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First Assessment of the Effects of the 2000 Southern Mozambique Floods on Coral Communities: The Case of Xai-Xai Lagoon

Marcos A. M. Pereira[1] & Paulo Miguel B. Gonçalves[2]

[1] CDS das Zonas Costeiras (Xai-Xai) – MICOA. e-mail: coastal@tropical.co.mz
[2] e-mail: chifununo@yahoo.comTitulo

ABSTRACT

The southern part of Mozambique suffered, at the beginning of the present year, the worst floods in the last 50 years, which caused several fatalities and high material losses. The objective of this study was to investigate the influence of this phenomenon on the coral communities of the Xai-Xai lagoon reef. Benthic category percentage cover was assessed in January 2000 (before the floods) and September 2000 (after the floods) using the line intercept transect (LIT). A decrease of hard coral percentage cover was observed, in the order of 58.5 %. The soft coral community was also affected, with a high decrease of percentage cover, about 90.4%. Other benthic category that showed an elevated decrease was coralline algae (85.1%). All other categories increased their percentage cover: turf algae (164.4%), other invertebrates (e.g. sponges, sea urchins – 111.1%), fleshy algae (80.4%), rubble (34.4%) and dead coral (379.0%). The main causes of this degradation scenario are the low salinity values and high amount of sediment discharged by the Limpopo River. Some massive (e.g. *Porites*, *Favia*, *Favites* and *Goniopora*) and encrusting (e.g. *Echinopora*) hard coral genera, seemed less affected, suggesting an elevated adaptation capacity to this kind of stress through massive mucus-sheet formation. The extension of the floods' effects on other reefs in the southern coast of Mozambique is discussed along with a proposed monitoring program for this reef.

RESUMO

No início do presente ano, a região sul de Moçambique sofreu as piores cheias dos últimos 50 anos, tendo causado elevados danos humanos e materiais. O presente trabalho teve como objectivo estudar a influência deste fenómeno sobre a comunidade de corais do recife da lagoa do Xai-Xai. A percentagem de cobertura de várias categorias bênticas foi estudada em Janeiro de 2000 (antes das cheias) e em Setembro de 2000 (depois das cheias) usando o método do transecto de linha interceptada (TLI). Foi observada uma diminuição da percentagem de cobertura de coral duro vivo na ordem dos 58.5 %. A comunidade de coral mole, foi igualmente afectada, tendo sido observada uma elevada diminuição da percentagem de cobertura, cerca de 90.4 %. Outra categoria bêntica que mostrou um elevado decrêscimo foi a das algas coralinas (85.1 %). Todas as outras categorias bênticas apresentaram um aumento na percentagem de cobertura: algas turfosas (164.4 %), outros organismos invertebrados como esponjas, ouriços, etc. (111.1 %), macroalgas (80.4 %), calhau (34.4 %) e coral morto (379.0 %). As principais causas deste cenário de degradação são as baixas salinidades e a grande quantidade de sedimento descarregadas pelo rio Limpopo. Alguns genéros de coral duro massivo (ex.: *Porites*, *Favia*, *Favites* e *Goniopora*) e encrustante (ex.: *Echinopora*), no entanto, mostram-se pouco afectados, sugerindo uma elevada capacidade de adaptação a este tipo de situações de stress através da produção massiva de muco. A extensão dos efeitos das cheias em outros recifes da zona sul de Moçambique é discutida além de um programa de monitoria proposto para este recife.

INTRODUCTION

From February to May 2000 the southern part of Mozambique suffered the worst floods in the last 50 years (INAM, 2000). The damage caused by this phenomenon was high with several hundred fatalities and millions of US dollars in prejudice. These are the first direct accounts of the damage. However, there are other not so direct and clear-cut damages to be assessed. The effect of the floods on natural resources is one of them.

Coastal ecosystems are one of the country's most valuable resources supporting about 42% of the Mozambican population that lives within the 48 coastal districts (INE, 2000). Therefore, there is a special concern about the effects of the floods on resources that are directly exploited by the population. Coral reefs are one of those ecosystems. They support the majority of the artisanal fisheries in Mozambique (Fischer *et al.*, 1990; Schleyer *et al.*, 1999). Various studies in the region have shown that fish communities are highly influenced by the physical characteristics and status of the reefs (e.g. McClanahan, 1994; Öhman, 1999; Öhman *et al*., 1999; Pereira, 2000), especially by the amount of live coral.

Floods may influence reef communities by decreasing the salinity, on the one hand, and increasing the turbidity and siltation on the other. Studies at Inhaca Island's coral reefs (Gonçalves, 2000 and Pereira, 2000) reported salinity values around 30 ‰, although these reefs locate quite far from the direct influence of Maputo Bay rivers' discharge. These were considered as very low values, especially if one considers the long period the reefs were subjected to such stress.

The Xai-Xai region was one of the most affected by the flooding of the Limpopo River. The reef communities at Xai-Xai lagoon were subjected to low salinity and especially high values of turbidity for almost six consecutive months.

The main objective of this study was to assess the effects of the flood phenomena on the coral communities of the Xai-Xai lagoon reef.

STUDY AREA AND FIELD METHODS

This study was conducted in Praia de Xai-Xai, a small village (1000 Hab.) located 10 Km southeast of the Gaza Province city capital Xai-Xai and about 216 Km northeast of Maputo. The Limpopo is the main river in the region with a catchment area of about 421 000 Km^2 (UNEP/FAO/PAP/MICOA, 1998). The region's average annual temperature is between 22.8 and 24 °C, annual rainfall is about 999 to 1400 mm and the winds are predominantly from the east (Couto *et al*., 1995). Tides are semi-diurnal with a maximum tidal range of about 3.2 meters. The study area is characterized by a Quaternarian beach rock, located parallel to the shoreline, forming a shallow lagoon (Barradas, 1965). It locates about 25 Km north of the Limpopo River mouth and is directly subjected to its discharges. A considerable coral community colonizes the beach rock and there at least 25 genera of hard coral and 4 genera of soft coral already identified (M. H. Schleyer, personal communication).

Table 1. Benthic categories studied in the present study.

Category	Code	Observations
Coralline algae	CA	Calcified, encrusting algae. Coloration may vary from whitish to dark brown.
Dead coral	DC	Recently dead coral. Coloration white, with no signs of algae colonization.
Fleshy algae	FA	Various species of macroalgae (red, brown or green) (e.g. *Halimeda*, *Sargassum*, *Padina*).
Hard coral	HC	All life forms of hard corals (massive, branching, encrusting, foliose).
Others	OT	Benthic organisms like sponges, zooanthids, sea urchins, clams, etc.
Rubble	R	Broken pieces of coral and shells.
Sand	S	
Soft coral	SC	
Turf algae	TA	Filamentous green algae.

Benthic composition was studied using the line intercept transect (LIT) technique (English *et al*., 1994). Cover of benthic categories under the line was classified into several categories (Table 1) and their length was measured to the nearest centimeter. Sixteen fixed 20-m LIT's were completed; eight in January 2000 (before the floods) and 8 in September 2000 (after the floods). From these measurements the percentage cover of the various categories was calculated.

RESULTS

Results are summarized in Figure 1 and 2. Appendix 1 shows raw data collected before and after the floods.

Coral and Invertebrate Communities

Hard coral percentage cover decreased from 19.9% to 8.3 % after the floods (Figure 1a). This represents a 58.4% decrease (Figure 2). Virtually all branching corals observed (e.g. *Acropora*, *Pocillopora*) were dead and/or covered by algae. The great majority of *Porites* colonies were bleached, and the small portion not affected was at least at 1 m deep. Massive (e.g. *Goniopora*, *Favia* and *Favites*) and encrusting (*Echinopora*) forms constituted most of the observed 8.3 % of hard coral cover.

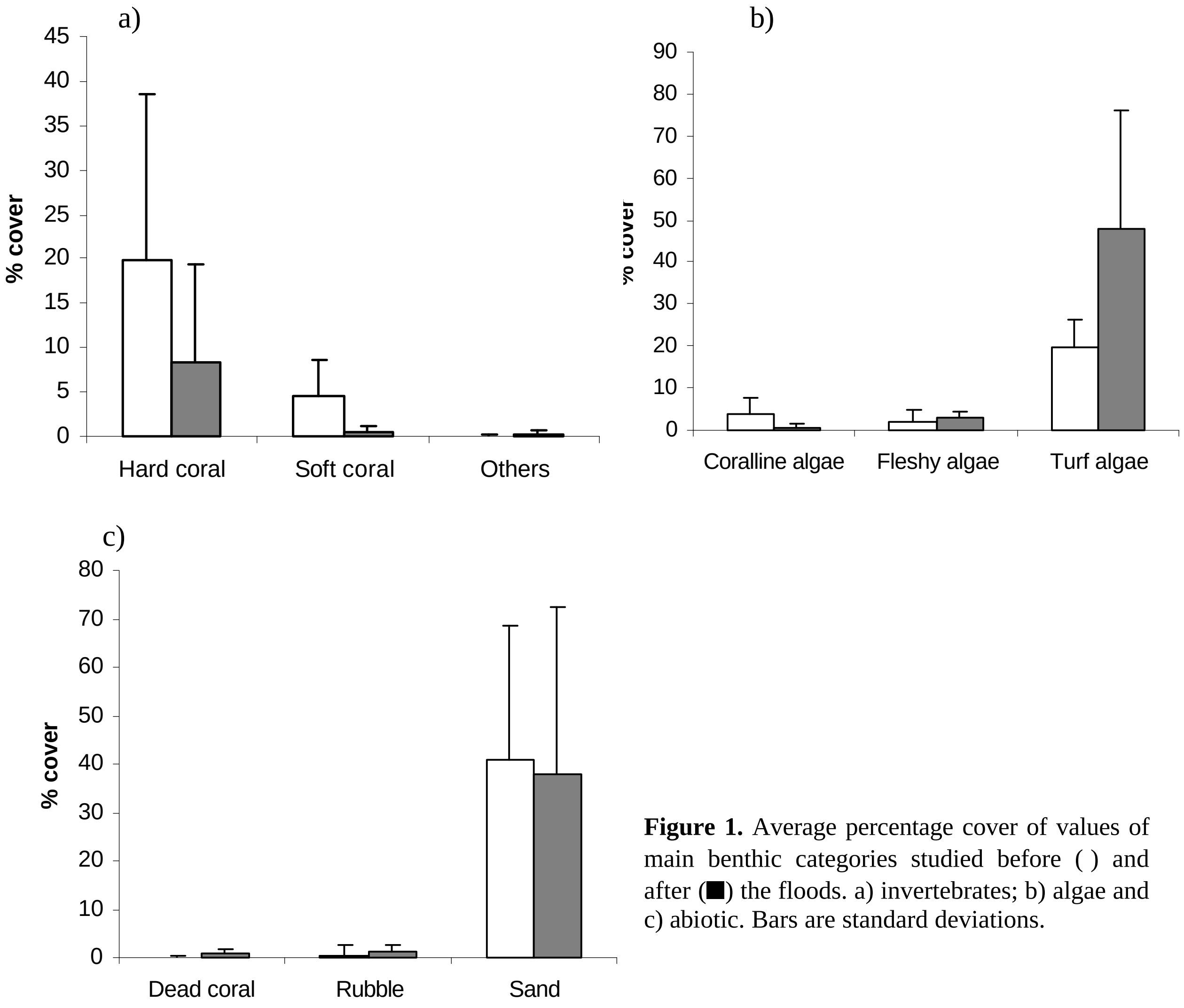

Figure 1. Average percentage cover of values of main benthic categories studied before ( ) and after (■) the floods. a) invertebrates; b) algae and c) abiotic. Bars are standard deviations.

The soft coral community suffered a significant decrease of 90.4 % (4.59% to 0.44%) (Figures 1a and 2). The majority of *Sinularia* colonies observed were bleached and those alive and apparently well, were small and located at depths greater than 1 m. Other organisms (which included sea urchins, sponges and zooanthids) where poorly represented (< 1%) (Figure 1a), nevertheless a high increase (111.1 %) of percentage cover was observed.

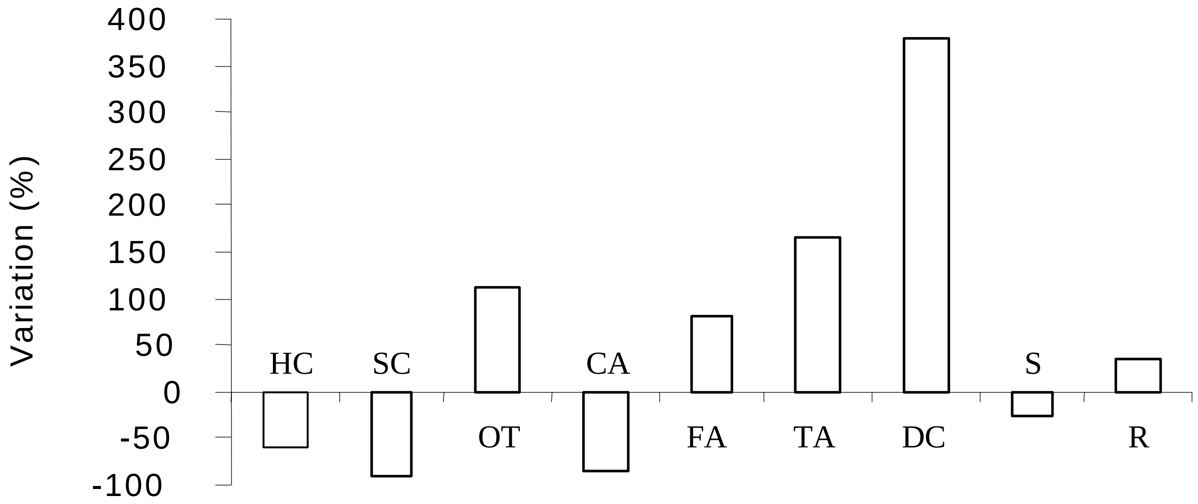

Figure 2. Variation (%) of percentage cover of each benthic category before and after the floods. Codes are same as in Table 1.

Algae Community

A considerable decrease (89.1%) (Figure 2) of coralline algae, was observed. Average percentage cover values ranged from 3.15% to 0.47 % after the floods (Figure 1b). On the other side, the percentage cover of fleshy algae was higher after the floods (Figure 1b) with an increase of 80.39 % (Figure 2). Turf algae also showed a very high increase (164.4 %) after the flood period (Figure 2), covering from 18.1 % to almost half the area sampled (47.9%).

Abiotic Categories

Although poorly represented in terms of the whole reef (0.19 and 0.91% respectively before and after the floods) (Figure 1c), dead coral showed the most dramatic variation (an increase of 379.0 %) of all benthic categories studied (Figure 2). Other abiotic categories did not show significant variation in the percentage cover. Sand decreased 26.6 % (from 51.45 to 37.8 %) and rubble increased 34.4 % (from 0.93 to 1.25% after the floods).

DISCUSSION

The Limpopo River Flow and Sediment Transport During the '2000 Flood Event

This study was conducted at Xai-Xai lagoon, which is located only 25 km north of the Limpopo River mouth. The Limpopo River discharges a monthly average of 132.2 m^3/s of water, with a peak of 556.98 m^3/s in February (1951 – 1995 DNA data). The maximal flow ever observed was 7800 m^3/s in the 1955 flood even (UNEP/FAO/PAP/MICOA, 1998). In the present year's flood event, a peak flow of 18 550 m^3/s was registered on February 27th (Vicente & Chivambo, 2000). Observations made in Xai-Xai between 1973 and 1978 showed that the highest mean load concentration of suspended sediments was 9680 g/m^3 and the minimum was 80 g/m^3. Using these figures, it was estimated that the total sediment transport of the Limpopo River is of the order of 10 million tons/year (UNEP/PAP/MICOA, 1998).

Using these figures, the amount of sediment transported during the 2 months flood period, was roughly estimated at about 233 million tons (Box 1).

Box 1. Rough estimation of the sediment amount discharged by the Limpopo River during the 2000 flood event.

Limpopo river total sediment transport = 10 million ton/year (UNEP/PAP/MICOA, 1998)
Limpopo river mean monthly flow = 132.2 m^3/s (UNEP/PAP/MICOA, 1998)
Average sediment transport per month = 0.83 million ton
Max. flow registered at this years' flood event = 18 550 m^3/s

0.83×10^6 ton ------- 132.2 m^3/s
X ton ------- 18 500 m^3/s

$X = 116.5 \times 10^6$ tons

116.5×10^6 ton x 2 months of flood event duration ≈ 233×10^6 tons of sediment.

This is a dramatically high amount of sediment discharged by the Limpopo River (a 2330% increase). At Xai-Xai lagoon for example, locals interviewed, stated that the lagoon waters had become red (due to the sediment amount) and there was no tidal movement during the flood period (February–March 2000). We visited the reef in mid July and the water was still very turbid, with an estimated horizontal visibility of about 20 cm. In September 2000, water turbidity showed a small improvement with the horizontal visibility being estimated at 40 cm.

Effects of the Floods on the Coral Community

The results of this study reveal a high degree of reef degradation with average coral mortality of 64.4%. This is well illustrated by the increase of dead coral amount (almost 400%) which had, though, a modest percentage cover in terms of the whole reef (< 1%, Appendix 1). Explained by the fact that we considered dead coral all the colonies, which were recently dead with no sign of colonization by algae (Table 1). However, the amount of dead coral colonized by algae was considerable.

Two main factors caused coral mortality: low salinity and high turbidity and sedimentation. Rapid and drastic decreases in salinity cause corals to die manly of physiological damages (Kato, 1987) and bleaching (reviewed by Hoegh-Guldberg, 1999). Turbidity and sedimentation negatively affect coral communities through light penetration reduction, resulting in less light energy available to its symbiotic algae within their tissues. Sediments settle onto the bottom and smother coral colonies, resulting in higher metabolic costs to remove sediments, reduced efficiency of gas exchange with seawater or reduced food capture (McClanahan & Obura, 1996).

One of coral's adaptation mechanisms against these stress factors is mucus-sheet formation (Kato, 1987), which is utilized for clearing of sediments and also for feeding (Barnes & Hughes, 1993). This phenomenon was widely observed in the present study, where the majority of massive (e.g. *Porites*, *Favia*, *Favites*, *Goniopora*) and encrusting (e.g. *Echinopora*) hard coral colonies were secreting high amounts of mucus. This reveals a high capacity of adaptation to these physical stresses. As pointed out by Veron (1993), all these genera occur where water turbidity is high, suggesting that turbid conditions are not absolutely detrimental to corals and that they could take nutritional advantages out of it (Anthony, 1999). At Inhaca Island, Kalk (1995) and Gonçalves (2000), also reported a dominance of these genera in reef environments subjected to high turbidity and sedimentation (Gonçalves, 2000; Pereira, 2000).

The data presented in this study, added to the location of the studied area, suggest that these coral communities may have been the most affected by the floods in southern Mozambique, as there are no river systems further south from Inhaca Island. Other areas in southern Mozambique, either are quite far from the influence of large river systems (e.g. Bazaruto Arquipelago), or lack any river systems at all (e.g. Inhambane Province). As such, these results offer by far the worst possible scenario of reef degradation, caused by the floods, in southern Mozambique.

Due to the degradation extent and relative easiness of sampling at the Xai-Xai lagoon reef, we suggest a set of trimestrial monitoring surveys to be undertaken, under the Mozambique Coral Reef Management Program (MCRMP). Its main objectives would be to monitor the trends in changes and possible community shifts of the biota in this reef, which could serve as a model to other reefs, subjected to similar environmental conditions, along the Mozambican coast.

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