An evaluation of the effectiveness of the Caye Caulker and Bacalar Chico Marine Reserves in Belize: an Ecological, Socioeconomic and Governance Analysis

Final Report

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Executive Summary
The Caye Caulker and Bacalar Chico Marine Reserves are two reserves in a network intended to protect coral reef ecosystems and associated marine resources of Belize. Ecological, Socioeconomic and Governance evaluations were conducted for both marine reserves from 2007-2009 following accepted international and local guidelines. These evaluations revealed that the fish and benthic communities within various zones of both reserves were similar to control sites; however, patch reefs within the Caye Caulker Marine Reserve appeared to be in better condition than those of Bacalar Chico, but reef fish resources of the Bacalar Chico Marine Reserve were more abundant than those of the Caye Caulker Marine Reserve.

Socioeconomic surveys indicated that there was a very close connection between local stakeholders and the sea as a source of food and income. Most stakeholders surveyed believed fishery resources to be in decline and that human impacts have had an adverse affect on these resources. There was a general agreement that effective management of marine resources was necessary and that the Caye Caulker and Bacalar Chico Marine Reserves were fairly effective at protecting resources, but there was some disagreement on the benefit that these Marine Reserves provide to local communities and the country as a whole.

Several issues were identified related to the governance of both MPAs. For Bacalar Chico, most stakeholders surveyed did not know much about the rules and boundaries of the MPA, or how decisions were reached regarding MPA management. Nevertheless, they believed that enforcement of rules and compliance with rules was fairly high. For Caye Caulker, there was a greater awareness of reserve boundaries and rules, although a significant percentage of stakeholders were not familiar with the boundaries and rules of the reserve. There was general agreement that compliance with reserve rules was low and that enforcement could be improved. Similar to Bacalar Chico, stakeholders were somewhat alienated from the decision-making process for the Caye Caulker marine reserve, and stakeholders in both locations expressed disagreement with some rules of the reserves and expressed interest in becoming involved in the management decision-making process.

Based on the results of these evaluations and observations made during evaluations, specific management recommendations include:

- Continued monitoring of fishery resources and benthic communities within zones of both MPAs and control areas outside the MPAs. Currently the conch monitoring program is effective and may serve as a model for monitoring other key species.
- While no changes in management to improve ecosystem health or populations of key species are suggested at this time, alternatives for improved management should be considered if positive changes are not observed in monitoring efforts over the next 5 years.
- Improve communication about the MPAs by using media that effectively targets local stakeholders (television for Caye Caulker and Radio for Bacalar Chico).

This should be accompanied by an educational campaign to improve knowledge of MPA boundaries, zones and rules.

- Promote greater visitation to the Bacalar Chico Marine Reserve to build awareness of its significance and value to Belizeans and foreign visitors alike. The visitor center is underutilized at present and may serve as an attraction to not only improve education, but the MPA may also provide economic opportunities to local tour guides
- Improve enforcement of the Caye Caulker Marine Reserve. While we did not measure enforcement in any way, public opinion of enforcement and voluntary compliance with rules of the Caye Caulker Marine Reserve is low.
- Provide a better visitor center for the Caye Caulker Marine Reserve that will educate visitors on the significance of the reserve, as well as its boundaries, zones and rules. This visitor center may be located in the current MPA headquarters facility of in the village itself, where it is likely to get greater traffic by visitors and locals alike.
- Reduce the threat of the drug trade for the Bacalar Chico Marine Reserve. While this may be outside the capabilities of MPA management authorities, partnership with law Belize's law enforcement and/or military services may facilitate this.
- Involve local stakeholders in decision-making regarding MPA governance. This may include holding community meetings or other forums for stakeholders to voice their opinions, establishing stakeholder advisory committees or other activities that increase stakeholder involvement in the MPA.
- Review sustainable funding plans for both MPAs. While these assessments did not specifically examine funding for either MPA, periodic assessments of MPA management costs and revenues from user fees, government funding, grants, and other sources should be conducted. Opportunities such as potential revenues from souvenirs sold at visitor centers should be examined.

Background

Belize has an established network of 13 Marine Protected Areas (MPAs) that are zoned for different uses and involve management by the Department of Fisheries and other co-management authorities. This study focuses on two of these MPAs. The first is the Bacalar Chico Marine Reserve and National Park located at the northern tip of Ambergris Caye along the Belize-Mexico Border. This MPA was created in 1996 and includes 6,303 hectares of marine area encompassing seagrass, coral reef (including patch reef, barrier reef and forereef areas), and mangrove habitats (Fig.1). The area is unique in that it is one of the few places where the Mesoamerican Barrier reef touches land (at Rocky Point or Reef Point). Furthermore, the area is of historical and cultural significance since it was an important site to the Mayans, who established Bacalar Chico as a trade center and maintained the channel and creek system (which now serves as the Belize-Mexico Border) to connect the inner lagoon to the Caribbean Sea. Thus, providing an important trade route to the interior of the Yucatan Peninsula. The area is now fairly remote, with the nearest large town being San Pedro, which is more than 20km away and no roads connecting the reserve's headquarters to San Pedro or any of the small settlements nearby.

The Caye Caulker Marine Reserve was established in 1998. Its headquarters are located at the Northern end of Caye Caulker and the Marine Reserve includes marine areas surrounding the northern tip of Caye Caulker, extending out to the barrier reef and then southward along the barrier reef to include reef areas as far south as Caye Chapel (Fig.2). The northern portion of Caye Caulker (i.e., north of the "Split") is largely uninhabited, but there is an increase in home sites being developed there. The southern portion of Caye Caulker was a traditional fishing village that has seen a tremendous increase in tourism over the past two decades.

The management plan for Belize's, Bacalar Chico Marine Reserve includes zoning for a National Park, a Preservation Zone (no-take and no recreational activities allowed), and two conservation zones (Zone 1 is no-take but allows recreational activities, Zone 2 allows catch and release fishing and other recreational activities) in addition to a General Use Zone (Fig. 1). The Caye Caulker Marine and Forest Reserve's management plan also has allowed for General Use Zones in which all uses are permitted, and zones which restrict (Conservation Zone) and prohibit fishing (Preservation Zone) (Fig. 2).

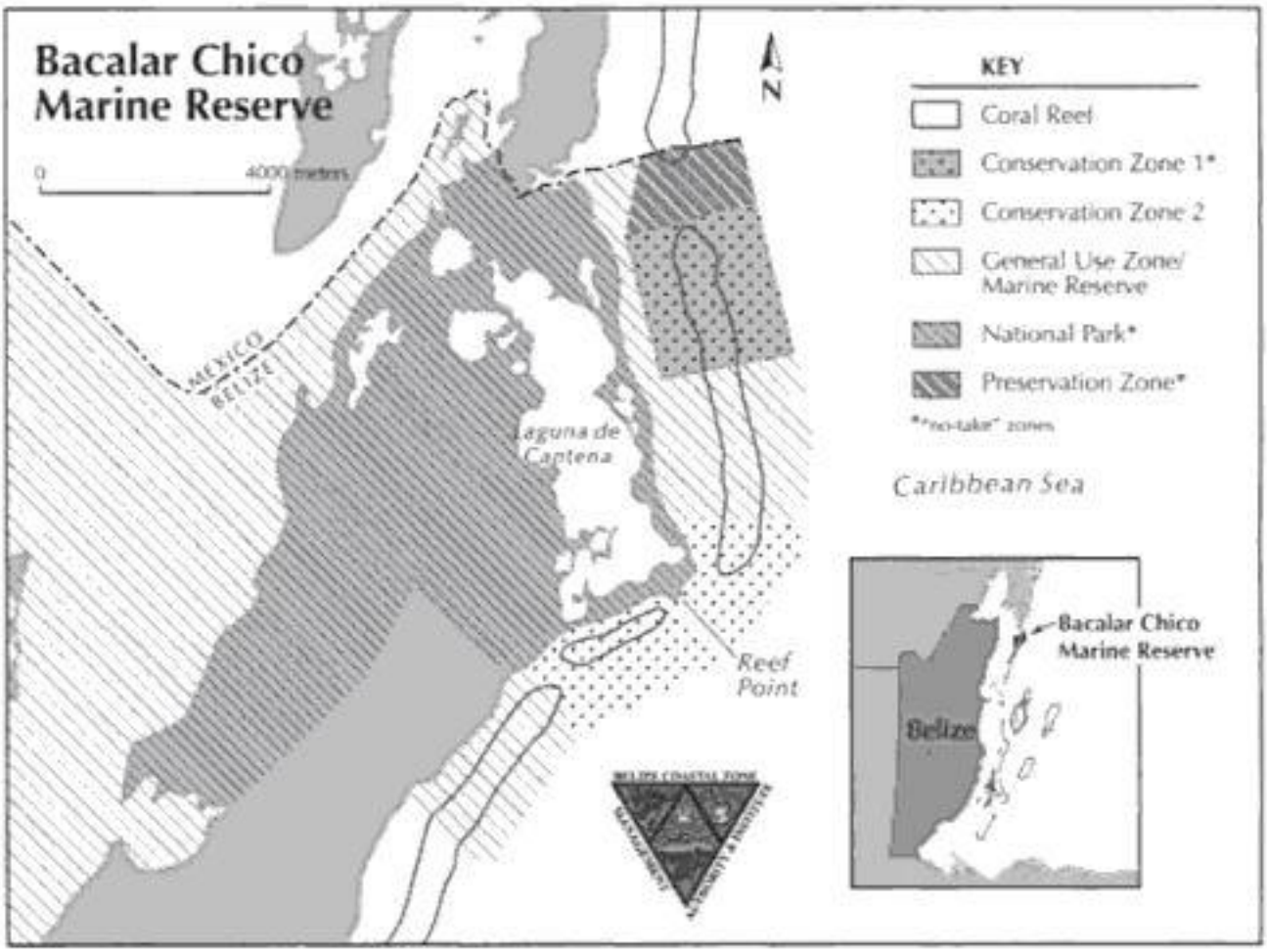


Figure 1. Map of the Bacalar Chico Marine Reserve showing zoning scheme. Map was created by the Belize Coastal Zone Management Authority and Institute (Sobel and Dahlgren 2004).

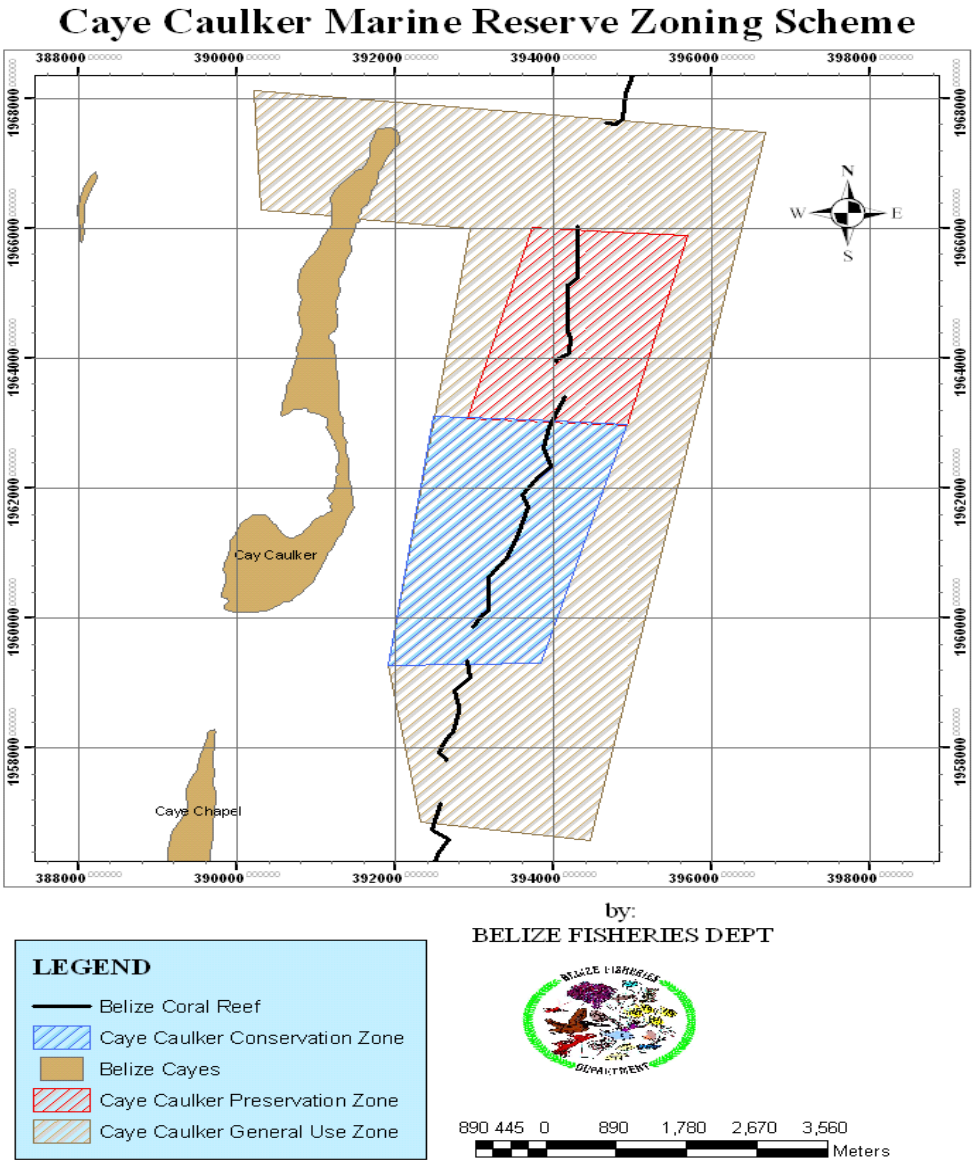


Figure 2. Caye Caulker Marine Reserve map showing zones. Map was provided courtesy of the Belize Fisheries Department.

While Belize has recently developed guidelines for monitoring MPAs (Young et al. 2005) that are consistent with the recommendations of Pomeroy et al. (2004), these guidelines have yet to be fully implemented at the Bacalar Chico and Caye Caulker Marine Reserves. In many MPAs in Belize, however, there is very strong program for monitoring corals and/or key fishery species, particularly queen conch. In both the Marine Reserves included in this study, such a program exists for queen conch. While coral monitoring has occurred in both areas, it has been limited in scope, reef areas, and has not been conducted consistently. Our monitoring efforts were designed to avoid

overlap with effective programs already in existence and provide resource managers with new information that would contribute to adaptive management decisions. As such, we did not include conch as a focal species, but we did include coral reef communities. Our simple survey design and involvement of local personnel is also intended to facilitate use these surveys for monitoring over time to assess changes within MPAs, with the current surveys establishing a baseline for future comparisons.

Methods

In July, 2007 surveys of both the Caye Caulker Marine Reserve and the Bacalar Chico Marine Reserve in Belize were conducted. During this expedition, we surveyed fish assemblages, key invertebrate resources, and benthic communities in various habitats and across different zones of each marine protected area. A list of habitats and zones surveyed in each MPA are provided in Table 1. In addition to surveys within zones, an unprotected area between Caye Caulker and Ambergris Caye was surveyed for comparison.

Table 1. Summary of habitat types and zones surveyed in each Marine Reserve and Control sites. Habitats and zones marked with an X indicate those included in surveys. Habitats and zones shaded in grey are those that are not present in each Marine Reserve or control area.

Habitat	Unprotected	General Use Zone	Conservation Zone	Preservation Zone
Caye Caulker Marine Reserve				
Mangrove		X		
Seagrass		X	X	
Patch Reef		X	X	X
Bacalar Chico Marine Reserve				
Mangrove		X		
Seagrass		X	X	X
Patch Reef		X	X	X
Control - between Caye Caulker and Ambergris Cay				
Mangrove	X			
Seagrass	X			
Patch Reef	X			

Following the Pomeroy et al. (2004) *How is your MPA doing?* guidebook and recommendations for monitoring Belize's MPA network (Young et al. 2005) several ecological (biophysical) indicators were selected for evaluation. Rather than trying to quantitatively assess all ecological indicators, efforts were focused on a few selected indicators. The selection of specific ecological indicators was based on a number of factors including recommendations from local marine resource management authorities and local monitoring plans, reduction in overlap with existing monitoring efforts, and logistics of conducting monitoring, particularly at the remote site of Bacalar Chico. As such, primary ecological indicators to be assessed quantitatively included: focal species

abundance; focal species population structure; habitat distribution and complexity; and community composition and structure. Qualitative observations of several other ecological indicators were also made.

Assessments of the ecological indicators was conducted using *in situ* survey techniques at multiple replicate sites within both MPAs as well as a nearby reference site outside of the MPAs. Surveys within and outside MPAs allowed a rigorous assessment of the impact that the MPA has on these indicators. To further enhance the ability of monitoring assessments to detect affects of MPA protection, replicate sites for monitoring inside and outside the reserve were stratified by representative habitat types (i.e., seagrass, mangrove, patch reef. Note that no forereef areas were surveyed due to poor weather conditions). Seagrass habitats were found between the shoreline and the barrier reef and included any areas dominated by seagrass species (usually *Thalassia testudinum*, *Syringodium filiforme*, although some *Halodule* sp. was also present), usually on sand or mud substrate. Patch reefs consisted of unconsolidated coral reef substrate in areas on the shoreward side of the barrier reef (including some present in or adjacent to cuts that connected the back reef system to the forereef and/or open water). Mangrove habitats included the mangrove fringe along the barrier reef or lagoon side of islands and, in the case of Bacalar Chico, tidal creek systems. Mangrove surveys were conducted primarily in areas dominated by red mangroves, *Rhizophora mangle*.

Such stratification by habitat increased our ability to detect MPA affects on indicators by accounting for variability in indicators that may result from in variability in habitat. Furthermore, our site selection included replication within MPA zones (e.g., General Use Zones, Conservation Zones and Preservation Zones). Sampling of multiple replicate sites from different habitats within and outside MPAs, and within different zones within MPAs is a powerful sampling design for determining MPA effects on ecological indicators and how different human uses affect these indicators

Key indicators listed above were assessed during *in situ* visual diver surveys, following techniques that the PI and others have effectively used for MPA site assessments and the collection of data from MPAs in the Bahamas and throughout the Caribbean (e.g., Eggleston and Dahlgren 2001, Crosby et al. 2003, Dahlgren et al. 2003, Eggleston et al. 2004). Habitat stratification for these surveys relied on habitat maps developed by the Belize Coastal Zone Management Authority and Institute, satellite imagery of the area, and local knowledge of sites from past and present MPA managers and staff. Using these sources, specific sites for assessment were selected haphazardly. The abundance and population structure of focal species (ecologically or commercially important species, endemic species and/or threatened species; e.g., several grouper and snapper species, lobster, *Diadema antillarum*), and other indicators were assessed in different habitat types using belt transect surveys. During surveys, all fish species and focal invertebrate species (e.g. lobster, urchins) were identified to species, and individual sizes and abundance quantified within 30 m long by 2 m wide belt transects. Two transects were conducted at each site. In addition a roving diver conducted two 10 minute surveys for *Diadema* and lobster at each site, since preliminary data indicated that these species

might not be detected frequently enough for statistical analyses using transect methodology.

Benthic substrate complexity and community composition surveys were conducted by divers use point-intercept transect survey techniques along the same transect lines used for fish surveys, following protocols adapted from AGRRA surveys. Benthic surveys included identifying substrate type and community composition to the finest taxonomic resolution possible (species in most cases) at 50 cm intervals along transects. Benthic surveys also incorporated key quantitative characteristics of different habitats (e.g., mangrove shoreline depth and root density, coral reef rugosity, percent of coral colonies that are alive, seagrass shoot density) that may be indicative of MPA effects or may serve as co-variates to factor in to analyses involving other indicators. Benthic surveys also incorporated key quantitative characteristics of different habitats (e.g., coral reef rugosity, percent of coral colonies that are alive, seagrass shoot density) that may influence ecological indicators.

Specific analyses include ANOVA comparisons of fish species richness, commercial species abundance (e.g., large grouper species, several snapper species, hogfish), and abundance of key species of groups, such as snappers, groupers, and parrotfish. Too few *Diadema antillarum* and Caribbean spiny lobsters (*Panulirus argus*) were observed for statistical comparisons, but a qualitative assessment of these species was conducted. ANOVA comparisons of benthic coverage for corals, macroalgae, turf algae, all algae (macroalgae + turf algae), sponges, gorgonians, seagrass (for seagrass habitats only), bare substrate, crustose coralline algae, and open substrate for colonization (bare plus crustose coralline algae) were conducted for each habitat type. For percent cover analyses in patch reef habitats, only data collected from points along hard substrate (hardbottom pavement, boulder and/or rubble) were included in analyses.

In addition, Bray Curtis similarity indices were calculated for sites within each habitat sampled at the two different times to assess changes in community structure for fish and benthic communities Similarity matrices were then used in cluster analyses and multi-dimensional scaling (MDS) analyses to determine how community structure varied based on location (Bacalar Chico or Caye Caulker) and level of protection (Unprotected, General Use Zone, Conservation Zone or Preservation Zone). Analyses of benthic communities focused on changes in the percent cover of various benthic community components within each habitat type and fish community analyses used density data. In both cases, data were fourth root transformed to lessen the effect of infrequently occurring species on community structure.

Socioeconomic and Governance

A broad range of Socioeconomic and Governance Indicators suggested by Pomeroy et al. (2004) were addressed this study. Socioeconomic indicators addressed include:

Local marine use patterns
Local values and beliefs about marine resources
Level of understanding of human impacts on marine resources

Perceptions of seafood availability
Perceptions of local seafood harvest
Perceptions of non-market and non-use value
Household income distribution by source
Household occupational structure
Nature of markets
Distribution of knowledge to the community.

Governance indicators addressed include:

Existence of a decision-making and management body
Existence and adoption of management plan
Local understanding of MPA rules and regulations
Existence and adequacy of enabling legislation
Existence and application of scientific research and input
Existence and activity level of community organizations
Degree of interaction between the manager and stakeholders
Level of stakeholder involvement in surveillance
Enforcement coverage
Information dissemination

All socioeconomic indicators and many of the governance indicators were addressed by surveying stakeholders. Information on governance indicators was also supplemented by conversations with past and present (at the time of the study) MPA staff. Stakeholder surveys were developed based on examples from Pomeroy et al. (2004).

Results

Ecological Indicators

Fish – Species richness was compared among MPAs and level of protection for each habitat type. The number of fish species observed within the two MPAs and unprotected area varied for both seagrass, and patch reef habitats. In seagrass beds, the number of species observed within the Preservation Zone of the Caye Caulker Marine Reserve and at the unprotected site were greater than all other zones within either the Caye Caulker or Bacalar Chico Marine Reserves ($F_{5,13} = 6.183$, $p=0.004$; Fig. 3). The number of species observed did not vary between any zones and unprotected areas for either MPA in patch reef habitats; however, the Preservation Zone of the Bacalar Chico Marine Reserve had a significantly greater number of species per transect than any zones within the Caye Caulker Marine Reserve ($F_{6,17} = 3.825$, $p = 0.013$; Fig 3). In contrast, species richness did not vary based on location or level of protection for mangrove habitats ($F_{2,8} = 0.316$, $p = 0.738$), but it should be noted that all mangroves within both MPAs were in general use zones.

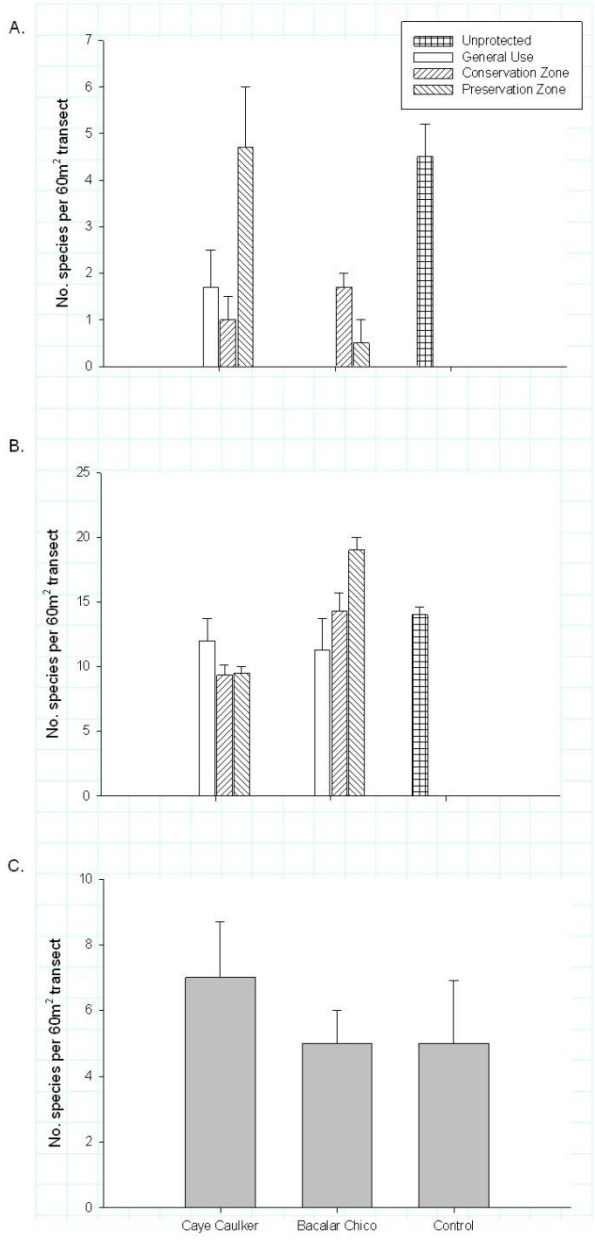


Figure 3. Species richness in different MPAs (divided by zone) and control sites for (A) seagrass, (B) patch reef, and (C) mangrove habitats. Note that Mangroves only occurred in one zone within MPAs.

Fish community structure was similar within each habitat strata, but varied among strata to a great extent, as was expected (Fig. 4). Within a habitat strata, however, community structure showed a great amount of overlap between sites, regardless of which MPA they were in or their level of protection (e.g., unprotected, General Use, Conservation Zone, Preservation Zone; Fig 5). In the seagrass habitat a few sites were outliers and quite different from the other sites; however, these sites were not from the same MPA or same level of protection (Fig. 5).

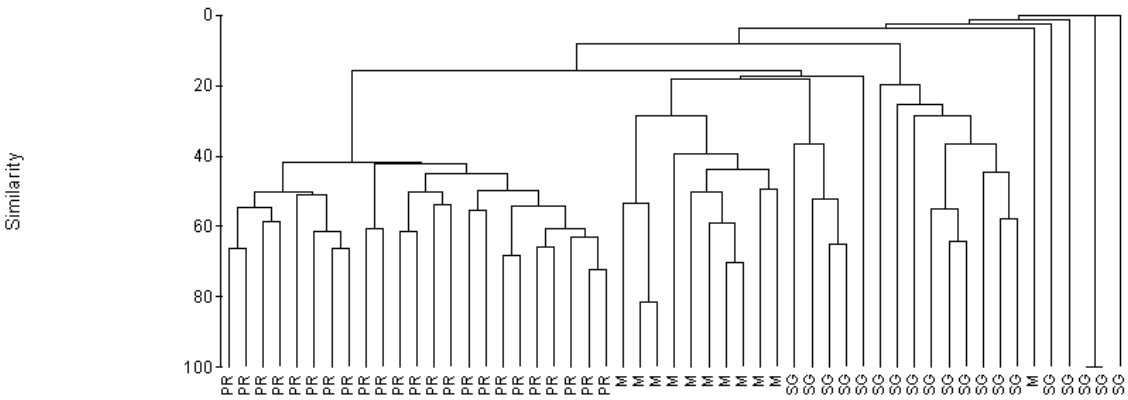
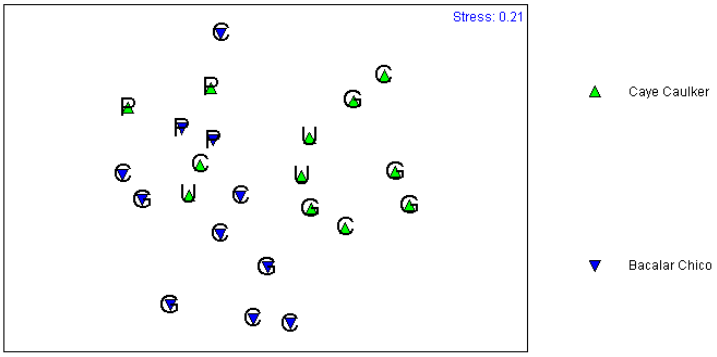


Figure 4. Bray-Curtis similarity analysis for Belize survey sites by habitat. PR = patch reef sites; M = mangrove sites; SG = seagrass sites.

For targeted fishery species, abundance did not vary among MPA zones and unprotected areas for any habitat (Seagrass: $F_{5,13} = 1.003$, $p = 0.454$; Mangroves: $F_{2,8} = 1.098$, $p = 0.379$; Patch Reefs:$F_{6,17} = 0.919$, $p = 0.506$). There was a trend for greater number of targeted species on patch reefs within the Bacalar Chico Marine Reserve than the Caye Caulker Marine Reserve; however, this was not statistically significant ($F_{1,22} = 3.855$, $p = 0.062$; Fig 6). There were no clear trends regarding the level of protection and its affect on fishery species abundance. Although Nassau grouper (*Epinephelus striatus*) and other targeted grouper species were observed during surveys, they were encountered too infrequently to be included in statistical analyses. Snappers occurred more frequently and were a major component in the composition of targeted fishery species.

Parrotfish were only observed frequently enough to be included in analyses of patch reef habitats. Their abundance did not vary significantly among MPA zones or between protected and unprotected areas for either MPA ($F_{6,47} = 2.057$, $p = 0.077$); however, there was a non-significant trend towards greater abundances in the Caye Caulker Marine Reserve Conservation Zone, as well as the Bacalar Chico Preservation Zone and Conservation Zones (Fig. 7). The failure of the detection of statistical significance in these comparisons, however, may be an artifact of low statistical power of these tests given the high observed variability between sites.

A.



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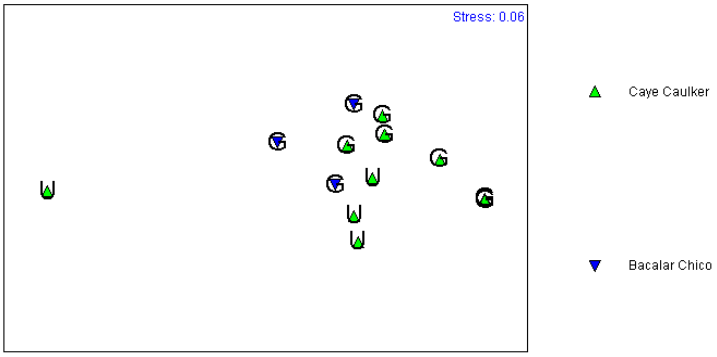

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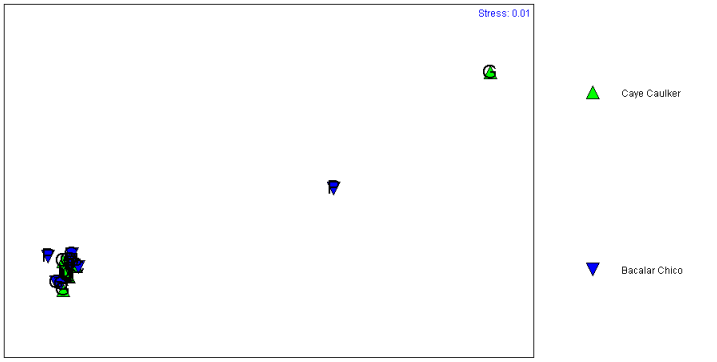

Figure 5. Multi-dimensional scaling (MDS) graphs of variability in community structure between sites according to levels of protection and locations for (A) patch reef, (B) mangrove, and (C) seagrass sites. Location is denoted by the symbol with ▼ marking Bacalar Chico sites and ▲marking Caye Caulker and Control sites. Level of protection is marked with a letter: U = Unprotected, G = General use, C = Conservation zone, and P = Preservation zone.

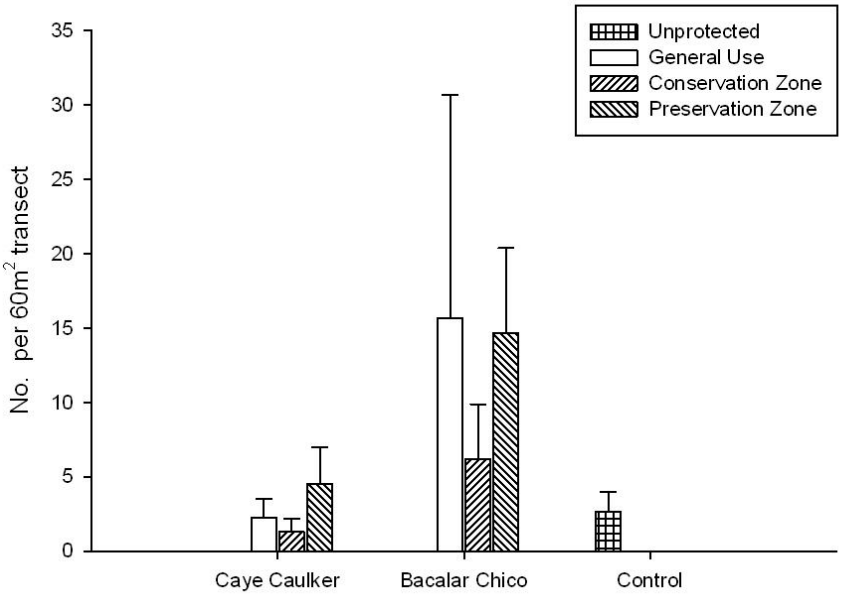

Figure 6. Abundance of target fishery species in each MPA and zone for patch reef habitats.

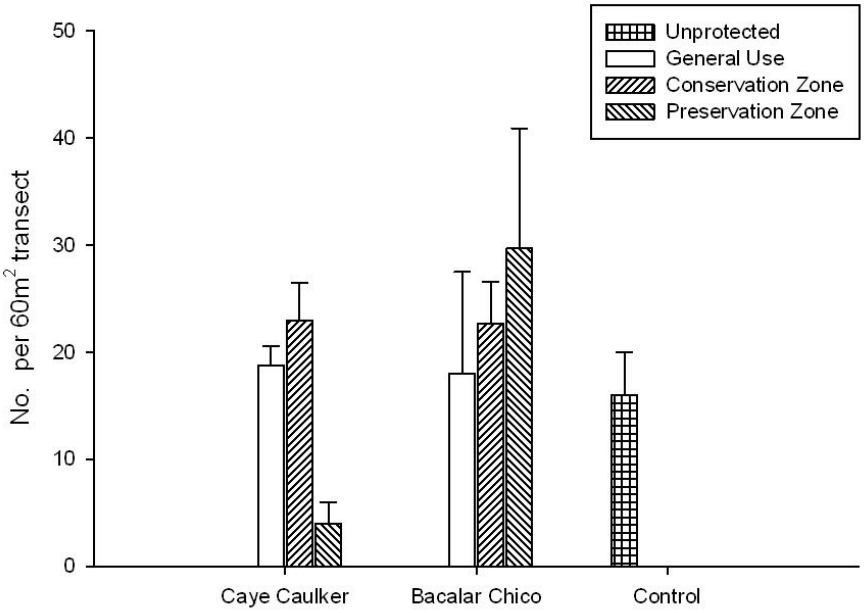

Figure 7. Abundance of parrotfish in each MPA and zone for patch reef habitats.

Key Invertebrates – The sea urchin *Diadema antillarum* was not observed in the Bacalar Chico Marine Reserve, but was observed on patch reef transects in the Caye Caulker Marine Reserve and at the unprotected site. There were no significant differences in *Diadema* density between the Marine Reserve and unprotected site or between zones within the Marine Reserve ($F_{3,8} = 1.458$, $p = 0.290$).

Similarly, lobsters were only observed on 5 transect surveys for a total of 10 lobsters. Seven of these lobsters were observed on the three transects conducted in the mangroves near the Caye Caulker Marine Reserve headquarters dock. The small sizes of these lobsters indicated that they were juveniles. Two adult lobsters (>8 cm TL) were observed at the patch reef site within the Bacalar Chico Marine Reserve and the last adult lobster was observed on a patch reef in Conservation Zone 1 of the Bacalar Chico Marine Reserve.

Benthic Communities – The percent cover of coral, macroalgae, turf algae, and bare substrate (including crustose coralline algae) were compared among MPA zones and the unprotected site for patch reef habitats. The percent cover of live coral varied significantly among sites ($F_{6,13} = 8.596$, $p = 0.001$), but these differences did not correspond to MPA or level of protection. The General Use Zone of the Caye Caulker Marine Reserve had significantly greater % cover of live coral than the Conservation and General Use zones of the Bacalar Chico Marine Reserve, and the Preservation Zone of the Caye Caulker Marine Reserve (Fig 8). Although macroalgae did not vary significantly among MPA or zone, but turf algae did vary significantly ($F_{6,13} = 15.121$, $p < 0.001$) among zones in the different MPAs with the cover of turf algae lower in the General Use zone of the Caye Caulker Marine Reserve than all other zones of either MPA or the unprotected area (Fig. 8). Bare substrate was greatest within the conservation zones and general use zones of the Caye Caulker Marine Reserve ($F_{6,13} = 9.109$, $p < 0.001$; Fig. 8)

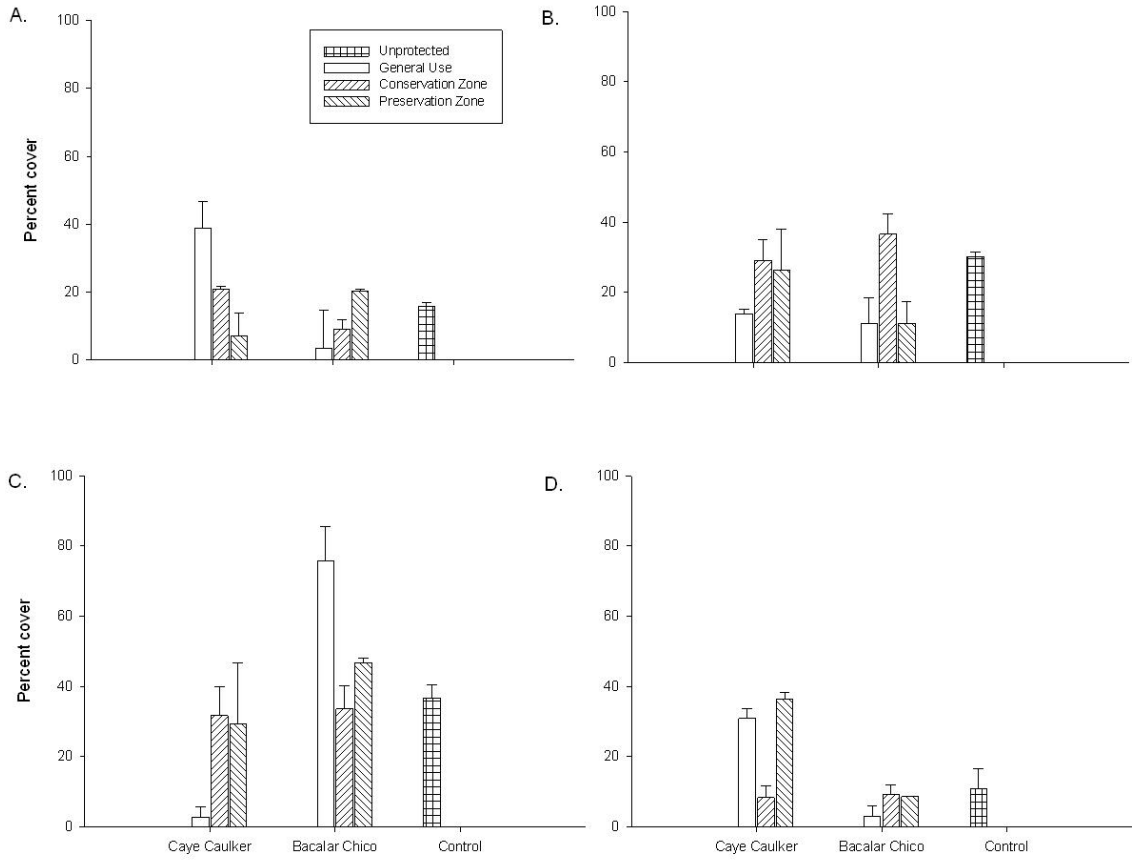

Figure 8. Percent cover of (A) coral, (B) macroalgae, (C) turf algae, and (D) bare substrate (crustose coralline algae + uncolonized substrate) for patch reef habitats within each zone of each MPA and the unprotected control site.

Socioeconomic Indicators

A total of 50 socioeconomic surveys were conducted, with 26 focused on the Caye Caulker Marine Reserve and 24 focused on the Bacalar Chico Marine Reserve. All survey respondents were males, since that was the demographic group most familiar with both reserves. The respondents represented ages from less than 20 years old to more than 70 years old (Table 2). Respondents for the Caye Caulker Marine Reserve were from Caye Caulker. Respondents for the Bacalar Chico Marine Reserve were from San Pedro and northward on Ambergris Caye. Of the respondents from Caye Caulker, 35% visited the MPA more frequently than once per month over the past 5 years (with several making weekly visits), and an additional 31% making several visits each year on average. 23% of respondents, however, report that they have not been inside the MPA in the past 5 years, if ever. For Bacalar Chico, 33% report having visited the MPA more frequently than once per month, on average, over the past 5 years. An additional 38% have visited the MPA several times per year over the past 5 years and only 10% had not visited the MPA in the past 5 years.

Table 2. Age of respondents to socioeconomic and governance survey for the Caye Caulker Marine Reserve (CCMR) and Bacalar Chico Marine Reserve (BCMR). Note that not all respondents provided age information.

MPA	<20	20-30	31-40	41-50	51-60	61-70	70+
CCMR	0	4	8	6	5	2	0
BCMR	1	3	5	4	4	1	2

The majority of the respondents used the sea for a variety of uses. Around Caye Caulker over 80% of respondents used the sea to fish for their own food and to feed there family, but from Ambergris Caye, this number was only 43%. 77% of respondents from Caye Caulker reported commercial fishing activity, as did 67% from Ambergris Caye. No respondents from Ambergris Caye reported non-consumptive recreational fishing and recreational boating or sightseeing, or guiding tourists, but 50%, 38%, and 38% of respondents from Caye Caulker reported recreational fishing, sightseeing, and guiding tourists respectively. In both locations, over water transportation was common with 69% from Caye Caulker and 95% from Ambergris Caye reporting water travel as a main means of transportation. Destinations for this travel varied however, with transportation from San Pedro to the mainland (Corozol, Sarteneja and Belize City being the most common destinations), whereas respondents from Caye Caulker reported some travel to Belize City (5) and Sarteneja (2), but more commonly other nearby islands (6).

Fishing frequency and destinations varied by the type of fishing and location of survey. For example, fishing for personal or family consumption from Caye Caulker occurred primarily on a weekly to monthly basis for most respondents (with only 1 respondent fishing for personal consumption daily and one respondent two times per week) and took place, primarily around Caye Caulker, but also around nearby islands (Caye Chapel, Long Island, Exis Caye). Commercial fishing activities however, occurred daily to multiple times each week for over 84% of commercial fishers for Caye Caulker. While much of this activity occurred around Caye Caulker, a greater proportion of those surveyed reported fishing at nearby islands and one individual fished as far away as Turneffe atoll. Recreational fishing occurred far less frequently (2 times a month or less) and was mostly a local activity.

Respondents near Bacalar Chico that fished for their personal or family consumption fished much more frequently than those from Caye Caulker, with 80% fishing weekly or more frequently. Commercial fishers all reported fishing at least twice each week, with most fishing 4 times per week or more. Destinations for both types of fishing were along the coastline near San Pedro with several fishers reporting traveling to Bacalar Chico.

In both locations, the majority of respondents listed fishing as their primary (Caye Caulker – 58%; Bacalar Chico – 65%) as their primary occupation and an additional 31% from Caye Caulker reported fishing as a secondary occupation. Guiding was another commonly reported occupation for Caye Caulker (35%). For Bacalar Chico, other occupations were varied among respondents. When asked about their sources of income, 54% of respondents from Caye Caulker reported fishing as their greatest source of income and another 31% reported guiding as their greatest source of income. For Bacalar

Chico, all but one commercial fisher reported receiving 100% of their income from fishing and that individual reported 70% of his income from fishing and 30% from construction. Nearly half respondents from both locations reported owning their own business (Caye Caulker – 46%, Bacalar Chico – 53%).

Of the species harvested, 15% of respondents from Caye Caulker and 38% of respondents near Bacalar Chico did not harvest conch. Of those that did harvest conch, harvest for persona consumption was only reported for 9-11% of respondents. Sale to local restaurants was reported by 15% of respondents from Caye Caulker and 9% of respondents near Bacalar Chico. Sale to co-ops was the most common venue for selling conch catch, with 38% of respondents from Caye Caulker and 33% of respondents from Bacalar Chico reporting conch sales to one or more co-op. Grouper were not fished for as commonly as conch with 46% of fishers from Caye Caulker and 81% of fishers near Bacalar Chico reporting not harvesting grouper. Of those that did harvest grouper, personal consumption, sale to local restaurants, sale in Belize City and sale to co-ops were all reported. Even fewer fishers fished for pelagics like dolphin and wahoo, within only 23% of respondents from Caye Caulker and no respondents near Bacalar Chico targeting these fish. Of fishers that harvested these fish, half fished for personal consumption and half for sale at local restaurants. Lobster was the most important commercial fishery species amongst those surveyed, with 69% of respondents from Caye Caulker and 62% of respondents near Bacalar Chico selling their catch to one or more co-op. There was also some sale to local restaurants near Bacalar Chico (19%) and one individual fished for personal consumption at Caye Caulker. Snapper harvest primarily went to local restaurants in both places (Caye Caulker – 42% of respondents, Bacalar Chico – 76% of respondents), but there was also some fishing for personal consumption and one individual near Bacalar Chico reported sales to co-ops.

When asked about their views on the value of marine systems and the need to protect these systems, there was a widespread recognition that there is a need to take care of the sea so that it will provide for us in the future (Caye Caulker – 88%, Bacalar Chico – 100%) and that peoples activities affect the sea and marine life (Caye Caulker – 92%, Bacalar Chico – 90%). In Caye Caulker, respondents recognized non-use values of coral reefs (81%) as well as the importance of mangroves as nurseries (73%) and the importance of seagrass beds (73%). Near Bacalar Chico, respondents were split on non-use value of coral reefs (50% citing value based on use for fishing and diving only and 50% citing other value), and the value of seagrass (35% saying that seagrass beds had no value to humans), but they unanimously agreed that mangroves are important nursery areas. When asked about restrictions on fishing and development, the majority of respondents from both places agreed that limits should be placed on these activities in certain areas (Caye Caulker – 73% supported limitations for both activities, Bacalar Chico – 71% for limitations on development and 76% for limitations on fishing).

Threats from specific human impacts were viewed similarly in both locations, although several activities were viewed as having a slightly greater impact by Caye Caulker respondents than those near Bacalar Chico. Use of chemicals (e.g., bleach), dredging,

cutting mangroves and dumping trash were all viewed as severe impact activities at both sites. Fishing using compressors and discharge from boats were also viewed as high impact activities y respondents from Caye Caulker, but were rated slightly less of an impact by respondents near Bacalar Chico. Coastal development and spear fishing were viewed as having minor to moderate impacts and diving and line fishing were viewed as having no noticeable impact at both locations.

Nearly all respondents from both sites claimed to regularly consume seafood (Caye Caulker – 85%, Bacalar Chico – 67%, with several not answering the question). Seafood consumption by individuals at both sites was generally greater than once per week (Caye Caulker 69%, Bacalar Chico – 81%). At Caye Caulker seafood appeared to be plentiful with only one respondent reporting an incident of not being able to get seafood on a regular basis. At Bacalar Chico, however, several individuals reported the lack of availability of seafood at least once per month. 85% of respondents from Caye Caulker and 81% from Bacalar Chico said that seafood availability has changed in the past 10 years and 62% from Bacalar Chico and 58% from Caye Caulker thought that the MPAs affected seafood availability.

Nearly all respondents from both sites report a decrease in abundance or landings of key fishery resources including conch, grouper, snapper, lobster and pelagic fish such as dolphin and wahoo (Table 3). Only one individual out of everyone surveyed believed that snapper abundance or landings have increased and 2 reported an increase in landings of pelagics.

Table 3. Number of respondents from near the Caye Caulker (CCMR) and Bacalar Chico (BCMR) Marine Reserves indicating change in abundance or landings of key fishery species over the past 10 years.

	Much less	Less	Same	More	Much More
CCMR					
Conch	18	1	2	0	0
Grouper	23	2	1	0	0
Snapper	16	1	2	1	0
Lobster	18	1	2	0	0
Pelagics	8	3	1	2	0
BCMR					
Conch	17	0	0	0	0
Grouper	13	0	1	0	0
Snapper	17	0	2	0	0
Lobster	17	1	1	0	0
Pelagics	2	0	0	0	0

When asked how these same resources varied between the MPAs and surrounding areas, most respondents indicated that there were more in the MPA for the Bacalar Chico Marine Reserve, but there was a mixed response for the Caye Caulker Marine Reserve (Table 4). At Caye Caulker, conch were generally agreed to be more abundant in the

park, but other species received a range of responses. At both sites, however, many respondents did not answer the question because they had no knowledge of the status of resources in the MPAs.

Table 4. Number of respondents from near the Caye Caulker (CCMR) and Bacalar Chico (BCMR) Marine Reserves indicating a difference in abundance of key fishery species between the MPA and unprotected areas.

	Much less	Less	Same	More	Much More
CCMR					
Conch	1	2	1	11	1
Grouper	2	0	2	4	1
Snapper	2	1	0	6	2
Lobster	3	1	1	9	1
Pelagics	1	0	0	2	0
BCMR					
Conch	0	0	1	9	3
Grouper	0	0	3	8	1
Snapper	0	0	2	6	5
Lobster	0	0	0	11	2
Pelagics	N/A	N/A	N/A	N/A	N/A

In general, respondents believed that the Caye Caulker and Bacalar Chico Marine Reserves supported fisheries for conch (73% & 57%, respectively), and lobster (69% & 76%, respectively). Although fewer people had an opinion of the MPAs' role in protecting grouper, roughly half of all respondents believed that grouper left the MPAs to spawn.

Governance Indicators

Both MPAs are somewhat remote from population centers, but the Bacalar Chico MPA is, by far, more remote than the Caye Caulker Marine Reserve. Both have on-site headquarters and management authorities that patrol the MPAs to ensure compliance. The Caye Caulker Marine Reserve headquarters is a facility located at the north end of Caye Caulker. At the time of the ecological surveys, this facility was not in use and had suffered fairly recent storm damage, particularly to its dock. Nevertheless, there was a management presence on the Island of Caye Caulker. At the time of the ecological surveys the Bacalar Chico Marine Reserve headquarters was manned by two staff members. There was also a visitor center with information on the MPA and an interpretive trail on land. The main headquarters was located on the western side of Ambergris Caye and patrols are run to the eastern side regularly. There is also an abandoned MPA management facility on the eastern side of Ambergris Caye, however, during the ecological assessment; there was concern over its periodic use as an outpost by drug traffickers. Apparently the remote location of the Bacalar Chico Marine Reserve immediately adjacent to Mexico has made drug trafficking somewhat of a problem in the area in the past.

During the ecological assessment at Bacalar Chico, the only park visitors were bonefish fishermen with guides who entered the area to fish. These fishers were staying along Ambergris Caye as far south as San Pedro. Visits to the Caye Caulker Marine Reserve occurred daily, primarily tourists visiting Caye Caulker's Shark and Ray Alley and other snorkeling spots. Immediately prior to the ecological assessment at both sites, annual monitoring of conch populations had been conducted by MPA staff and visiting scientists.

When asked survey questions about the MPAs, many of the respondents were able to describe the boundaries for the Caye Caulker Marine Reserve (42%). One respondent from Caye Caulker incorrectly identified the boundaries of the Caye Caulker Marine Reserve, but their response was inclusive of the actual boundaries. For Bacalar Chico, most respondents claimed to not know the boundaries (57%). Of those that claimed to know the boundaries, only one was correct and the rest correctly identified the northern boundary (the Mexico border), but incorrectly identified Rocky Point as the southern extent of the MPA. Rocky Point is actually approximately at the center of the MPA's eastern portion.

69% of respondents from Caye Caulker and 62% of respondents near Bacalar Chico claimed that the rules of their local MPA were clear to them. When asked to identify rules and regulations of their local MPA, most Caye Caulker respondents identified "no fishing" as being a rule (46%) or no spear fishing (8%). 19% did not know the rules and one individual incorrectly claimed that swimming was not allowed in the MPA. Only one individual mentioned that rules varied by zone. For Bacalar Chico, 47% identified no fishing as a rule with an additional 14% citing no spear fishing as a rule and 29% claimed to not know the rules of the MPA. Nobody made mention of rules varying by zone.

Agreement with the rules ranged from 58% from Caye Caulker (38% disagree) to 67% for Bacalar Chico (10% disagree). Compliance with rules, however, was much lower. When asked if people followed rules and regulations, only 23% of respondents from Caye Caulker said yes and 54% said no. For Bacalar Chico, 53% said yes and 29% said no, with several individuals indicating that they thought there was partial compliance with rules. Similarly, 62% of respondents from near Bacalar Chico thought MPA rules were well enforced, but only 15% from Caye Caulker thought rules were well enforced. 35% of respondents near Bacalar Chico claimed that they reported a violation of MPA rules and all but two of those respondents indicated that there was adequate follow-up on their report, with several arrests warnings or fines resulting from their report. At Caye Caulker, 38% of respondents claim that they reported violations of park rules with 70% of those reports resulting in what was believed to be adequate follow-up, including several arrests and warnings (60% of reports), but several instances (40%) of the person reporting the violation not knowing the end result.

When asked which rules they disagree with 2 individuals from Caye Caulker and one from near Bacalar Chico disagreed with rules prohibiting fishing and an additional individual from Caye Caulker specifically disagreed with rules against spear fishing and having spear guns confiscated. 15% of respondents from Caye Caulker disagreed with

some of the boundaries and one respondent disagreed with "all rules" of the Caye Caulker Marine Reserve. A few people took issues with things that are not necessarily MPA rules such as the amount of fishing licenses and prohibition on diving in the Bacalar Chico Marine Reserve (while this is not a rule, they may have meant diving for fish, conch or lobster).

While most respondents from both area believed that science played a role in making management decisions for their local MPA (81% for both sites), the vast majority of respondents from both areas did not feel they were involved in the decision-making process for either MPA. 77% of respondents from Caye Caulker and 71% from near Bacalar Chico had no idea how decisions were made regarding their local MPA. 29% of respondents from near Bacalar Chico and 8% from Caye Caulker believed that their community had input into MPA management decisions. Only one individual from Bacalar Chico and two from Caye Caulker believed that they contributed to the decision-making process for their local MPA. Most respondents from both sites indicated a desire to play a greater role in the decision-making process (Caye Caulker – 85%, Bacalar Chico – 71%).

When asked about how they get their news and information about Belize, the most common media reported from near Bacalar Chico was radio (nearly 100%) followed by word of mouth (38%) newspaper (33%), community meetings (29%) television (19%) and posters or flyers (14%). For Caye Caulker, Television played a much larger role (85%), followed by radio (65%), newspapers (38%), community meetings (12%), posters or flyers (8%) and one respondent reported getting information via the internet and one through word of mouth. News about local MPAs, however, came to people via different media. For Bacalar Chico, only 10% reported getting their information via the radio and only 1 person reported getting information about the Bacalar Chico Marine Reserve through the newspaper. Instead most respondents (67%) reported getting their information about the Bacalar Chico Marine Reserve via word of mouth. For Caye Caulker, sources of information were varied, with word of mouth playing the greatest role (27%) closely followed by newspapers (23%) and radio (19%). Television, community meetings, posters, schools and other sources were also mentioned.

Finally, when asked if their local MPA was protecting marine resources for present and future generations, 81% from Caye Caulker and 90% from near Bacalar Chico said yes and only 12% from Caye Caulker said no (no one near Bacalar Chico said no). When asked if local MPAs benefited local communities 88% from Caye Caulker said yes (12% no), but only 71% near Bacalar Chico said yes (14% no). When asked if they benefited Belizeans in general, 73% from Caye Caulker said yes (19% no) but only 43% near Bacalar Chico said yes (43% no).

Discussion

Ecological assessments of the Bacalar Chico and Caye Caulker Marine Reserves show little difference in fish and benthic communities between MPAs and a nearby control site. Similarly there were no consistent results showing differences in fish and benthic communities based on the level of protection (zone) within either MPA. *A priori*

predictions of greater abundance of target fish, and possibly greater fish diversity, and coral coverage in zones with greater levels of protection (i.e., Preservation Zones>Conservation Zones>General Use Zones≥Unprotected areas) were not observed. While some differences were observed for specific variables in certain zones or habitats (e.g., high coral cover on patch reefs in the General Use zone of the Caye Caulker Marine Reserve), these differences may be due to local environmental conditions or ecological factors that are operating in an area that overlaps with a particular zone, but might have little to do with the protection or allowed uses within that zone.

There were some statistical and anecdotal differences detected between the two MPA sites that are worth noting. The first is that patch reefs in the Bacalar Chico Marine Reserve had high amounts of turf algae, particularly in the General Use Zone. In contrast, zones within the Caye Caulker Marine Reserve had greater amounts of live coral and bare substrate. This finding may be related to the finding of no *Diadema antillarum* in the Bacalar Chico Marine Reserve, but 46 were observed on patch reefs within the Caye Caulker Marine Reserve (with 34 being reported from a single transect). *Diadema* were a major grazer in Caribbean coral reef systems prior to a massive die-off in the early 1980s and populations have been slow to recover throughout their range. Variation in the rate of natural recruitment and survival of *Diadema* between the two areas may account for these differences, but it is unclear what role protective management plays in *Diadema* population recovery rates.

Relatively high abundance of target species within the Bacalar Chico Marine Reserve compared to the Caye Caulker Marine Reserve and nearby control site suggests that the Bacalar Chico Marine Reserve may be more effective at protecting populations of target species on patch reefs. This may be the result of protective management in one reserve being more effective than the other, but there may be other factors responsible for this observation. The relatively remote location of the Bacalar Chico Marine Reserve may reduce overall fishing pressure in the area, regardless of the level of protective management. Furthermore, patch reefs surveyed may be difficult for fishers to access. Because the Barrier reef touches land at Rocky Point within the Bacalar Chico Marine Reserve, small boats fishing in the area do not have an easily corridor to travel in the shelter of the reef. To reach these patch reef sites, fishers would have to go into open water outside the reef south or Rocky Point and return to the shelter of the reef once they are north of Rocky Point. Alternatively they could travel on the lagoon side of Ambergris Caye (western side) and go through the channel that separates Ambergris Caye from Mexico at the northern end of the Bacalar Chico Marine Reserve and then head back south on the eastern side of the Caye to reach these reefs. The first option would put fishers in rough seas for several kilometers and involves two potentially dangerous passages through the barrier reef. The second option involves adding several kilometers to the trip. These factors, plus the great distance of the Bacalar Chico Marine Reserve from any population center may make fishers less likely to fish there, than they are in and around the Caye Caulker Marine Reserve.

Differing fishing pressure at the two Marine Reserves is supported somewhat by socioeconomic surveys which show nearly twice the percentage of respondents from

Caye Caulker were fishers for personal consumption compared to those near Bacalar Chico and Caye Caulker also had a greater percentage of commercial fishers. Furthermore, reports on the location of the majority of fishing activities in the Bacalar Chico area did not specifically include Bacalar Chico, but many fished around Caye Caulker. While few lobsters were seen on surveys, they were a major component of the commercial fishery. This may be because the majority of the commercial lobster fishery uses traps and artificial habitats (i.e., condos or casitas, locally called "shades") in seagrass beds, so few lobsters may make it to natural reefs. On the other hand, the fact that grouper were rarely seen may, at least in part, explain why they are not an as important in the fishery.

In general socioeconomic surveys revealed a close connection with the sea and a dependence on the sea for food and income a large percentage of respondents. There was also recognition that resources have declined recently, that various human activities impact resources negatively, and that actions must be taken to protect and preserve resources. Based on public opinion of the status of resources in both MPAs, it would appear that there is a belief that the MPAs are effective at protection key fishery species. The value of the local MPAs, however, was seen to vary from benefiting local communities to having lesser value for the country as a whole, particularly in the case of Bacalar Chico. This may be because of the remote nature of the Bacalar Chico Marine Reserve making it fairly inaccessible to many Belizeans and tourists.

From a governance perspective, both MPAs are actively managed. The visitor center at the Bacalar Chico Marine Reserve is an excellent resource; however, the MPA appears to have fewer visitors than the Caye Caulker Marine Reserve. At Caye Caulker there are many more visitors, but there is not the land-based facility for providing education and outreach.

While there was a good awareness of both MPAs amongst the general public, the general understanding of the MPA rules, regulations and boundaries could be improved. Particularly for the Bacalar Chico Marine Reserve, where the majority of respondents claimed to not know the reserve boundaries and many that claimed to know them mis-identified them when asked. The knowledge of boundaries was somewhat better for Caye Caulker, but a large percentage of the population could not identify them, even though the majority of those surveyed actively fished in the area. There also needs to be a better understanding of the rules and MPA zoning for both MPAs.

Lack of understanding of the rules and boundaries of both MPAs may be partly responsible for the view that compliance with MPA rules is low, particularly for Caye Caulker. While opinions of compliance were higher for Bacalar Chico, this may be due to the remote location of the MPA and infrequent visits to the area by fishers and others. Enforcement is also a major factor influencing compliance. There was generally a poor opinion of enforcement for Caye Caulker, but a belief that enforcement was good at Bacalar Chico. While this study did not assess the frequency or type of enforcement activities *per se*, anecdotal observations while conducting field work at the two sites were made. At Bacalar Chico, there was a well maintained and staffed headquarters for the

MPA and daily patrols were observed during our short stay there. At Caye Caulker, the headquarters was not in use and its dock was in disrepair, but this may have been due to relatively recent storm damage. In addition, there was less of a management presence on the water, when compared to the overall activity in the MPA. Management authorities were observed approaching boats taking tourists snorkeling at Shark & Ray Alley, but not elsewhere in the MPA.

Despite claims of lack of enforcement at Caye Caulker, however, when potential violations of MPA rules were reported by stakeholders, the majority resulted in what the individual reporting the incident thought was adequate follow-up, which was often some form of penalty (arrest or warning).

Another issue detected in the surveys is that the majority of the respondents felt removed from the decision-making process for both MPAs. Most had no idea how decisions were made regarding MPA boundaries and rules. Several of these individuals also took issue with some of the reserve rules and boundaries. Most respondents also expressed a desire to be more involved in the decision-making process. While many factors may contribute to these sentiments, there appears to be a greater need to inform and involve the public in decision-making. This does not necessarily mean that every stakeholder will have a hand in making rules, but a greater degree of transparency in decision-making and perhaps providing a forum for local stakeholders to at least have their opinions heard may alleviate these issues.

Another factor that may improve understanding of rules, boundaries and decision-making is more effective communication about the MPA. At present, the media used by stakeholders to get their information varies among the two MPAs, with the Caye Caulker public relying on television, radio and newspapers, but the public near Bacalar Chico relying heavily on radio. Information about the MPAs, however reaches the public primarily by word of mouth for Bacalar Chico and both word of mouth and newspapers for Caye Caulker. While word of mouth may always be a part of the way news travels in small island communities, it is problematic in that there is no way of assuring the accuracy of the information being passed on. More effective direct communication from MPA management authorities and partners via the media that is most used locally would greatly facilitate getting accurate information about the MPAs to stakeholders.

Conclusions and Management Recommendations

Based on ecological, socioeconomic and governance evaluation, there are several recommendations that can be made at this time. From an ecological perspective, the quality and quantity of resources was not directly related to the level of protection afforded an area. This may be due to a number of factors including, environmental factors or ecological processes outside the control of management may play a greater role than managing human uses in the MPAs; poor compliance with MPA rules; or that the size of the areas protected or rules within each area are not adequate for positively affecting resources. While this study was not able to determine which of these factors, or combination of factors was responsible for the status of resources within the MPAs, observations of greater fish resources and opinion of better compliance and enforcement

within the Bacalar Chico Marine Reserve than the Caye Caulker Marine Reserve suggest that effectively managing human activities may improve the status of resources. Nevertheless, findings of greater *Diadema* abundance and less turf algae in Caye Caulker suggest that ecological processes and environment also play a great role.

From socioeconomic and governance perspectives, both MPAs have a role to play in conserving resources for the benefit of stakeholders that rely on these resources to feed their families and earn a living. Such a strong connection between the sea and its resources and people makes effectively managing MPAs a priority, especially given the consensus that fishery resources are on the decline and that management is necessary to reduce adverse human impacts. Nevertheless, there is some concern over the benefits that the MPAs provide and/or the efficacy of management. There is also a need for improved communication, education and outreach, as well as transparent decision-making that takes stakeholder input into account.

Specific recommendations include:

- Continued monitoring of fishery resources and benthic communities within zones of both MPAs and control areas outside the MPAs. Currently the conch monitoring program is effective and may serve as a model for monitoring other key species.
- While no changes in management to improve ecosystem health or populations of key species are suggested at this time, alternatives for improved management should be considered if positive changes are not observed in monitoring efforts over the next 5 years.
- Improve communication about the MPAs by using media that effectively targets local stakeholders (television for Caye Caulker and radio for Bacalar Chico). This should be accompanied by an educational campaign to improve knowledge of MPA boundaries, zones and rules.
- Promote greater visitation to the Bacalar Chico Marine Reserve to build awareness of its significance and value to Belizeans and foreign visitors alike. The visitor center is underutilized at present and may serve as an attraction to not only improve education, but the MPA may also provide economic opportunities to local tour guides
- Improve enforcement of the Caye Caulker Marine Reserve. While we did not measure enforcement in any way, public opinion of enforcement and voluntary compliance with rules of the Caye Caulker Marine Reserve is low.
- Provide a better visitor center for the Caye Caulker Marine Reserve that will educate visitors on the significance of the reserve, as well as its boundaries, zones and rules. This visitor center may be located in the current MPA headquarters facility of in the village itself, where it is likely to get greater traffic by visitors and locals alike.
- Reduce the threat of the drug trade for the Bacalar Chico Marine Reserve. While this may be outside the capabilities of MPA management authorities, partnership with law Belize's law enforcement and/or military services may facilitate this.
- Involve local stakeholders in decision-making regarding MPA governance. This may include holding community meetings or other forums for stakeholders to

voice their opinions, establishing stakeholder advisory committees or other activities that increase stakeholder involvement in the MPA.

- Review sustainable funding plans for both MPAs. While these assessments did not specifically examine funding for either MPA, periodic assessments of MPA management costs and revenues from user fees, government funding, grants, and other sources should be conducted. Opportunities such as potential revenues from souvenirs sold at visitor centers should be examined.

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