

Belize's Evolving System of Marine Reserves

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The nation of Belize stretches along the Caribbean coast of Central America between Mexico and Guatemala and is home to the Belize (Meso-American) Barrier Reef system, second in length only to Australia's Great Barrier Reef. This national landmark, along with other natural and cultural treasures, has transformed the former British colony of British Honduras into a mecca for tourism, especially ecotourism, since it declared its independence in 1981. Despite a land area of just less than 23,000 km² and a population of about a quarter of a million people, Belize possesses a spectacular coastline nearly 400 km long and is home to a trove of coastal and offshore resources. Three largely undeveloped and awe-inspiring "atolls" (Turneffe, Lighthouse, and Glover's Reefs) lie offshore of the internationally acclaimed barrier reef. Belize continues to develop one of the world's most advanced and visionary systems of marine protected areas (MPAs).

MPAs, including marine no-take reserves, are an essential component of Belize's Coastal Zone Management Strategy, consistent with its overarching goal of "improved management of coastal resources to ensure economic growth is balanced with sound environmental management" (CZMAI 2001a). As in many countries, MPAs are being established in Belize with a variety of objectives, including tourism management, biodiversity protection, and fisheries management. Management of tourism is particularly important given that tourism, much of it marine oriented, is one of the most important sources of foreign exchange in Belize and that the diversity and comparatively healthy condition of reefs and other marine ecosystems are of recognized international

importance. MPAs are therefore being established with zoning schemes designed to benefit various stakeholders.

Most of the scientific work conducted within MPAs in Belize has focused on measuring the effectiveness of the no-take zones for enhancing commercial fish stocks within MPAs as a means of fisheries management. Less work has been focused on measuring the effectiveness of MPAs to maintain ecosystem function. Stakeholders and the general public readily acknowledge the tourism and educational values of the MPAs. However, some commercial fishing interests have recently raised concerns about and opposition to MPAs, illustrating that their value as a fisheries management tool is not universally recognized within this sector in Belize.

An existing network of thirteen MPAs, designed to encompass the range of marine habitat diversity in Belize and conserve overall ecosystem functions, was already developed and approved by 2002. This MPA network includes a number of no-take areas or marine reserves (as defined in this book). In 2002, additional legislation was enacted strengthening this MPA framework by creating eleven new no-take marine reserves to protect known spawning aggregation sites for Nassau grouper and other reef fish and providing additional nationwide protection for Nassau grouper during its spawning season. This case study emphasizes four MPAs that have had active management for several years, but also discusses other sites and recent developments. Belize's system of MPAs is an important component of the wider integrated coastal zone management program that is guiding marine conservation efforts in Belize.

THE BELIZEAN FISHING INDUSTRY

The fishing industry in Belize is still characterized by small-scale commercial interests involving about 800 boats, some of them sailing boats, and employing between 2000 and 3000 fishermen. Most fishers are members of the five active fishing cooperatives, which purchase, process, and export fishery products. The fishery is essentially "open access," although there appear to be some traditional areas and grounds, the use of which warrants further study. Fisheries production is the country's third largest foreign exchange earner (Iioka 2001), with about 80 percent being exported, of which most goes to the United States. Exports of lobster, conch, finfish, wild-caught marine shrimp and shark were worth over \$12 million in 2000; farmed shrimp has expanded so rapidly that it now surpasses the capture fisheries and generated \$23 million in 2000.

Table 10.1 Exports (lbs. x 1000) of Marine Products

Commodity	Average 1995–1998	1999	2000
Whole fish	240.7	60.9	73.9
Fish fillet	3.2	0.0	0.0
Shark fins	3.5	4.8	12.7
Lobster tails	488.5	566.0	646.1
Lobster meat	88.4	89.8	26.7
Whole lobster	61.3	0.0	0.0
Aquarium fish	100.3	49.9	6.1
Pink sea shrimp	49.8	33.7	33.9
Conch	421.3	392.9	517.4
Crab	8.3	11.8	4.0
SUBTOTAL	1465.3	1209.8	1320.8
White farmed shrimp	1786.6	4658.0	4945.6
TOTAL	3251.9	5867.8	6266.4

The full extent of the direct and indirect contribution of fishing to the economy is not known because fish sold in local markets are not recorded, and a growing volume of sea food products are sold directly to restaurants and hotels or illegally across international borders. Subsistence catch and consumption are also significant and similarly not recorded. Sport and recreational fishing are becoming increasingly important activities that target a range of species, including permit, tarpon, bonefish, snook, marlin, and tuna.

The principal fisheries are for conch and lobster, which constituted 90 percent of all fisheries exports (excluding farmed shrimp) in 2000 (Table 10.1; CZMAI 2000, 2001b). Lobster is the most lucrative and the 2000 exports, totaling 672,800 pounds were worth over \$9 million. Conch exports have in general declined since the 1970s but in 2000 they reached a high of over 0.5 million pounds. Exports of finfish and marine shrimp have declined since 1989. Of the finfish that are exploited, grouper (*Serranidae*) and snapper (*Lutjanidae*) are of greatest commercial value and are fished mainly at the traditional spawning banks. Two of the four licensed aquarium fish collectors were active in 2000 with 6000 aquarium fish and invertebrates exported with a total value of over \$46,000.

The status of commercial fish stocks in Belize is not known with any great certainty because catch and effort data have not been systematically collected and analyzed. Although Koslow et al. (1994) suggested that some elements of Belize's finfish fishery are underutilized, there is general consensus within the country that overfishing is occurring, at least for certain species (Carter et al.

1994b; McField and Wells 1996), particularly aggregating species like the Nassau grouper (Heymen 2001; Paz and Grimshaw 2001; Sala et al. 2001).

The pattern of peaks and troughs in lobster production over recent years suggests that this fishery is being exploited at, or just above, its maximum sustainable yield. The conch fishery has declined dramatically from the 1970s, when Belize was one of the largest producers in the world, exporting over 1.2 million lbs. in 1972. This fishery is presumed to be overexploited. The grouper spawning banks are heavily overfished, as elsewhere in the Caribbean, and at some sites such as Rocky Point it appears that spawning migrations have ceased (Carter et al. 1994b). Recent conservation efforts have focused attention on these spawning banks, several of which are already within protected areas. The Gladden Spit Marine Reserve was created primarily to conserve its unparalleled fish spawning and whale shark aggregations. The recently enacted legislation provides additional protection for the remaining viable spawning banks.

The fisheries sector is currently managed largely by traditional methods. All vessels and fishermen must be licensed, but at present the fee is so low (\$12.50 per annum) that it plays an insignificant role in regulation of fishing effort. There are a number of gear restrictions, including the prohibition of scuba gear, poisons, and explosives for any form of fishing. The conch and lobster fisheries are regulated through minimum size limits, closed seasons, and, in the case of lobsters, protection of soft-shelled and berried individuals. There is a closed season for shrimp and efforts are under way to restrict the size of the fleet. Guidelines have been prepared for the aquarium fish industry, and the Fisheries Department has an in-house policy by which it regulates this. Professional sport fishing guides voluntarily adhere to a catch and release policy for tarpon, permit, bonefish, and snook, but this does not extend to billfishing tournaments. Bonefish is protected as a sport fish species by a ban on its sale and purchase. A similar law is being drafted for tarpon, permit, and snook.

The Conservation Compliance Unit of the Fisheries Department enforces fishery regulations. When first established, with funding from the United States Agency for International Development (USAID), was well equipped and provided an enforcement capability considerably greater than that found in most other Caribbean countries. Although government resources have proved insufficient to maintain this original level, the Unit remains active, conducting patrols while staying within its severely limited budget. Nevertheless, there is illegal fishing of undersized conch and lobster, and fishing also occurs in the closed seasons; illegal foreign fishermen are a major problem particularly in the south of the country.

MARINE PROTECTED AREAS (MPAS) IN BELIZE

In Belize, MPAs can be designated under two pieces of legislation, the Fisheries Act and the National Parks Systems Act. Use of the term *marine reserve* in Belize is not consistent with the definition used elsewhere in this book and is not synonymous with *no-take*. Belizean marine reserves are designated under the Fisheries Act, zoned for multiple use, and administered by the Fisheries Department, sometimes in partnership with nongovernmental organizations (NGOs) via formal comanagement agreements. For clarity, throughout this chapter we will try to avoid confusion on this by adding *no-take* where appropriate, by capitalizing *Marine Reserve* when used in the Belize sense, and by limiting such use to proper names or references to actual named areas. There are currently eight such designated Marine Reserves: Hol Chan, Glover's Reef, Bacalar Chico, Caye Caulker, South Water Caye, Sapodilla Cayes, Port Honduras and Gladden Spit.

National parks, wildlife sanctuaries, natural monuments, and nature reserves are strictly no-extraction and are administered by the Forest Department or designated comanaging organizations. There are two natural monuments, Half Moon Caye and Blue Hole; two national parks, Laughing Bird Caye and Bacalar Chico; and two wildlife sanctuaries, the Corozal Bay (Manatee) Sanctuary and the Swallow Caye (Manatee) Sanctuary. In some cases, adjacent marine and terrestrial protected areas were designated and are managed jointly, as with the Bacalar Chico National Park and Marine Reserve, and the Caye Caulker Forest Reserve and Marine Reserve. The Caye Caulker Forest Reserve was declared under the Forests Act. Table 10.2 provides details of the thirteen MPAs (CZMAI 2001); the locations of both marine and coastal protected areas are shown in Figure 10.1.

In December 1996, seven of the MPAs were declared the Belize Barrier Reef Reserve System World Heritage Site, under the United Nations Educational, Scientific, and Cultural Organization's (UNESCO's) World Heritage Convention. These include Bacalar Chico Marine Reserve and National Park, Blue Hole Natural Monument, Half Moon Caye Natural Monument, Glover's Reef Marine Reserve, South Water Caye Marine Reserve, Laughing Bird Caye National Park, and Sapodilla Cayes Marine Reserve.

The Hol Chan Marine Reserve was especially successful in terms of visibly increasing fish populations and attracting overseas visitors, leading to widespread enthusiasm for establishing MPAs in communities with tourism potential. Given the small size of the country and the limited management resources

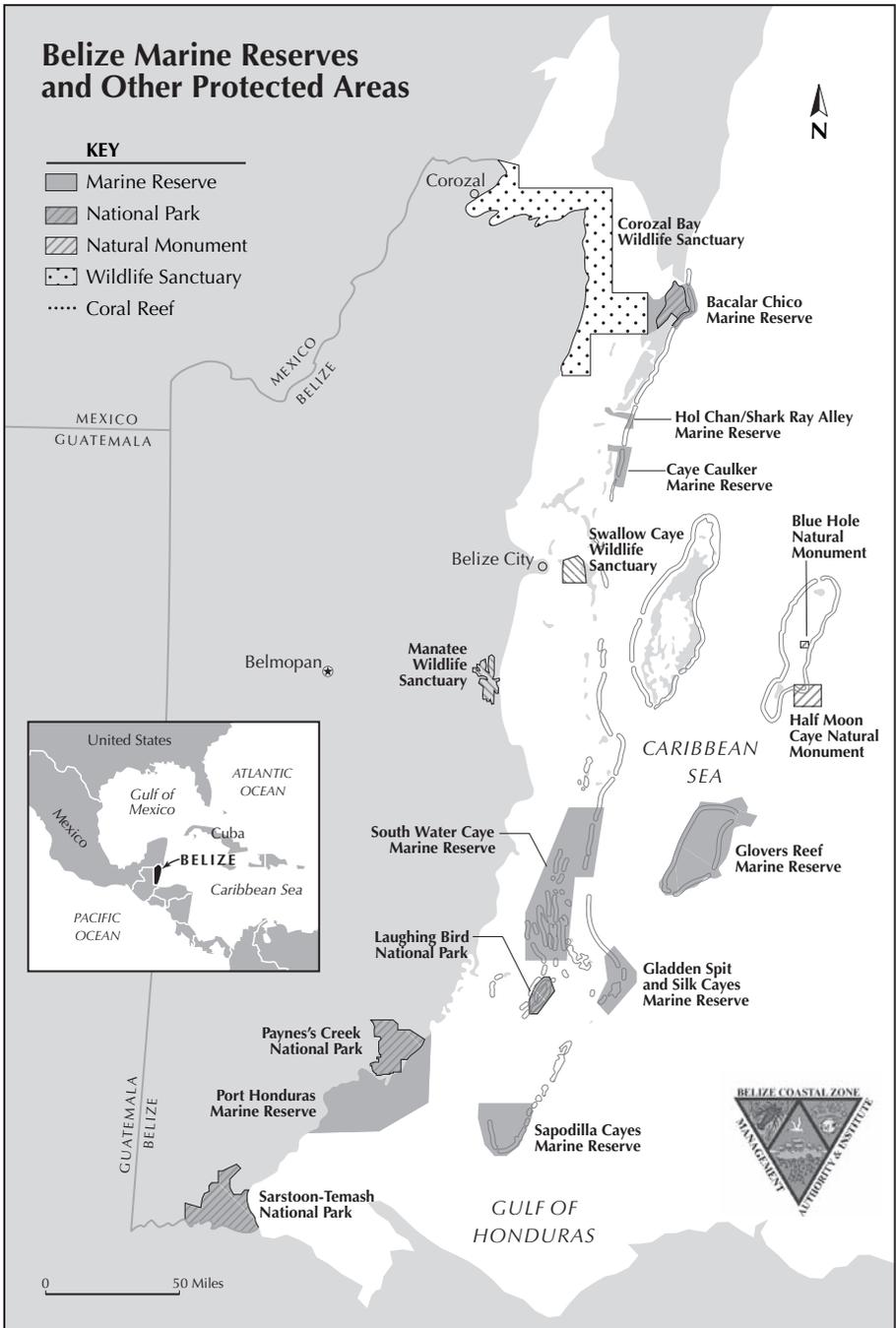


FIG. 10.1 Belize Possesses a Network of 13 Marine Protected Areas (Not Including 11 Spawning Aggregation Sites Declared in 2002). These include several marine reserves (In Belize, marine reserves are not all no-take), which have been established under the Fisheries Act and are administered by the Fisheries Department, and also wildlife sanctuaries, national parks, and natural monuments, which were declared under the National Parks System Act and are the responsibility of the Forest Department. Seven of the marine protected areas comprise the Belize Barrier Reef Reserve System World Heritage Site.

available, Belize has a remarkably ambitious MPA program that has resulted in a network of protected sites along the length of the Barrier Reef, on two of the three atolls, and along the mainland coast. To date the existing MPA network system is believed to include virtually all the main and unique habitats, as recommended in the National Protected Areas Systems Plan (Programme for Belize 1995), with the exception of Turneffe Atoll.

Although most of the MPAs have a management presence, with basic infrastructure and equipment in place, management plans need to be completed or updated, and the MPA staff need training in all aspects of MPA management because many of them are newly appointed and inexperienced. A recent evaluation of management effectiveness of four MPAs (Hol Chan, Glover's, Bacalar Chico, and Half Moon Caye) found that overall management effectiveness was "moderately satisfactory," with common problems regarding administration and some management programs, like environmental education and research (McField 2000).

Funding support for the MPA system is presently being provided by donor agencies such as the Global Environment Facility/United Nations Development Programme Coastal Zone Management Project, the European Union, the GEF/World Bank Mesoamerica Barrier Reef System Project, The Nature Conservancy, World Wildlife Fund, and the Summit Foundation. However, a long-term financial strategy for the MPAs needs to be developed and implemented as soon as possible.

DESCRIPTION OF SITES AND STUDIES IN BELIZE MPAS

Hol Chan Marine Reserve

Hol Chan Marine Reserve, lying on the northern part of the Barrier Reef off the southern tip of Ambergris Caye, was established in 1987 with the support of the Wildlife Conservation Society and World Wildlife Fund U.S. It was established at the request of the local community in San Pedro to reduce conflict between fishermen and dive operators, and covers a transect across the barrier reef from the mangrove cayes at the southern end of Ambergris Caye to the outer reef. Before protection, it was one of the most productive and heavily fished cuts on the Barrier Reef (Carter et al. 1994a). Covering just 1545 ha (3816 acres), this protected area has experienced the longest period of full management and successfully enforces its regulations by having a warden on duty throughout each day. The reserve's overall management effectiveness was rated as satisfactory (76 percent) with the primary problems being administration

Table 10.2 List of Marine Protected Areas

Name of MPA	Total Area (ha)	Marine Area (ha)	Marine No-Take Area (ha)	Year Established	Responsible Agency	Comanagement Organization
Bacalar Chico Marine Reserve and National Park*	11,487	6303	1699	1995	Fisheries Dept. and Forest Dept.	—
Blue Hole Natural Monument*	414	414	414	1996	Forest Dept.	Belize Audubon Society
Caye Caulker Marine and Forest Reserve	3951	1545	(zoning under preparation)	1998	Fisheries Dept. and Forest Dept.	Forest and Marine Reserve Association Association of Caye Caulker (FAMRACC)
Corozal Bay Wildlife Sanctuary	73,050	72,350	—	1998	Forest Dept.	—
Gladden Spit Marine Reserve	10,523	10,463	153	2000	Fisheries Dept.	Friends of Nature
Glover's Reef Marine Reserve*	32,876	32,834	7226	1993	Fisheries Dept.	—
Half Moon Caye Natural Monument*	3954	3921	3921	1982	Forest Dept.	Belize Audubon Society
Hol Chan Marine Reserve	1545	1452	273	1987	Fisheries Dept.	—
Laughing Bird Caye National Park*	4095	4077	4077	1991	Forest Dept.	Friends of Nature
Port Honduras Marine Reserve	40,457	39,748	1277	2000	Fisheries Dept.	Toledo Institute for Development and Environment (TIDE)
Sapodilla Cayes Marine Reserve*	15,619	15,591	(zoning under preparation)	1996	Fisheries Dept.	Toledo Association for Sustainable Tourism and Empowerment (TASTE)
South Water Caye Marine Reserve*	47,703	46,833	(zoning under preparation)	1996	Fisheries Dept.	—
Swallow Caye Wildlife Sanctuary	3630 ha	3230 ha	—	2002	Forest Dept.	Friends of Swallow Caye

*Denotes the marine protected areas that make up the World Heritage Site.

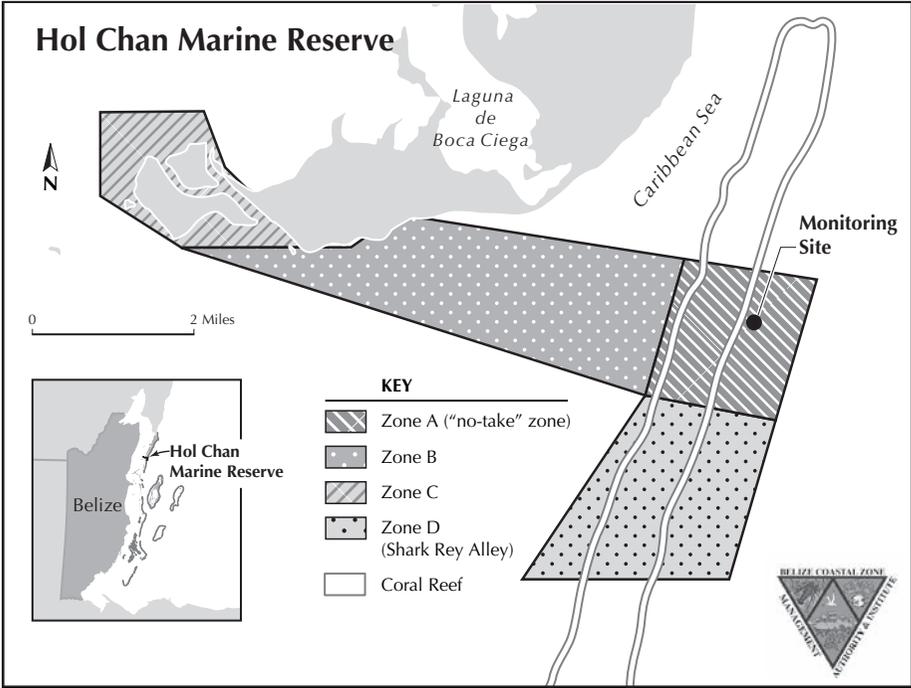


FIG. 10.2 The Marine Reserve Has Been Zoned to Allow for Multiple-Use. Zone A, the coral reef zone, is the fully protected area where no extraction is permitted. Traditional fishing is allowed in Zones B, C, and D, but there are some restrictions on gear and other special regulations. Zone D, added in 1999, provides for the protection for the Shark Ray Alley area and the management of visitors to this attraction.

and threats (McField 2000). Threats include natural disasters, pollution, development, dredging, illegal fishing, and so forth. It is run by a “semiautonomous” staff within the Fisheries Department, which is financed primarily by a trust fund established through visitor fees. Despite its small size, Hol Chan has attracted much international attention as a “successful” MPA. Its principal appeal lies in the large fish (including groupers and snappers) that can be seen there, even by snorkelers. Hol Chan receives nearly 40,000 visitors a year, each paying an entrance fee of \$2.50 and a separate fee for zone D of \$3.50. which sustains basic operating costs. However, there are concerns about its carrying capacity, particularly given the concentration of visitors in the cut area.

The Marine Reserve originally included three zones, which reflect the main habitat divisions as well as different uses (Fig. 10.2). Zone A is almost 300 ha (741 acres) in area and comprises the segment of barrier reef that lies within the reserve. It is a no-take zone in which nonextractive recreational activities, such as snorkeling and diving, are permitted, and boats may moor at desig-

nated sites near the natural “cut” in the reef, for which it is named (Mayan for “little channel”). In Zone B, which is predominantly sea grass habitat, in addition to those activities permitted in Zone A, fishing is permitted with a special license, but trawling is prohibited, and spearing and netting of fish are prohibited at the Boca Ciega Blue Hole. It is Fisheries Department policy that licenses for this zone are issued only to fishermen who had traditionally used the area before it was protected. In Zone C, which comprises the mangroves and channels off the southern tip of Ambergris Caye, activities permitted in both Zones A and B are allowed, as well as sportfishing provided boats are registered, but the setting of nets across channels and the cutting of mangroves is prohibited.

In 1999 Zone D, also called Shark Ray Alley, was added to the southeastern portion of the reserve. It encompasses a portion of the barrier reef, south of Zone A, which is popular with tourists for snorkeling with the nurse sharks and southern stingrays, which have congregated there at a traditional site where fishermen cleaned their conch before bringing them to market. Fishing is allowed in Zone D, except in the special exclusive recreational areas surrounding the Shark Ray Alley and Amigos del Mar Dive Wreck sites. Scuba diving and feeding of the fish by tourists are not permitted in the Shark Ray Alley recreational area, although the snorkeling guides are allowed to feed the fish in this zone.

In 1988 and 1989, one to two years after the reserve had been established, Sedberry et al. (1992) compared Hol Chan cut with the Tres Cocos cut, a heavily fished cut about 5 miles to the north, as well as two other unprotected sites, Mexico Rocks and Rocky Point. Hol Chan had significantly more fish per observation than Tres Cocos; species diversity was also higher but not significantly so. The snappers, *Lutjanus griseus*, *L. mahogani*, and *Ocyurus chrysurus* were among the most abundant species at Hol Chan but were rare at Tres Cocos, as were groupers. The results were complex, but total abundance was higher at the protected site than at the unprotected sites. This was predominantly due to Nassau and black groupers (*Mycteroperca bonaci*), although graysby (*Cephalopholis cruentatus*) and snappers were also found to be more abundant in the protected area than in unprotected areas. Conversely, Acanthuridae, Scaridae, and small coney (*Cephalopholis fulvus*) were more abundant in unprotected areas, this abundance of herbivorous species suggesting that a prey-release effect had occurred.

A second study was carried out in 1991–1992 at Hol Chan, four years after protection was initiated (Polunin and Roberts 1993; Roberts and Polunin 1993). Sites at the Hol Chan cut, at two different depths, were compared with

similar sites at three fished but similar cuts to the north (Mata Cut, San Pedro Cut, and Basil Jones Cut). Significant differences were found in fish abundance and diversity between habitat types and cuts at different depths for some but not all species. In Hol Chan, 45 percent of the target species showed abundance, size, or biomass increases. Several commercial species, such as school master snappers (*Lutjanus apodus*) had a higher frequency of very large individuals within the protected area. At the family level, differences were much clearer, with predatory families (groupers, snappers, and grunts) having greater biomass in Hol Chan.

Data were also collected by the reserve staff on lobster (*Panulirus argus*) and conch (*Strombus gigas*) populations about four to five years after protection (Hol Chan 1991a, 1991b, 1992a, 1992b). Data for lobsters, collected in June 1992 near the end of the lobster closed season, using timed-swimming counts of individuals per hour on the back reef, showed a significantly larger population in Hol Chan (30 lobsters/hr) than in similar habitats at Mexico Rocks (1.6 lobsters/hr) and Robles Point (2.4 lobsters/hr), which are unprotected areas to the north. Data for conch, collected in July–September 1991, gave similar results: averaging across all habitats, there were counts of 33 conch/km² in Hol Chan and 4 conch/km² at Mexico Rocks. The size distribution of conch also differed between the two sites, with mature conch (with flared, thick lips) accounting for 42 percent of the conch population on the reef flat and reef crest in Hol Chan (where this habitat lies in Zone A and is totally protected) and only 14 percent in the same habitat at Mexico Rocks. At both sites, the lagoonal and sea grass bed populations were dominated by juvenile conch, with only 10 percent mature conch at Hol Chan and 2 percent mature conch at Mexico Rocks.

The Hol Chan studies lack strong baseline data from before the reserve was established, which would further strengthen their results, although Sedberry and Carter (1993) studied the fish population of the mangrove habitat in Zone C before it was protected. Nonetheless, local people claim that fish populations in the reserve have greatly increased since protection (Carter et al. 1994a), and the scientists who have worked in the area have made qualitative observations that confirm this.

In 1998, Hol Chan was included as one of the protected area sites in a regional study to investigate the causes of the widespread increase in macroalgal cover on reefs (Williams and Polunin 2001). Findings of the study showed that there is a higher biomass of herbivorous fish inside MPAs like Hol Chan, and there is also a negative correlation between the macroalgal cover and the biomass of herbivorous fish in shallow reefs. However, at middepth reefs, which

often have low cover of corals even inside protected areas, herbivorous fish populations seem unable to exclude macroalgal cover, which may have been previously controlled via sea urchin (*Diadema antillarum*) grazing, prior to its Caribbeanwide die-off (see earlier discussion).

Half Moon Caye Natural Monument

The first marine habitat to be included in a protected area in Belize was at Half Moon Caye, on Lighthouse Reef atoll, which was designated as a natural monument in 1982 (a portion of the caye itself having been protected since 1928 due to its booby colony). Its total area is 3954 ha (9766 acres), of which 3921 ha (9685 acres) is marine habitat in which fishing is prohibited. Presently, there are no provisions for zoning of the marine habitat. The Belize Audubon Society (BAS) manages Half Moon Caye on behalf of the Forest Department. In the past, limited funding restricted active enforcement by BAS. However, regular visiting by dive boats and other tourists has tended to discourage fishing activities within the protected area. Volunteers from BAS and other organizations have carried out management activities such as beach cleanups, bird counts, marine resource monitoring, and construction of visitor facilities. Since 1996, however, with funding support from GEF/UNDP and the Summit Foundation, active management has been under way. Overall management effectiveness has been evaluated as satisfactory (77 percent), with the main problems being legal issues and threats such as hurricanes, coral bleaching, water pollution, visitor impact, and illegal fishing (McField 2000).

Between 1988 and 1990 Sedberry et al. (1992) compared sites in Half Moon Caye (six to eight years after legislative protection) with similar sites at Glover's Atoll, which at that time had not been designated a marine reserve. Forereef sites at Half Moon Caye, legally protected for six to eight years, were found to have significantly more fish per observation than similar unprotected sites at Glover's Reef. However, unlike Hol Chan, fish populations at Half Moon Caye were not strikingly abundant to the casual observer, and individuals were not unusually large. Less effective enforcement and lack of compliance at the time are among possible explanations for the failure to see more striking differences. Other sites on Lighthouse Reef atoll that are not protected, such as the Aquarium dive site, have a greater reputation for fish size and abundance, probably due to fish feeding by dive guides.

On-site management by BAS began in 1997, with increased enforcement in 1999. A survey by park staff in November–December 1999 found approxi-

mately 250 percent more lobster inside (five/hr searching) versus outside (two/hr searching) the park boundaries, with all large (greater than 30 cm) lobsters found inside the park (Belize Audubon 2001). Likewise, a July 1999 survey found approximately 650 percent more conch inside (30.3 conch/150 m² belt transect) versus outside (4.6 conch/150 m² transect) the park boundaries (Belize Audubon 2001).

A study conducted in 2001 comparing herbivorous fish populations (Acanthurids and Scarids) at shallow reefs inside and outside Half Moon Caye Natural Monument found that the biomass of Acanthurids and total herbivorous fish surveyed was significantly higher inside the MPA (Sandman 2001). Inside the MPA there was also a higher proportion of large fish (Sandman 2001). A negative correlation between percent algal cover and fish biomass was also demonstrated (Sandman 2001). Although this study was rather limited in scope, it represents additional evidence supporting the theoretical ecological benefits (reduced algal cover) resulting from no-take zones and increased fish populations.

Glover's Reef Marine Reserve

Glover's Reef Marine Reserve, only part of which is no-take, was established in 1993 with the assistance of Wildlife Conservation Society and the UNDP/GEF Coastal Zone Management Project. It has an area of 32,876 ha (81,204 acres), covering the entire atoll, and is zoned for multiple uses. There are six privately owned cayes on the atoll, on which are situated three resorts, a marine laboratory and the reserve headquarters, and a few small private houses. These are excluded from the reserve statutes, which do not apply to private land. The reserve is managed by the Fisheries Department and has "moderately satisfactory management" (68 percent), with the main problems related to its administration and management programs (McField 2000). The atoll suffered serious overfishing in the 1970s, by both Belizean and foreign fishermen, largely from Honduras. With increased human presence on the atoll and public awareness of the Marine Reserve, illegal fishing by aliens has declined, although poaching remains a problem. Several dive boats and commercial and recreational fishermen also visit the atoll.

The regulations for the reserve were gazetted in 1996 and then revised in 2001 in response to new data (Acosta 1998). Changes to the boundaries of the zones were made that reflect more accurately the location of the Seasonal Closure Area to encompass the grouper spawning bank, standardize the shape of

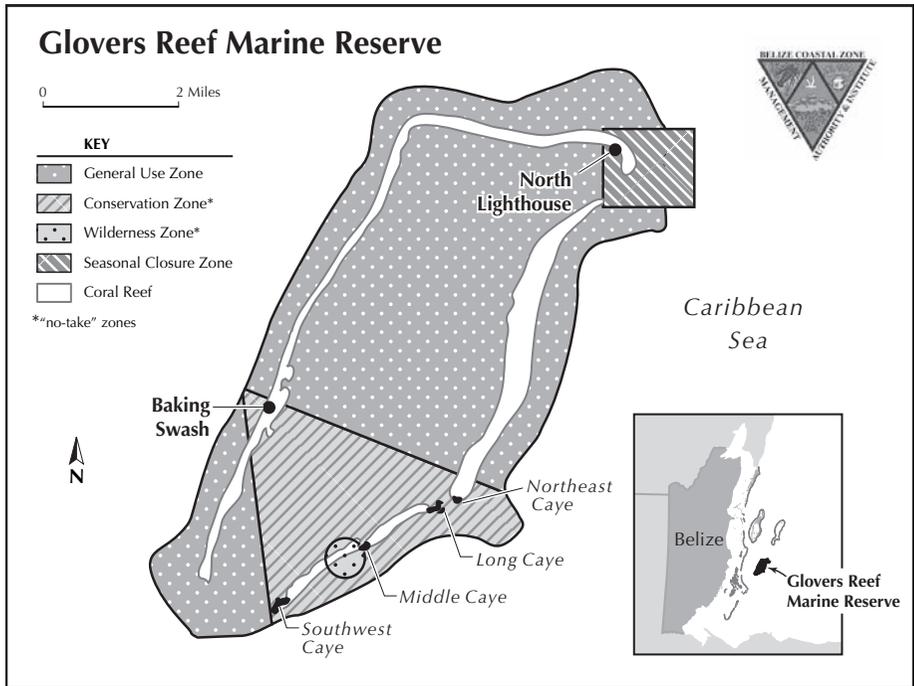


FIG. 10.3 Glover's Reef. The southernmost of Belize's three atolls is zoned for multiple use and possesses the largest fully protected area in Belize's marine protected area system. This no-take area includes the wilderness and conservation zones.

the Conservation Zone for ease of demarcation and enforcement and to more effectively protect its populations of lobster and conch and place the Wilderness Zone in a more effective area, away from its previous location in a highly used operational zone centered around the north end of Middle Caye (Fig. 10.3). Fishing of any kind as well as diving and other water activities are prohibited in the wilderness zone or no-take area. In the Conservation Zone, which covers much of the southern third of the atoll, nonextractive recreational activities such as snorkeling and diving are permitted, and boats are required to use designated moorings and to register with the reserve. Subsistence fishing by island residents (these include staff of the two resorts, and marine reserve and research station personnel) and sportfishing (catch-and-release only) are also permitted under special license. In the General Use Zone, fishing, tourism, and other activities are permitted, but commercial fishing is restricted to those fishermen who currently use the area, a special license is required, and fish traps and nets are prohibited. The Seasonal Closure Area, which covers the grouper spawning bank, has been replaced with a no-take area, closed to all fishing.

A study designed to test the effectiveness of the no-take area of the reserve was initiated in 1994 (Carter 1994). Researchers and park staff used visual census methods to assess abundance and diversity of nineteen diurnally active fish families, including economically valuable species (e.g., snappers, groupers, and porgies), site-specific species (e.g., damselfishes), transient species (e.g., jacks, barracudas), and different trophic levels (e.g., filefishes, grunts, surgeonfishes, parrotfishes, barracudas). The censuses, which also included conch and lobster, were carried out in three habitats (patch, backreef, and forereef) at complementary sites in the Wilderness Zone (no-take) and outside the boundary of the marine reserve. Local fishers assisted in the collection of commercial fishing data. With the reserve staff and the researchers, they helped to devise a data collection kit (consisting of waterproof data collection sheets with fish names in English and Spanish, a handheld spring balance, and a measuring tape) for each boat that uses the atoll. The legislating of the reserve regulations was critical to the progress of the study because it was based on a comparison of populations within the fished and nonfished areas. However, because this action was delayed by a couple of years, the investigation ultimately served as baseline data for the premanagement condition of fishery stocks.

In 1996, Acosta (1998) initiated a study on the movements of lobster and conch, and the tidal transport of recruits within the reserve. This was carried out to evaluate how the original boundaries of the no-take areas affected the function of the reserve. He concluded that the configuration of the Conservation Zone was only effective in protecting the more sedentary species, such as conch. However, the more mobile adult lobsters were capable of dispersing into the General Use Zone in a relatively short time. To make the protection more effective, he recommended some changes to the boundaries. The southwestern portion of the atoll was recommended for inclusion in the Conservation Zone to protect the highly productive conch grounds and an important area for larval recruits due to the southwesterly current regime. In addition the inclusion of the "cuts" (tidal or current passes) in the fringing reef and a reduction in the perimeter:area ratio of the Conservation Zone were recommended. The data collected during this study were used to develop a predictive framework to evaluate reserve effectiveness in protecting target species.

Acosta and Robertson (2001) followed up this initial study with further investigations in Glover's Reef and South Water Caye Marine Reserves and the Half Moon Caye and Blue Hole Natural Monuments. During his initial study, enforcement in the no-take areas was minimal at Glover's Reef, and the density of lobster and conch in the protected areas were not different from the

fished areas. However, with increased enforcement starting in late 1998, he noted an increase in the density of conch and lobster in the protected area. Density of spiny lobsters increased by 300 percent, and biomass by over 700 percent, due mainly to growth of large adults in the area. The density of conch increased by over 200 percent. Key fish species were also monitored, with black grouper, mutton snapper, and hogfish twice as abundant in the protected area than in the fished area.

In preliminary comparisons between the MPAs, Acosta and Robertson (2001) noted that Blue Hole and Half Moon Caye had substantially higher densities as well as larger average sizes of lobsters and conch than in the adjacent fished habitats. In the case of South Water Caye, however, which has no enforcement yet of no-take areas, the populations of conch and lobsters consisted of small juveniles only, although their densities were high. This is indicative of severe recruitment overfishing. These comparative studies are providing valuable information for the development of a protocol of rapid ecological assessments of marine reserves, which will assist in economic cost-benefit analyses to evaluate no-take areas.

A year long study of the interactive role of MPAs and direct macroalgal reduction was conducted in 1997–1998 on the lagoonal patch reefs (McClanahan et al. 2001). This study found that the no-take zone had higher densities for thirteen of thirty fish species, and higher rates of fish herbivory than the general use zone. However, the two management zones did not differ in the effects of the experimental algal reduction. It was hypothesized that the higher fish populations in the no-take zone would prevent the return of high algal cover to these patch reefs. Between 1970 and 1996 these patch reefs experienced a community shift, with the coral:algal ratio changing from 4:1 to 0.25:1, with continued coral declines in recent years (McClanahan and Muthiga 1998; McClanahan et al. 2001). Thus this study indicated that the benefits of MPAs to the benthic reef community may require a longer timeframe to take effect or may be influenced by other uncontrolled confounding factors, such as the coral bleaching event and catastrophic hurricane that intervened during the course of this study. Results of more recent experiments indicate that high nutrient levels negatively influence brown frondose algal cover. They also suggest that coral mortality, due to disease and bleaching, and low herbivory due primarily to the *Diadema* die-off and over fishing of grazers, are the most likely factors responsible for the high levels of brown fleshy algae on the patch reefs of Glover's Reef (McClanahan et al. 2003).

Bacalar Chico

The Bacalar Chico National Park and Marine Reserve lies 10 to 15 miles north of San Pedro, Belize's most popular tourist destination, and has long been used by commercial fishermen (from both San Pedro and Xcalak, a small Mexican town 5 miles to the north) and for sport and recreational fishing. Rocky Point was once a major spawning bank for Nassau and black grouper and is now a popular spot for sport fishermen. The reserve was established in 1996, with support of the International Tropical Conservation Foundation/European Union. The fisheries department manages the reserve, along with a local advisory committee that has remained active over the past seven years. The reserve has "moderately satisfactory management" (61 percent), with the main problems being administration, threats, and illegal uses (McField 2000).

The marine reserve's zoning plan was legally implemented in 2001 and includes a Preservation Zone lying immediately south of the Mexican border, which is a no-take area and in which recreational activities are also prohibited; a Conservation Zone 1, also a no-take area but where recreational activities are permitted; a Conservation Zone 2, which includes the Rocky Point area, and in which only catch-and-release sportfishing and other recreational activities are allowed; and General Use zones throughout the remainder of the reserve where fishing is permitted, but the use of gill nets, spearguns, and traps (other than beach traps established before or during 1996) is banned (Fig. 10.4).

Studies of fish, conch, and lobster populations are ongoing, using methods similar to those used in the other reserves. Although the no-take areas have just recently been legally established, reserve staff members have been informally enforcing the zone regulations for several years. Results of lobster surveys conducted at the opening of the lobster season have consistently shown that densities are higher in the protected areas compared to the fished areas (Alegria 2000; Gomez 1998). Catch per unit effort (CPUE) is being measured for beach traps. In 1995, over 16,000 pounds of fish were caught by nine beach traps (Gibson et al. 1996). In 1997, over 22,000 pounds were caught by eight traps, with the catch consisting of mainly yellow fin mojarra (*Gerres cinereus*), grey snapper (*Lutjanus griseus*), great barracuda (*Sphyraena barracuda*), and the blue-striped grunt (*Haemulon sciurus*; Gomez 1998).

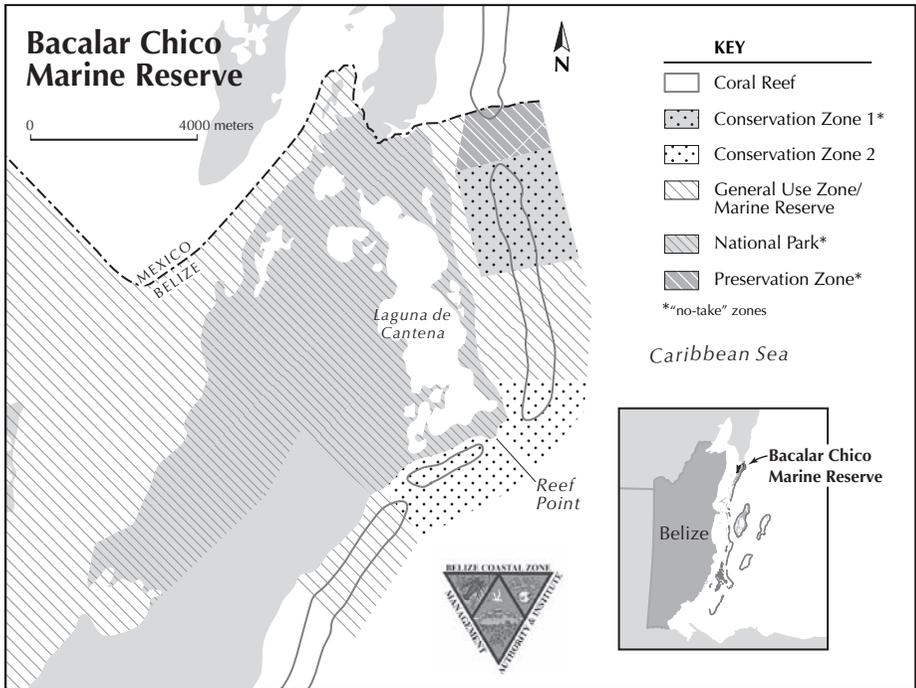


FIG. 10.4 Bacalar Chico Marine Reserve, Located Offshore Ambergris Caye on the Border with Mexico, Is Zoned for Conservation, Recreational Activities, and Traditional Fishing. The northern end of the caye comprises the Bacalar Chico National Park. Conservation Zone 1 and the Preservation Zone are both no-take.

Gladden Spit and Silk Cayes Marine Reserve

Fishermen of southern waters have fished at “the Elbow” or Gladden Spit since the 1920s, capitalizing on the healthy spawning aggregations of mutton snapper (*Lutjanus analis*) in April and May each year. These fishermen have also recognized that whale sharks (*Rhincodon typus*) frequent the area during spawning time. The area attracts the most predictable and dense aggregation of whale sharks in the world; whale sharks are attracted to the site to feed on the freshly released spawn from cubera (*Lutjanus cyanopterus*) and dog snapper (*Lutjanus jocu*; Heyman et al. 2001). It was further recognized that over twenty-five species aggregate at the site for spawning at various times of year (Heyman and Requena 2002). One mutton snapper tagged at Gladden traveled over 200 miles in less than three weeks, and another returned to the site two years after tagging, indicating long migration distance and site fidelity for spawning (Heyman, unpublished data).

A local community-based organization, the Friends of Nature (FoN), held a

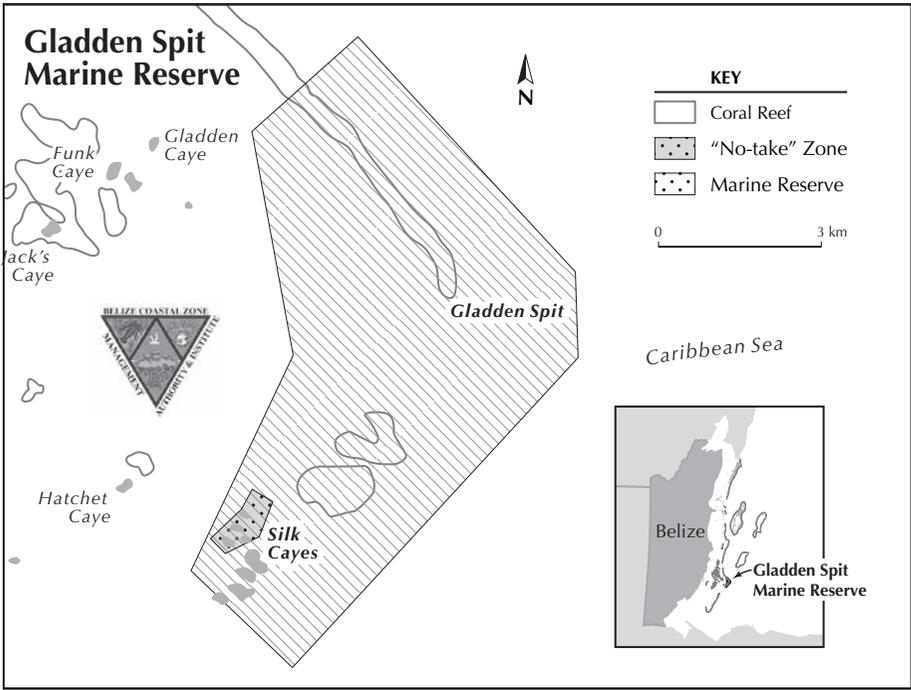


FIG. 10.5 Gladden Spit and Silk Cayes Reserve and Spawning Aggregation Site Closures. This marine reserve, spanning a large opening in the central portion of the barrier reef, Gladden Entrance, encompasses an important spawning aggregation site for mutton snapper and many other species. Only the marked area near the Silk Cayes is no-take.

series of community consultations over a two-year period that culminated in the designation of the reserve on May 18, 2000 (Government of Belize SI [Statutory Instrument] #68 of 2000). FoN subsequently signed a Memorandum of Understanding with the Fisheries Department for the comanagement of the reserve, and the organization assumed management of Gladden Spit in January 2002. FoN now operates two vessels and has a biologist and four rangers on staff for the marine reserve. A number of local and international organizations, such as the Coastal Zone Management Authority and Institute (CZMAI), The Nature Conservancy (TNC), World Wildlife Fund (WWF), the Oak Foundation, and others, have assisted FoN with institutional strengthening, community consultations, planning, and reserve management.

The total reserve area is 10,523 ha (25,992 acres) of which 153 ha (378 acres), Conservation Zone 1 surrounding the Middle Silk Caye was designated as no-take, while the remainder is designated as a General Use Zone (Fig. 10.5). FoN has developed a draft management plan for the reserve and is sharing the plan with communities via public consultations. The plan includes two additional

areas within the Conservation Zone 2—the spawning area and the restoration area. The spawning area of whale shark zone, which encompasses the multi-species spawning aggregation on the northern and eastern edge of the reef, will be carefully managed for tourism and limited traditional fishing. The reserve issues special licenses for boats and guides within the whale shark zone, in addition to strict carrying capacity limits, and an entrance fee of \$25 per person per day for diving during the peak whale shark times. Recognizing its international importance as a spawning site and the economic value of the whale shark tourism industry, traditional fishers have agreed to severe fishing restrictions at the site and to work closely with scientists.

The development and management of Gladden Spit serves as an excellent example of comanagement by local communities. The FoN board of directors is composed of local community leaders, and all decisions regarding the reserve operation are based on thorough discussion and consensus amongst the communities. Managing the reserve will be a challenge, given the rapid increase in visitors interested in whale shark watching.

PROTECTION OF SPAWNING AGGREGATION SITES

Most larger reef fish species aggregate to spawn at specific times and locations. This has long been recognized by fishers from Belize who have traditionally fished Nassau grouper (*Epinephelus striatus*) during the December and January full moon period at a variety of traditional spawning sites throughout Belize (Carter et al. 1994b). Glover's Reef Marine Reserve included seasonal protection for one such site, and Bacalar Chico had the area around its spawning bank at Rocky Point zoned to allow for only sport fishing and recreational activities (see earlier discussion). Investigations at Glover's Reef demonstrate that fishing during the spawning season by even a limited number of traditional hand-line fishermen can easily remove more than 10 percent of the spawning population; tag returns also show that spear fishing over the balance of the year takes a further 14 percent of the population (Sala 2002). Fisheries models indicate that this level of fishing is unsustainable; if continued, the population will disappear by 2013, with commercial extinction even sooner (Sala et al. 2001).

In 1998, investigations were initiated by TNC on the spawning aggregations of snapper at Gladden Spit, which led to year-round assessments at that site for the period between March 1998 and May 2002 (Heyman 2001). Recognizing the need for protection of the Nassau grouper, Green Reef Environmental In-

stitute developed and implemented the first national synoptic assessment of spawning aggregations during the 2000–01 Nassau grouper season (Paz and Grimshaw 2001). This project also contained a major education and advocacy program, culminating in a national workshop, the creation of a Spawning Aggregation Working Group, and ultimately policy recommendations for national legislation. A similar national study was sponsored in January 2002, along with spot checks at various reef promontory spawning sites at varying times of year, with data from these studies compiled into a status report on multispecies spawning aggregations in Belize (Heyman and Requena 2002). It appears from the report that many reef promontory sites serve as multispecies spawning aggregation sites through much of the year.

Based on the need to protect Nassau groupers, a coalition of seven national and international NGOs (BAS, FoN, Green Reef Environmental Institute, TNC, Toledo Institute for Development and Environment [TIDE], Wildlife Conservation Society, and WWF) jointly advocated for new legislation to protect Nassau grouper spawning aggregation sites, and in November 2002, two new laws were enacted. The first protects the Nassau grouper from December through March each year, the time when this species is known to breed; the second created eleven new no-take marine reserves at Nassau grouper spawning aggregation sites, which are also known to host multiple species of spawning aggregations throughout the year. Taken together, these two pieces of legislation provide unprecedented protection for aggregating finfish and serve as a model for other countries. Similarly, the development of the legislation represents unprecedented collaboration between conservation groups, the commercial fishing industry, and the government of Belize. To evaluate the effectiveness of the closures and the possible migration to and from these sites, the coalition of NGOs and the participating MPAs will continue to monitor the spawning aggregation sites in January and April each year.

ECONOMIC ALTERNATIVES

Perhaps Belize's most effective tool for the development of marine reserves has been the use of economic alternatives for fishers. Marine reserves, by definition, restrict fishing activity. Although it is understood that the reserves will contribute to the long-term management of the fishery, fishermen are often more supportive of the reserves when offered alternative livelihoods in the short term. TIDE and FoN have been particularly cognizant of this fact and have included extensive economic alternatives training in their conservation

programs. The most effective of these have been fly-fishing guide training and scuba diving guide training, which have led to the inclusion of many ex-fishermen into the guide business.

LESSONS LEARNED

Conservation of ecosystem functions and biodiversity, and management of tourism and recreational activities, are the major roles of MPAs in Belize, and to achieve these objectives strict no-take zones may not be essential. However, the potential importance of marine refugia to fisheries management is recognized in Belize's fisheries legislation, with its provisions for the designation of marine reserves. Designation of MPAs often comes under the general legislation for establishment of protected areas. In the past, marine reserves were viewed as a response to tourism, and fisheries management policy focused primarily on enforcement of traditional management practices and diversification to different species and to aquaculture to reduce pressure on stocks that are being overexploited. However, recently there has been greater recognition of the role of marine reserves in fisheries management (Carter and Sedberry 1997), although some commercial fishing interests are not in full agreement with the concept. In the recently revised Fisheries Act (2003), the primary purposes for declaring marine reserves are to maintain commercial fishing, encourage research, and protect fish habitat (section 47 (2)).

Carter and Sedberry (1997) recommend that 30 percent of the coastal zone of Belize should be closed to fishing, the remainder to be managed by traditional methods. This recommendation is based on the work of the Plan Development Team (1990), which concluded that if 20 percent of the southern U.S. coastal waters were to be closed to fishing, a sustainable fishery in the remaining 80 percent of the waters would be achievable. The total marine area with statutory protection in Belize is about 238,761 ha (587,610 acres), but only about 19,040 ha (47,028 acres), or 8 percent, of these protected areas are strictly no-take. Thus less than 4 percent of the estimated 500,000 ha (1,235,000 acres) of reef and sea grass habitat, or 1 percent of the country's territorial waters (1,881,400 ha [19,467,058 acres]), are in no-take zones.¹ Closure to fishing of 30 percent of just the reef and sea grass habitats (as opposed to the entire territorial waters) would involve the creation of no-take zones over a total area of some 150,000 ha (370,500 acres).

¹ These figures do not include the recently protected spawning aggregation sites.

Traditional fishery management methods will continue to play an important role. It will be important to have a range of management methods, and certain aspects of the fishery will still need the species approach to management. MPAs, including no-take marine reserves, should be viewed not as a replacement for such methods and approaches, but rather as complementary. The recent revision of the legislation previously discussed recognizes this. The act requires the preparation of management plans for prime commercial species, and newly passed legislation creates a seasonal closure to protect Nassau grouper and creates a network of small no-take areas to protect key reef fish spawning sites. Since the snapper and grouper (reef fish) fishery is seasonal and site specific, these new seasonal and area closures should be highly effective, particularly where such areas can be incorporated within an MPA and thus have regular surveillance. This was investigated and some boundary adjustments were made to ensure inclusion of entire spawning sites. These closures will be most effective if implemented in conjunction with other traditional fishery management approaches. The shrimp fishery and sportfishing industries may also benefit from specific regulations such as those on gears and closed seasons.

The data available at present are insufficient to conclusively demonstrate that the existing marine reserves contribute significantly to the sustainable management of Belizean fisheries. However, they indicate several potential benefits. The research at Hol Chan, Glover's Reef, and Half Moon Caye illustrate that MPAs protected from fishing enhance fish stocks, and significant differences can appear within two to four years after closure of the no-take zones. In these protected sites, abundance and size of certain species of fish, conch, and lobster were higher than in other sites (Acosta 1998; Carter and Sedberry 1997; Hol Chan Marine Reserve 1991a, 1991b, 1992a, 1992b; McClanahan et al. 2001). Such populations, particularly given the larger sizes and resulting greater reproductive output, could act as breeding stock and result in improved recruitment outside the no-take zones. It can also be presumed that total protection in MPAs of habitats important to certain life stages of commercial species will also benefit the fishery. Once Belize's network of MPAs is completely established and enforced, a significant area of mangroves, sea grass beds, and other habitats important for juvenile commercial species will be protected and could be expected to increase populations. However, studies confirming this or showing higher yields in adjacent areas have not been collected yet, and more research is required on the extent to which populations, particularly of relatively sedentary species such as conch and lobster, migrate out of protected

areas. The role of no-take zones in the management of the shrimp and aquarium fisheries and in sport and recreational fishing, other than the general direct benefits described following here, will need further study.

It is also expected that MPAs may lead to a reduction in fishing effort by providing alternative sources of income. This is already being seen in San Pedro, where tourism has increased dramatically since the establishment of Hol Chan Marine Reserve, which now receives almost 40,000 visitors a year. The large fish in the reserve are undoubtedly one of the main attractions and can be equated with elephants in Africa because visitors have an almost guaranteed certainty of seeing large fish at a location such as Hol Chan.

The MPAs in Belize can greatly facilitate Conservation Compliance Unit (CCU) operations and the enforcement of fisheries regulations, as has already been demonstrated with Hol Chan, Glover's Reef, and Bacalar Chico. The resources of CCU are insufficient to police the entire Belize exclusive economic zone. MPA rangers have certain enforcement powers, and fisheries officers may only need to be called out in special circumstances. Furthermore, because of the focus on one area, reserve staff can develop closer relationships with the local fishermen who use the area, helping to educate them in the rationale for the MPA and additional fisheries regulations and thus ultimately reducing the need for surveillance and enforcement. MPAs adjacent to international borders can also play an important role in reducing illegal harvesting by foreign fishermen. This has already been noticed at the Bacalar Chico Marine Reserve, where the presence of reserve staff has reduced incursions by Mexican fishermen. Similarly, the Glover's Reef and Port Honduras Marine Reserves near the southern border have helped reduce illegal fishing by Honduran and Guatemalan fishermen. MPAs must be effectively managed and enforced to fully attain this potential benefit, and some parks have not yet attained satisfactory management. However, the enforcement or protection programs generally received higher scores, although there was wide variability between MPAs (McField 2000).

MPAs may also play an important educational role in the context of fisheries management. The establishment of MPAs in Belize involves holding public forums, which are invariably attended by fishermen whose livelihoods are potentially affected by the reserve. Representatives of the fishing community also sit on the advisory or management committee, which is generally established to assist with the development and management of the MPA. These processes are designed to ensure that fishermen are generally well informed about the purpose of the reserve and that they develop an understanding of

the rationale behind various fishery management strategies. They are also encouraged to participate in the preparation of the management plan for the area, a process that generally ensures much greater cooperation and willingness to obey regulations once these are in force. However, there may not be adequate flow of information from the representatives on these committees to the active fishermen in the reserves. Recently there have been several instances of groups of fishermen calling for the dereservation of MPAs or reductions of their no-take zones.

Education of other marine users, such as tourists and residents, may also have a long-term indirect benefit, enhancing the conservation ethic, and potentially reducing demand for out-of-season or undersized fisheries products. Over the past couple of years there has been a growing move toward comanagement of the MPAs by NGOs and community-based organizations. Presently, comanagement agreements are in place for seven MPAs (see Table 10.2). This type of comanagement arrangement provides a mechanism for community involvement not only in the planning for MPAs but also in their day-to-day management. Such comanagement arrangements were also found to be more effective than direct governmental management of the reserves, although this was based on only four MPAs (McField 2000).

The hypothesized benefits of MPAs, particularly the no-take zones on benthic reef community structure, have not been adequately addressed by research. McField (2001) analyzed the influence of environmental and management-linked variables (including protected areas status) on reef community structure for twelve moderate-depth forereef sites, including seven sites within MPAs under various levels of active management. This work applied a multivariate analysis technique of Clarke and Ainsworth (1993) that links the matrices of biotic community data and the environmental and/or management linked variables to determine the selection of variables that best fit or explain the community patterns. The results indicate that the MPA status was among the most influential factors shaping reef community structure prior to the catastrophic disturbances of 1998, after which the best fit was attained with only the fluvial variable, indicating that run-off associated with Hurricane Mitch had a greater role in shaping the postdisturbance communities. Although more testing of this method is recommended, this approach and others are needed to holistically examine the ecological effects of the MPAs system. The few other site-specific studies of benthic MPA effects that have been conducted have produced somewhat mixed results. Sandman (2001) and Williams and Polunin (2001) reinforced the hypothesized benefit of reduced macroalgal abundance corre-

lated with increased herbivore biomass at shallow reef sites in Half Moon and Hol Chan, respectively. However, Williams and Polunin (2001) found that the results did not hold for intermediate-depth forereef sites. Furthermore, McClanahan et al. (2001) did not find any “beneficial” effect of the no-take zone in shallow patch reefs in the Glover’s Reef Marine Reserve, although there were confounding disturbances. Clearly, this is an important area of research that requires further attention.

Research in Belize has reinforced the priority areas for further research that have also been identified in the literature (Roberts, 1995; Roberts and Polunin 1991; Wells 1995), including the following:

- The movements of fish and invertebrates in and out of reserves and the potential of reserves to export fish to adjacent fished areas, enhancing yields or catches.
- The level of fish catch per unit effort inside MPAs and in adjacent areas over time following enforcement of regulations.
- Larval dispersal in relation to prevailing currents (to identify the sources of recruits to reserves and to fishing stocks) and the fate of progeny spawned in reserves; this may influence the choice of location of no-take zones and provide some guidance as to how effective the proposed network of MPAs will be in Belize and in the wider Mesoamerican reef system; this may require a search for genetic markers and work on both local and large-scale oceanographic processes.
- Optimum sizes for no-take zones; in the absence of relevant information, recommendations have been made that, where a protected area is large enough, two or more no-extraction zones should be established as replenishment areas, and that these should be as large as possible.
- Impact of fish feeding and diver tourism within the MPAs, particularly at locations such as Hol Chan where both are important issues.
- Impact of changing the trophic structure of fish communities; for example, if carnivorous species increase in MPAs at the expense of herbivores, including sea urchins, will this result in an increase in algal cover and deteriorating corals?
- Comparison of genetic diversity in fished and unfished areas.
- Relationship of no-take zones and increased fish abundances on benthic community structure, particularly on the hypothesized reduction in macroalgal cover.

Equally important is the establishment of long-term monitoring and data-gathering programs, including the compilation of locational catch per unit effort data on important fisheries. Despite several efforts, such a fisheries data management program has not become fully successful. The recent opposition to the enforcement of additional no-take zones within established MPAs attests to the importance of working closely with commercial fishermen to adequately demonstrate the effectiveness of these zones at enhancing fisheries yields outside the MPAs. The importance of collecting accurate catch and effort data cannot be overestimated, and methods that are simple to use, easily replicated, and involve local fishermen and park staff should be used. Belize's network of MPAs provides a unique opportunity to carry out a long-term, large-scale study on the role of marine refugia in fisheries management, using a variety of methods. Finally, given the numerous threats to coral reefs emanating from local, regional, and global anthropogenic sources, including from global climate change, the potential ecological benefits of MPAs are paramount and should be more adequately addressed through scientific investigations.

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