.) completed their first surveys, a detailed picture of changes within the ecosystems and populations of PHMR is being constructed, with a view to assessing the efficacy of PHMR and its no-take zones.

The Biological Monitoring Program is critical to the management and conservation of the ecosystems and populations within PHMR. Regular data collection allows any changes or fluctuations from baseline trends to be identified and investigated further, if required. The following report will focus specifically on the results of the 2009 monitoring program, but references will be made to data collected in previous years.

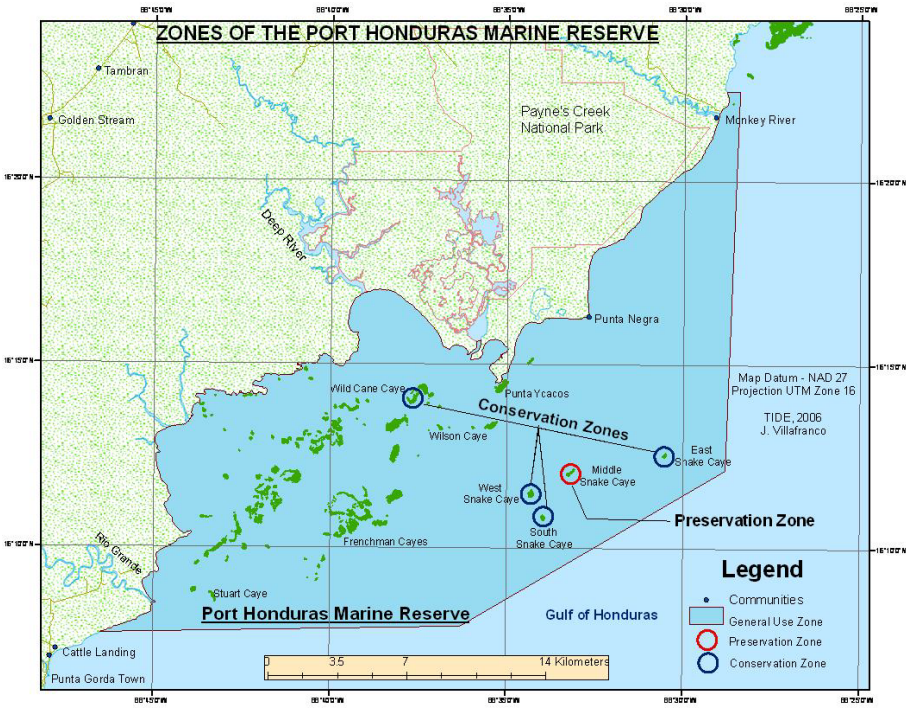

Figure 1: Area of Port Honduras Marine Reserve where all monitoring occurs. Shown are the three zones (General Use, Conservation and Preservation) of the reserve.

Methodology

Water Quality

The water quality parameters of temperature, salinity and dissolved oxygen are important components of the monitoring program. Variations in these parameters can greatly affect the health of the ecosystem and organisms within it. For example, an increase in temperature can initiate a bleaching response in hard and soft corals (Brown 1997; Fitt et al. 2001) and may affect the metabolism of many fish and invertebrates, especially during their early life history (Munday et al. 2008). Changes in salinity can affect reproduction and physiological responses in many organisms including fish and corals (Vermeij et al. 2006; Koenig et al. 2007), and the level of dissolved oxygen in the water column determines the numbers of organisms it can support (Dubinsky and Stambler 1996).

Water quality is assessed on a monthly basis at 17 sites across PHMR. Data for temperature, salinity, pH, conductivity and dissolved oxygen are collected using an YSI water quality meter. The probe is placed in the water at a depth of approximately 0.50 – 1.00 metres and left for 1 minute to adjust. The data are then recorded from the screen. Vertical visibility is estimated using a secchi disk which is lowered into the water from the side of the boat.

Conch Populations

Strombus gigas (Queen Conch) is one of the major commercial fisheries species harvested from within the general use zone of PHMR and populations have been monitored since 2004. One role of the no-take zones (conservation and preservation zones) within the reserve is to provide a refuge for species

from fishing, including queen conch. These areas enable populations to reproduce and reach maturity without the threat of being caught. Eventually population numbers within no-take zones become large enough that spill-over into the surrounding general use zone is inevitable and fisheries are supplemented.

Conch populations are surveyed at 16 sites within the Port Honduras Marine Reserve twice a year, immediately before and after the closed season from July 1 to September 30. Sites are located in both the general use zone (up to 8 sites) and no-take zones (up to 8 sites). At each site five, 50 x 2 metre transects are laid parallel to one another and at least 5 metres apart. All queen (*Strombus gigas*) and milk conch encountered on the transects are measured and data regarding species, maturity (adult or juvenile), shell length, lip width and lip thickness are recorded. The number of sites surveyed in each zone varied between monitoring periods and years, for a number of reasons. To allow comparisons to be made between the zones and years, average numbers of conch were used in the statistical analysis.

Lobster Populations

As with queen conch, *Panulirus argus* (spiny lobster) is also a major commercial fisheries species harvested from the general use zone of PHMR. To assess population numbers and determine the effectiveness of the no-take zones on spiny lobster abundance, monitoring of populations began in 2003.

Lobster (*Panulirus argus* and *Panulirus guttatus*) populations are surveyed at 12 sites within the Port Honduras Marine Reserve twice a year, immediately before and after the closed season from February 15 to June 14. Sites are located in both the general use zone (up to 7 sites) and no-take zones (up to 6 sites). At each site either, 2, 30 minute timed swims are conducted simultaneously by two diver pairs or a 60 minute timed swim is conducted by a single diver pair. For each lobster located, species, sex, maturity (tar spot, eggs) and carapace length are recorded. The number of sites surveyed in each zone varied between monitoring periods and years for a number of reasons. To allow comparisons to be made between the zones and years, average numbers of lobster were used in the statistical analysis.

Benthic Cover and Coral Health

Coral reefs are an essential component of the Port Honduras Marine Reserve and the health of coral reef habitats has a significant influence on the vertebrate and invertebrate populations that inhabit them. Most importantly, healthy coral reefs, in conjunction with seagrass and mangrove habitats, support larger populations of species compared to unhealthy reefs.

A total of 8 sites within the Port Honduras Marine Reserve are surveyed twice a year to assess benthic cover, live coral cover and coral health. To assess benthic cover and estimate live coral cover, a minimum of 5, 30 metre point intercept transects are conducted at each site. The transects are laid parallel to one another at a minimum of 5 metres apart and benthic cover is recorded every 25cm (coral and algae are recorded to species level if possible). To assess coral health, a minimum of 50 colonies (hermatypic coral species) are surveyed at each site. Each coral colony surveyed has to be >10cm in diameter and measurements of height, width, length, mortality (recent and old), disease and bleaching are recorded.

Reef Fish Abundance

Reef fish are essential components of a healthy coral reef ecosystem. Herbivorous fish maintain areas free from macroalgae to enable settlement of coral recruits, while other species maintain the balance between the trophic levels within the ecosystem.

A total of 8 sites within PHMR are surveyed twice a year to assess adult and juvenile fish abundance. At each site, fish abundance is assessed through a 30 minute rover diver swim, where all fish species encountered are recorded. In addition, eight, 30 x 2 metre transects are laid across the reef and the number and approximate size of adult fish and juvenile fish encountered on the transect are recorded.

Coral Bleaching

Bleaching surveys are carried out as and when required in coordination with the Belize Coral Reef Monitoring Network to assess levels of bleaching, recovery and mortality throughout Belize. At each of the sites, 200 colonies are assessed for 3 levels of bleaching (pale, partial bleaching and whole bleaching (>90% of the colony is bleached)), mortality and disease, using the weighted bar swimming technique. A diver swims parallel to the reef crest and every 3 kick cycles places a 1 metre t-bar (divided into 5 equal sections) on to the reef. Each coral species that falls within one of the five sections is surveyed. A maximum of five corals are surveyed at each stop.

Fisheries Stock Assessment

A fisheries stock assessment for the Port Honduras Marine Reserve commenced in January 2009. Data are being collected for conch (*Strombus gigas*), lobster (*Panulirus argus*), and all finfish species at Monkey River and Punta Gorda markets and Punta Gorda Cooperative one day a week, and on boats within the reserve four consecutive days every month. Measurements for each of these species include, number of fishers, area fished, equipment used, hours fished, weight of each species caught. For finfish, fork length and tail length are also recorded where possible. For Lobster, carapace length, tail length, segment width, sex and reproductive stage are also recorded where possible. For conch, shell length, lip width, lip thickness and maturity are recorded where possible.

Seagrass

Seagrass is monitored at two sites on a quarterly basis in conjunction with SeagrassNet. At each site, three permanent transects are surveyed and measurements of seagrass species, percent cover, density, canopy height and grazing are recorded in 12 random quadrats placed along each transect. Seagrass specimens and sediment samples are collected from each transect. Temperature and light loggers are deployed at the shallowest and deepest transects, continuously recording data in between sampling periods.

Mangroves

An annual assessment of mangrove health is undertaken at East Snake Caye during July. Community composition (species, tree height and diameter) is recorded for 3 plots within the mangrove. In addition, productivity of each plot is estimated by collecting leaf litter over a one month period.

Results

Water Quality

Table 1: Monthly sea water temperature (^{o}C) at sites within Port Honduras Marine Reserve (PHMR) during 2009. Also shown are average values across PHMR for each month during 2009 and 2008. N/D denotes no data available.

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Joe Taylor Creek Mouth	27.2	26.7	28.3	32.2	35.2	28.9	31.4	27.1	32.5	28.6	30.3	27.4
Rio Grande	26.2	26.3	28.5	28.5	30.4	30.3	29.1	31.0	30.9	29.7	29.0	27.4
Moho/Stuart	26.2	26.4	28.5	28.6	30.4	30.3	29.0	29.2	30.8	29.8	28.7	27.2
Hen & Chicken	26.4	26.3	29.5	29.0	31.5	30.6	28.6	31.3	31.3	29.6	28.7	26.8
Golden Stream	26.8	28.0	29.7	30.1	32.2	31.3	29.1	32.5	31.6	30.2	29.5	27.8
Deep River	26.0	26.5	28.8	28.8	31.2	30.7	29.4	30.3	31.1	30.1	28.5	27.3
Man O War	25.8	26.2	28.5	29.0	30.7	30.4	29.2	30.0	30.3	29.8	28.6	27.2
Wilson Caye	26.0	25.9	28.1	29.0	30.8	30.5	30.2	30.1	30.8	30.2	28.3	27.2
S of West Snake Caye	25.9	25.9	27.8	28.9	30.2	30.1	29.3	29.8	30.4	29.7	28.5	27.6
East Snake Caye	25.8	26.0	27.9	28.8	29.7	30.5	29.1	29.9	31.2	29.7	28.5	27.8
N of Middle Snake Caye	25.7	26.0	27.7	28.7	29.4	30.6	28.1	30.1	30.1	29.8	28.3	27.6
S of Punta Negra	25.6	26.0	28.4	29.2	29.9	30.7	29.5	30.3	31.3	30.1	28.6	27.9
Astera Site (Punta Negra)	26.1	26.8	29.6	30.9	30.4	30.5	28.8	31.5	31.5	30.1	28.9	26.9
Monkey River Mouth	26.3	25.9	29.5	31.3	31.4	30.2	30.1	30.4	29.0	30.5	28.3	20.2
N of Monkey River	26.0	25.8	30.6	29.5	30.5	30.1	31.6	30.4	32.0	29.9	28.6	26.8
Punta Y Cacos	26.0	26.3	29.2	29.7	30.2	30.9	29.7	30.9	31.7	29.8	28.7	27.2
Inside Monkey River	25.4	24.9	30.6	30.4	31.3	28.4	27.2	27.0	28.5	28.1	26.2	24.0
Average – 2009	26.1	26.2	28.9	29.6	30.9	30.3	29.4	30.1	30.9	29.8	28.6	26.7
Average – 2008	N/D	N/D	27.2	29.3	30.3	28.8	29.3	31.1	30.2	27.3	26.1	26.9

Water temperature fluctuated among sites in PHMR on a monthly basis, and between months (Table 1, Figure 2). Despite the variations among sites, a clear pattern can be seen in water temperature over the year with October to February being the coldest period and May to September the warmest period. In comparison to 2008, water temperature was, on average, higher for the majority of the year. Despite a widespread bleaching alert for the Caribbean, including Belize, minimal coral bleaching was observed in PHMR (see below).

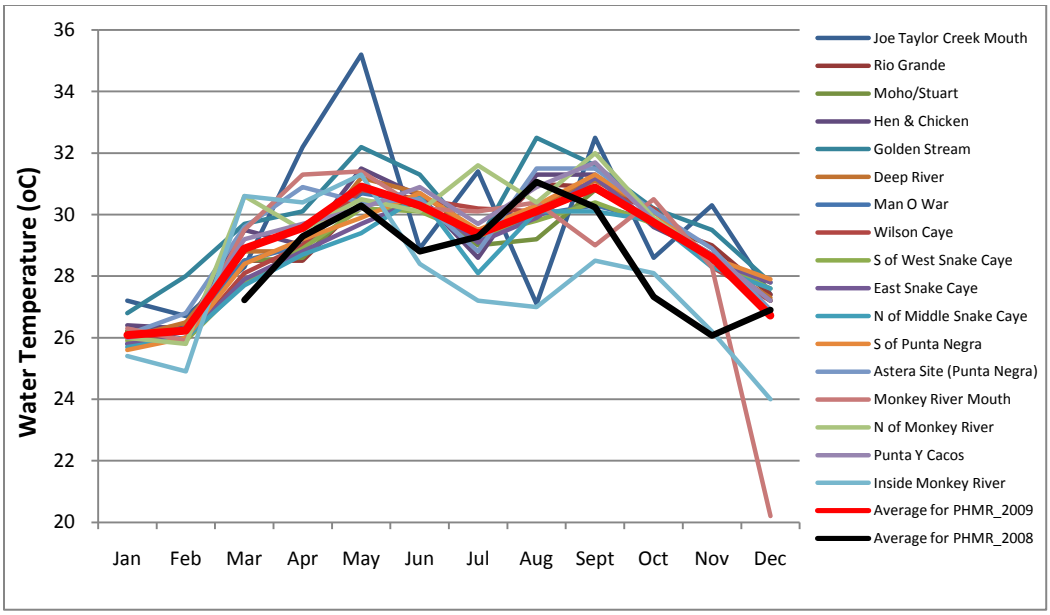

Figure 2: Water temperature at sites across PHMR during 2009. Also shown is the average water temperature each month in PHMR for 2008 and 2009.

Table 1: Monthly salinity (ppt) at sites within Port Honduras Marine Reserve (PHMR) during 2009. Also shown are average values across PHMR for each month during 2009 and 2008. N/D denotes no data available.

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Joe Taylor Creek Mouth	32.9	32.7	30.8	34.1	30.8	22.5	22.6	22.6	17.0	27.2	20.0	20.0
Rio Grande	32.8	33.6	33.2	33.2	32.4	30.7	24.3	28.9	33.0	30.0	34.0	30.0
Moho/Stuart	33.1	30.0	33.6	34.2	31.5	30.4	27.3	29.3	33.0	35.0	35.0	35.0
Hen & Chicken	32.7	33.1	33.8	34.1	33.3	32.2	26.8	21.4	25.0	35.0	34.0	32.0
Golden Stream	32.8	32.5	33.8	34.4	33.0	27.1	23.5	20.2	20.0	34.0	20.0	25.0
Deep River	32.8	32.0	34.0	35.2	33.2	28.7	29.6	26.4	29.0	32.0	35.0	35.0
Man O War	32.9	33.7	34.7	35.2	34.2	32.6	27.3	28.6	30.0	33.0	35.0	35.0
Wilson Caye	33.2	32.6	34.7	35.2	33.2	32.8	29.2	30.8	30.0	33.0	34.0	36.0
S of West Snake Caye	33.2	33.6	34.5	34.8	34.0	31.1	30.0	29.2	31.0	35.0	35.0	35.0
East Snake Caye	33.5	33.8	34.0	35.4	35.1	31.0	30.2	29.4	31.0	35.0	35.0	35.0
N of Middle Snake Caye	33.6	33.8	34.4	35.4	35.5	31.3	29.3	28.2	30.0	32.0	35.0	35.0
S of Punta Negra	33.5	33.8	34.7	35.6	35.2	34.2	29.0	28.0	30.0	29.0	35.0	32.0
Astera Site (Punta Negra)	33.6	33.7	35.0	35.6	35.0	29.6	29.6	29.1	30.0	30.0	33.0	36.0
Monkey River Mouth	31.4	26.0	35.1	33.2	30.7	28.4	29.7	28.4	0.0	29.0	28.0	5.0
N of Monkey River	33.4	33.4	2.6	35.7	36.3	31.7	27.0	27.9	20.0	34.0	34.0	15.0
Punta Y Cacos	33.2	33.8	35.1	35.8	34.6	31.2	28.6	28.0	20.0	34.0	35.0	36.0
Inside Monkey River	0.1	1.1	2.6	4.2	1.3	0.1	0.1	0.1	0.0	5.0	0.0	0.0
Average -2009	31.1	30.8	30.4	33.0	31.7	28.6	26.1	25.7	24.1	30.7	30.4	28.1
Average - 2008	N/D	N/D	36.0	N/D	35.7	26.4	24.5	32.0	30.3	29.8	31.1	31.2

Salinity showed some variation among sites, in particular between those sites close to a river outflow and those sites at the cayes, furthest from the sources of freshwater (Table2, Figure 3). An obvious pattern in salinity is evident over the year with June to October having the lowest salinity values, coinciding with the rainy season. Salinity was lower during the majority of 2009 compared with 2008.

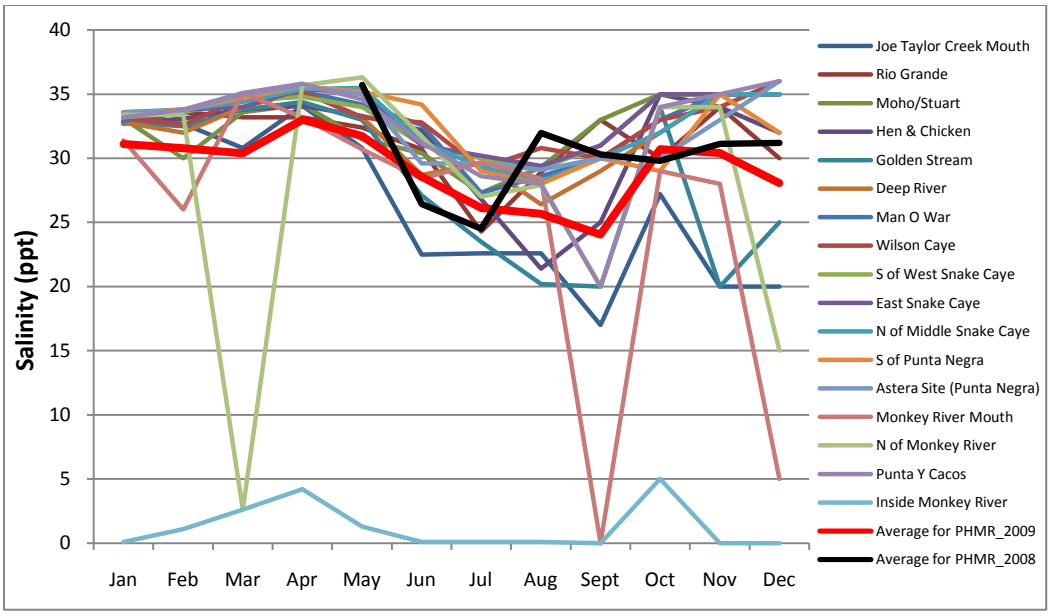

Figure 3: Salinity at sites across PHMR during 2009. Also shown is the average salinity each month in PHMR for 2008 and 2009.

Dissolved oxygen concentrations showed slight variations among sites throughout 2009 and large differences among months (Table 3, Figure 4). January to April saw a large increase in dissolved oxygen concentrations at all sites across PHMR and from May to December concentrations have remained fairly stable at approximately 6mg per litre. Dissolved oxygen concentrations were noticeably higher, and more stable, throughout 2009 compared to 2008, indicating a healthier, more stable, environment in PHMR.

Port Honduras Marine Reserve is a notoriously turbid environment and during 2009 turbidity (measured as vertical visibility) was highly variable among sites and among months (Table 4, Figure 5). The lowest visibility (highest turbidity) at all sites was observed during June and July at the onset of the rainy season, when sediment laden freshwater outflow into the reserve was likely to be highest. March and November were both periods of high visibility at the majority of sites, which may be linked to lower rainfall and/ or less wind during these periods.

Table 3: Monthly dissolved oxygen concentrations (mg/l) at sites within Port Honduras Marine Reserve (PHMR) during 2009. Also shown are average values across PHMR for each month during 2009 and 2008. N/D denotes no data available.

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Joe Taylor Creek Mouth	2.9	3.9	5.5	9.7	3.3	7.7	8.0	7.1	7.4	7.4	7.4	6.4
Rio Grande	2.8	4.2	4.3	9.1	7.2	7.3	7.3	7.8	7.2	6.3	6.6	7.6
Moho/Stuart	2.8	4.1	4.0	9.1	7.5	7.2	7.3	6.4	7.1	6.6	7.1	7.1
Hen & Chicken	2.9	4.1	3.8	8.9	7.3	6.6	7.6	7.1	7.1	6.7	7.1	7.2
Golden Stream	2.6	3.9	3.5	8.3	7.1	8.0	6.9	8.4	8.2	5.7	8.5	6.4
Deep River	3.0	4.1	6.6	8.7	7.0	7.5	7.2	6.5	7.5	5.7	6.0	6.9
Man O War	3.0	3.9	6.7	8.7	7.6	7.5	7.1	6.9	7.0	6.3	6.3	7.4
Wilson Caye	3.1	4.0	6.9	8.5	7.6	7.3	7.2	7.2	6.7	5.8	6.8	7.2
S of West Snake Caye	3.2	4.0	6.8	8.5	7.7	7.2	6.3	6.9	6.9	7.6	7.4	7.6
East Snake Caye	3.1	4.1	6.9	8.5	7.8	7.4	7.0	7.3	7.2	7.2	6.9	6.9
N of Middle Snake Caye	3.1	4.0	6.8	8.7	7.6	7.5	7.4	7.2	7.0	7.5	7.1	7.6
S of Punta Negra	3.2	4.0	4.1	8.7	7.6	7.4	7.4	7.1	6.9	6.8	6.8	7.1
Astera Site (Punta Negra)	3.0	3.8	4.0	10.3	8.0	6.9	6.4	7.2	7.1	6.3	6.7	7.2
Monkey River Mouth	3.0	3.8	3.5	8.6	7.1	6.9	11.1	7.7	6.4	7.5	7.1	7.5
N of Monkey River	3.0	3.5	3.5	9.1	7.4	7.0	7.2	6.2	6.9	6.8	6.3	7.0
Punta Y Cacos	3.2	3.9	3.6	9.3	7.2	7.4	7.0	6.9	7.9	5.9	6.6	7.2
Inside Monkey River	2.9	3.6	3.5	7.6	6.1	6.6	6.1	6.6	5.8	6.3	6.6	6.7
Average -2009	3.0	3.9	4.9	8.8	7.1	7.3	7.3	7.1	7.1	6.6	6.9	7.1
Average - 2008	N/D	N/D	5.9	4.9	5.0	5.3	4.8	5.7	3.5	3.2	2.1	2.3

Table 4: Monthly vertical visibility (cm) at sites within Port Honduras Marine Reserve (PHMR) during 2009. Also shown are average values across PHMR for each month during 2009 and 2008. N/D denotes no data available.

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Joe Taylor Creek Mouth	40	50	75	100	80	60	30	80	300	100	390	175
Rio Grande	260	600	1100	1200	400	470	80	750	800	400	650	780
Moho/Stuart	130	500	550	400	400	450	230	820	800	400	500	550
Hen & Chicken	170	250	150	300	200	190	180	350	250	250	210	250
Golden Stream	80	50	100	150	160	85	75	100	200	150	200	100
Deep River	120	250	200	200	200	550	130	450	600	200	150	150
Man O War	240	300	700	450	500	560	150	550	500	300	400	250
Wilson Caye	500	550	1100	900	600	650	190	700	600	350	1000	350
S of West Snake Caye	510	700	800	1000	800	730	350	1400	600	650	1200	1150
East Snake Caye	600	900	1500	1200	1500	750	480	1550	900	750	1200	1355
N of Middle Snake Caye	590	600	1350	1000	1200	680	255	1300	850	700	1250	1200
S of Punta Negra	400	400	1050	700	600	580	220	750	780	550	1225	1125
Astera Site (Punta Negra)	180	50	150	150	160	120	200	150	350	200	100	150
Monkey River Mouth	200	100	700	100	80	60	50	50	120	100	100	50
N of Monkey River	400	130	150	300	210	170	200	75	100	350	300	75
Punta Y Cacos	300	200	400	300	520	330	220	550	220	300	500	200
Inside Monkey River	100	150	150	150	30	50	50	20	20	100	120	20
Average – 2009	284	340	601	506	449	381	182	567	470	344	559	466
Average – 2008	N/D	N/D	N/D	N/D	N/D	N/D	225	N/D	552	430	449	387

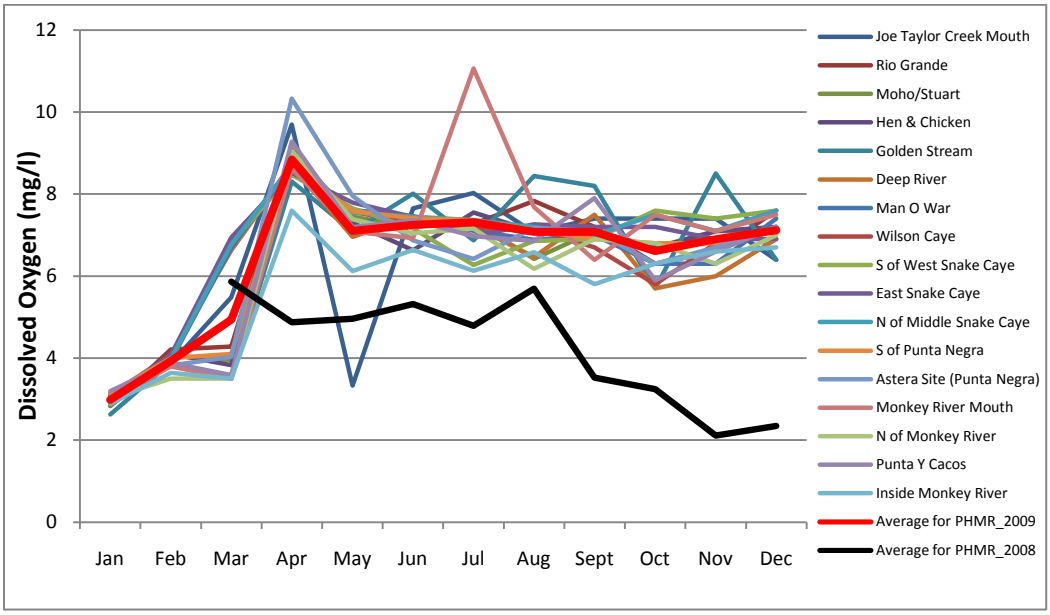

Figure 4: Dissolved oxygen concentrations at sites across PHMR during 2009. Also shown is the average dissolved oxygen each month in PHMR for 2008 and 2009.

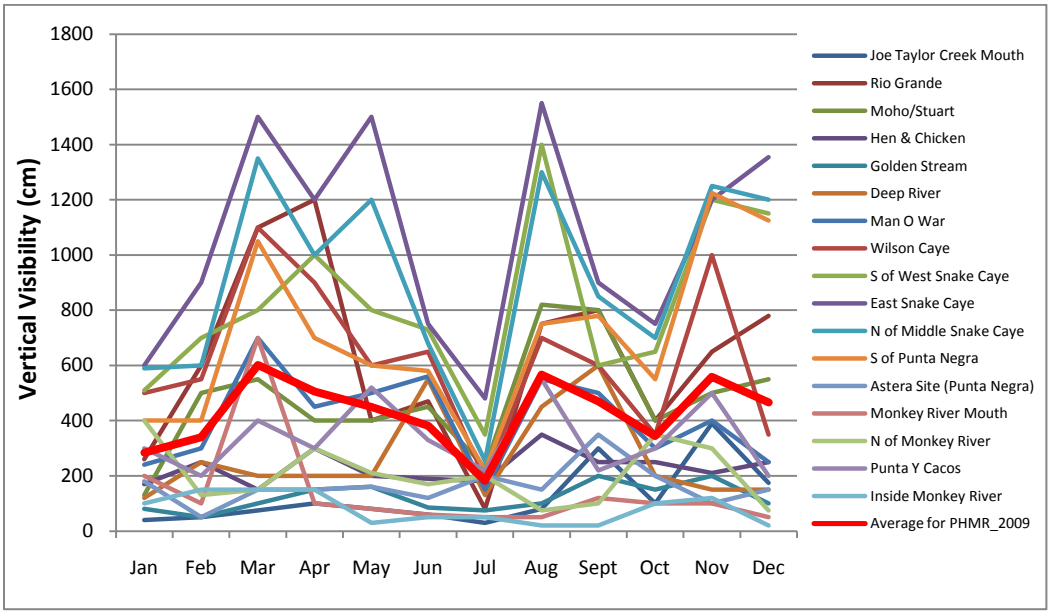

Figure 5: Vertical Visibility at sites across PHMR during 2009. Also shown is the average vertical visibility each month in PHMR for 2009.

Conch Populations

The average number of conch observed in PHMR gradually increased between 2004 and 2008, but showed a decline between 2008 and 2009 (Table 5, Figure 6). Initially, no difference was observed in the numbers of conch between the general use zone and no-take zones; however, since 2008 numbers of conch in the no-take zones have been higher. The results do not show any significant increases in the numbers of conch over the years, or any significant differences in the numbers of conch between the zones. However, there are positive signs that the no-take zones may be having an effect and any increase in the area of this zone during 2010 would further benefit the conch population in PHMR.

Table 5: Average number of conch per hectare within Port Honduras Marine Reserve (PHMR) from 2004 to 2009. Data are shown for NTZ and GUZ combined and NTZ and GUZ separately. NTZ denotes no-take zones, GUZ denotes general use zones, SE denotes standard error of the mean.

Year	Average Number Ha^{-1} NTZ & GUZ Combined	SE	Average Number Ha^{-1} in NTZ	SE	Average Number Ha^{-1} in GUZ	SE
2004	41.6	7.1	50.6	13.4	33.9	5.9
2005	24.4	6.6	13.3	3.9	30.0	9.1
2006	64.3	22.0	20.0	17.9	86.5	29.3
2008	95.7	20.1	132.8	36.8	37.7	10.2
2009	58.7	7.4	85.0	11.4	22.9	6.0

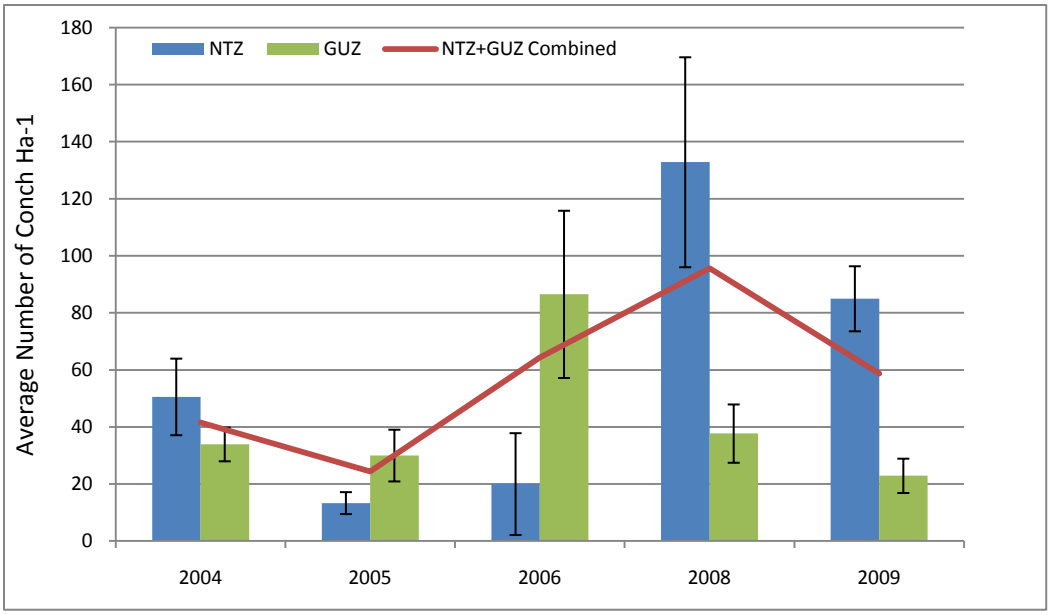

Figure 6: Average numbers of conch (± 1 SE) across sites surveyed in PHMR between 2004 and 2009. Numbers in the General Use Zones (GUZ) and No Take Zones (NTZ) are shown separately. The red line indicates the average number of conch across all sites.

Lobster Populations

The average number of lobsters observed in PHMR gradually increased between 2003 and 2009, with a slight decline between 2006 and 2008 (Table 6, Figure 7). The numbers of lobsters observed in the no-take zones is marginally higher than observed in the general use zones, but this difference is not statistically significant. In addition, the results do not show any significant increases in the number of lobsters in PHMR since 2003 indicating that the no-take zones are having minimal effect on the lobster population. An increase in the area of no-take zones in PHMR during 2010 would benefit the lobster population by allowing more individuals to reach maturity and reproduce before being fished.

Table 6: Average number of lobster per hour within Port Honduras Marine Reserve (PHMR) from 2003 to 2009. Data are shown for NTZ and GUZ combined and NTZ and GUZ separately. NTZ denotes no-take zones, GUZ denotes general use zones, SE denotes standard error of the mean, N/D denotes no data available.

Year	Average Number Hr^{-1} NTZ & GUZ Combined	SE	Average Number Hr^{-1} in NTZ	SE	Average Number Hr^{-1} in GUZ	SE
2003	7.5	1.0	7.5	1.0	N/D	N/D
2004	6.0	2.4	6.0	2.4	N/D	N/D
2005	11.2	2.9	14.1	5.0	9.5	3.7
2006	8.8	1.6	8.9	2.3	8.6	2.2
2008	8.4	1.4	5.7	1.5	10.0	2.1
2009	13.5	2.3	15.0	5.7	13.0	2.3

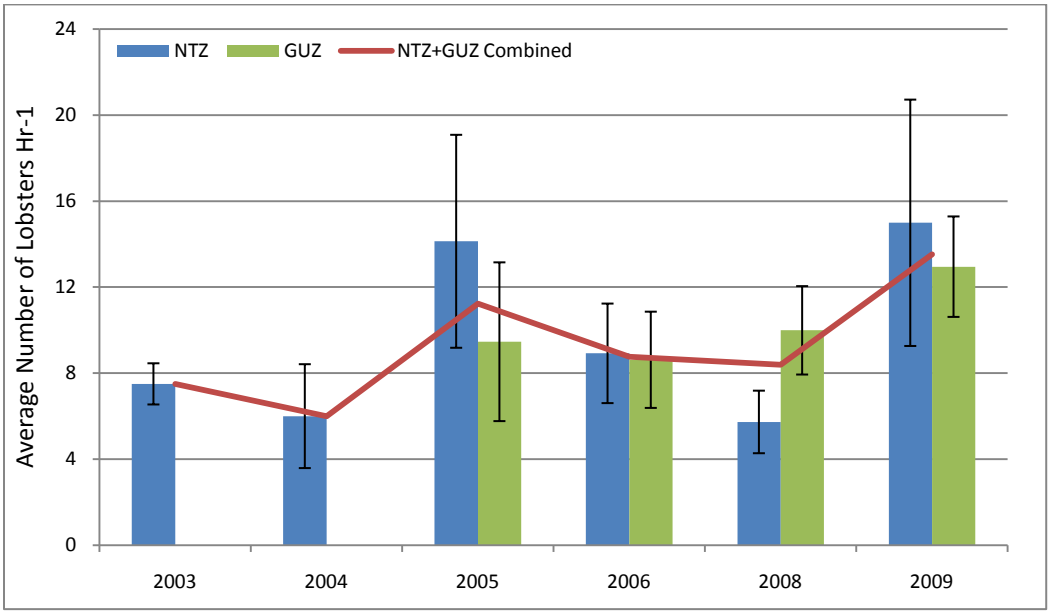

Figure 7: Average numbers of lobster (± 1 SE) across sites surveyed in PHMR between 2003 and 2009. Numbers in the General Use Zones (GUZ) and No Take Zones (NTZ) are shown separately. The red line indicates the average number of lobster across all sites.

Benthic Cover

The average percent cover of live coral across sites in PHMR has increased between 2003 and 2009 indicating an increase in the health of the coral reefs (Table 7, Figure 8). The average cover of coral was less than 7% in 2003 and increased to over 14% in 2009, indicating that the presence of the marine reserve and the no-take zones has had a positive effect on the benthic cover within PHMR. An increase in coral cover will have a positive effect on the other organisms within PHMR, providing a 3-dimensional structure for other fish and invertebrates to inhabit.

Table 7: Average percent cover of live coral and macroalgae, and reef fish density (numbers per 100m^2) within Port Honduras Marine Reserve (PHMR) from 2003 to 2009.

Indicator	2003	2004	2005	2006	2008	2009
Live Coral (%)	7.7	6.7	9.1	10.6	16.5	14.7
Macroalgae (%)	21.6	16.6	12.7	23.3	12.6	19.2
Reef Fish (numbers/100m^2)	73.3	28.5	30.0	43.7	40.7	37.9

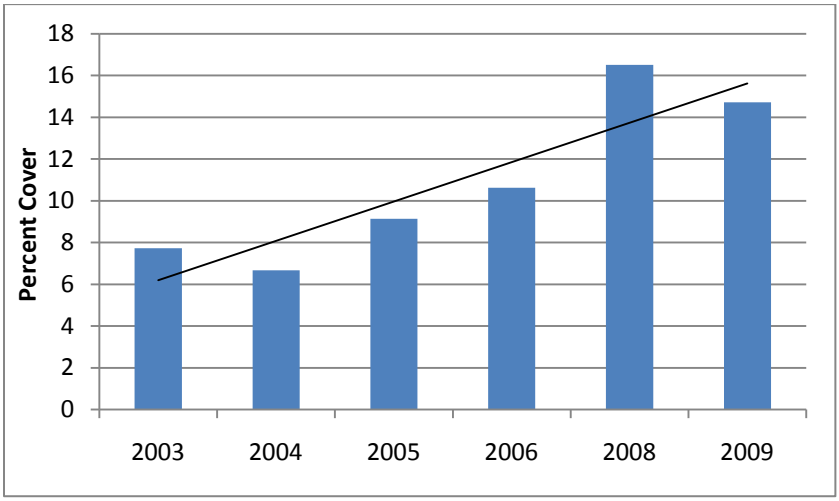

Figure 8: Average percent cover of live coral across sites in PHMR between 2003 and 2009. The black line indicates the linear change in coral cover between years.

The cover of macroalgae at sites within PHMR fluctuated between 2003 and 2009 but has not shown any significant increase or decrease (Table 7, Figure 9). A decline in macroalgal cover was observed between 2003 and 2005; however this was not maintained beyond 2006. A region-wide mass coral bleaching event during 2005 may have increased coral mortality and allowed macroalgal cover to increase in subsequent years. Given the decline in reef fish density in PHMR since 2003 (see below), macroalgal cover is unlikely to decline significantly until reef fish density increases. Low macroalgal cover is essential to allow space for settlement of coral recruits to the reef.

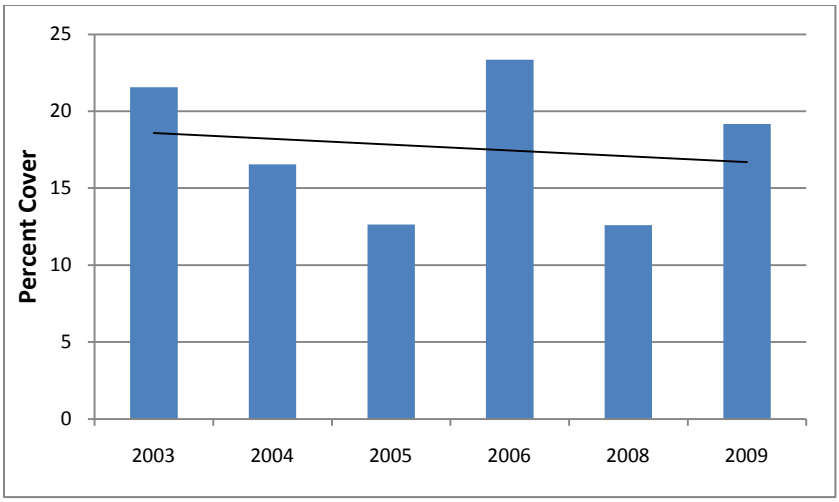

Figure 9: Average percent cover of macroalgae across sites in PHMR between 2003 and 2009. The black line indicates the linear change in macroalgal cover between years.

Reef Fish Abundance

Reef fish density has declined at all sites in PHMR between 2003 and 2009 (Table 7, Figure 10). The largest decline was observed between 2003 and 2004 but reef fish density has shown little recovery since then. Increased fishing pressure within PHMR may have caused the decline in reef fish abundance as these reef species have become more popular as the populations of traditional commercial species (e.g., snapper and grouper) have declined. The recent legislation banning fishing of herbivorous fish species will help to alleviate some of the pressure and an increase in the No Take Areas within PHMR would also assist reef fish population recovery.

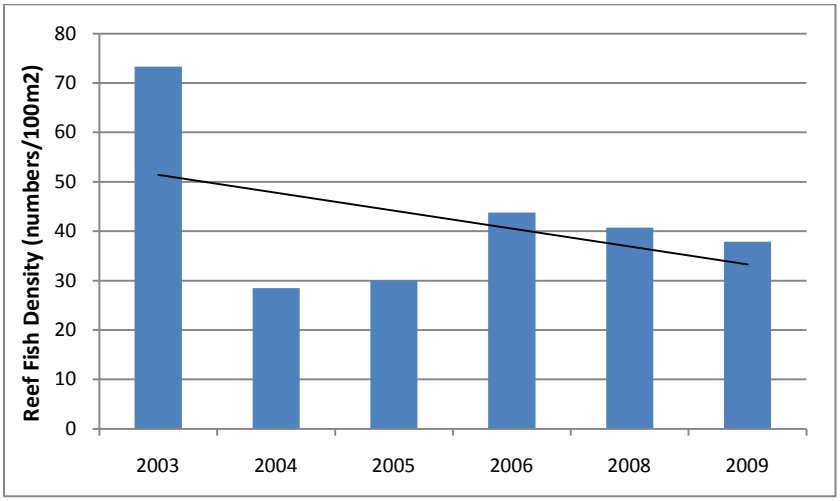

Figure 10: Average reef fish density across sites in PHMR between 2003 and 2009. The black line indicates the linear change in reef fish density between years.

Coral Bleaching

Coral bleaching was observed at sites within PHMR during October 2009 while conducting national bleaching monitoring surveys coordinated by the Belize Coral Reef Monitoring Network. Colonies affected by bleaching were observed at all six sites surveyed during October 2009 (Table 8, Figure 11). The two most severely affected sites were East Snake Caye 2 and Middle Snake Caye (Figure 11), two of the shallowest sites surveyed. The site at Frenchman Caye was least affected by bleaching, with less than 10% of colonies exhibiting signs of bleaching. The percent of colonies affected by bleaching (pale, partial and whole) was notably less than that observed during the surveys 12 months previously in October 2008, 18% versus 48%, respectively (Table 9, Figure 12). The lower number of colonies affected by bleaching in the October 2009 surveys suggests that bleaching was not as severe as 2008 within PHMR, which was surprising given the higher water temperatures in 2009 compared to 2008 (Figure 2).

Table 8: Percent of colonies affected by bleaching at six sites within PHMR in October 2009. Three levels of bleaching are shown. N denotes number of colonies surveyed.

Bleaching Level	East Snake Caye 1	East Snake Caye 2	West Snake Caye	South Snake Caye	Middle Snake Caye	Frenchman Caye
N	200	200	200	200	200	200
Pale (%)	11.5	21.0	13.5	12.0	15.5	6.5
Part Bleached (%)	5.5	7.0	3.5	3.0	3.5	2.5
Whole Bleached (%)	0	0.5	0	0.5	0.5	0

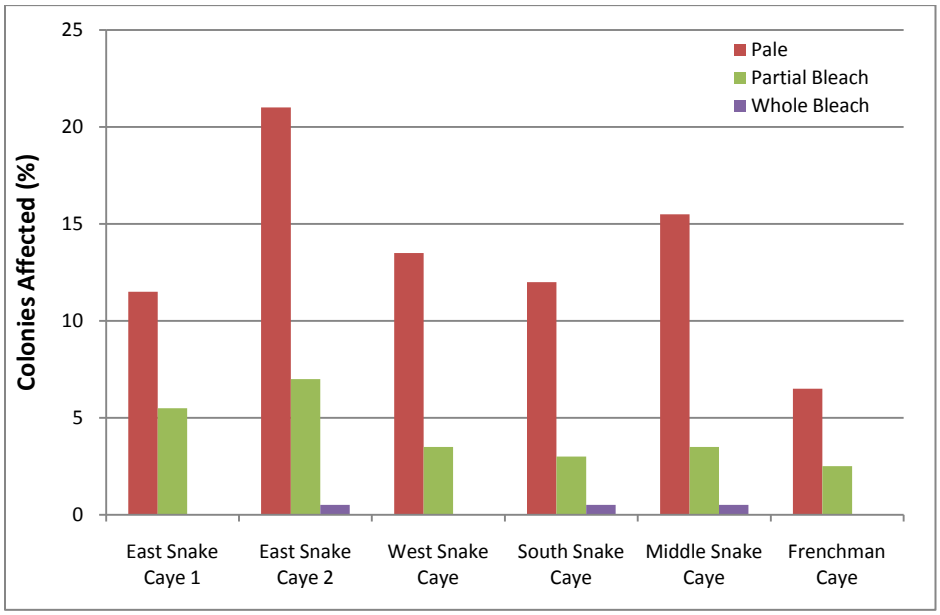

Figure 11: Percent of colonies affected by bleaching at sites within PHMR in October 2009.

Table 9: Total percent of colonies affected by bleaching at six sites within PHMR in October and November 2008 and February, October and December 2009. N denotes number of colonies surveyed.

	East Snake Caye 1		East Snake Caye 2		West Snake Caye		South Snake Caye		Middle Snake Caye		Frenchman Caye	
Date	%	N	%	N	%	N	%	N	%	N	%	N
October 2008	45.5	99	59	100	59	100	36.7	98	41.8	98	48.0	98
November 2008	19.0	200	17.2	198	9.5	200	21.8	202	27.5	200	20.9	201
February 2009	6.0	200	9.5	200	10.0	200	5.5	200	9.5	200	5.0	200
October 2009	34.0	200	57.0	200	34.0	200	31.0	200	39.0	200	18.0	200
December 2009	16.0	200	15.5	200	9.0	200	5.5	200	8.0	200	12.9	147

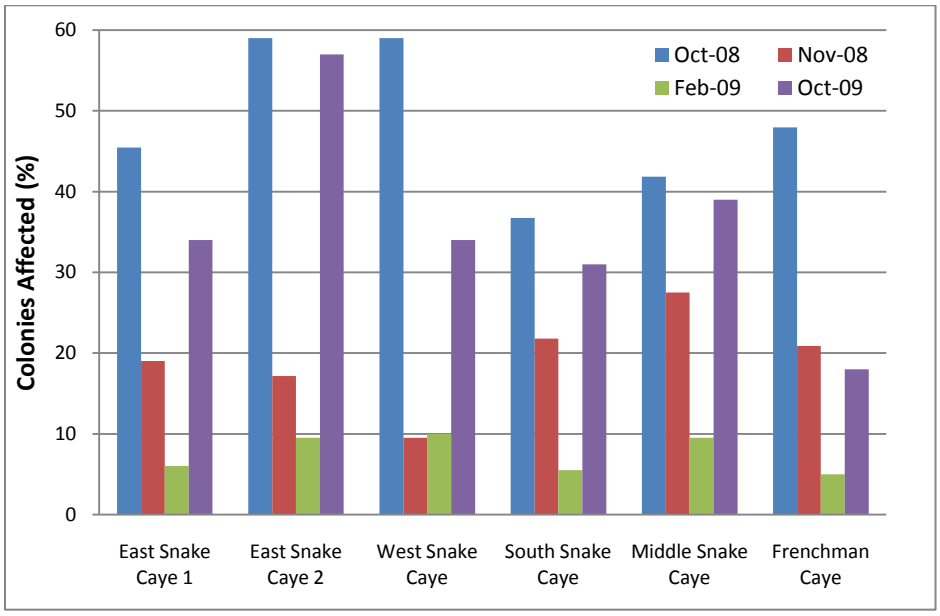

Figure 12: Percent of colonies affected by bleaching at sites within PHMR in October and November 2008 and February and October 2009.

An additional survey was conducted in mid-December 2009 that identified a reduction in the severity of bleaching and the number of colonies affected compared to the October 2009 survey (Table 9, Figure 13). In December, the most severely affected sites were East Snake Caye 1 and East Snake Caye 2 with approximately 16% of colonies affected by bleaching and the least affected site was South Snake Caye, with less than 6% of colonies exhibiting signs of bleaching. The percent of colonies affected by bleaching (pale, partial and whole) was less than that observed during the October surveys, 11% versus 18%, respectively, indicating that the reefs are recovering from this bleaching event. Despite East Snake Caye 2 showing the highest level of bleaching during the December surveys, it was also the site showing the most recovery with a decline from 57% of colonies affected in October to 15.5% of colonies affected in December (Table 9, Figure 13).

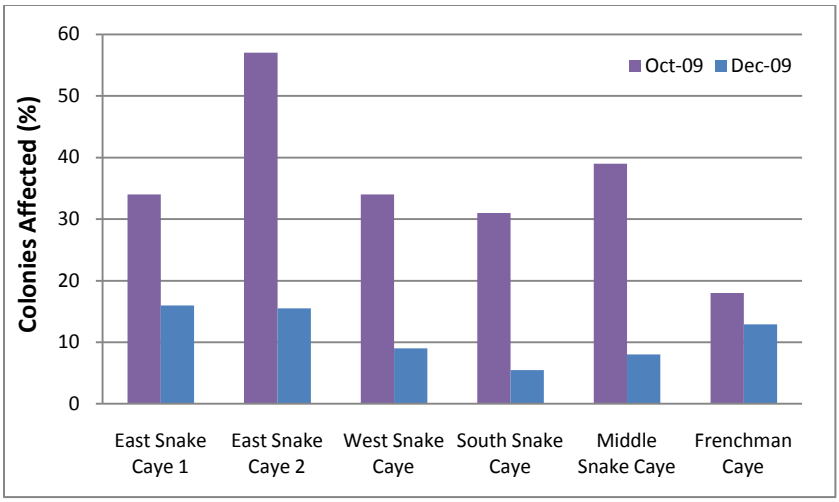

Figure 13: Percent of colonies affected by bleaching (pale, partial and whole bleach) at sites within PHMR in October and December 2009.

Fisheries Stock Assessment

Since late January 2009, data have been collected on over 1100 conch, 900 lobster and 1300 finfish caught within and around PHMR. Once a full 12 months of data have been collected a more detailed analysis of the fish stocks within PHMR will be conducted. A separate report detailing these results will be published.

Seagrass

Data collected during the seagrass monitoring are analysed by SeagrassNet and included within international reports and publications. An analysis of seagrass data collected over the last 3 years will be undertaken by TIDE during 2010 and a report will be published in due course.

Mangroves

An analysis of mangrove data collected over the last 5 years will be undertaken by TIDE during 2010 and a report will be published in due course. In addition, a comparison of mangrove community structure and productivity was carried out by a student at the University of Belize during 2009 and the report for this study will be distributed during 2010.

Conclusions

The aim of this report is to present the results of the monitoring program for PHMR during 2009 and to highlight any major fluctuations in the health of the ecosystems and populations in relation to previous years. The results presented here demonstrate that PHMR is relatively healthy in terms of its coral reefs; however, more can be done to improve the protection provided for many key species within the reserve.

Water quality monitoring shows that regular freshwater input from rivers can affect even the most distant sites of PHMR (the Snake Cayes) through changes in salinity and sedimentation. Dissolved oxygen content has improved throughout 2009 and has been at a consistent level for the last six months of the year. Water temperature was, on average, higher than in 2008, yet the bleaching event observed during the last quarter of the year was mild compared to the bleaching event of 2008. Further monitoring during 2010 will help to determine the level of coral mortality experienced within PHMR.

Coral cover was shown to decline slightly between 2008 and 2009; however, this was not significantly different to the cover observed in 2008. Macroalgal cover showed a large increase between 2008 and 2009 indicating a possible decline in reef health. Associated with the low density of reef fish at many sites, an increase in macroalgal cover is a cause for concern and will be closely monitored during 2010. Herbivorous fish, such as parrotfishes, provide a fundamental role in maintaining the balance between coral and algal cover on reefs (Mumby et al. 2006) and maintaining healthy fish stocks is a key component in preventing phase shifts to algal dominated reefs (Hughes et al. 2007). A considerable decline in population numbers can be sufficient to allow a rise in macroalgal cover and subsequent decline in coral cover and reduced coral recruitment (Aronson and Precht 2000; Lirman 2001; Jompa and McCook 2002). The introduction of new regulations during 2009 prohibiting fishing of herbivorous species may have a positive impact on the fish populations within PHMR, and combining this with an increase in the no-take zones within PHMR would be a positive next step in enhancing fish populations and coral reefs.

The two major fisheries species of PHMR, queen conch and spiny lobster, have shown minimal recovery since the implementation of the monitoring program in 2003 and 2004. There are indications that the populations may be improving slowly, however, numbers between no-take zones and general use zones, and monitoring times are highly variable. An increase in the area of no-take zones would provide a large benefit to these populations and this maybe the next step required to enhance these fisheries.

While some of the results collected during monitoring activities in 2009 indicate an improvement of ecosystems and populations within PHMR, it is evident that the reserve is not functioning as effectively as it could in preserving population numbers and benthic habitats. The area of no-take zones within PHMR accounts for only 5% of the reserve area, which is less than the area recommended by many reports. Recommendations for a minimum MPA size, specifically designated as a no-take area, range from 4-20km in diameter to effectively conserve biodiversity (Salm 1984; Friedlander et al. 2003; Shanks et al. 2003). In addition, studies have shown that many species utilise seagrass beds, mangroves and coral reefs at various stages of their life history (Roberts et al. 2003; Mumby 2006). Thus, an increase in the no-take area of PHMR would ensure inclusion of a larger area of each of these key habitats, thereby protecting connectivity between functionally linked habitats (McLeod et al. 2009). An increase in the no-take zones within PHMR from 5% to 20% is recommended as a management action in order to protect and enhance the diversity and functioning of the ecosystems and populations within the reserve. The

extension to the no-take zones can occur, either through the expansion of the existing conservation and preservation zones or through the creation of new conservation and preservation areas, or a combination of both. Recommendations from stakeholders, along with support and guidance from the Belize Fisheries Department, will form a crucial part of defining new areas to be included within no-take areas. While the results of this expansion in no-take zones will not be evident immediately, the long-term benefits to the Port Honduras area could be substantial.

Acknowledgements

The biological monitoring program for PHMR would not exist without the hard work and support of TIDE staff, volunteer researchers, stakeholders and community members, and the generous funding received from national and international organisations.

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