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18A Evaluating management success

Effectiveness of Different Levels of Management on Three Belizean MPAs

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Abstract. Coral reefs worldwide are degrading at an accelerated rate. Coupled with predictions of near-future climate change, increased coastal development and increased dependence on reef resources, the future for coral reefs looks bleak. The need for improved management is paramount in order to preserve reefs for the future. Belize hosts the longest barrier reef in the Western Hemisphere, which forms part of the Mesoamerican Reef (MAR) system. In addition to climate change threats, localized risks to reefs within this area include over-fishing, coral disease, and coastal and caye development. An effective network of marine reserves with good connectivity between sites is essential. Marine Protected Areas have the ability to act as 'stepping stones' allowing larval supply and dispersal from one region to another. Southern Environmental Association co-manages 3 Marine Protected Areas within the Southern Belize Reef Complex; Laughing Bird Caye National Park (LBCNP), Gladden Spit and Silk Cayes Marine Reserve (GSSCMR) and Sapodilla Cayes Marine Reserve (SCMR). The three reserves exhibit a gradient in their level of protection, ranging from a fully protected no-take national park, to a marine reserve with established zoning, to a marine reserve with new zoning that has only been enforced since 2010. Abundance and size data for commercially important species (lobster and conch) is presented and recent historical trends are displayed over time in order to show the effectiveness of the differing levels of management. The future of these southern Belize reef ecosystems is considered in the context of future threats and potential management strategies.

Key words: Lobster, Conch, No-take area, Mesoamerican, Zoning.

Introduction

In the Caribbean, live coral cover has been reduced by 80% (from 50% to 10% cover) in the last three decades (Gardner et al. 2003). It has been suggested that recent coral mortality in the Caribbean has led to several critical function groups being either removed from the reef ecosystem, or being represented by only a few species (Bellwood et al. 2004). Critical function groups of fish have been reduced through over-fishing, resulting in a shift from fish-dominated to echinoid-dominated herbivory. These recent degradation events have not been due to global phenomena, but have resulted from local natural and anthropogenic impacts occurring at a Caribbean-wide scale, within the context of overfishing. Current predictions for increased human activity in the Caribbean, coupled with predicted global climate change suggests that in neither the short nor the long term does the situation for Caribbean coral reefs look set to change (Gardner et al. 2003).

Belize is a small country (22,960 km^2) home to approximately 300,000 people, giving it the lowest population density in Central America (United Nations 2009). The country hosts the 280 km long, 1,400 km^2 Belize Barrier Reef (McField and Bood 2007). Running from the Mexican border in the north (18°N) to Sapodilla Cayes in the south (16°N) at a longitude of approximately 88°W, this is the longest barrier reef in the western hemisphere and the second longest in the world. Forming part of the Mesoamerican Reef (MAR) system, the Belize Barrier Reef has been recognized for its high level of biological diversity, ecological processes and natural beauty, by being declared a UNESCO World Heritage Site in 1996.

The value of Belize's reef resources (reef and mangrove related fisheries, tourism, and shoreline protection) has been estimated at US$395 - $559 million per year (Cooper et al. 2009). With such a valuable asset lying just offshore (300 m offshore in the north, 40 km offshore in the south), the protection of Belize's coral reefs is paramount.

Belize's Conch Fishery

The queen conch (*Strombus gigas*) is a targeted fishery throughout the Caribbean and was once the second most valuable fishery throughout the region, generating US$30 million in 1992 (Appeldoorn and Rodriguez 1994). Due to a steady decline through overfishing, conch are now protected under the

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) agreement. Although not endangered, it is a commercially threatened species in many areas of the Caribbean. Unlike some other Mesoamerican Reef countries, Belize does not have commercial fishing fleets. A closed season for conch has been implemented by Belize Fisheries Department (1 July to 30 September). Other management strategies include; size restrictions (shell length must exceed 7 inches / 17.8 cm), the market clean and fillet weight should exceed 3 ounces (85 g) and 2.75 ounces (78 g) respectively, and no one should buy, sell, or have in possession diced meat.

Belize's Lobster Fishery

The Caribbean spiny lobster (*Panulirus argus*) is a targeted fishery throughout its range and in Belize generates approximately US$9 million annually (Greenreef 2010). Belize's lobster fishery is also conducted on an artisanal scale. The closed season for spiny lobster is 15 February to 14 June and other management strategies include; size limits (minimum carapace length of 3 inches / 7.6 cm), minimum tail weight of 4 ounces (113 g) and no fisherman should have in possession fillet or diced lobster tail, soft shell, berried (egg bearing) lobster or lobster with tar spots.

Material and Methods

Marine conservation efforts in Belize have grown significantly in the past two decades (Cooper et al. 2009) and there are now 18 Marine Protected Areas (MPAs) throughout the country, covering approximately 250,000 ha (McField et al. 2008) (Fig. 1). The Belizean NGO 'Southern Environmental Association' (SEA) co-manages 3 MPAs within the system-level management unit of the Southern Belize Reef Complex; Laughing Bird Caye National Park (LBCNP), Gladden Spit and Silk Cayes Marine Reserve (GSSCMR) and Sapodilla Cayes Marine Reserve (SCMR) (Fig. 2). GSSCMR and SCMR are co-managed with Belize Fisheries Department and LBCNP is co-managed with Belize Forest Department. The three MPAs exhibit differing levels of protection, exhibiting a gradient in the levels of legal extraction, ranging from 'no-take areas' where all extraction is illegal to 'general use' zones where fishing is allowed, but controlled through techniques.

Marine Protected Areas can only be effective through enforcement. In addition to SEA's marine park rangers who patrol the parks twice a day, SEA employs a special enforcement team to focus on combating illegal fishing activities day and night, in the buffer zones between the reserves. These buffer zones, outside the reserves, are integral to the effectiveness of the MPAs in terms of connectivity between adjacent reserves.

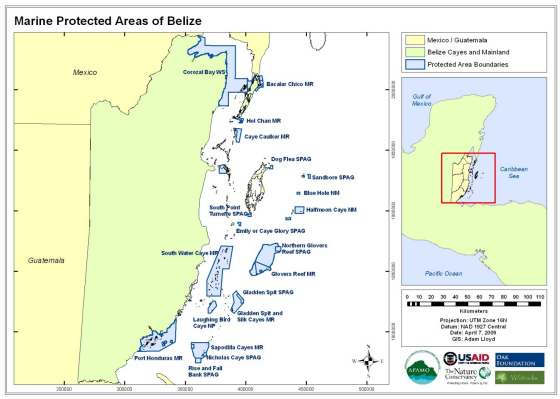

Figure 1: Map of Belize showing all Marine Protected Areas.

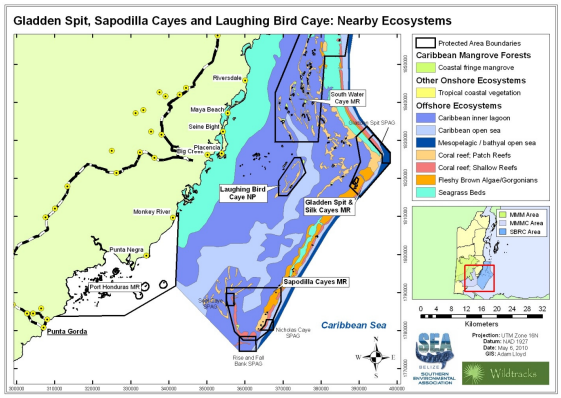

Figure 2: Benthic habitats for the marine reserves that comprise the Southern Barrier Reef Complex.

LBCNP is located 18 km east-southeast off the coast of Placencia, (16°27'N; 88°11'W). LBCNP was designated a National Park in 1991 and declared part of the Belize Barrier Reef UNESCO World Heritage Site in 1996. LBCNP (total size = 4,095 ha; island size = 0.57 ha) is a fully protected no-take area (NTA). Only non-extractive recreational activities can be undertaken. Park regulations are well enforced; a ranger station is situated on the island, and there is permanent presence by 2 full time SEA rangers.

GSSCMR (total size = 10,523 ha) lies 36 km east of Placencia (16°30'N; 87°59'W) and was declared in 2000, in part due to its importance as a spawning aggregation site. Deep water (up to 250 m) to the east, bathymetry and associated upwelling attract up to 30 species of fish (many of which are of commercial value), making it the highest priority fish spawning aggregation site in the country. At full moon from March to June, thousands of fish (particularly snappers) congregate here. The reserve has a multi-zone approach, with 98.6% (10,370 ha) being designated for 'general use' where regulated fishing activities are allowed (no nets or spear guns and no fishing whilst SCUBA diving) and the remainder (153 ha), around the Silk Cayes, being designated a NTA.

There is permanent ranger presence at Little Water Caye, adjacent to the reserve.

SCMR is located at the southern extremity of the Barrier Reef system (16°8'N; 88°2'W), 75 km east off the coast of Punta Gorda, within the Gulf of Honduras. SCMR (total size = 15,618 ha) was declared as part of the Belize Barrier Reef World Heritage Site in 1996, but remained a 'paper park' until 2001. A zoning scheme encompassing a large general use zone (13,145 ha), 2 conservation zones and a preservation zone has recently been established; enforcement of these zones is in its inception. A ranger station is situated on Hunting Caye within the park boundary.

SEA's commercial species monitoring records the abundance and size of conch, lobster and commercially important finfish. Commercial species monitoring is conducted quarterly; the survey method is based on Dr Charles Acosta's Long-term Atoll Monitoring Protocol (LAMP), whereby a 30 minute timed swim is undertaken to cover the entire survey site. If zoning exists, monitoring is conducted in all zones. As a 'control', sites are also monitored outside of the parks. At LBCNP 14 sites are monitored (9 inside NTA, 5 outside the reserve), at GSSCMR 12 sites are monitored (3 inside NTA, 6 in the 'general use' zone and 3 outside the reserve) and at SCMR 12 sites are monitored (all considered 'general use' as enforcement of new zones is in the early stages).

Results

A way of measuring the effectiveness of marine protected areas is through the fisheries resources they provide; their ability to provide a coral and fish larval supply, and their ability to produce larger and more abundant products. Lobster and conch data (from snorkel/SCUBA surveys) have been analyzed to determine a baseline for stocks, and to compare between years and zones of each of the marine reserves. 2008 is the first year in which monitoring was conducted 4 times in the year, and at all 3 parks. For this reason, only recent historical data have been presented. Monitoring is conducted at the same sites 4 times per year; data displayed shows the average number of encounters (±1 standard deviation) per year. The *t*-test was used to compare datasets between two years and ANOSIM (Analysis of Similarities) was conducted using the Bray-Curtis similarity coefficient to test for statistically significant differences between zones and between years.

Laughing Bird Caye National Park

For each of the years 2008 to 2011, higher numbers of lobster were recorded within the park compared to outside it but these differences were not significant (no take vs. control across all years; ANOSIM; $P > 0.05$). From 2010 to 2011 there were statistically significant (*t*-test; $P < 0.05$) increases in abundance (3 fold increase) both inside and outside the park (Fig. 3).

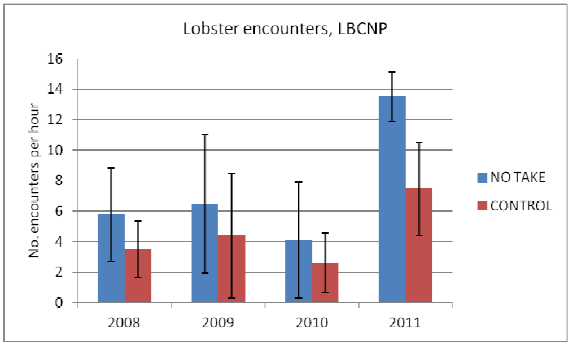

Figure 3: Average (±1 s.d.) number of lobster encounters per hour inside and outside LBCNP 2008-2011 based on 4 monitoring sessions per year.

Significantly greater numbers of conch were observed in LBCNP compared to outside the park (no take vs. control across all years; ANOSIM; $P < 0.05$). The number of encounters inside the park remained stable 2010-2011, but a non significant (*t*-test; $P > 0.05$) increase was seen outside the park (Fig. 4).

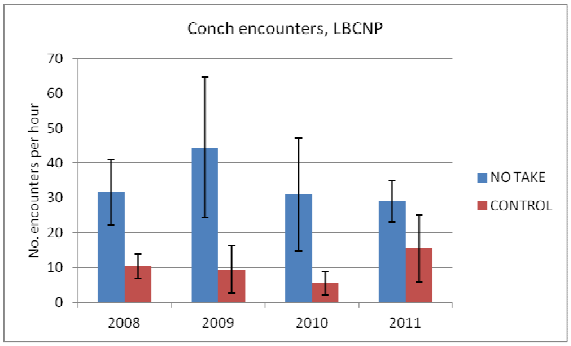

Figure 4: Average (±1 s.d.) number of conch encounters per hour inside and outside LBCNP 2008-2011 based on 4 monitoring sessions per year.

Gladden Spit and Silk Cayes Marine Reserve

Lobster encounters at GSSCMR in 2010 and 2011 showed similar patterns (Fig. 5). The number of encounters in the reserve ('general use') remained stable 2009-2011. An increase in number of encounters both within the no-take area and outside the reserve (control) occurred 2010-2011 and within the NTA, this was a 1.6 fold increase. Lobster encounters were particularly low in all zones in 2008.

Conch encounters in the no-take area of GSSCMR showed a decline from a mean of 38 encounters per hour in 2008 to 8 per hour in 2011 (Fig. 6). In the reserve ('general use' zone) numbers were relatively stable 2008, 2010 and 2011, with a small peak in 2009. Outside the reserve (control), numbers showed a steady increase 2009-2011.

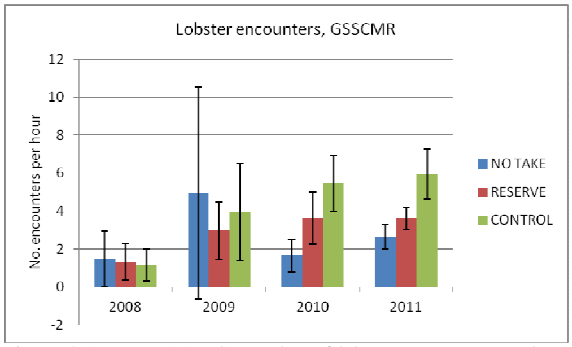

Figure 5: Average (±1 s.d.) number of lobster encounters per hour at GSSCMR 2008-2011 based on 4 monitoring sessions per year.

When all years were compared for conch abundance at GSSCMR, a statistically significant difference in encounter numbers was calculated between the reserve ('general use') zone and outside the reserve (ANOSIM; $P < 0.05$).

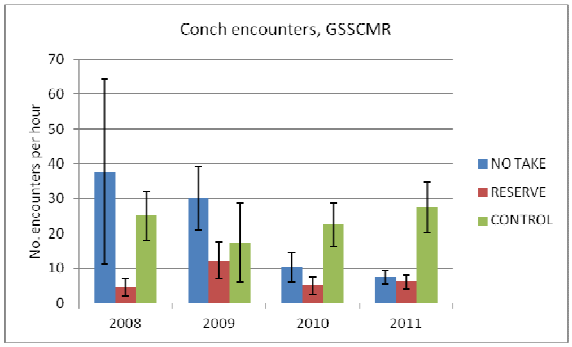

Figure 6: Average (±1 s.d.) number of conch encounters per hour at GSSCMR 2008-2011 based on 4 monitoring sessions per year.

Sapodilla Cayes Marine Reserve

There was no clear pattern to inter-annual lobster encounters at SCMR.

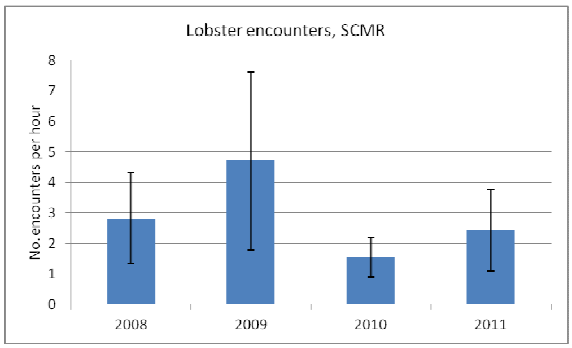

Figure 7: Average (±1 s.d.) number of lobster encounters per hour at SCMR 2008-2011 based on 4 monitoring sessions per year.

An increase in number of lobsters encountered was observed 2008-2009 but this was followed by a (not statistically significant; *t*-test; $P > 0.05$) decrease in 2010 when the lowest number of individuals (1.5 h^{-1}) encountered in the time-series was recorded. An increase was seen by 2011 (2.4 individuals h^{-1}).

Conch numbers at SCMR showed a marked decline 2008 - 2009, but there was great variability in the 2008 data and this decline was not statistically significant (*t*-test; $P > 0.05$). Numbers remained stable 2009-2011 (Fig. 8).

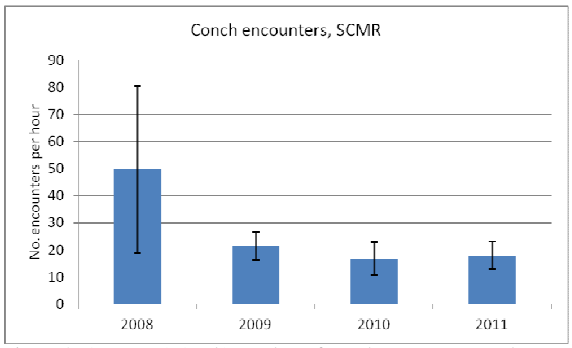

Figure 8: Average (±1 s.d.) number of conch encounters per hour at SCMR 2008-2011 based on 4 monitoring sessions per year.

Discussion

This paper provides some evidence that effectively enforced no-take areas offer a suitable strategy to fisheries management. Having been a fully protected area since 1996, the concept of a no-take area appears to be working at Laughing Bird Caye National Park (LBCNP), at least in terms of conch. LBCNP is renowned nationally for its high conch abundance. It is important that an area such as this maintains its high level of protection, and that fishing regulations are enforced effectively. On the strength of 2010 data which showed a reduction in stocks of conch and lobster inside LBCNP (implying illegal fishing activity), night patrols of the park commenced in 2011; an increase in stocks 2010-2011 may indicate that improved management, based on scientific data, has reduced illegal activities in the reserves, thus leading to an increase in commercial stocks.

The high productivity within LBCNP will enable larval dispersal to adjacent marine reserves, allowing for connectivity between sites. A 'spill-over' effect, whereby adults / juveniles cross the boundary to areas outside the park would be expected. The lower numbers of conch and lobster encountered outside the park implies that this area is heavily targeted by fishermen. Due to the historic nature of LBCNP being highly productive, coupled with the effective enforcement of the no-take area (NTA), it seems likely that fishermen actively target the areas surrounding the boundary of the reserve. By 2011, increases in abundance (of conch and lobster) were observed at the LBCNP control sites, possibly indicating a 'spill-over' effect is occurring.

The reserve effect is considerably less at Gladden Spit and Silk Cayes Marine Reserve (GSSCMR). Here, less than 2% of the entire reserve is designated a NTA and even within this zone, some level of illegal extraction is likely to occur; 2008 and 2009 conch numbers peaked within the NTA, but a marked decline was seen in later years. Numbers of conch and lobster in the reserve's 'general use' zone were lower than outside the reserve for all years. This may imply that fishermen target their efforts in the general use area as there is the perception that a marine reserve will host greater abundance of lobster and conch. The very low numbers encountered in the general use zone indicate high fishing pressure (especially as numbers at the control sites outside the reserve show a rising trend, particularly for lobster). The results imply that the size of the no-take area at GSSCMR is too small to have a spill-over effect (the no-take area appears not to be able to successfully contribute to increasing the stocks of such a large surrounding area). With fishing allowed in almost 99% of the marine reserve, the pressure on this park is substantial.

Sapodilla Cayes Marine Reserve (SCMR) has been considered here entirely as 'general use', where fishing is allowed. It is anticipated that the new zoning scheme, coupled with effective enforcement, will increase biological productivity. Greater enforcement efforts will be needed in this area due to the trans-boundary issues that are faced in the far south. Guatemalan and Honduran fishermen are known to illegally target this area, especially at night.

As pressures on reefs increase due to direct human activities and climate change, refining reef management is imperative. It is recommended that future reef resource management strategies should consider more numerous and larger no-take areas on a national scale. Although this would cut down the available fishing grounds, it is anticipated that through the spill-over effect, long-term benefits could be created for those that depend on these fisheries resources. Since early 2011, SEA has been working with stakeholders (fishermen and tour-guides) through interviews and consultations to gain support in increasing the size of the NTA at GSSCMR. Coupled with this is the prospect of finding alternative livelihoods and supplemental income generating activities for fishermen.

Comparison has been made between three different reef areas, which are subject to differing levels of protection. In addition to the degree of protection through management, the spatial differences in physical and environmental processes which the three parks experience will, to a certain extent, influence their biological productivity. For example, LBCNP is a faro, with a shallow central lagoon containing extensive seagrass beds, surrounded by deep water. Water circulation patterns will be modified by the faro's structure and the shallow, sheltered lagoon may facilitate larval accumulation and provide a good nursery habitat. GSSCMR typically presented the results from patch reef and back reef communities, on the eastern-most stretch of the Belize Barrier Reef; a high energy environment. Similarly, SCMR at the southernmost point of the Belize Barrier Reef system is an exposed environment. Extensive terrestrial run-off and riverine input following heavy rains impact these southern reefs, due to the numerous rivers entering the Gulf of Honduras from Honduras, Guatemala and southern Belize (Paris and Chérubin 2008). In light of these geographical factors and associated biological and physical processes it should be noted that the results presented here should be treated with caution. It may be that external factors, additional to management techniques and enforcement regimes have considerable power in controlling the success of fisheries resources.

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