Annual Report

ANNUAL REPORT OF RESEARCH ACTIVITIES TO THE GOVERNMENT OF BELIZE & PRIMARY NGO PARTNERS FROM THE WILDLIFE CONSERVATION SOCIETY (WCS)

2012

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Acknowledgements

We are grateful to the Departments of Fisheries and Forestry for the research permits extended to us in 2012 and to the support in the field, notably the staff and rangers of the Hol Chan Marine Reserve, Bacalar Chico Marine Reserve, Caye Caulker Marine Reserve, and the Sapodilla Cayes Marine Reserve. Institutionally we wish to thank the staff of the Belize Audubon Society, the Southern Environmental Association, The Toledo Institute for Development and Environment, and the Sarteneja Association for Conservation and Development for support in the field and use of their research stations. We thank the Summit Foundation, the Whitley Fund for Nature and the Belize Diving Services Fund for supporting our field research, conservation and outreach initiatives. Special thanks go to Andrew Wilson and Ben Fitzpatrick for the easy BRUV design that has yielded good results. Special thanks for assistance in fieldwork at the various sites go to fisher partners Angel and Evaristo Muschamp, Orrington 'Tiger' Burgess, and boat captains Dan Castellanos, Alex Garbutt, Leonel "Yogi" Garbutt, Matthew "Tamba" Nicholas, Miguel Alamilla, Kirah Forman, Torben Brydges, Josh Morey, Nelson, James 'Chip' Petersen and to Brendan Godley for identifying capable MSc students. We are grateful for the unstinting support from the staff at Belize Diving Services, to Shelley Ashley and Ecologic Divers, and to Adam Lloyd for mapping support.

This report should be cited as: Graham, R.T., Salazar, H., Muschamp, E., Garbutt, A., Castellanos, D., Strindberg, S., Seymour, A., Philpot, K., O'Brian-Moran, C., Lees. K. 2012. Annual Technical Report to the Government of Belize. Wildlife Conservation Society, San Pedro, Belize. 24p.

Summary of Results

Large marine vertebrate surveys conducted in 2012 across three distinct habitats and nine protected areas throughout Belize using three methodologies assessed the relative diversity and abundance of target species and the role of MPAs in providing protection from fishing or capture. Species surveyed included sharks, rays, turtles and piscivorous fish and methods included underwater visual census transects (n = 182), baited remote underwater video (n = 204) and fisheries independent longline surveys (n = 92). Survey results suggest that habitat plays an important role in stratifying diversity and abundance for numerous species with an increase in diversity and abundance from West to East and from national borders to Belize's center. Lack of difference in catch per unit effort between protected and unprotected areas for all surveyed species and estimates of piscivorous finfish biomass actually suggest a lower total biomass inside protected areas compared to open access areas. These findings suggest that the current incarnation of Belize's MPAs are not affording sharks, rays, turtles and large piscivorous fish sufficient protection. Expansion of MPA size and of the no-take zones as well as national measures to curb and/or ban unsustainable fishing gears (e.g. nets and longlines) and renewed vigor in enforcement are suggested as key means to better protect vulnerable marine megafauna.

Research Objectives - 2012

In 2012, we aimed to continue working on our core mission to conserve sharks through research and monitoring augmented by outreach, education, training and capacity building, and policy support. We specifically set out to conduct:

1. Annual monitoring of elasmobranchs at Lighthouse Reef Atoll and capacity building of new partners
2. Create a fisheries-independent baseline for sharks and rays in Northern Belize
3. Assess the effectiveness of MPAs in the protection of marine megafauna throughout Belize using multiple survey methods
4. Raise awareness for marine megafauna conservation in the public and specific sectors (fishing, academic, conservation community)
5. Support the development of regional and international policies favoring the effective management of elasmobranchs.

Study sites and methods

All research and surveys were conducted throughout the Belize Barrier Reef System (BBRS), the second largest barrier reef system in the Western Hemisphere. Data presented in this report were collected over a 12-week period from March to mid June 2012 and encompassed sites in northern, southern and offshore Belize (Figure 1). Of the country's 14 marine protected areas, surveys were conducted inside and out of nine protected areas included Caye Caulker, Gladden Spit, Sapodilla Cayes and Lighthouse Reef Atoll's Blue Hole and Half Moon Caye, Hol Chan and Bacalar Chico, Port Honduras as well as the Corozal Bay Wildlife Sanctuary. Although Port Honduras and Corozal Bay were sampled, a lack of visibility hampered survey efforts.

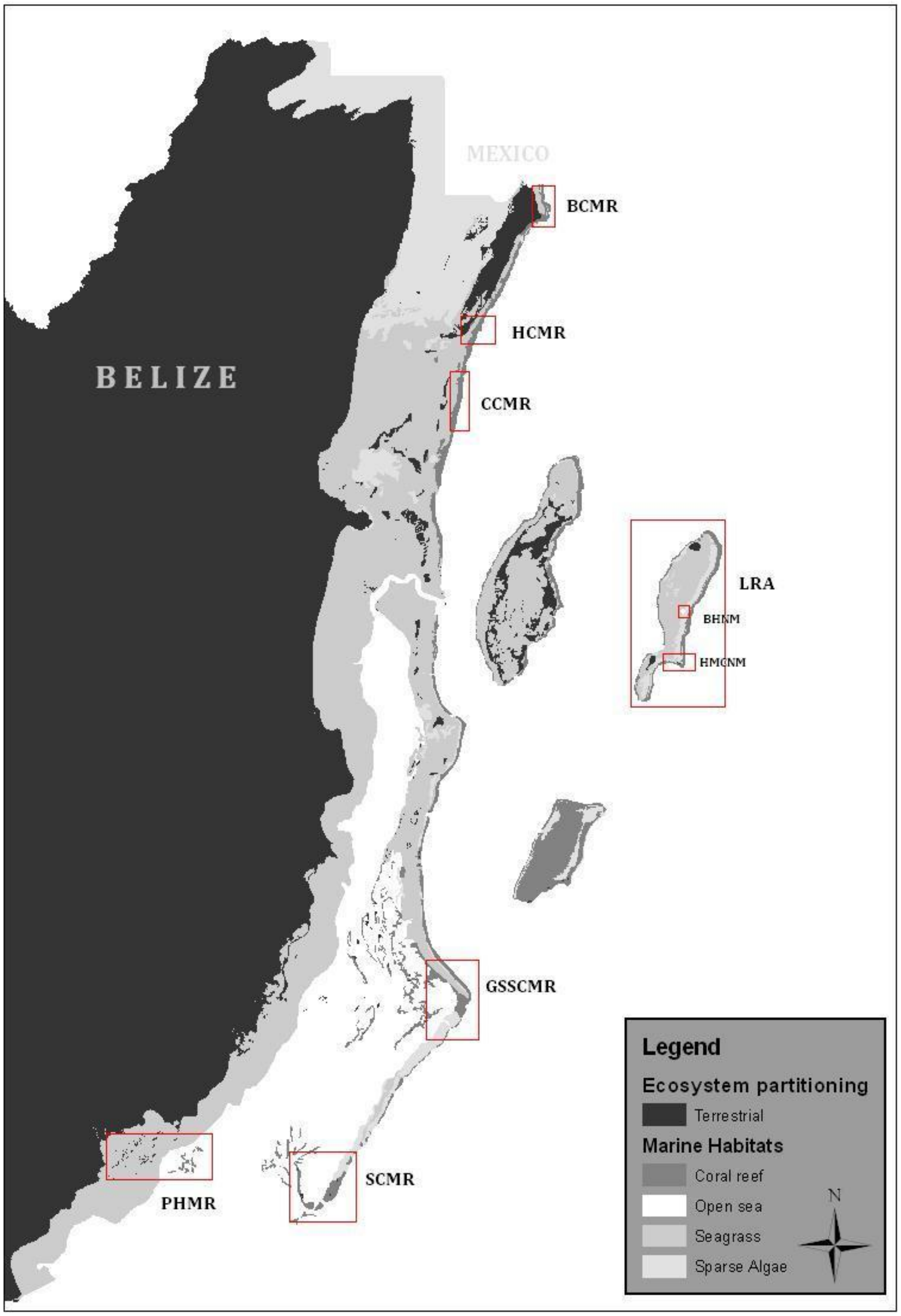

Figure 1. 2012 Megafauna rapid assessment study sites throughout Belize.

Survey locations were developed by Graham and Strindberg derived using a stratified random survey structure that covered three habitat types (lagoon/seagrass, backreef and patch reef, and forereef) and location for robust statistical analyses of results (See Appendix 2 for survey locations). Methodologies were standardized throughout the country and sites. Northern Belize fisheries-independent longline surveys were initiated in September but were not completed until early 2013. These data are being processed and will be available in the 2013 Research report.

Underwater Visual Census (UVC)

Prior to carrying out snorkeling transects all swimmers were required to undertake a size and distance estimation test on land and underwater to ensure that measurements were within a tolerable range of accuracy. Estimations were required to be within 10% of the correct measurement to be deemed acceptable for transect surveys. Transects were carried out at pre-decided start coordinates. Each survey team consisted of four snorkelers spaced 15m apart, swimming parallel to each other southwards for 1000m – thus creating a 60m x 1000m belt transect. Each surveyor swam in a straight line and recorded all turtles observed in his/her individual belt transect (7.5m to the left and 7.5m to the right of the swimmer's transect line), the distance of each animal sighted from the transect line was estimated thus avoiding pseudoreplication of individuals sighted by two different swimmers. Upon sighting an animal the species, sex, estimated minimum straight carapace length (SCL_{min}, cm), and specific habitat type being utilized by the animal were recorded on underwater slates.

Baited Remote Underwater Video (BRUV)

BRUV / transect replicates were conducted at the predetermined survey locations generated in the stratified random survey plan. Each point was systematically separated in order to ensure independence of results and prevent interference of the bait plumes. Sufficient replicates were allocated to ensure a robust nature of the study. Each survey point corresponded to the location of a BRUV deployment (n=204), as well as the transect start point (n=157). BRUV deployments and transects were never done simultaneously at the same GPS point or within a 1km radius of any active deployment. In some instances inclement conditions (sea condition, visibility) did not permit transects to be completed at all replicate sites during the time permitted, hence n BRUV > n UVC. At other sites, e.g. Sapodillas Cayes Marine Reserve (SCMR), it was not possible to complete sufficient 'non-protected' replicates and the data has consequently been excluded. Aside from being divided into protected and non-protected areas, sampling effort was split between the three coarse habitats, fore reef (1), patch reef / back reef (2) and sea grass / lagoon (3). This would allow any habitat effect on elasmobranch presence / abundance to be examined as explanatory variables and increase the robustness of the observations.

A minimum of one hour was left between BRUV deployments and snorkel transects at the same point to reduce disturbance effects confounding the results of either method. For a description of the BRUV unit see Appendix 1. A single BRUV unit was deployed at each transect start point and was placed on the sea-floor by a free-diver to ensure stability and maximum spread of the bait plume using the prevailing current. BRUVs were left to soak for a minimum of 65 minutes: allowing a five minute adjustment period after the disturbance caused by deployment and a 60 minute total recording time. Each BRUV video was analysed by two observers, maxN of each species in frame at the same time was used to calculate the total number of target species per video.

All of the BRUV recordings were watched in regular speed play-back by two specialist observers. The first 5 minutes were omitted in order to allow for fish activity and sediment to return to an undisturbed state and the subsequent 60 minutes were analysed. Elasmobranch presence on screen was annotated in a video time log in order to permit future referral. Abundance was quantified according to MaxN - where only the maximum number of a given species seen at any one time was recorded. This method generates a conservation estimate of abundance but avoids pseudoreplication of individuals. However, where distinguishing characteristics, size, and / or markings allowed individuals to be discerned from one another, the total number of individuals was recorded.

Longline survey

Fisheries independent longline deployments were conducted at Lighthouse Reef Atoll and throughout Northern Belize using preset station points with a stratified random survey plan. The deployment method is standardized with the floating longline is paid out by hand that consists of 50 x 4m gangions with terminal circle hooks. Sets of five gangions are interspersed with buoys to suspend the longline. Soak times were kept to 90 minutes and all captured animals were brought boat-side for measurement, sexing, sampling and tagging with conventional numbered rototags prior to release, as described in previous reports.

Statistical analyses

Longline surveys were assessed through catch per unit effort or Number of sharks/100 hooks/ hour of soak. With high variability in set captures at Lighthouse, CPUE was log transformed. These results were compared to previous CPUE results from LRA to assess inter-annual changes in abundance of sharks.

R statistical software was used to analyse data (R Project v. 2.14.2) derived from UVC transects and BRUVs. Generalised Linear Mixed Modelling (GLMM) tests were used to analyse the effect of habitat type, protection status and study site on the presence of turtles, rays and sharks (a binomial error structure was utilised and study site was a random effect).

Results

Annual Elasmobranch Monitoring at Lighthouse Reef Atoll

From 30 April to 8 May we conducted our annual elasmobranch monitoring with longline sets deployed for a total of 1718 hooks and 54.3 hrs of soak time throughout forereef, reef pass and lagoon habitat in the atoll (Figure 2). Set captures ranged from 0 to 11 sharks per set with “0” sets dominant (Figure 3). A total of 74 elasmobranchs across three species were captured Table 1) with clear dominance of catches by Caribbean reef sharks. Small size classes dominated with 67% of all captures classified as juveniles under 165cm, the minimum size at maturity for males (reach maturity earlier than females) at LRA based on our records of clasper calcification versus total length (Figure 4). Notably no captures of Caribbean reef sharks over 220 cm total length were made in 2012. Log transformed catch per unit effort reached 0.34 sharks/100hooks/soak hour representing a decline from 2011 CPUE of 0.4. Captures were concentrated in the two protected areas of Blue Hole and Half Moon Caye and along the eastern edge of the southern arm of the atoll (Figure 5). Notably there were no captures on the southern tip or the southern and mid western wall where sharks were frequently captured during previous annual surveys (Figure 2). The relative scarcity of nurse sharks in captures is due primarily to low sampling effort in lagoon versus forereef habitats.

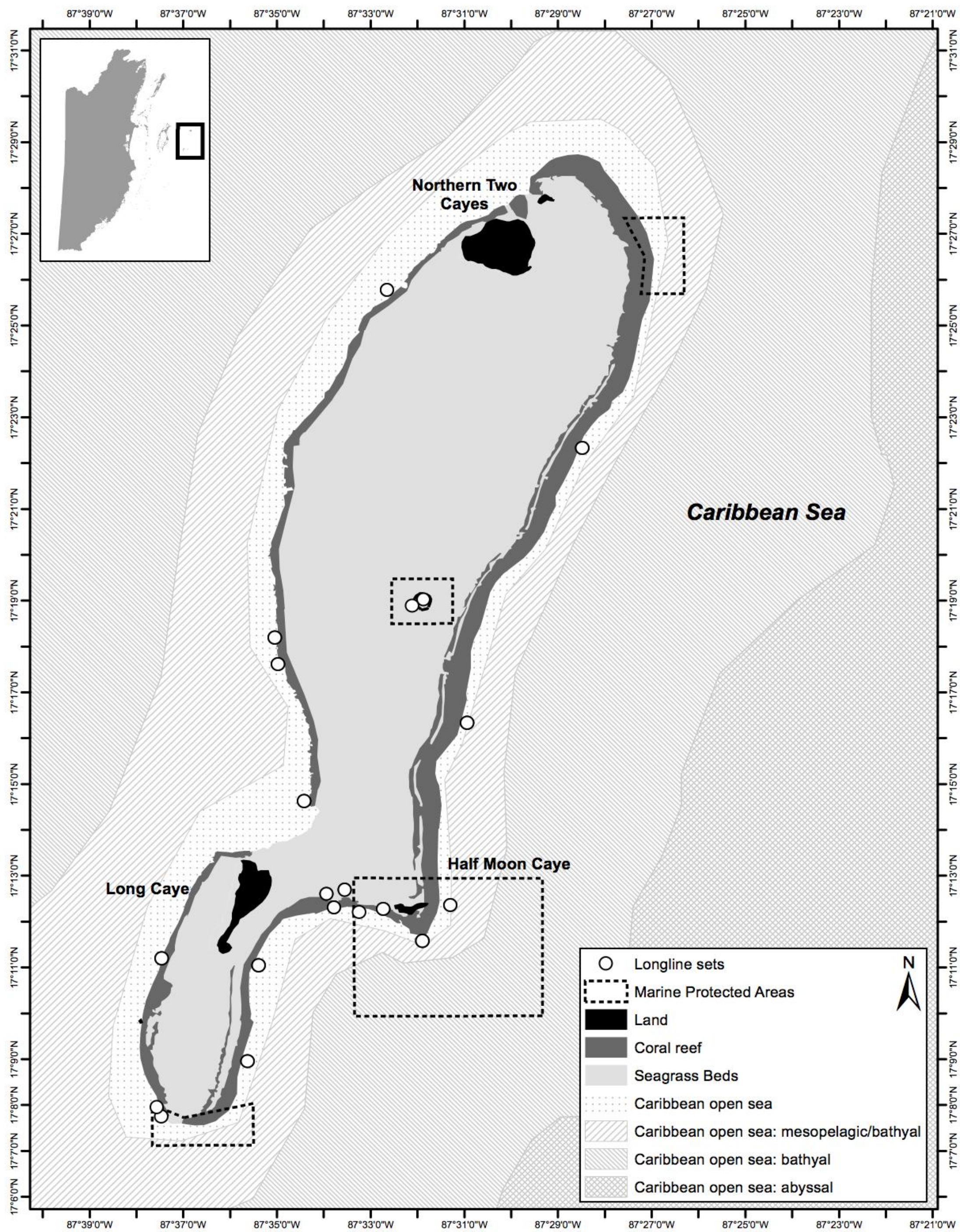

Figure 2. Longline set locations during the 2012 Annual Elasmobranch Survey at Lighthouse Reef Atoll.

Table 1. Elasmobranch captures at Lighthouse Reef Atoll per species and sex

	Total #	M	F
Carcharhinus perezi	70	28	41
Ginglymostoma cirratum	3	2	1
Rhizoprionodon porosus	1	0	1
Total	74	30	43

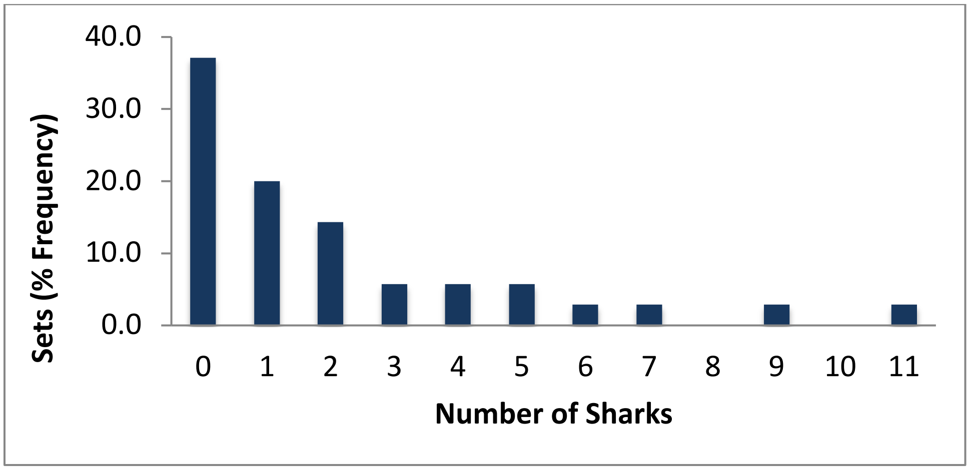

Figure 3. Frequency of "0" versus positive sets with shark captures during the 2012 Annual Elasmobranch Survey at Lighthouse Reef Atoll.

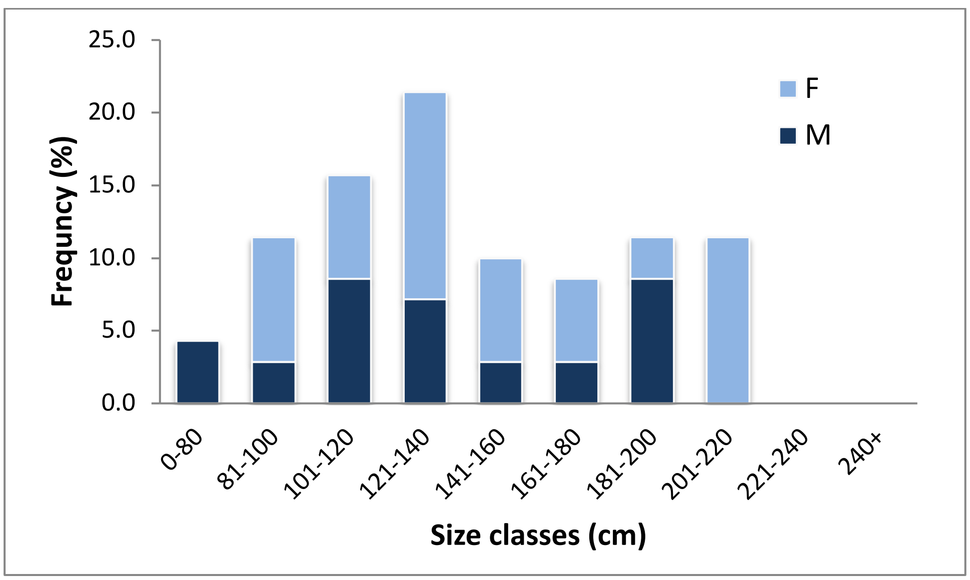

Figure 4. Size frequency of male and female *Carcharhinus perezi* (n = 70) captured during the 2012 Annual Elasmobranch survey at Lighthouse Reef Atoll. 67% of all captures were below the minimum size at maturity for males captured at LRA. Male Caribbean Reef Sharks reach sexual maturity at a smaller size than females.

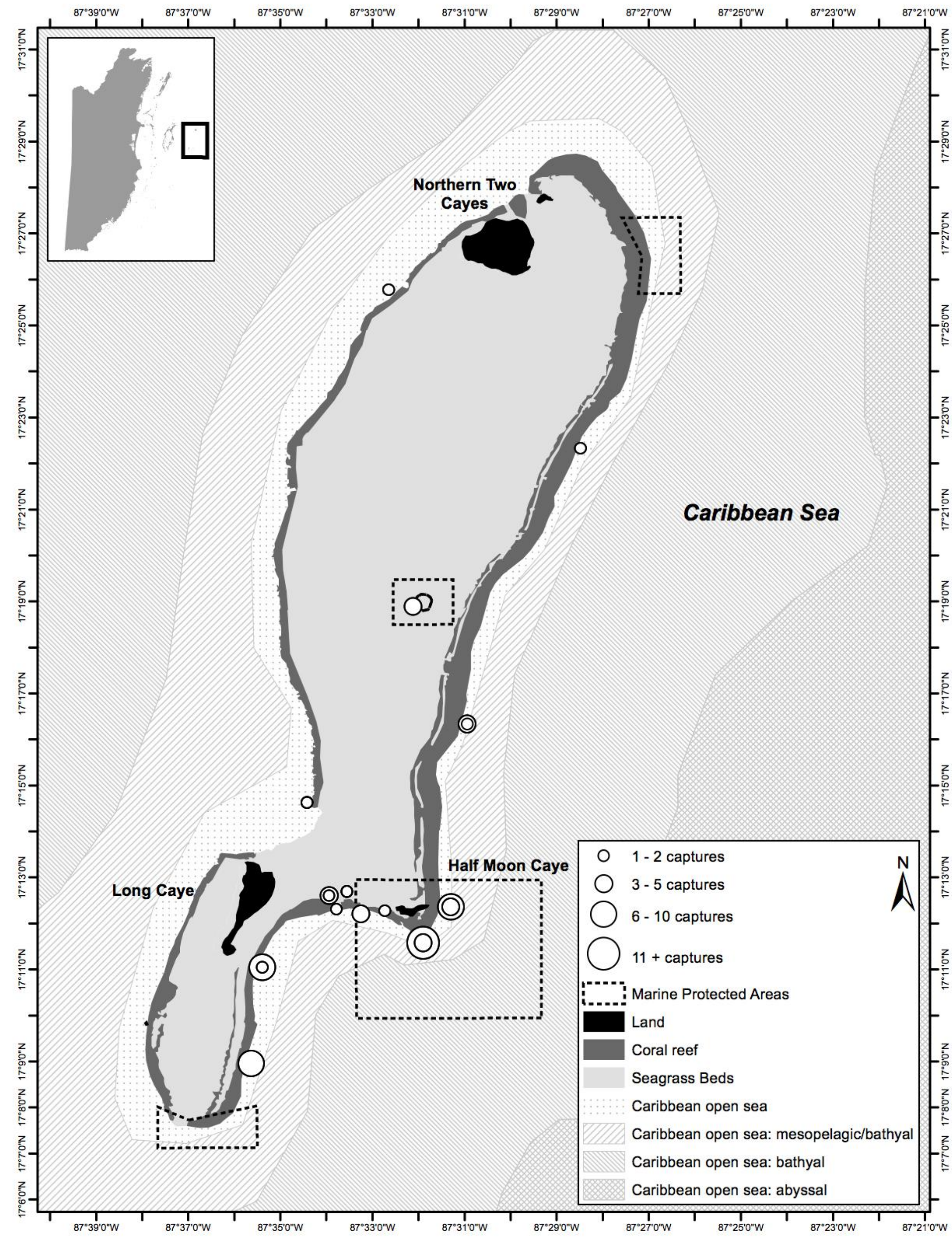

Figure 5. Shark captures during the 2012 Annual Elasmobranch Survey at Lighthouse Reef Atoll.

Assessment of sharks and rays using BRUVs and UVCs – Alexander Seymour

During the survey we deployed 204 Baited Remote Underwater Video (BRUV) systems (Appendix 1 for descriptive image) across seven sites that were selected in order to sample a variety of MPAs throughout Belize. BRUV deployments generated a total of 12,240 minutes of analyzable footage [total soak time-period of adjustment] (Figure 6). Of these, 43 deployments resulted in at least one shark being observed (1 / presence) and 162 contained no sharks (0 / absence). In addition 157km of belt transects were completed, generating an overall area surveyed of 9.42km$_2$. Catch Per Unit of Effort (CPUE BRUV-1 / transect-1) was calculated for both methodologies.

Out of the 43 positive BRUV deployments, 26 contained an individual shark and 17 were confirmed as having 2 or more sharks present in the recording. A total of 6 different species of shark were observed during analysis. These species pertained to 3 different orders, - carpet sharks (orectolobiformes), ground sharks (Carcharhiniformes) and guitarfishes (rajiformes). Nearly 99% of all sharks observed on BRUV recordings belonged to either the carpet sharks (47%) or ground sharks (51%). Nurse sharks (*Ginglymostoma cirratum*), a protected species in Belize, constituted 32 of the 68 sharks observed across all recordings. Caribbean reef sharks occupied the second most prevalent species (n=28) found during this study.

Caye Caulker Marine Reserve (CCMR) recorded the highest species richness of all sites, however, it was found to be higher outside the protected area than inside. The lowest species richness was found in those sites at the geographical periphery, Bacalar Chico Marine Reserve (BCMR) and Port Honduras Marine Reserve (PHMR). The data indicated that on the barrier reef, there is to some extent a positive correlation between levels of diversity and distance away from national borders. Lighthouse Reef Atoll possessed appreciably higher rates of reef shark abundance than all other sites (Figure 7).

44 sharks were observed during the completion of UVC surveys. These sharks belonged to 3 families across 2 orders (carpet and ground sharks). CPUE was calculated as the number of sharks observed per transect / km. The effect of protection was also found to have a non-significant impact on shark abundance according to the transect methodology (χ21=0.068, p=0.79), which corroborates the results accrued from BRUV recordings. However, latitude as a solitary variable was found to affect overall shark abundance significantly (χ25=6.11, p<0.05), and this was reaffirmed by their respective CPUE's, which was 3 times greater in the south (0.35) than the north (0.11).

Figure 6. Sample images of elasmobranchs captured on BRUVs deployed throughout the Belize Barrier Reef in 2012.

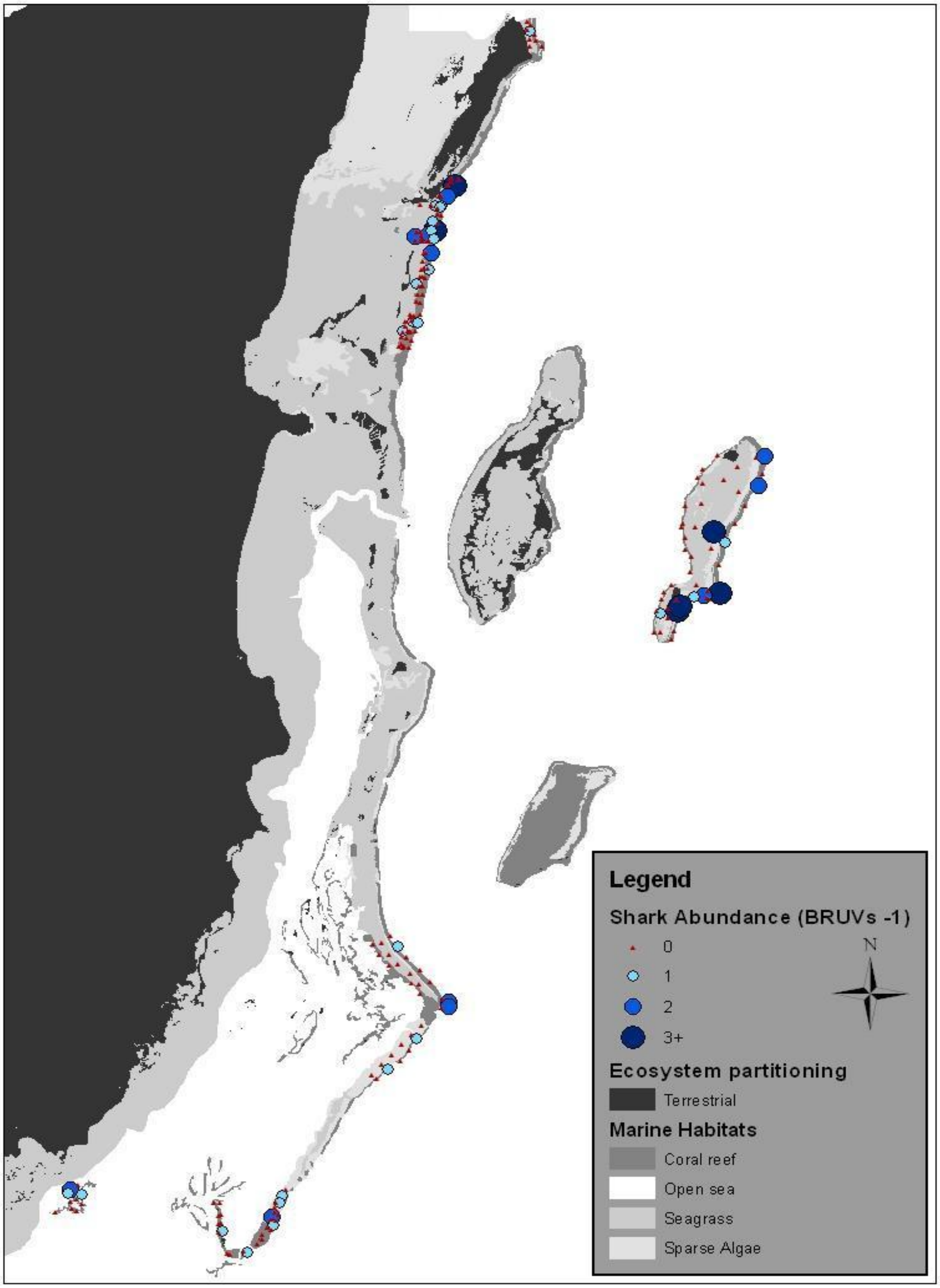

Figure 7. Shark abundance per *MaxN* recorded on 204 Baited Remote Underwater Videos deployed throughout Belize between March and June 2012.

Rays – Kate Philpot

Over the study duration 182 transects were carried out on which 546 rays were observed. Species recorded included the Southern Stingray (*Dasyatis americana*), Yellow Spotted Stingray (*Urobatis jamaicensis*), Spotted Eagle Ray (*Aetobatus narinari*) and the Caribbean Whiptail (*Himantura schmardae*). Southern Stingrays, Yellow Spotted Rays, Caribbean Whiptails and Spotted Eagle Rays were all distributed as far North as Bacalar Chico and as far South as Sapodilla Cayes, Yellow spotted stingrays were not observed at the Eastern most study site of Lighthouse Reef Atoll.

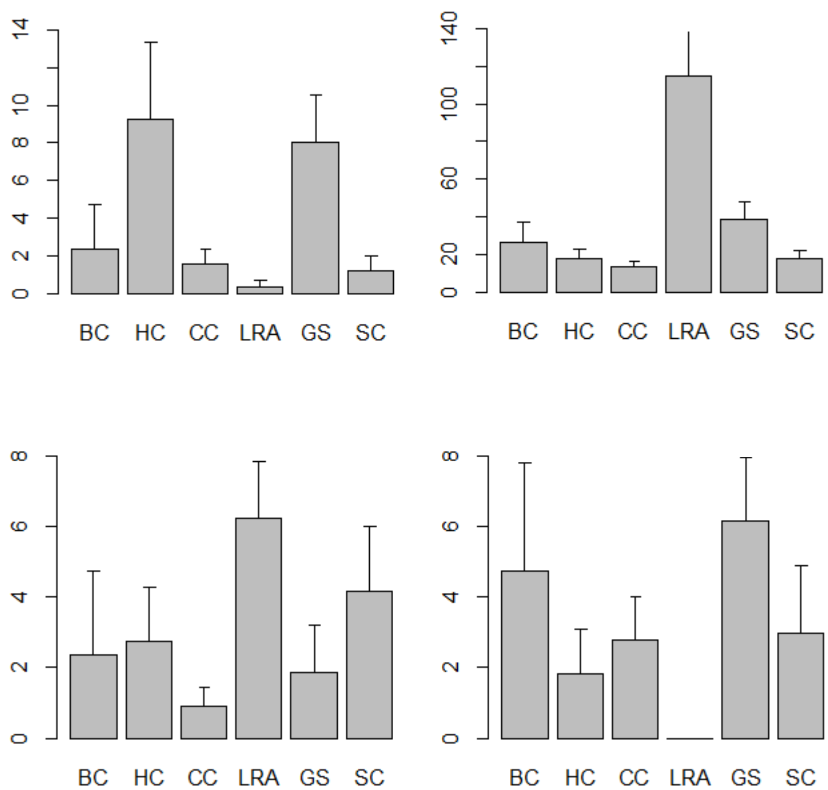

Figure 8. Catch per unit effort of rays recorded throughout six regions of Belize between March and June 2012.

LRA had the highest catch per unit effort (CPUE) (Number of rays per km$_2$) for Southern (113.5/km$_2$) and Spotted Eagle Rays (5.9/km$_2$), and Caye Caulker had the lowest CPUE for both Southern (12.7/km$_2$), and Spotted Eagle Rays (0.9/km$_2$). Caribbean Whiptails had a CPUE ranging from 9.3/km$_2$ at Hol Chan to 0.3/km$_2$ at Lighthouse Reef Atoll. Gladden Spit had the highest CPUE of Yellow Spotted Stingrays (6.2/km$_2$) (Figure 8).

Estimated disc width for Southern Stingrays (n=469) ranged from 18cm to 121cm with a mean of 53.2cm ± 16.0 s.e. Spotted Eagle Rays (n=31) ranged from 56cm to 175cm with a mean of 108.4cm ± 25.9 s.e.

Yellow Spotted Rays (n=24) ranged from 10cm to 40cm with a mean of 19.92cm ± 6.9 s.e. and Caribbean Whiptails (n=22) were estimated to range from 46cm to 165cm with a mean of 96.32cm ± 28.1 s.e.

The number of male and female observations of Southern Stingrays (X^2_1=27.3246, p<0.001), Caribbean Whiptail (X^2_1=12.5, p<0.001), and Spotted Eagle Rays (X^2_1 =8.7576, p<0.01) were all significantly different with significantly more females being seen. Yellow Spotted Rays showed no significant difference between numbers of males and females (Figure 9).

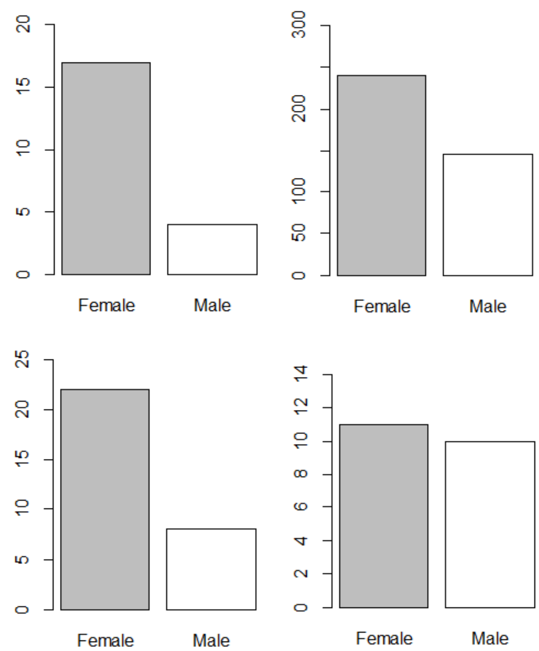

Figure 9. Differences in observations by sex for four ray species surveyed throughout Belize between March and June 2012.

Piscivorous Fish – Kimberly Lees

BRUV surveys (n=204) yielded identification of 32 piscivorous species of non-cartilaginous fish from 9 families: Carangidae, Lutjanidae, Serranidae, Scombridae, Sphyraenidae, Megalopidae, Rachycentridae, Muraenidae and Echeneidae. No difference was found in species richness or total abundance between protected and open access areas, and an estimate of biomass actually suggested a lower total biomass inside protected areas compared to open access areas. Of the four main families observed (Carangidae, Lutjanidae, Serranidae and Sphyraenidae), none were significantly more common in protected areas. Biomass estimates indicated a potential increase in Serranid biomass within protected areas, and a decrease in Carangid and Lutjanid biomass. The data suggests that the Belizean MPA network is currently not sufficient to maintain the piscivorous fish populations in the face of ever increasing human-induced pressures. Loss of the piscivorous fish populations and the ecosystems surrounding it could cause top-down effects, resulting in problems for both the marine life and the local communities that depend on the barrier reef.

A total of 1810 piscivorous fish from 32 species and 9 families were recorded on 201 baited remote underwater video deployments throughout Belize. Each deployment recorded an average (+/- SD) of 3.45 +/- 2 species, with a range of 0 to 9. Species composition varied across the deployment locations with approximately 78% of species seen at less than 20% of sites. The most common species were bar jack (*Caranx ruber*), yellow jack (*Caranx bartholomaei*), great barracuda (*Sphyraena barracuda*), mutton snapper (*Lutjanus analis*), Graysby (*Cephalopholis cruentatus*) and Coney (*Cephalopholis fulva*), with only one species, Bar jack, seen at more than half the sites. Abundance (MaxN) varied considerably between the four major families observed (Carangidae, Lutjanidae, Serranidae and Sphyraenidae), with jacks often seen in large schools, and much variation at both the species and family level between study sites. The four major families were recorded both within and outside of all protected areas surveyed across the country. None were significantly more prevalent at any study site over others. This indicates a nationwide distribution for these families, both in terms of moving along the coast, and moving between coastal, reef, and atoll sites. A species accumulation curve for all deployments approaches asymptote, indicating that most species that could have been observed were detected, however curves for individual sites indicate that more replication in some sites may have been beneficial.

There was no significant difference between protected and unprotected areas for species richness (X^2 = 0.091, d.f. = 1, 4, $p = 0.764$) or abundance (X^2 = 0.033, d.f. = 1, 4, $p = 0.855$) across all deployments. However estimated biomass was significantly higher outside of protected areas (X^2 = 15.444, d.f. = 1, 4, $p < 0.001$). At the family level, Carangidae and Lutanidae were slightly more common in unprotected areas, and Serranidae and Sphyraenidae (one species seen, great barracuda) were more common in protected areas. None of these differences were statistically significant resulting in no effect of protection on the 4 major families of piscivorous fish observed.

Turtles – Caoimhne O'Brian

The results of 182 UVC transects yielded abundance (total number observed using in-water transect surveys) for each species at each study site. Hawksbill turtles made up the majority of animals seen (n = 81), while loggerheads were rarely encountered (6.6% of transects).

Lighthouse Reef Atoll was the site with the highest overall turtle abundance for transects (n = 60). The location of each site can be observed in Figure 10, which maps the relative abundance of each species at each site. Statistical analyses were carried out on overall turtle abundance, as due to the small size of the individual species datasets it was not possible to successfully model for each species.

A one-way ANOVA was used to determine if protection status had an effect on the total abundance of turtles observed but the results were not significant: $F(1, 155) = 0.18$, $p = 0.673$. In order to perform more robust analyses it was necessary to convert data to binary form and simply test turtle presence/absence on transects. It was found that habitat type has a significant effect on the presence of turtle species (mixed effects model test using maximum likelihood of minimum adequate model, ANOVA x_2 (2, 4) = 34.134, $p < 0.001$), with both seagrass and patch reef habitats being significantly less likely to have turtles present than fore reef habitats. There was no significant effect of protection status on the presence or absence of turtles (mixed effects model test using maximum likelihood of minimum adequate model, ANOVA x_2 (1, 5) = 0.0542, $p = 0.816$).

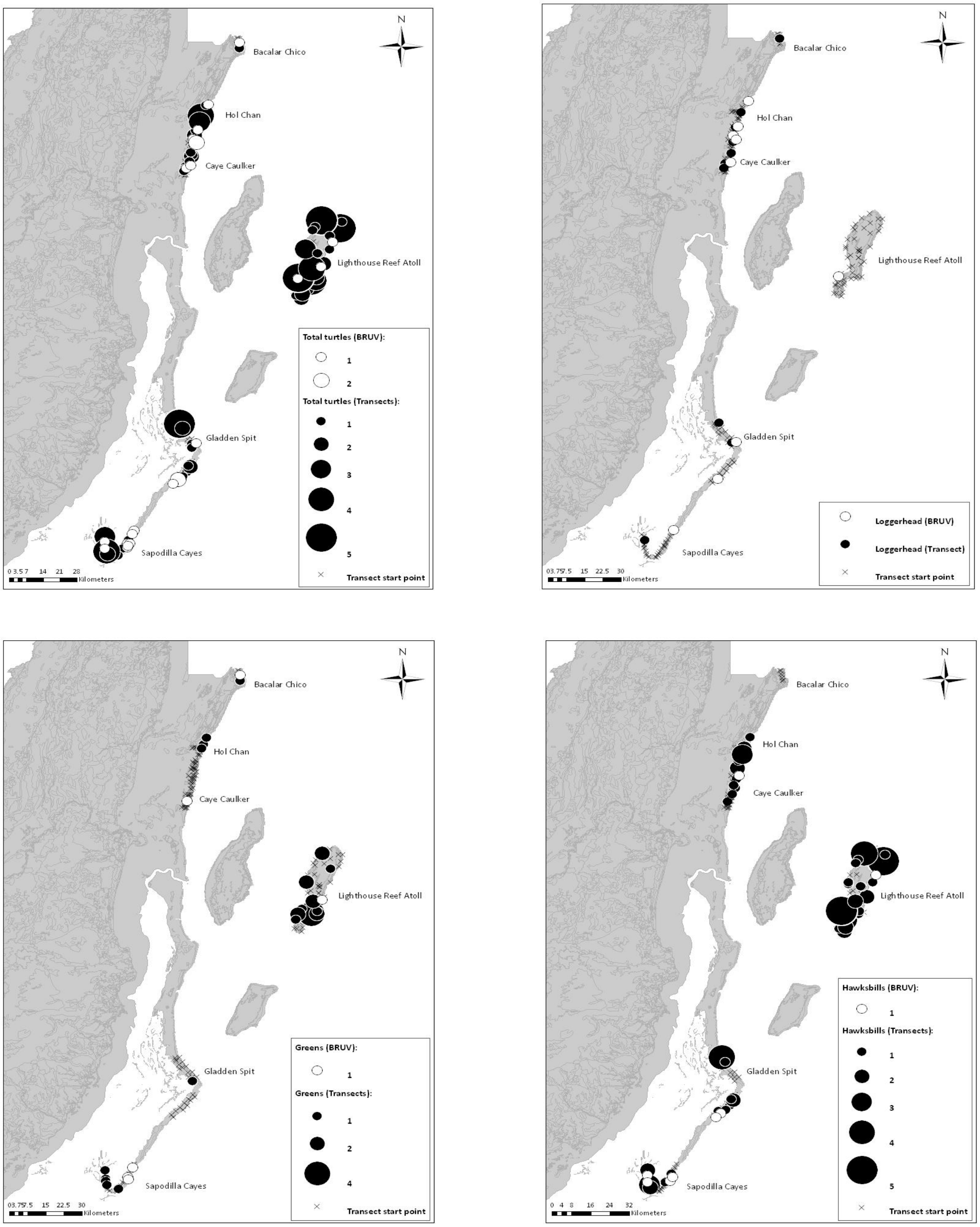

Figure 10. The abundance (total number) of a) all turtle species, b) loggerhead, c) green, d) hawksbill turtles at six study sites across Belize using BRUVs and UVC transect surveys.

Results from the UVCs showed overall lower abundances of turtles inside MPAs than in adjacent unprotected areas; there was no significant effect of protection status on turtle presence (GzLMM, ANOVA x^2 (1, 5) = 0.0542, p = 0.816). The site with the highest CPUE was Lighthouse Reef Atoll, it is hypothesized that this may be due to the spill-over effect of the two no-take MPAs encompassed by this study site. It is recommended that the no-take zones of all the surveyed MPAs are extended and a review of the enforcement of fisheries regulations is undertaken. In addition, the use of baited remote underwater video as an alternative to UVC was investigated. It was found that BRUV can provide a low-disturbance technique for measuring species richness but may greatly underestimate animal abundance (Total turtles observed using BRUV n = 24; UVC n = 121). Morphometric data collected simultaneously indicate that Belize provides important developmental habitat for green and hawksbill turtles and may act as a foraging ground for adult loggerheads. There was no significant effect of habitat type on turtle size (SCL_{min} (cm)).

Outreach

Through our Kids Meet Sharks Program we introduced 20 high school children from Chunox and 20 primary school (STD VI) children from Punta Gorda to their Barrier Reef and to sharks and rays. The Punta Gorda children also visited the Belize Zoo to learn about terrestrial predators and expanded their horizon and independence by spending their first overnight away from home at the Tropical Education Center. Hilmar Salazar, Community Coordinator from Sarteneja ran the successful and popular shark and ray booth at the popular Sarteneja Annual Easter Regatta.

During 2012, we worked with rangers and biologists from four NGOs (BAS, TIDE, SEA and SACD) and the Hol Chan Marine Reserve. We trained 7 new fishers, 8 guides/captains, one promising high school intern, one MAR leader and regional partner in field methods. Rachel T. Graham co-supervised four MSc students from the University of Exeter (Alexander Seymour, Kate Philpot, Caoimhne O'Brian-Moran, Kim Lees) who are listed as co-authors in this report.

The Belize Shark Project produced or co-authored five publications including two peer-reviewed papers (Appendix 3) and reviewed five peer-reviewed papers for international journals and numerous reports and briefs. We held seven community-based presentations on sharks and rays and presented in two international conferences (International Coral Reef Symposium, Cairns Australia and MarCuba congress, Havana, Cuba) and one international symposium (International Sawfish Workshop, London, UK).



Images of the Kids Meet Sharks Punta Gorda event in 2012

Policy Support

As Lighthouse Reef Atoll has some of the healthiest populations of Caribbean reef sharks in the country that in fact seed other parts of the reef, we provided the impetus and justification for a gear ban on the use and nets and longlines for Lighthouse Reef Atoll (out to 5 nm form the forereef crest) to Belize Audubon Society partners and GOB that would match the regulations of MPAs previously declared to encompass Turneffe Atoll and Glover's Reef Atoll, and we will be championing this effort with Government partners. At a regional level, we participated in the regional elasmobranch management OSPESCA meeting in San Pedro Sula, Honduras, where whale sharks and sawfish were proposed as protected species throughout Central America. In the run up to the Conference of the Parties for the 16th Convention on International Trade in Endangered Species of Fauna and Flora (CITES) we provided justification and supporting materials to the Belize Government for supporting the listing of eight species of elasmobranchs proposed by the IUCN.

Conclusions and Recommendations

Our multi-method survey data suggest that Belize's marine protected areas currently do not offer superior quality habitat and are not acting as important refugia for marine megafauna including piscivorous fish, with the possible exception of LRA's Half Moon Caye. This exception may be due to both its remote location and the constant presence of rangers stationed nearby.

Overall, Belize's MPAs appear to be hampered by their small size, 13% of Belizean territorial waters are protected in 14 MPAs. Numerous small MPAs have been documented to be less successful than few larger MPAs (Walters, 2000). Few large MPAs prevent the high edge to area ratio, reducing the loss of potential increases in biomass due to high dispersal (Walters, 2000). Yet prohibition of fishing and enforcement is also critical for large MPAs to be effective. To improve protective measures of MPAs, larger no-take zones are need and effective transparent enforcement is required. As fisheries are being driven to deeper waters due to resource depletion in the near shore coastal waters, MPAs also need a greater representation of the lower euphotic and higher abyssal zones.

Thankfully, the aspects of MPA creation and expansion in Belize are being addressed with the recent declaration of Turneffe in 2012, the suggested expansion of no-take zones and the incorporation of deep-water habitats into existing MPAs. Accompanying these efforts is the ever present need for increased enforcement to ensure the maximum efficiency of each MPA and to reduce the instance of illegal fishing. Although MPAs are an important tool in marine conservation, they are not sufficient on their own (Allison et al. 1998), and this is often the case for highly mobile megafauna (Mora et al. 2006).

With a global impetus to declare 10% of the world's seas as MPAs by 2020 and reach five strategic Goals in the Aichi Biodiversity Targets as recommended by the Convention on Biological Diversity, it is clear that additional efforts are required to both increase the effectiveness of current and future MPAs and to find novel solutions to improve the conservation of highly migratory marine species. Most importantly, this year's survey results reveal the continued need to legislate, implement and enforce country-wide measures such as a net and longline ban that will improve both the conservation of migratory species and Belize's recreational and finfish fisheries. Greater transparency, dialogue, collaboration and inclusivity across all stakeholder sectors represent additional aspects needed to better reverse fisheries declines and underpin the sustainable conservation of threatened and often highly migratory species such as sharks, rays and turtles.

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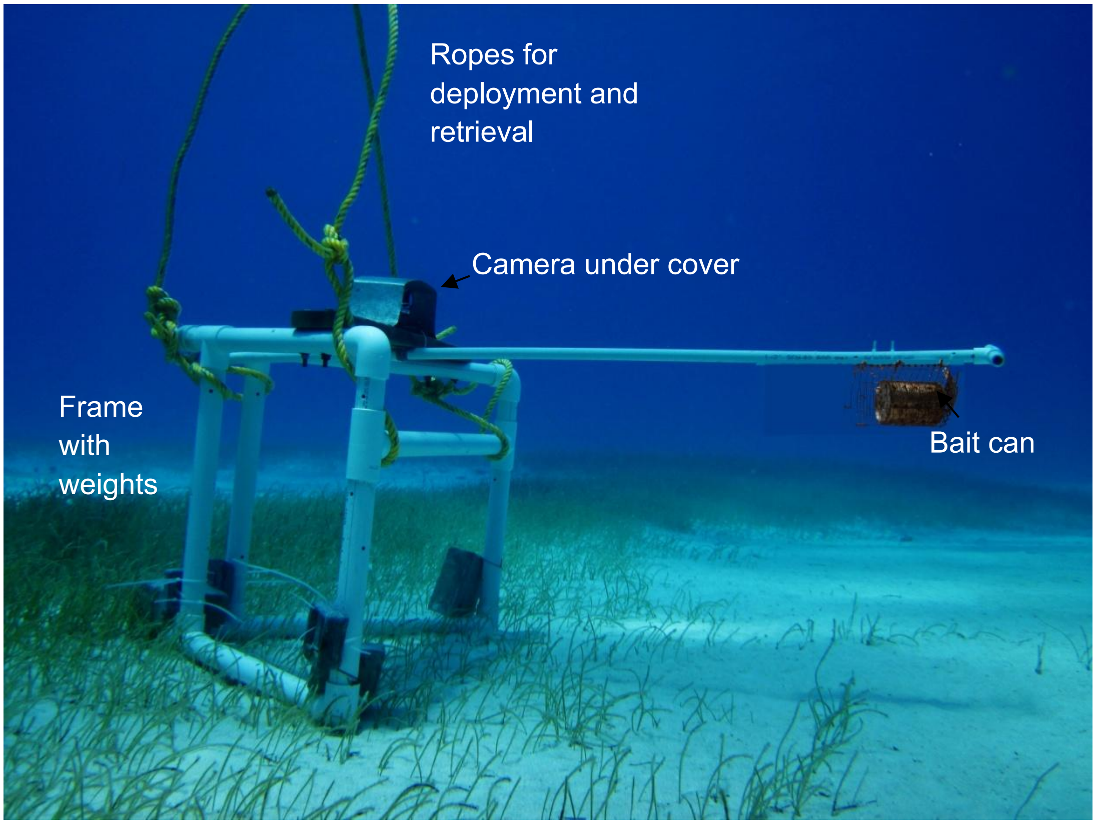
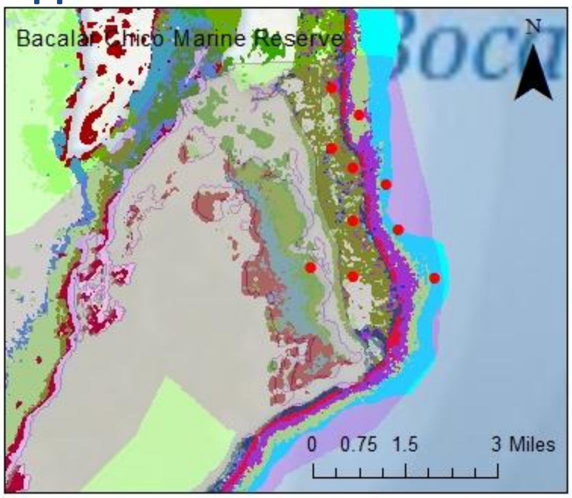
Walters, C. (2000). Impacts of dispersal, ecological interactions, and fishing effort dynamics on efficacy of marine protected areas: how large should protected areas be?. *Bulletin of marine science*, *66*(3), 745-757.

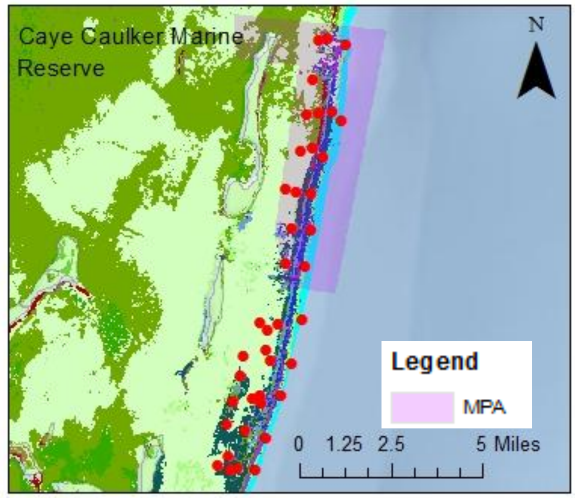
Appendix 1

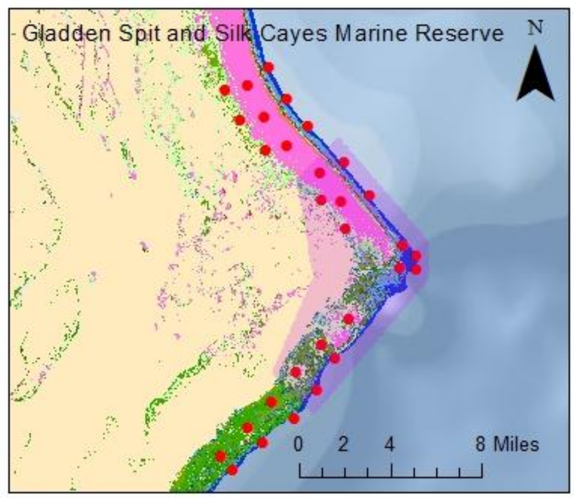


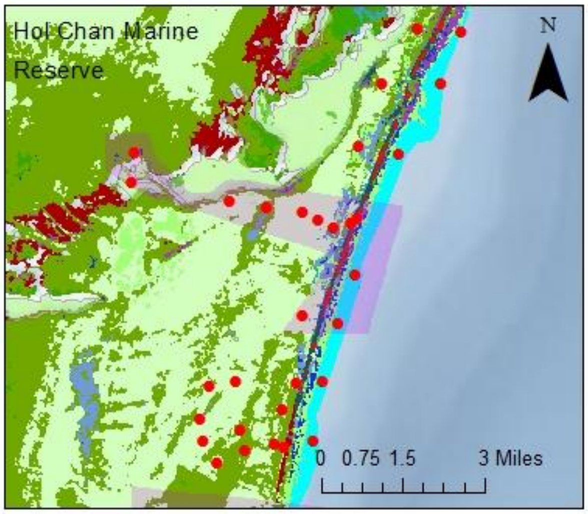
Baited remote underwater video unit. BRUV's were constructed from 2.5 inch PVC piping and weighed down with lead weight and concrete blocks to prevent movement on the sea floor. A single camera was supported by a detachable wooden cross bar on top, covered with a sheet of zinc above to protect against damage. 1 inch PVC bait arms were removable and had a metal mesh bait bag attached which sat approximately 1m in front of the camera and 60cm from the benthos. Bait bags contained a metal can with 50 holes drilled into the sides and ends. Original image courtesy of Alexander Seymour.

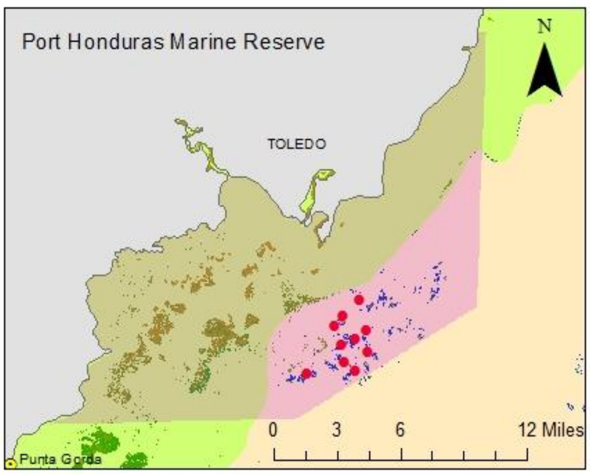
Appendix 2

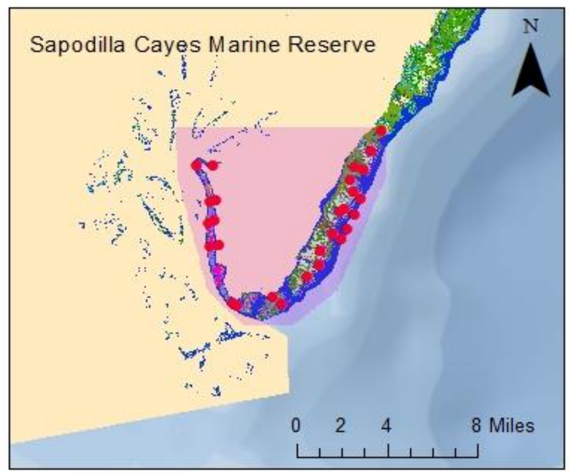

Bacalar Chico Marine Reserve
N
0 0.75 1.5 3 Miles

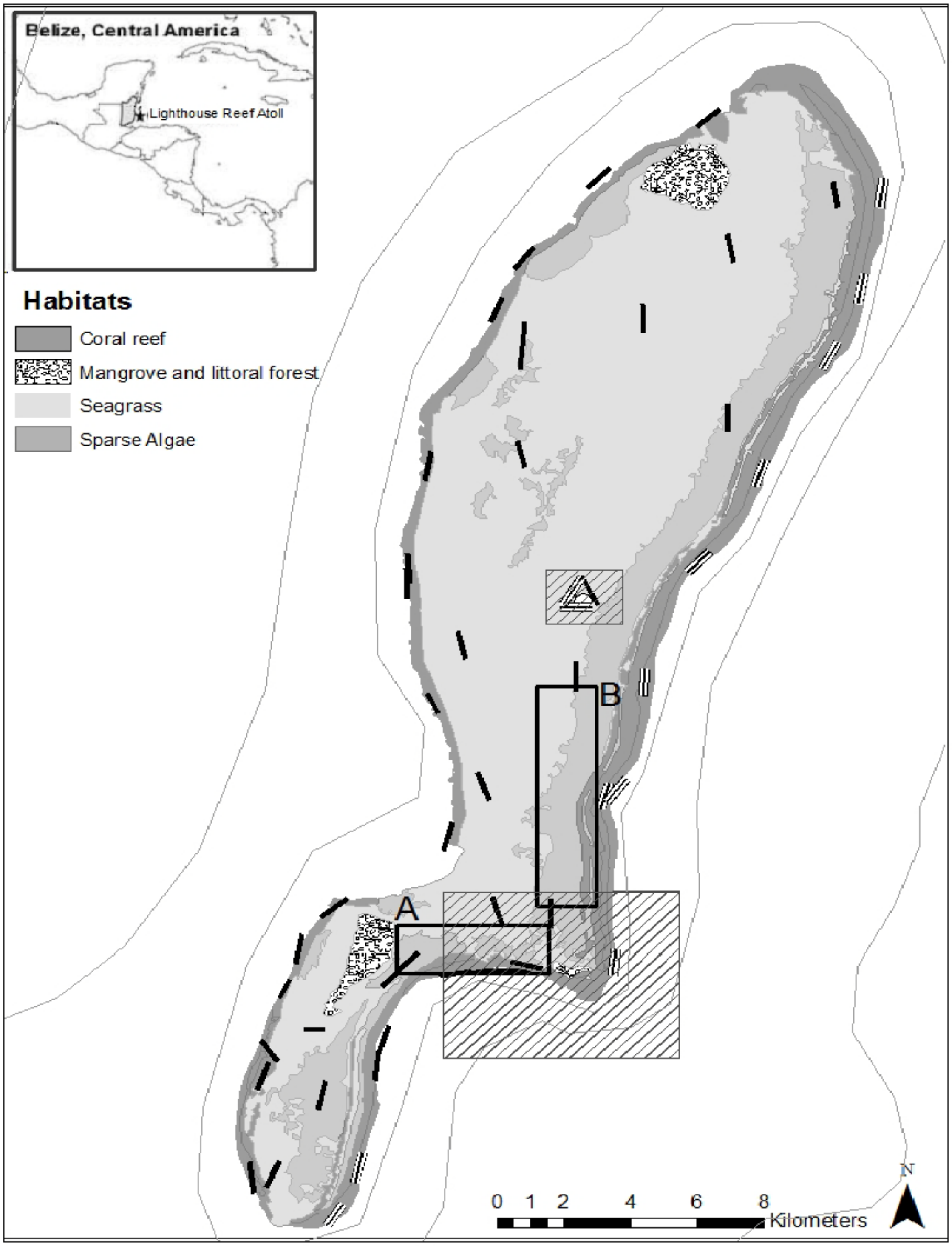

Caye Caulker Marine Reserve
N
Legend
MPA
0 1.25 2.5 5 Miles


Gladden Spit and Silk Cayes Marine Reserve
N
0 2 4 8 Miles


Hol Chan Marine Reserve
N
0 0.75 1.5 3 Miles


Port Honduras Marine Reserve
N
TOLEDO
0 3 6 12 Miles
Punta Gorda


Sapodilla Cayes Marine Reserve
N
0 2 4 8 Miles



Baited remote underwater video and UVC deployment sites throughout Belize

Appendix 3

Graham, R.T. in press. *Status of sharks in Belize 2003-2010.* In: State of the Coast, Ed., Nicole Auil. Coastal Zone Management Authority and Institute, Belize City, Belize.

Kyne, P.M., Carlson, J.K., Ebert, D.A., Fordham, S.V., Bizzarro, J.J., Graham, R.T., Kulka, D.W., Tewes, E.E., Harrison, L.R. and Dulvy, N.K. (eds). 2012. The Conservation Status of North and Central American and Caribbean Chondrichthyans. IUCN Species Survival Commission Shark Specialist Group, Vancouver, Canada.

Graham, R.T. and D. W. Castellanos. 2012. Apex predators target mutton snapper spawning aggregation. Coral Reefs. DOI 10.1007/s00338<012<0921<0

Graham, RT, Hawkes, L, Castellanos, DW, Remolina, F, Maxwell, S, Godley, BJ, MJ Witt. 2012. Satellite tracking of manta rays highlights challenges to their conservation. PlosOne 7(5): e36834

Graham, R.T. 2012. A Most Peculiar Fish: Insights into the rarely encountered sawfish. Shark Focus 43: 14-15.