A String of Pearls for Belize: An Alternative Strategy in Conservation and Fisheries Management for the Belize Barrier Reef Ecosystem

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ABSTRACT

Belize is endowed with abundant marine resources and has a complex tropical coastal ecosystem which includes the second longest barrier reef in the western hemisphere. Management of marine fisheries resources has traditionally been based on the biology and population dynamics of individual target species such as lobster, conch, shrimp, and grouper. Efforts to attain maximum sustainable yields and protect the stocks are exercised through limits on individual sizes, seasons of harvest, catch limits and restrictions on gear. As an alternative approach we recommend a mixed management strategy whereby 30% of the coastal zone resources are set aside as marine fisheries reserves (MFRs), areas with no consumptive usage, while the remaining 70% is managed for optimal yield by traditional options. These protected areas will provide recruits to adjacent harvest zones, protect critical spawning stock biomass, maintain genetic diversity of wild stocks, enhance yields in adjacent areas, insure against management and recruitment failures, simplify enforcement, reduce data collection needs, and serve as experimental controls for testing accepted theories from ecology and conservation biology. Finally the MFR concept is compatible with the multisectoral integrated coastal zone management approach currently underway by the Government of Belize. This plan calls for a mosaic of zones for special uses throughout the reef complex ranging from strict protection to commercial development.

KEY WORDS: coral reef conservation, parks, fisheries reserves, Belize, coastal zone management.

INTRODUCTION

The major dilemma facing conservationists today is how to balance often mutually exclusive human activities against the intrinsic value of the land and sea (Hatcher *et al.*, 1989). This problem is nowhere more evident than in the emerging nation of Belize. For more than two centuries, following the collapse of the Mayan civilization (Thompson, 1991), the natural resources of Belize's Barrier Reef Ecosystem were sustained by natural ecological processes. During colonial times, the economic development in the country focused primarily on the extraction of tropical hardwoods for the lumber industry, harvesting of logwood for the production of dyes, and the tapping of Sapodilla trees for the production of chicle, a basic ingredient of chewing gum. Throughout this same period of time and in stark contrast, Belize's vast shallow water tropical marine resources were left virtually pristine and intact. A relatively small artisanal fishery placed only modest demands on the marine environment in specific areas by harvesting local populations of commercially important conch (*Strombus gigas*), spiny lobster (*Panulirus argus*) and several species of coral reef fish. Vast portions of the barrier reef complex went largely unharvested and consequently served as adequate sources of replenishment for more heavily harvested areas closer to mainland shore and coastal communities. Unfortunately, this historic pattern of use of Belize's marine resources has rapidly been lost to the country's development needs over the past three decades. In recent years, rapid economic growth in tourism and fishing, coupled with an increasing human population, have placed new and unprecedented demands on these once pristine and abundant coastal marine resources.

Today Belize must employ modern fishery management techniques in order to ensure the persistence of its reef fisheries. Research indicates solutions to most fishery management problems require decreased total fishing mortality which involves either reduced total fishing effort, sanctuaries in space and time, or greater population numbers of target species, or a combination of these approaches (PDT, 1990). Munro and Williams (1985) recognized ten traditional administrative management options applicable to multi-species tropical reef fisheries (Table 1). The majority of these management options such as size limits, gear restrictions and catch quotas pose serious limitations for fisheries management in Belize in that they require precise biological information about the growth and mortality of each species. Acquisition of such knowledge requires years of careful detailed study and is often unavailable for use by fisheries managers in developing tropical countries. This is particularly true for Belize, where fisheries managers must protect and maintain a complex and highly diverse multispecies fishery in the absence of adequate technical, logistical, and financial resources. In response to this need, the Belize Fisheries Department, with support from CARICOM, has embarked on a major program to upgrade and expand the department's data gathering capabilities over the next

Table 1. MFR designation in Belize; anticipated benefits and obstacles.

BENEFITS	OBSTACLES
1. Protection of critical spawning stock biomass. 2. Protection of genetic diversity. 3. Maintenance of ecosystem balances. 4. Public understanding and acceptance. 5. Simplified enforcement and data collection needs.	1. Local opposition and resistance to change. 2. Site uncertainty. 3. Short-term landings decline. 4. At-sea surveillance and enforcement.

Modified from PDT

several years. But at the present time, Belize is unable to meet or sustain data collection needs as required for traditional management options.

Meanwhile environmental stress imposed by commercial development, pollution, and overfishing continues to increase resulting in a marked decline of the carrying capacity and productivity of the reef. Clearly a deteriorating reef ecosystem left unchecked poses serious threats to the regions ecological balance and socio-economic development. And as Aldo Leopold (1975) so eloquently expressed nearly six decades ago, "A loss of our wild and natural places robs future generations of their rich biological heritage." In this spirit, we believe that a bold and different approach to the management of Belize's marine and coastal fisheries resources is necessary, particularly if current efforts underway by the government of Belize to conserve and protect the barrier reef, while maintaining a viable commercial fishery, are to succeed. As an alternative approach to present traditional management practices, we recommend a mixed management strategy where 30% of the Belize coastal zone is designated as a strict marine fisheries reserve (MFR) while the remaining 70% is managed by traditional options for optimal yield (Figure 1).

The conservation and preservation of marine fisheries resources in Belize will require designation of several carefully placed marine fisheries reserves or refugia. Marine fisheries reserves represent a powerful yet under-utilized management tool for the coastal and marine resources of Belize. These refugia are designed to primarily protect commercially important reef-dependant species, such as scale fish (groupers and snappers), conch and lobster, and their respective habitats, from all consumptive exploitation within specified geographical areas. However, *de facto*, these marine fisheries reserves also afford protection to the vast majority of other marine organisms that are of little

commercial importance, thereby helping to ensure the long-term biological integrity of the entire ecosystem.

The concept is simple. We propose setting aside and protecting selected ecologically discrete sections of the reef habitat that are naturally buffered from environmental perturbations associated with human activities. These protected and undisturbed areas in turn will produce larval and juvenile recruits of commercially important species for sustainable harvest in adjacent habitat zones. Implementation of such a management strategy will require personal sacrifice and significant social and economic change for many Belizeans whose livelihood is dependent on the resources of the sea. However, the people and government of Belize have repeatedly chosen not to follow the typical path of hyperdevelopment and resource exploitation characteristic of other developing tropical nations. And by taking bold action today, Belize can insure the integrity of its coastal and marine resources for tomorrow's generations. In this paper, we briefly review both the progress and problems associated with conservation of the Belize Barrier Reef Ecosystem, propose a new strategy based on the concept of marine fisheries reserves and discuss the advantages and disadvantages of this plan.

BACKGROUND

Coastal Resources and Ecosystems

Belize is endowed with a wealth of marine resources and lays claim to the longest barrier reef in the Northern Hemisphere. The Belize barrier reef stretches some 250 kilometers (155 miles) from the tip of Mexico's Yucatan peninsula southward where it fragments into deep patches in the Gulf of Honduras (Figure 2). The main spine of the barrier reef is properly described as a "fringing barrier reef complex" (Kaplan, 1982). To the east of the main barrier reef lie abyssal waters of the Caribbean Sea. The boundary between the shelf and the deep Caribbean is the continental margin, which is defined by a down-to-basin fault along nearly the entire length of Belize (Mazzullo, 1991). The submerged coastal shelf of Belize is divided into bathymetrically distinct northern and southern halves: a flat, shallow karst surface north of the Belize River delta, and a deeper, wider zone with high relief south of the delta. The shelf edge is characterized by a series of five discontinuous submarine ridges or plateaus that run in a north-northeast direction. Geological studies indicate the topography of the shelf and deep oceanic basins formed as a result of plate tectonic spreading that began 220 to 80 million years ago. Seaward of the barrier reef are three large reef-rimmed atolls (Turneffe, Glovers and Lighthouse) which emerge from abyssal depths on uplifted fault blocks formed during this time. Each atoll has a distinctive morphology due primarily to differences in their size and proximity to oceanic and mainland environments. Glovers reef atoll has been described as

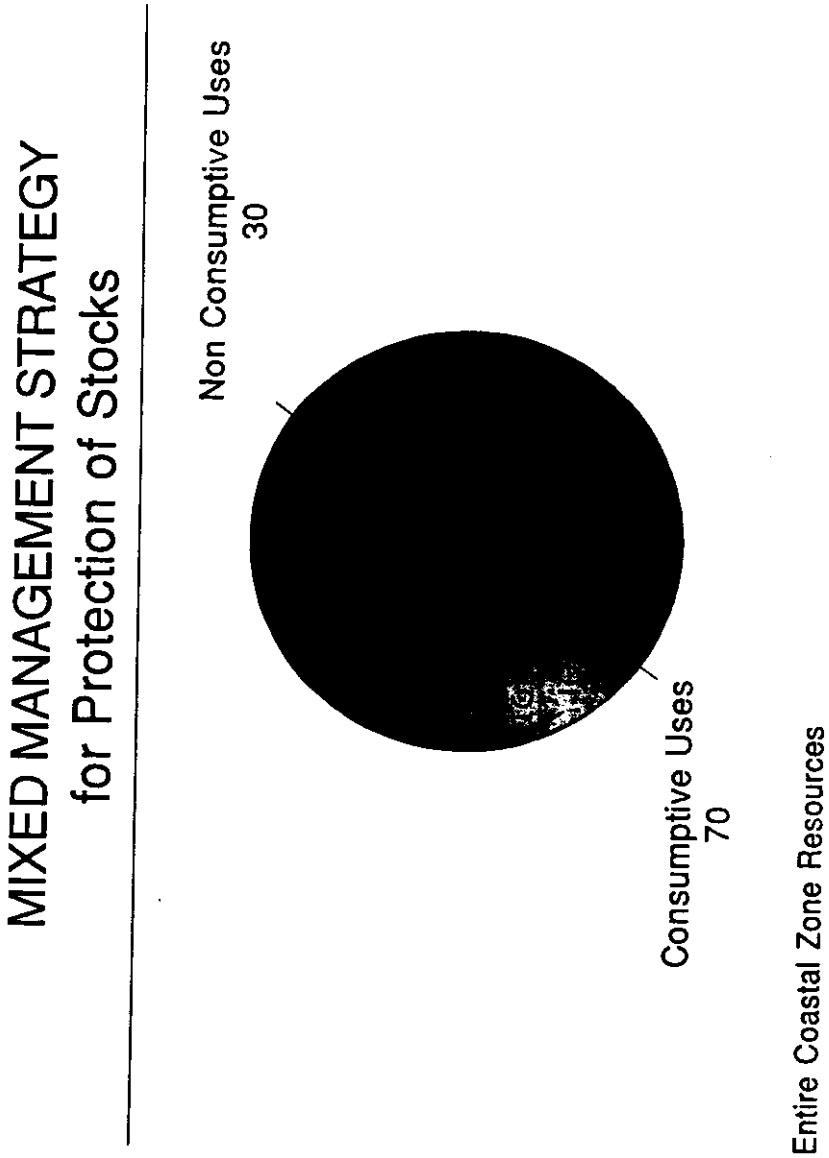

Figure 1. Mixed management strategy for protection of Belize's fishery

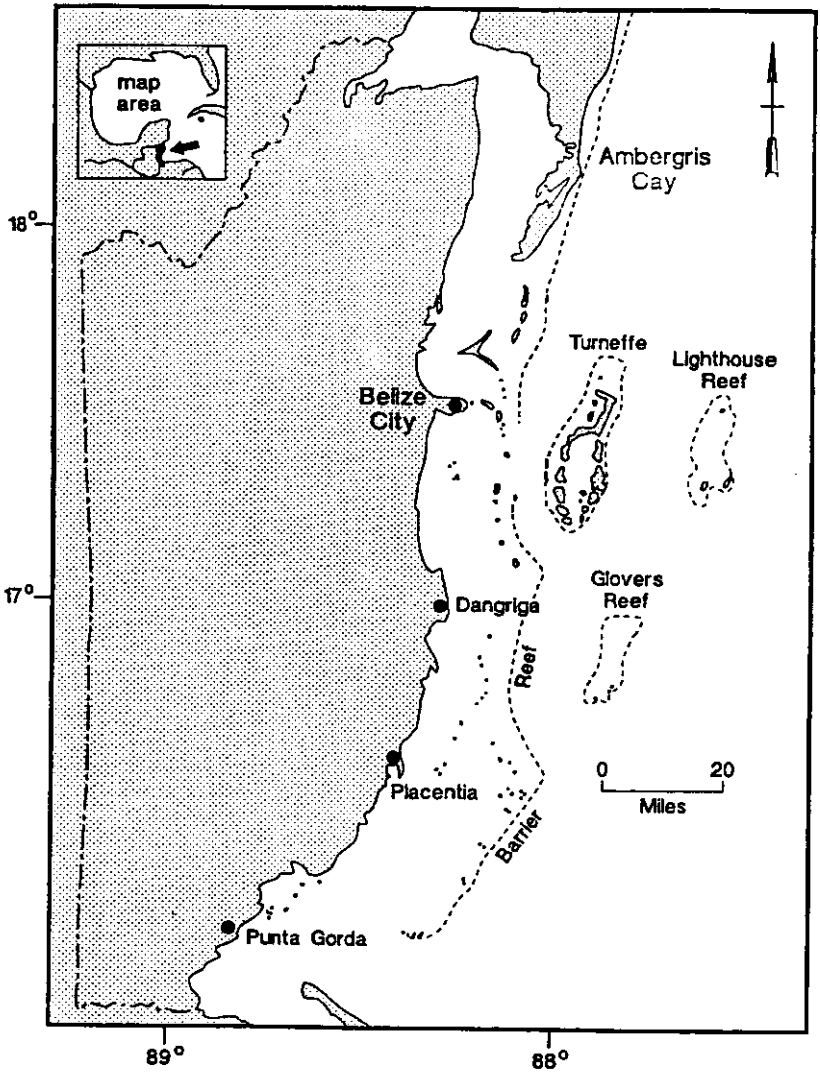

Figure 2. Map of Belize depicting the barrier reef, three offshore atolls, and sites referred to in the text.

the best example of a flourishing atoll ecosystem in the Caribbean (Dahl *et al.*, 1974).

The barrier reef complex is mainly constructed of massive stony corals such as *Montastrea annularis, M. cavernosa, Diploria, spp., Acropora cervicornis, A. palmata* and *Agaricia*, spp., soft-coral gorgonians, encrusting algae, and the red encrusting foraminifera, *Homotrema*. The reef complex is separated from the mainland by a deep and wide lagoon, which grades into shallow seagrass bottoms, patch reefs and mangrove cays on the outer barrier platform. A transect west (lagoon) to east (open ocean) shows a distinct zonation of substrates and organisms that reflects primarily water depth and the prevailing wave and current regime (Rutzler and MacIntyre, 1982). The shallow back reef shows massive coral growth and rubble and is separated from the inner fore reef by a narrow reef crest. The inner fore reef (to 14 m depth) shows a characteristic spur and groove structure, with high buttresses in the shallow depth zone (to 10 m depth) and low-relief formations on the deeper terrace. The outer fore reef includes a steep inner reef slope, a sand trough and an outer coral ridge. The fore-reef slope drops off at the top of the outer ridge.

The reef ranges from only a few hundred meters offshore along Ambergris Cay in the north to about 40 kilometers offshore in the south. Along the reef and between the reef and the mainland are about 450 cays of various sizes. The majority of these are mangrove islands, though a number are covered by a sand shingle and coconut palms. The mainland coastline consists of low-lying coastal plains, largely dominated by mangrove swamps and narrow beaches. Numerous lagoons, rivers and estuaries are located along the coast. In the southern half of the country, run-off from heavy rains in the nearby mountains has a significant impact on the ecology of the coastal zone.

Existing Marine and Coastal Protected Areas

Several marine and coastal protected areas have been established throughout Belize. These areas include the Hol Chan Marine Reserve at Ambergris Cay, the Half Moon Cay Natural Monument on Lighthouse Reef, and eight Crown Reserves and Bird Sanctuaries that include offshore mangrove cays and small islands in coastal lagoons where seabirds, wading birds and song birds nest. The purpose of these Crown Reserves is to maintain breeding populations of certain birds and their nesting habitat from degradation and destruction. The Half Moon Cay Natural Monument, established in 1982, affords protection to Half Moon Cay, which is home to a red-footed booby bird colony, as well as significant portions of the reef, inner lagoon, and deep water offshore. The Hol Chan Marine Reserve, established in 1987, is the only marine reserve actively supervised and managed on a daily basis by staff of the Belize Fisheries Department. The five square mile reserve encompasses approximately 300 ha of core protected area and includes a portion of the barrier reef as well as adjacent

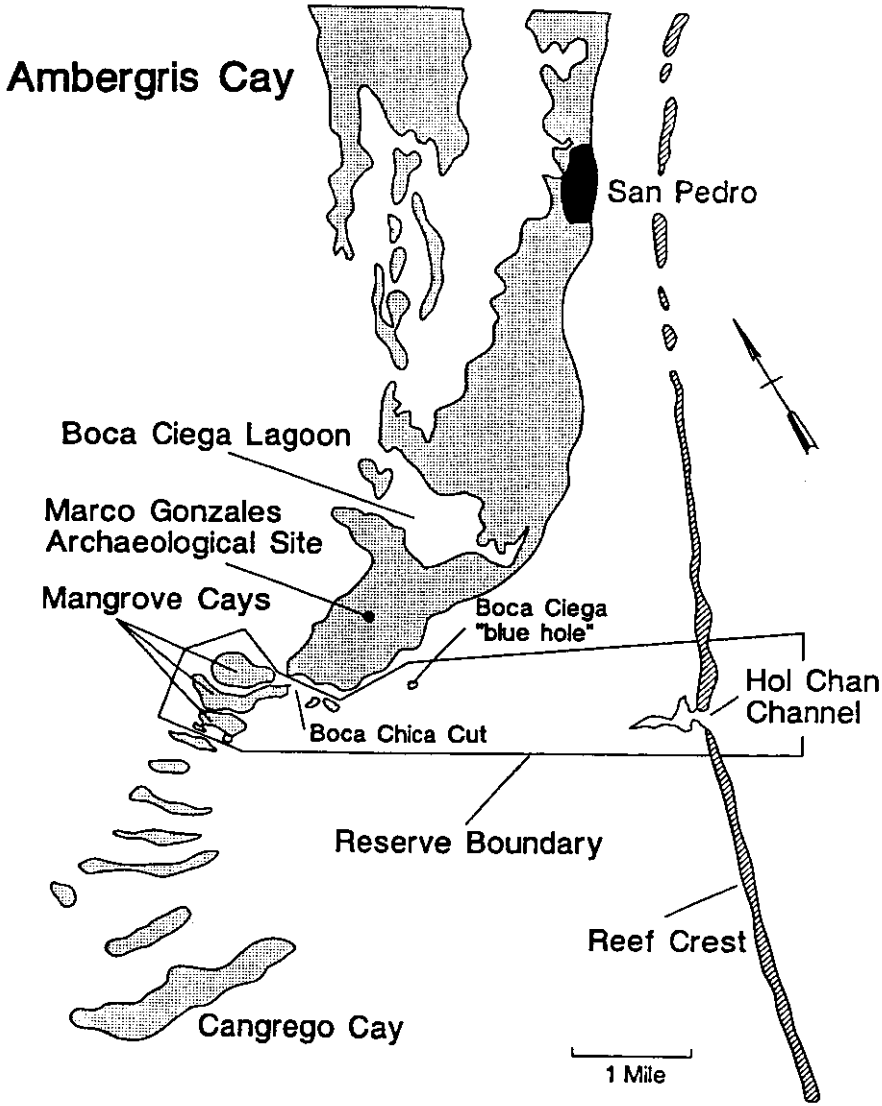

Figure 3. Map of the Hol Chan Marine Reserve. Created in May 1987, it is Belize's second marine park.

grass beds and mangroves (Figure 3). A drowned Pleistocene river channel in the reef known locally as Hol Chan, is the major attraction of the reserve and has long been a popular dive spot for the many tourists visiting San Pedro because of its unique coral formations and varied fauna. The area has historically produced an abundance of fish, conch and lobster for the local fishing industry (Schmidt, 1990). This channel, with its surrounding reefs, lagoon and mangrove habitats represents an extremely valuable resource for the people of Belize.

The Hol Chan Marine Reserve has demonstrated that protected areas can dramatically increase local populations of marine organisms, especially fish, while generating substantial revenue from tourism. Hol Chan's success has encouraged people elsewhere in the country to propose the establishment of several additional reserves. A formal proposal has been submitted by Wildlife Conservation International (WCI) and the Belize Fisheries Department for a multiple use plan for Glover's Reef Atoll, including a substantial reserve (Gibson, 1990). Other proposed sites are Laughing Bird Cay, Sapodilla Cays, the Tobacco Reef area off Dangriga (including South Water Cay, Carrie Bow Cay, Wee Cay and possibly Tobacco Cay) and a manatee biosphere in Northern and Southern Lagoons.

At the present time, there is no common agency or governmental policy responsible for the management of these various protected areas. For example, the Belize Audubon Society has a formal agreement with the government to manage Half Moon Cay and the other six protected nesting colonies while the Hol Marine Reserve is managed by the Fisheries Department under the auspices of the Ministry of Agriculture and Fisheries.

However, in recent years there has been a growing involvement by a wide variety of international conservation agencies and governments in the planning and development of a comprehensive coastal zone management program for Belize. As ecologists, we know that it is often difficult to identify the boundaries of marine habitats. In theory, we strive to delineate reserve boundaries so that a balance between the rates of species loss and replacement can be naturally maintained. This equilibrium is best achieved in large areas, because portions of reef damaged by natural and human activities can be replenished from undamaged parts of the same reef. Yet, when practice meets theory, it is not always possible-for financial, political, or logistical reasons- to protect big tracts of reef. Therefore, in Belize, we proposed a few years ago, a plan to establish small parks, individual gems or pearls along the barrier reef that will eventually be strung together in a necklace of protected marine habitats representing as much of the reef as possible (Carter, 1990). This concept coincides with a regional Mesoamerican plan, *Paseo Pantero*, sponsored by RENARM and WCI, which calls for marine reserves along the coasts of Mexico, Guatemala, and Honduras. In addition, efforts are also underway by government to designate a portion of the Belize Barrier Reef as a World Heritage Site.

Current Status of Reef Fisheries

Historically, the economy of Belize was almost entirely dependent upon the logging industry (85% of the total domestic exports in 1950). Today, the fishing industry ranks third behind tourism and agriculture in foreign exchange. Over 90% of the traditional products, lobster, conch, shrimp and reef fish, are exported. Lobster is the most lucrative product, accounting for 64% of the export revenue. It is managed by a minimum size limit, a four-month closed season and protection of soft-shelled and berried lobsters. The fishery, however, is showing signs of overexploitation, with evidence of decreasing catch-per-unit effort and decreasing size of lobster being landed. In 1972, the exports of conch reached 1.25 million pounds and, in 1990 this had plummeted to only 365,000 lbs. Despite management measures introduced which include a closed season and a minimum size limit, the fishery is over-exploited. The shrimp fishery has expanded rapidly and now ranks second in importance. The shrimp grounds are trawled by Honduran boats working in joint ventures with Belizean co-operatives. There are concerns, however, that the trawlers may be damaging the sea grass beds. Many species of finfish are commercially important with grouper and snapper comprising the bulk of the catch. The majority of fish are landed seasonally at traditional "fishing banks" scattered throughout the barrier reef complex. For example, populations of Nassau grouper, *Epinephelus striatus*, gather annually in large aggregations at six specific localities along the reef to spawn over a two week interval. Recent studies in Belize and elsewhere indicate that sustained and unmanaged fishing pressure on these banks may result in changes to population structure leading to a collapse of the fishery (Carter *et al.*, 1991; Colin, 1992). A management plan has recently been submitted to the government of Belize for consideration that endeavors to maintain long-term viability of stocks by setting at least one spawning bank aside as a strict reserve while managing the remaining five banks by traditional options (*e.g.* size limits, limited entry, etc.).

A serious problem facing the fishing industry is illegal fishing and poaching by alien fishermen. The Belize Fisheries Department, with support from the United States Agency for International Development (U.S.A.I.D.) is addressing this issue by increasing its surveillance and enforcement capability. Another major problem is the increasing numbers of fishermen entering the fishery, leading to increasing pressure on the limited stocks. Preliminary results from a recent survey of the entire finfish fishery for Belize suggest that the CPUE is stable for most stocks in Belize. However, more research is necessary to substantiate these claims and it is generally agreed that a strategy to diversify the fishery and target new unexploited species needs to be adopted. Through a CARICOM regional project, supported by the Canadian International Development Agency (CIDA) and the International Council for Ocean Development (ICOD), assessment studies on reef fisheries and deep-slope and

pelagic fisheries will be conducted. Further efforts by the Department of Fisheries to expand and diversify the commercial fishery include support and expansion of a variety of aquaculture programs, particularly shrimp, conch, and mullet farming. Finally, Belize has one licensed aquarium fish collector/exporter.

Current Status of Coastal Zone Management Activities in Belize

The coastal area of Belize is very complex, consisting of a wide variety of habitats that support two of the country's major industries: tourism and fisheries. Recognizing that the impact of development activities in this critical zone needed to be monitored and guidelines introduced to protect the integrity of the country's coastal resources, an international Coastal Resources Management Workshop was convened in Belize (Gibson, 1990). Based on the recommendations of the workshop, a Coastal Zone Management Unit (CZMU) was established under the Fisheries Department. The management of the Unit is under the direction of the Fisheries Administrator and is presently staffed by a Project Coordinator, a Research Assistant, and an Environmental Educator. In 1990, the major components required for coastal zone management in Belize and an action plan were drafted by CZMU staff with assistance from IUCN experts. Using these guidelines, the data collection and compilation or Phase I of the Project was completed (Figure 4). All data relevant to the coastal zone, including physical parameters, habitats and resources, and uses/impacts were mapped on a series of overlays at the 1:250,000 scale. This data has also been stored on a computerized database. An inventory of the cays demonstrating ownership and use was also completed. In 1991, these maps were digitized and the data entered in a Geographic Information System (GIS) using ArcInfo at IUCN's World Conservation Monitoring Center. Digitized data has been transferred to the Land's Information Centre (Ministry of Natural Resources) in Belmopan. More recently, these maps and databases are being used as part of a management strategy to guide use and development, and to assist in the policy-making process. They are also proving to be a useful reference in conducting basic impact assessments. Phase II, or the data analysis section of the project, is now in progress. The major issues facing the use of the coastal complex are being identified and the map overlays will be analyzed with the assistance of a planner. An integral part of this phase is the preparation of management plans for specific critical areas. Working with non-governmental organizations, the CZM Unit is drafting plans for four marine protected areas. The CZM Project is based on the principle of integrated coastal resources management. With many sectors having an interest in the coastal zone, coordination is of paramount importance. In an effort to ensure coordination, a CZM Technical Committee has been established which has representatives from the various government agencies and non-governmental organizations. The

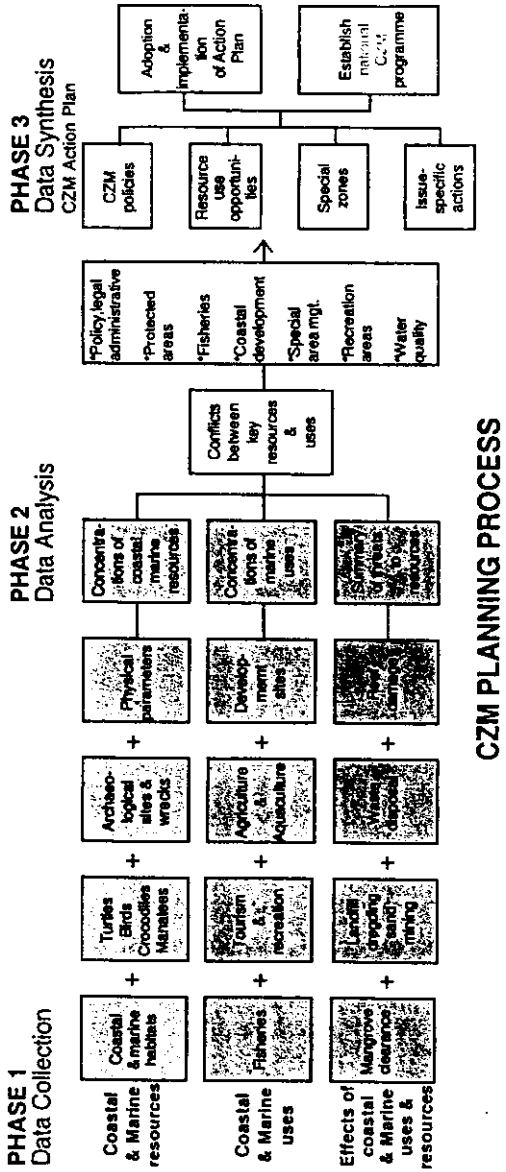

Figure 4. Flow chart depicting phases in the development of a coastal zone management program for Belize.

recommendations put forward by this committee should result in improved planning for development projects.

To enhance public awareness of the importance of the coastal area and to increase general understanding of the ecosystem involved, an education program is an essential component of the project. Weekly radio programs are being broadcast and slide shows presented to school children. Plans are being made to hold workshops for small farmers, dive guides and fishermen. Recently, an exhibition was held to explain the role of the CZM Project and to underline the value of mangroves to the country. This aspect of the project is being spearheaded by the Belize Audubon Society.

The project is also actively promoting the introduction of a marine and coastal studies program at the University College of Belize, and strongly recommends the establishment of a marine research station which is appropriate to the country's world-class marine resources. The final phase of the project will involve the development of an action plan which will include a zoning scheme for the barrier reef complex, definitions of a management framework, policies and legislation, recommendations for additional protected areas, introduction of monitoring mechanisms and a description of priority areas for further research. Immediate future activities will concentrate on establishing a coral reef/water quality monitoring program, providing adequate protection for mangroves, developing a comprehensive policy governing development of cays, assessing the problem of shoreline erosion, and completing management plans for some areas of special concern.

The reef/water quality program will involve the setting up of permanent stations along the reef to detect changes in reef ecology. Concerns have been expressed about the effect of increased sediment and the run-off of agro-chemicals on coastal water quality and the coral reef. The need to develop the human resources required to implement the Action Plan is recognized and thus training at all levels is a high priority of the Project.

The Importance of Reef Fish Ecology

The Belize Barrier Reef and associated coastal habitats represents a complex and highly productive ecosystem that supports a fishery that is typically multispecific and employs a wide variety of methods of capture. The ecology and life history traits of reef fishes combined with the nature of the fishery make reef fish populations highly vulnerable to overfishing (Ralston, 1987; PDT, 1990; Roberts and Polunin, 1991). Reef fish are characterized by a slow growth, low adult natural mortality, long life, multiple reproductions, increased fecundity with size, restricted distributions, sedentary post-settlement larval and juvenile stages, and large body size (Manooch, 1987; PDT, 1990; Sale, 1991). Larger body size confers an advantage to reef fish by enabling individuals to acquire more food, secure mates, defend territories and escape

predation (Menge and Sutherland, 1976, 1987). Reef fish also exhibit a life cycle consisting of pelagic larvae and demersal adults. Eggs and larvae disperse during a free floating stage lasting from a few days to two-three months (Sale, 1980; Richards and Lindeman, 1987). Furthermore, field studies indicate adult natural populations are controlled by the number of postlarval survivors and not necessarily the amount of habitat available (Doherty and Williams, 1988).

Evolutionary theory predicts certain life history traits such as age, size and reproductive strategy will arise in response to natural selection pressures operating over time in the environment (Murphy, 1968; Rago and Goodyear, 1987). Reef fish history traits such as large body size, long life and late reproductive maturity are appropriate responses for organisms experiencing the high uncertainty of larval survival and limited adult mortality typical of reef environments (Partridge and Harvey, 1988). Fishing in contrast to natural selection selects for increased reproductive effort at younger ages, resulting in early sexual maturity, shorter life spans, smaller sizes and single reproductive episodes (Table 2).

Fishery effects on tropical stocks have been documented by field studies (Munro and Williams, 1985; Thompson and Munro, 1978; Pauly, 1979; Polovina and Ralston, 1987) and by theoretical models using groupers (Bannerot, 1984, 1990) and the red snapper as a typical commercially important and widely distributed reef species (PDT, 1990). These studies revealed that high fishing mortality resulted in fewer adults, less total egg output, and reduced average spawning age. These changes in turn lead to a loss in genetic diversity, an increased chance of recruitment failure, and population collapse triggered by natural stochastic events. In an effort to assess changes in stock due to fishing, Goodyear (1988a, 1988b, 1989) has shown that the spawning potential ratio (SPR) can be a good predictor of reproductive potential and recruitment overfishing. These studies indicate that stock collapse is likely when spawning stock biomass (weight of spawning fishes) drops below a critical level of 20% of the unharvested level. An effective fishery management strategy should guard against stock collapse by providing protection for natural population age structure, species composition, and genetic variability.

PROPOSED REFUGIA MODEL

Rationale

Marine fishery reserves (MFRs) proposed for Belize are defined as sections of reef permanently closed to any extractive activities. Consumptive activities such as commercial and sportfishing would be prohibited in these regions. These MFRs would afford complete protection to portions of reef fish populations ensuring the long term maintenance of undisturbed reef fish communities. MFRs will serve as fish sanctuaries that protect genetic diversity and ensure larval recruitment by protecting large, older spawning individuals with high

Table 2. Administrative management options for reef resources.

1. Size Limits
2. Catch Quotas
3. Seasonal Closures
4. Pulse Fishing (Periodic Closures)
5. Annual Limited Entry
6. Permanent Limited Energy
7. Habitat Alteration (Artificial Reefs)
8. Supplementary Stocking
9. Gear Restrictions
10. Permanent Reserves

Modified from Munro and Williams, 1985

fecundities. Adjacent harvested habitats will benefit from the dispersal of eggs and larvae from core protected ares.

In recent years many sanctuaries, parks, and preserves have been established worldwide for a wide variety of purposes (Clark *et al.*, 1989; Foster and Lemay, 1989; Tisdel and Broadus, 1989). Although most marine parks have failed to achieve their stated goals (Davidson and Gjerde, 1989) a few have been successful due primarily to local community involvement, adequate funding and active management (White, 1986, 1988; Alcala, 1988; Foster and Lemay, 1989; Tisdell and Broadas, 1989).

The idea of setting aside sections of reef as inviolate sanctuaries is not new and was in fact widely practiced by Islamic people of the Indo-west Pacific centuries ago as a means of sustaining their local reef fishing (Johannes, 1981, 1982). However, the deliberate use of sanctuaries as tools by fisheries managers to enhance and sustain tropical reef fisheries today is relatively new. In recent years a series of recommendations for establishing reserves for fisheries purposes has appeared in the literature (Davis and Dodrill, 1980; Randall, 1982; Davis, 1989; Roberts and Polunin, 1991; Bohnsack *et al.*, 1989; PDT, 1990).

Recently the potential success of MFRs in a variety of regions is predicted based on dramatic increases in fish abundance observed in areas protected from fishing activities (Goeden, 1982; Randall, 1982; Russ, 1985; White, 1986, 1988; Kenchington, 1988; Polunin and Roberts, 1992). Russ and Alcala (1989) were able to show significant decreases in both species richness and density of target and non-target species compared to control sites eighteen months later following the breakdown of ten years of protective management at Sumilon Island Reserve, in the Philippines. In the southeastern U.S., partial fishery protection has been shown to be effective in increasing abundance and size of lobster (Davis, 1977; Davis and Dodrill, 1980) and coral reef fishes (Bohnsack, 1982; Clark *et al.*, 1989).

Design

Several intrinsic and extrinsic factors must be considered in the ultimate design of marine fisheries reserves in Belize. Although little information and research data exists to evaluate the relative importance of various design factors, several recommendations have been proposed (PDT, 1990; Kenchington, 1988). Marine fishery reserve design in Belize should focus primarily on populations of commercially important target species such as lobster, conch, shrimp, and finfish such as snappers and groupers. Care should be taken to ensure adequate habitat area to support adult breeding populations with a stable age structure. Marine fishery reserve design should also adequately account for the shelter and food needs of target species' early life history stages. And finally, extrinsic factors such as social and economic issues must be considered in order to fully evaluate the overall effectiveness of the reserve area in meeting its objectives.

Specific Recommendation

We recommend marine fishery reserves be established for 30% of the coastal zone of Belize while traditional fishery management practices be applied to the remaining 70% of the available habitat. A series of carefully selected marine fishery reserves are to be established throughout the coastal zone of Belize with the goal of protecting a minimum of 30% of the reef fish spawning stock biomass (SSB). To achieve this goal MFR sites throughout the Belize coastal ecosystem will include representative shelf habitats in proportion to their occurrence and importance to target species. The rationale being that removing 30% of the habitat from fishing protects 30% of the population and therefore 30% of the spawning stock at equilibrium. Along the mainland coastline, particular consideration will be given to linkage habitats such as river mouths, estuaries, embayments and mangrove swamps. Further offshore, consideration will be given to sea grass, sand and reef habitats characteristic of the main barrier reef complex as well as unique habitats associated with the three offshore coral atolls. The remaining 70% of the shelf will be managed by several traditional options selected by the Department of Fisheries for optimizing yields. Non-consumptive resource use such as scuba diving and snorkeling will be allowed in MFRs. The 30% MFR option for Belize was chosen based on theoretical and empirical evidence that stocks are likely to crash when they fall below 30% of the unexploited spawning stock biomass (SSB) level. Goodyear, (1989) recommended a lower 20% SSB option. However, this value was based on the assumption that the remaining 80% of the shelf would be effectively managed to optimize yield. Until Belize acquires adequate financial, logistical and technical resources necessary to achieve this goal we strongly recommend an increased SSB level of 30% as a minimum.

We recommend to the appropriate government agencies that Belize declare at least 30% of its coastal ecosystem as exclusive MFRs taking great care to

ensure that the diverse habitats of the ecosystem are well represented. Today only that small portion of the Belize coastal zone contained within the boundaries of the Hol Chan Marine Reserve and Half Moon Cay National Monument can be considered fully protected in the sense of a strict fishery reserve. If pending proposals for additional marine fishery reserve sites are approved and implemented, the percentage of coastal zone protected as a strict fishery reserve would increase substantially. A map depicting existing and proposed sites throughout the coastal zone of Belize is presented in Figure 5. Since these existing and proposed protected areas were established for a variety of reasons, it is not known to what extent these sites meet the needs of commercially important target species in Belize. We fully expect the optimum number, location and sizes of fishery reserves proposed to date to change as appropriate government agencies and various user groups consider the plan in greater detail. We further recommend that the actual planning and implementation of the plan proceed as an activity of the coastal zone management unit (CZMU) under the direction of the Belize Fisheries Administrator. CZMU and Belize Fisheries Unit (BFU) biologists should be responsible for determining the biological criteria and intrinsic factors necessary for MFR design. Extrinsic socio-economic factors should also be considered and incorporated into the MFR design as a result of discussions with representatives of local user groups (such as fisheries cooperative members, tourism operators, and private coastal land owners). It is also anticipated that the CARICOM regional fisheries project, headquartered in Belize, would play a major role in assisting the BFU and CZMU staff with developing the best strategy of traditional management options for optimizing yield while maintaining stocks in the remaining 70% of the coastal zone habitat.

Other Considerations

In 1990, the Reef Fish Plan Development Team (PDT, 1990) evaluated a series of traditional management approaches in addition to MFR's for their potential to meet a series of defined management objective. Several of the traditional options fell short of meeting their goals in that they did not address critical fishery problems and were easily circumvented. In addition, they compared and contrasted major anticipated benefits and obstacles associated with establishing MFR's (Table 3). Team participants concluded that of all the management options, MFRs represented the best management approach overall for protecting stocks and reducing overfishing problems.

CONCLUSIONS

Natural populations of coral reef fishes in Belize possess certain life history traits, such as long life, slow growth and maturity, and high recruitment uncertainty, that make them particularly susceptible to overfishing. When stocks

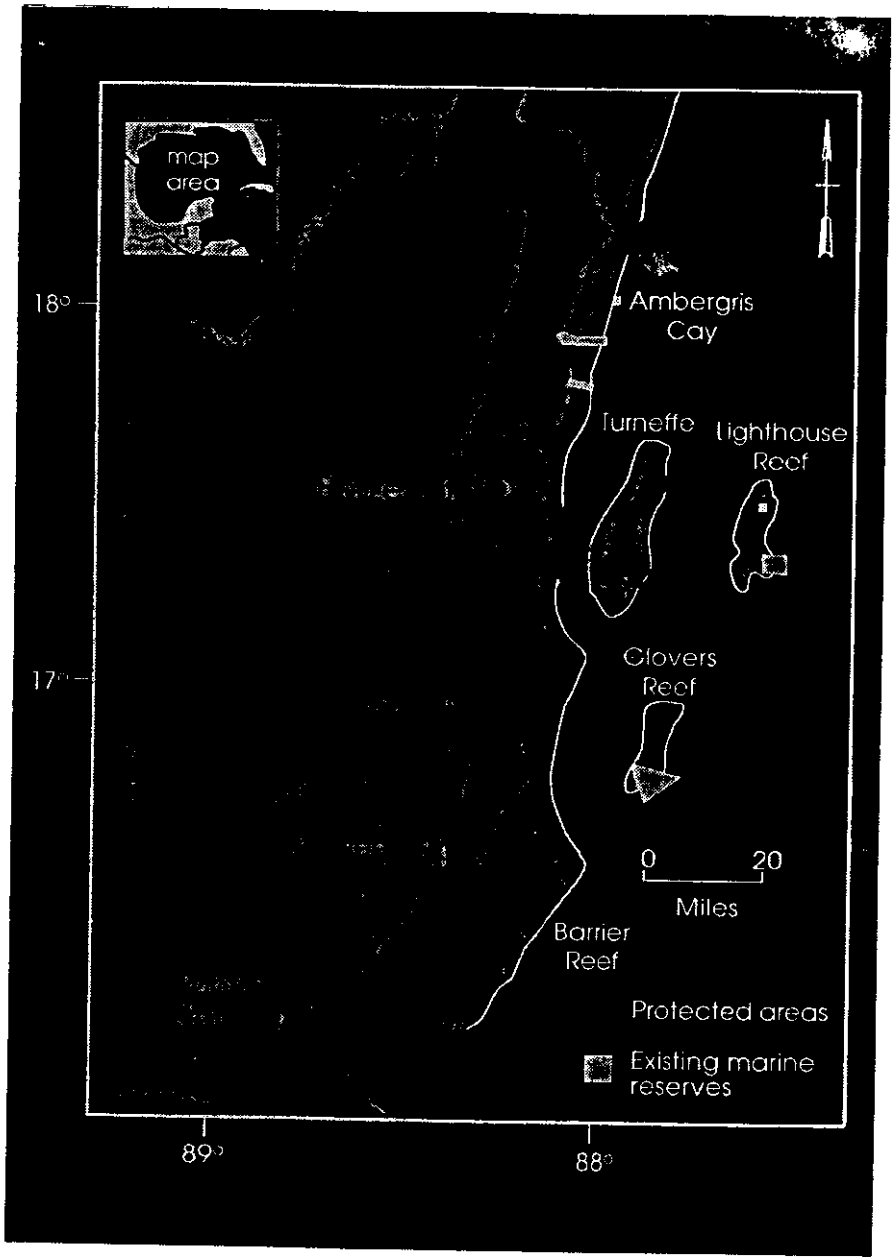

Figure 5. Map of Belize coastal zone depicting location and relative size of existing and proposed marine protected areas.

Table 3. Rationale for MFR's.

• Reduced Data Entry
• Cost Effective
• Integrated Approach
• Low Maintenance

of many commercially important reef fish are faced with uncontrolled fishing pressures, their populations often collapse or show signs of stress. Over time, genetic diversity is diminished and important species become permanently scarce or diminuitive in size. To protect stocks and reduce overfishing effects, we propose a mixed management strategy where 30% of the shelf is designated as a MFR while the remaining 70% is managed by traditional options for optimizing yields. MFRs differ from traditional management options in that they provide refuge in space rather than in numbers and seek to protect older and larger individuals which supply the bulk of eggs and genetic input under natural conditions. Furthermore, MFRs are ideal management tools because they protect genetic diversity and species diversity, maintain stable population age structures, and maximize the recruitment supply, minimize environmental variability, and decrease dependence on expensive, techno-centric, data-dependent traditional fishery management options.

Conceptually, MFRs are a simple and easily understood idea. There is intrinsic value and common-sense appeal in setting a portion of the marine habitat aside in its natural state. Although we believe MFRs will ultimately benefit all people, their primary purpose is to benefit the fishery sector by enhancing production in adjacent harvested areas and protecting the quantity and quality of recruits. We further believe that obstacles and resistance to MFRs can be largely mitigated by careful attention to public awareness and education about fishing problems and limitations of existing traditional approaches. We strongly encourage public involvement at all stages of MFR planning and implementation.

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