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The Belize Barrier Reef: Status and Prospects for Conservation Management

Judith S. Perkins*

Yale School of Forestry and Environmental Studies
205 Prospect St, New Haven, CT 06511, USA

&

Archie Carr III

New York Zoological Society
Bronx, NY 10460, USA

ABSTRACT

The Belize Barrier Reef ecosystem is composed of the largest barrier reef in the Western Hemisphere, numerous patch reefs, faroes, fringing reefs, cays, extensive mangrove swamps, and an abundance of reef and associated biota. It is one of the few remaining examples of a flourishing and nearly pristine reef environment in the Caribbean. Endowed with this unique global treasure, yet faced with new pressures resulting from recently gained independence, the task of maintaining the integrity of such a diverse and extensive ecosystem will be a vital challenge for Belizeans. It is a challenge deserving of modern management methods and international assistance.

INTRODUCTION

The Belize Barrier Reef is the greatest manifestation of the coral reef ecosystem in the Western Hemisphere for its size, unique array of reef types and luxuriance of corals thriving in such pristine condition (Dahl *et al.*, 1974). Traditionally, the people of Belize (formerly British Honduras) have used the reef to make a living. Setting forth in dugout canoes in the

* Present address: 322 Barrett's Mill Road, Concord, MA 01742, USA.

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calm waters behind the barrier reef, generations have harvested fish, conch, lobster, turtles, crocodiles and manatees. The pattern changed little until recently. Now, more and more Belizeans are turning toward the sea for very practical economic reasons, placing new demands on marine resources and bringing visitors to share them.

The stimulation for this study was the observed paucity of conservation mechanisms appropriate to the task of managing such a large and diverse ecosystem. In seeking to learn about this situation, one of us (J.P.) spent six months in Belize between November 1981 and May 1982. The purpose of the research was to compile and evaluate available data apropos the long-term ecological well-being of the Belize Barrier Reef and its support systems, the role of the reef in the society, and the readiness of Belize to maintain the biological integrity of this truly remarkable and unique marine resource (Perkins, 1983). We present a summary of our findings here and offer some tentative management recommendations for the reef ecosystem in an effort to highlight what we view as a conservation crisis in the making.

THE BELIZE BARRIER REEF ECOSYSTEM

The variety of reef types in Belize is unparalleled in the Caribbean (Dahl *et al.*, 1974) and includes a long, well-developed barrier reef (second in length only to the Great Barrier Reef in Australia), three oceanic atolls, faroes or continental shelf atolls, numerous patch reefs, and fringing reefs near the mainland coast. The barrier reef is a nearly continuous continental shelf edge boundary, forming a bulwark approximately 220 km from the Sapodilla Cays on the southernmost part of the reef crest, to the Mexican border (Fig. 1). The barrier reef is not a solid rampart, but is divided into linear segments of 'ribbon reefs' of different lengths. At the ends of individual barrier reef segments, stands of elkhorn coral *Acropora palmata* curve westward in response to retracting channel currents. Around some short segments, reef growth becomes arcuate or circular forming 'halos' as a result of this wave-refracting process (Longman & Wantland, 1978). These are especially common along the southern part of the barrier reef, where the waters of the shelf lagoon are considerably deeper than farther north.

Modern reef growth in Belize veneers pre-existing geological features, which formed between the Cretaceous and Tertiary Periods as continental blocks rotated with respect to their pre-drift location on

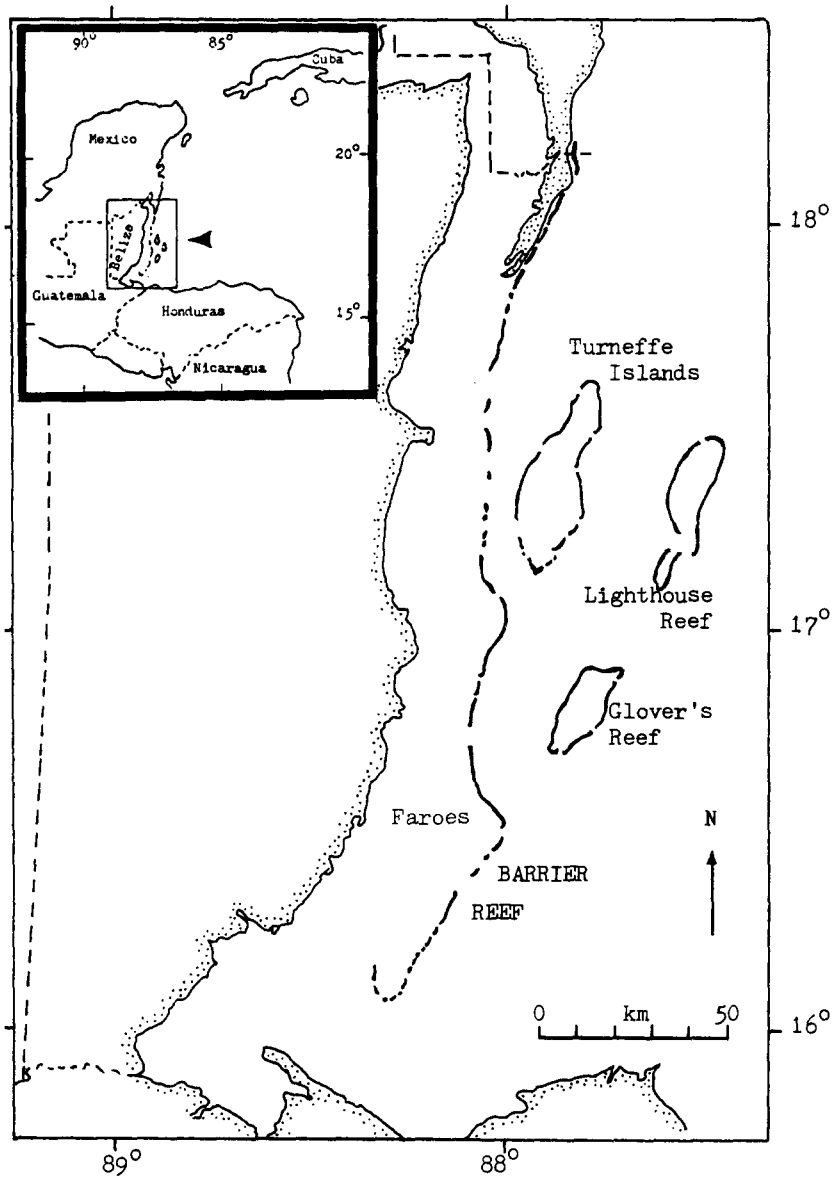

Fig. 1. The Belize Barrier Reef and its oceanic atolls.

Pangaea. During this movement, a series of parallel submarine ridges and scarps were created, corresponding to strike-slip shears. The Belize Barrier Reef and its atolls grow upon three of the ridges, which were substantially modified by karst erosion, sedimentation and reef growth during Pleistocene sea level changes (Purdy *et al.*, 1975; James & Ginsburg, 1978). One of the most interesting and unusual formations of geological origin are faroes: rhomboid-shaped, steep-sided continental shelf atolls, whose central lagoons are speckled with coral pinnacles. They are believed to be uplifted fault blocks (horst blocks) resulting from tectonic movement (Wantland & Pusey, 1971). Presumably because of this, they are clustered in a 30 km area on the southern part of the shelf lagoon (Fig. 1).

The Belize Barrier Reef complex is a sprawling ecosystem bounded on the east by the barrier reef, which protects the continental shelf lagoon and mainland from erosion by dissipating the energy of battering waves. In the calm waters of the shelf lagoon to leeward of the barrier reef are sandy islands and unique offshore mangrove cays, whose origins are marine (K. Rützler, pers. comm.). There are also extensive sea grass meadows, predominantly *Thalassia testudinum*, numerous patch reefs of different sizes, a complex maze of faroes, and vast mangrove swamps interfacing marine and terrestrial environments along virtually the entire coastline. In some cases, the mangrove swamps extend more than 80 km inland. They are used by crocodiles *Crocodylus acutus* and *C. moreleti* and manatees *Trichechus manatus*, and by many reef organisms during various life-cycle stages. Mangroves may also augment reef growth by filtering out terrestrial sediments that might otherwise smother them (Salm, 1980). Because of these different life-sustaining functions, mangrove swamps are critical components of the barrier reef complex.

The barrier reef is characterised by well-developed zones, where physical and ecological differences are reflected in biotic associations signalled by one or more dominant species (Stoddart, 1969). In general, the barrier reef consists of three major subdivisions: (1) the reef crest, which separates (2) the back reef and (3) the fore-reef (Wantland & Pusey, 1971; Miller & MacIntyre, 1977). The reef crest is a high energy surf zone consisting of a shallow rampart built of coral rubble and *A. palmata* (James & Ginsburg, 1978). To leeward is the back-reef zone, a physically harsh environment possessing a variety of sediment textures, grading from a rubble pavement nearest the reef crest to an apron of shifting sand abutting meadows of sea grass on the westward margin. The fore-reef

occurs immediately seaward of the reef crest. In the shallower parts of this zone, interdigitating coral buttresses and sandy troughs form a massive spur and groove system. These function as efficient wave baffles, and they prevent debris from suffocating living polyps by transporting wave-broken fragments away from them via downsloping chutes. In deeper water, beyond (seaward) the spur and grooves, is a nearly vertical reef wall, which becomes buried at its base (about 100 m) by blocks of limestone in the talus slope (Miller & MacIntyre, 1977).

Three oceanic atolls—Glover's Reef, Lighthouse Reef and Turneffe Islands—lie 7, 45 and 20 km east of the barrier reef, respectively (Fig. 1). Coral zonation on their seaward margins is analagous to that found on the barrier reef (Stoddart, 1962). Glover's Reef is the prototypic atoll of the Caribbean: biologically it is the best developed, possesses the greatest diversity of reef types, and is in almost pristine condition (Dahl *et al.*, 1974). Lighthouse Reef, to the north, is comparably spectacular. One of its islands, Half Moon Cay, has the only nesting colony (about 4000 birds) of red-footed boobies *Sula sula* in Belize (Belize Audubon Society, pers. comm.). It is the first national monument to be gazetted under the new National Parks System Act of 1981. Blanketed from easterly trade winds by Lighthouse Reef, the central lagoon of Turneffe has become a mangrove swamp, containing a large population (perhaps 200–300) of American crocodiles *C. acutus* (A. Aldonna, pers. comm.).

The Belize Barrier Reef complex harbours a varied array of fauna. Three different species of turtles, the American crocodile and many kinds of birds nest on mangrove islands located in the shelf lagoon and on sandy cays, which emerge on the rim of the barrier reef and atolls. Dolphins forage in these waters for fish, and manatees graze on rooted aquatics and bear young in cul-de-sacs or narrow channels in mangrove swamps. Fish and invertebrates are numerous. Although several new species have been found in Belizean waters (e.g. Fauchald, 1980; Kensley & Grove, 1980; Greenfield, 1981; Rützler, 1981), there is still a great potential for new discoveries, since many of these animals are just beginning to be documented.

RESOURCE USE

Maya Indians used cays in the shelf lagoon between 300 BC and AD 1500 as fishing stations, trading posts, ceremonial centres and burial sites

(McKillop, 1980). Artefacts and exotic flints excavated at some of the larger sites, such as Moho and Wild Cane Cays, provided clues that prove these Mayas traded actively with important inland ceremonial centres by paddling their canoes along large riverways (Craig, 1966; Hammond, 1982; J. Awe, pers. comm.).

Until now, the small population of Belize (about 145 000) has placed fairly modest demands on the resources of the barrier reef complex. An artisanal fishery, a small tourist industry, small-scale shipping and oil exploration have been its principal users. For some species, such as spiny lobsters *Panulirus argus*, conch *Strombus* sp., several groupers Serranidae and turtles, stocks have been heavily fished, but are not yet commercially depleted. Tourism, which attracts primarily scuba divers, sport fishermen and sun-worshippers, is in its infancy but has excellent prospects for expansion. No commercially productive oil deposits have been found, but Belize's proximity to large Mexican and Guatemalan discoveries is encouraging further testing.

The barrier reef ecosystem is inextricably linked to mainland activities via numerous rivers that transport and deliver inland runoff to the sea. In other parts of the world, impacts of various land use practices have had severe and deleterious impacts on corals. Soil erosion related to deforestation and chemical contamination from pesticides, insecticides and fertilisers associated with agriculture have led to degradation or death of reefs by suffocation and poisoning. Excessive sedimentation of corals caused by dredging and filling operations during construction (e.g. tourist facilities, urbanisation), have caused asphyxiation of polyps. Effluents and waste from other land-based industrial sources have also destroyed portions of coral reefs in different oceans around the world.

Agriculture is the largest industry in Belize, and it ranks as the top-most development priority for increasing the nation's revenue base. Belize's long-range plans include incentives for industrial growth in general. Although economic viability is a primary concern, a variety of alternatives could be used to achieve this goal. In other developing countries, ecological assets have too often been compromised in this process. The situation can almost be thought of as third world hyperdevelopment. The Belize Barrier Reef is an unspoiled and unique endowment, both for its biological and cultural richness and for its potential to contribute to economic development. In this regard, economic strategies which encompass the barrier reef complex should

favour alternatives that encourage benign and conservative reef-related projects.

MANAGEMENT CONSIDERATIONS

The Belize Barrier Reef ecosystem has remained relatively pristine because Belize has existed on the periphery of global commerce and the very small, subsistence-level population has not stressed it unduly. Recently gained independence from Britain (21 September 1981), however, has created a new set of pressures and a sense of urgency to attain economic viability. In seeking to reach this goal, Belize is focusing more on the development of its natural resource base, including its most unusual asset of all, the barrier reef. Expansion of the fishing industry and tourism are imminent, and while both are inherently dependent on the sustained integrity of the reef, both have the potential to inflict undesirable changes in the natural structure of biological communities. Oil exploration on the barrier reef complex will also continue, and while rigs *per se* may be relatively innocuous, the impact of drilling muds can be harmful to biota, at least on a local scale (D. Rhoads, pers. comm.). The task of managing this unique and diverse ecosystem so that it remains 'healthy' and continues to provide for future generations presents a tremendous challenge.

In discussing aspects of conservation management, the premise here is that whereas undisturbed biological communities are self-regulating, when influenced by man they are likely to deteriorate if left unmanaged. In support of this view are numerous examples of human-related damage to, and/or contamination of, coral reefs (e.g. Banner, 1974; Wood & Johannes, 1975; Endean, 1976; Salm, 1980). Therefore, the view is held that ecosystem management fundamentally entails regulation of humans. It follows that because Belizeans are ultimately responsible for maintaining the integrity of the barrier reef complex, indigenous social, economic and political considerations must be integrated into management strategies and tactical methodologies. Planning must be culturally appropriate.

A multi-disciplinary approach to natural resource management is considered the most effective means of integrating humans and the environment. It has become widespread in land use and park planning, economic development and many other fields. It attempts to perceive the

ecosystem holistically with man as an active component. Basically, a sequence of three major phases forms the overall framework.

(1) Amassing the data base
Good management of such an interconnected ecosystem as the Belize Barrier Reef complex rests upon the possession of adequate knowledge about its components, processes, dynamics and sensitivities—a situation that is difficult to attain and infrequently reached. It is equally important to characterise the social, economic and political qualities of the country in order to design culturally appropriate programmes.

(2) Planning a management strategy
In addition to the sort of inventory mentioned above, a management strategy needs to be formulated. Miller (1978) has amalgamated useful guidelines for the planning of national parks in Latin America, a process that has utility in many different professions. This conceptual plan involves setting forth (a) management objectives, accompanied by a list of facts and assumptions concerning (b) the capacity to achieve the stated goals—the identification of limitations, constraints and conflicts involved. At this stage, (c) certain activities or actions necessary to meet the objectives should become evident.

(3) Implementation and monitoring of the strategy
The tactical phase begins when the strategy is put into operation. At this point, three modes function simultaneously: (a) a data system collects, analyses and monitors information about the ecosystem; (b) an enforcement system acts to regulate human activities in conjunction with the management objectives, and (c) an administration and maintenance system directs, coordinates and supports the management programmes. In this way, a feedback loop is set in motion allowing the management strategy to be periodically assessed and revised in keeping with the initial management goals. Often this phase becomes truncated prior to implementation of the monitoring system. We think the importance of monitoring strategy components, a stage that is frequently overlooked, needs to be stressed more strongly. It is a step that is necessary for keeping the management programme relevant and on target.

This study sought to compile data on the resources of the Belize Barrier Reef, its conservation status, and the strengths and weaknesses of the existing administrative framework in protecting the reef and its support

systems—to initiate phase 1 of the overall management plan as described above. The data illustrate the complexity of the Belize Barrier Reef ecosystem and the many human-affiliated intricacies associated with it. They lead us to the conclusion that no single action is likely to be sufficient to protect its biological integrity.

A reef conservation programme in Belize would require (1) strengthening of marine-oriented research and enforcement capabilities; (2) streamlining relevant legislation to provide better implementation for the goals of marine conservation; (3) establishing criteria for, and demarcation of, a variety of zones for particular uses; and then establishing them (with enabling legislation) for particular areas or districts, based on defined criteria; (4) monitoring of a carefully determined set of ecological variables and initiating in-depth research on priority subjects; (5) launching and monitoring local and national education programmes.

Education has a particular value because it may lead to an improved outlook for the reef irrespective of whatever other programmes may or may not be implemented. If a value system becomes entrenched, fostering a 'reef ethic' (*sensu* Leopold, 1949), Belizeans may respond with more resistance to actions that threaten to undermine their precious natural resources.

We distinguish a need for four types of education in Belize: (1) general public education, illuminating the economic and cultural values of the barrier reef ecosystem, as well as its vulnerabilities; (2) expansion of formal education of young Belizeans in marine sciences and conservation, from elementary school through university; (3) training of marine conservation specialists; and (4) education of political and administrative leadership both in basic principles of applied ecology and management options available to government.

A single programme with the capacity to integrate these varied recommendations and giving the objective—barrier reef conservation—the national stature it deserves, might be modelled on the ecosystem-wide scheme currently employed in Australia to manage the Great Barrier Reef. In addition to a centralised regulatory bureaucracy, the Australian system features a mosaic of zones for special uses throughout the reef that range from strict protection to mineral exploration and development. The Australian system, properly tailored to Belize, is attractive because it is comprehensive, diversified and has the potential to achieve conservation goals without stifling economic enterprise or cultural traditions.

At the moment, there is no format in Belize for giving recognition or protection to an entire ecosystem, nor are there adequate human and financial resources to do so. The British Commonwealth of Nations might supply the framework for exchanges between Belizean and Australian reef specialists, but there is also a need for greater international assistance, through bilateral initiatives or through the World Heritage Convention or the Man and the Biosphere Programme, for example.

We believe a conservation crisis will develop in Belize unless modern management methods are put in place. For the late 20th century Caribbean, the Belize Barrier Reef is an unexpected wonder. It is almost inconceivable that it escaped the vagaries of development, pollution and exploitation that are now painfully attended to by other states in the Greater Caribbean Basin. By accident of history the Belize Barrier Reef has survived. It must now become a subject of international attention.

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