RAPID ASSESSMENT OF THE CORALLINE AND ICHTHYOLOGICAL COMMUNITIES OF THE CORAL REEFS OF THE PRIMEIRAS AND SEGUNDAS ARCHIPELAGO (NAMPULA AND ZAMBEZIA PROVINCES)

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SUMMARY

The archipelago of the Primeiras and Segundas, in the North of Mozambique, comprises an almost continuous chain of coralline islands that are fringed by reefs. A rapid and preliminary study employing visual techniques for both ichthyological and benthonic communities was conducted in the shallow (<15m) reefs of the islands' eastern coast. A total of 194 fish species representing 42 families was identified. Cumulatively, 43 genera of stony coral and 15 genera of soft coral were also identified in the area.

The average coral cover was 62.2% (± 2.0, standard deviation), having varied between 52.4 ± 5.3 % (on Fogo Island) and 71.2 ± 3.8 % in Epidendron, composed primarily of stony coral. Ramified corals of the *Acropora*, *Pocillopora*, *Seriatopora* and *Porites* genera were the dominant elements of the benthic fauna of the southernmost islands (Fogo and Epidendron), while the massive (*Porites*, Favids, *Lobophyllia corymbosa* and *Diploastrea heliopora*) and sub-massive (*Porites*, *Goniopora djiboutiensis* and *Acropora palifera*) ones were conspicuous in reefs situated more towards the north (Puga-Puga and Mafamede). The survey area presented the following average values for fish density, biomass and diversity: 35 specimens/154 m^2, 380 g/154 m^2 and 11 species /154m^2, with Acanthuridae (surgeon fishes), Scaridae (parrot fishes) and Chaetodontidae (butterfly fish) representing the most important families. Signs of over-fishing are evident, especially on the Primeiras Islands where, in general, one does not encounter specimens that are of commercial value or larger (a size category smaller than 10 cm was predominant, comprising more than 85% of the specimens observed). All said, the conclusions support the idea that the Primeiras and Segundas Islands reefs are among the most remarkable in Mozambique, both as regards biodiversity and state of conservation. This was the second quantitative study of the area, but the first to measure the coverage size. Proposals are offered for a program to monitor the coralline communities, relevant indicators and methodology. The need is stressed for implementation of a formal system of ecosystem protection and the following immediate administrative measures: (i) restrictions on underwater fishing and pelagic species; (ii) prohibitions against dropping anchor above the reefs and use of destructive fishing techniques (including trawls, poisons and explosives); (iii) adoption of good practices by tour guides, especially as regards activities that directly affect coral reefs, such as diving and use of vessels; and (iv) a better control over the local community's collection of invertebrates (clams, starfish, etc.).

TABLE OF CONTENTS

INTRODUCTION

Corals are animals of the coelenterate group, such as the anemones, medusas or jellyfish, the majority of which form colonies. Typically, corals have tentacles that contain nematocysts. The most researched corals are those that form reefs, typically the stony, herma-typic variety. Though members of the animal kingdom, herma-typic corals posses symbiotic algae (Zooxanthellae) in their tissues that form an association in which nutrients and the products of the photosynthetic activity of algae are shared. As a result of their growth and their metabolism, corals deposit an aragonite (calcium-carbonate) skeleton which, after accumulating of the course of thousands of years, forms reefs (Veron, 1993; Sorokin, 1995).

Some stony corals contain symbiotic algae and are denominated non-hermatypic as they do not build reefs. Another large corals group, one that possesses symbiotic algae but does not deposit solid skeletons, is that of soft corals. The structure and consistency of soft corals is leathery and, for structural support, they produce miniscule calcareous structures, or sclerites. Soft coral colonies do not become reefs but turn to sediment when dead (Veron, 1993; Sorokin, 1995).

The formation of reefs – and indeed corals themselves – requires very specific conditions of warm, flowing, limpid waters of normal salinity (approximately 35%). Water limpidity is essential for the photosynthesis of the symbiotic algae. In East Africa, the true coral reefs are found along the equatorial zone. In Mozambique in particular, corals develop over a rocky base of cemented dunes formed by events induced by the lowering of average sea level during the Pleistocene, between 100,000 to 18,000 Ma. At approximately 6,500 Ma, the sea level rose again, transforming the cemented dunes to reefs colonized by various levels of coral (Ramsay, 1994; 1996). Independent of their geologic origins, Mozambique's reefs play an essential ecological and socioeconomic role owing to their biodiversity and productivity.

Coral reefs rank among the planet's most productive ecosystems; surely, they are the most diverse marine ecosystems and as such are often compared with the world's humid tropical forests. Millions who live in tropical regions rely upon the reefs' nutritional, socio-cultural, pharmaceutical and recreational resources (Spalding *et al*., 2001). The reefs play a crucial role as reproductive zones, providing shelter and food for young species. Coral reefs are equally critical to the protection of coastlines, particularly as regards erosion and the effects of cyclones and storms.

As a result of their high productivity, coral reefs encompass the greatest portion of the fisheries areas along the coasts of developing tropical countries, where the majority of the coastal population depend upon fishing as the main source or to supplement their animal protein consumption. The production potential in terms of fish catch was estimated at several tons per km^2 per year.

The reefs that fringe the Primeiras and Segundas Islands are known as the most developed in Mozambique (Salm, 1983; Schleyer and Celliers, 2000). Few studies, however, have been

conducted in this area and a general ignorance prevails concerning the reefs' nature, size and state of conservation. Quantitative research was carried out only on Caldeira Island (Schleyer and Celliers, 2000) as part of the Environmental Impact Study of the Thopuitho heavy-sands extraction project. The referenced study confirmed the presence of a high diversity of corals and other benthic organisms characteristic of reefs, along with the occurrence of equally-diverse ichthyofauna. Very little information, however, was offered with respect to the other islands.

The Primeiras and Segundas and the adjacent coastal region are rich in biodiversity and are in the category of regionally-important eco-regions (Horrill, 2001), but few quantitative studies of the area have been conducted. By way of example is the recent discovery of the *Icuria dunensis* tree genus that occurs in almost mono-specific forests of the continental zone (Fourier & Lubke, 2000).

This work presents the conclusions of a rapid quantitative and preliminary assessment carried out on five islands of the Primeiras and Segundas archipelago. The field work, conducted over a period of ten days in October and November of 2006, had the following objectives in mind:

- Describe the coralline and ichthyological communities of select representative areas of the Primeiras and Segundas Archipelago;

- Identify potential natural and anthropogenic factors that can threaten the future and integrity of the reefs;

- Contribute to the establishment of a monitoring system for the region's coralline and ichthyological communities.

More specifically, the following objectives were outlined:

- Describe the coralline cover and diversity of the reefs and potential threats to their conservation;

- Describe the reef-associated biota, including macro-algae, seagrasses, invertebrates (zoanthidea , gastropods, equinoderms, etc.) in terms of abundance and commercial value;

- Describe the reef fish community in terms of its diversity, abundance, biomass and size structure, particularly those having commercial value;

- Evaluate and quantify potential threats to reef conservation, including pollution, spiny starfish and coral bleaching

METHODOLOGY

Benthic Communities

The coralline communities and other benthic organisms were studied by divers using Scuba equipment and high resolution digital cameras (Nikon Coolpix 4800, 4 megapixel), according to the method developed by Celliers & Schleyer (in prep). Photo-squares measuring approximately 0.3 m^2 were taken at regular intervals of approximately two minutes along transects parallel to the reefs. Approximately 40 photo-squares were obtained for each transect. The transects were approximately 10 m apart. Two distinct reef zones were considered: a deeper zone or "reef slope" of between 5 to 10 meters, and a shallower one, or "back reef", of between 1 to 4 meters. Three transects were placed in each of the zones and a last one was placed perpendicularly over the two zones ("cross reef").

Before each dive, geographic coordinates for the point of entry were annotated employing the Garmin *eTrex* GPS system. Depth, current, wind, temperature and visibility parameters were gathered as part of each diving routine. The presence of *Acanthaster planci* (spiny starfish), coral bleaching and signs of destructive fishing were likewise annotated as part of the diving routine.

The JPEG images from the field were later analyzed in a laboratory. Employing a precise interpretative technique with CPCe software, the biotic categories and substratum were analyzed through eight points distributed randomly in each of the photographs. Organisms found under each of the eight points were identified and classified according to categories suggested by English *et al*. (1994), based upon the growth method. The organisms, furthermore, though submitted for analysis according to their genera, were identified to the lowest possible taxonomic level.

The coralline benthic organisms present differing levels of susceptibility to the physical stress caused by recreational scuba divers. The potential for damage to the coralline communities of the surveyed areas was quantified using the percentage of coral cover and a consideration of the susceptibility of each species or genus within a simple qualitative system: resistant, susceptible and very susceptible (Table 1).

Table 1. Susceptibility to damage of the various sub-categories of corals found at the surveyed reefs (1= resistant; 2= susceptible and 3= very susceptible).

Categories	Susceptibility	Genera
Stony ramified coral	3	*Acropora*, *Pocillopora*, *Seriatopora*, *Stylophora*, *Porites rus*
Stony finger coral	3	*Acropora*
Stony tabular coral	3	*Acropora*, *Turbinaria*
Stony encrusting coral	1	*Echinopora*, *Montipora*
Stony foleaceous coral	3	*Pachyseris*, *Merulina*, *Pavona*
Stony massive coral	1	*Favia*, *Favites*, *Platygyra*, *Diploastrea*, *Porites, Lobohyllia*
Stony sub-massive coral	2	*Porites*, *Acropora pallifera*, *Goniopora*
Fire coral	2	*Millepora*
Stony fungiid coral	1	*Fungia*
Soft coral	1	*Sarcophytum, Lobophytum, Sinularia, Cladiella, Xenídeos, Neftídeos*

Ichthyological Communities

The method employed in this study was based upon the "point count" (PC) technique described by Bohnsack & Bannerot (1986). The fish within a 7m (or less depending on visibility) radius and 5 m above the substrata were counted. The observer would initiate the count after a few minutes, once the fish settled into normal behavior. Each PC took approximately three minutes to be implemented and would be randomly placed 15 to 20 meters from the next. Table 2 indicates the number of PC's implemented in each reef. The sizes of commercially-significant fish species were estimated according to 10 cm size categories, utilized to estimate biomass employing weight-dimension relationships (Froese & Pauly, 2007).

Owing to the elevated number and diversity of fish species found in these reefs, only the previously-identified species were counted (Appendix I). The species selection was based upon various criteria, including:

- Species sought by fishermen in tropical coral reefs (e.g., groupers –Serranidae family);
- Indicative species (indicative of the general health of the reef, e.g., butterfly fish of the Chaetodontidae family); and
- Visually obvious species representative of the largest trophic categories.

To obtain a general idea of fish species diversity, all species observed during each dive were recorded on Perspex plaques by the observer and his diving partner.

FINDINGS

Sampling Effort

The work team's logistical and safety conditions in great measure conditioned the sampling effort and coverage. All told, six islands were visited: Fogo, Coroa and Epidendron in the Primeiras and Ndjovo Archipelago and Puga-Puga and Mafamede in the Segundas Archipelago (Figure 1). Table 2 presents a summary of the sampling effort that was conducted. A total of 34 photo transects and 1421 photo squares were sampled covering a reef area of approximately 454.7 m^2 . Subsequent visits by the first author and reviews of published articles (Celliers & Schleyer, 2000 and Schleyer, 1999, for example) corroborated this information.

Table 2. Sampling coordinates and effort in each reef visited.

Site	Latitude	Longitude	Transects	Photo-squares	PC
Primeiras Islands					
Fogo	S17° 13.890'	E038° 52.267'	6	239	4
Coroa	S17° 11.323'	E038° 56.283'	*	*	*
Epidendron	S17° 05.082'	E039° 07.722'	7	273	7
Segundas Islands					
Ndjovo	S16° 33.880'	E039° 48.563'	7	332	7
Puga Puga	S16° 26.546'	E039° 56.886'	7	282	7
Mafamede	S16° 21.340'	E040° 01.250'	7	295	7
Total			**34**	**1421**	**32**

* = quantitative sampling not conducted. PC =Point Count

Description of Coralline and Ichthyological Communities

General Description

Each of the islands is fringed with reefs, at times completely encircling them so as to form an atoll (as in the case of Silva Island; Schleyer, 1999) or a semi-circle. The Silva, Coroa, Mafamede and Puga-Puga Islands, all relatively small (<2 ha), are covered by little or no vegetation. The Islands of Casuarina, Fogo, Epidendron and Ndjovo are somewhat larger and contain more developed vegetation, including large trees.

The lakes surrounded by rocky atolls are shallow, containing sediment, coal shards and seagrass beds. In the lakes' southwest zone facing the open sea, colonies of massive coral (chiefly *Porites* and favids) occur sporadically. The average coral coverage was 62.2% (± 2.0, standard deviation), having varied between 52.4 ± 5.3 % (on Fogo Island) and 71.2 ± 3.8 % on Epidendron, where stony corals predominate. On some of the islands that were visited (Caldeira, Ndjovo, Puga-Puga), anemones (*Heteractis magnifica*) and macroalgae (*Halimeda*, *Sargassum* and *Padina*) are common. Reef development and an abundance of corals are generally found in the more protected areas on the islands, particularly those facing the continent where one finds greater coralline coverage and diversity. The reef's highest points become exposed at low tide to the pounding of waves and current. The extent of the maximum high tide around the islands is approximately 4.5 m.

As regards ichthyofauna, the study area presented, respectively, the following average values in terms of density, biomass and diversity: 35 specimens/1 54 m^2, 380 g/1 54 m_2 and 11 species /154m^2 (Appendix II). Of the 10 families that were studied, four demonstrated superior importance in terms of both specimen and species numbers: surgeonfish (Acanthuridae), butterfly fish (Chaetodontidae), parrotfish (Scaridae) and snappers (Lutjanidae). As regards biomass, the surgeonfish and parrotfish were clearly the most notable. The most represented trophic group in terms of density, biomass and diversity was the herbivore, followed by carnivores and omnivores.