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A PRELIMINARY ASSESSMENT OF CORAL BLEACHING IN MOZAMBIQUE

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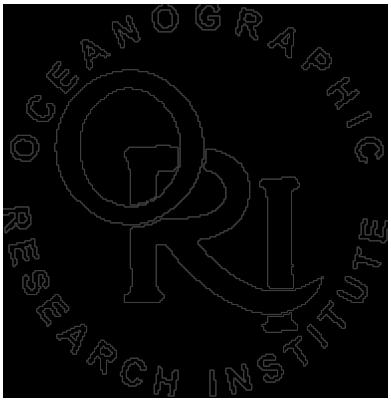

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A CORDIO survey undertaken by MICOA and supported by SIDA/Sarec

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EXECUTIVE SUMMARY

The 1997-1998 El Nino southern oscillation (ENSO) caused elevated sea temperatures that resulted in global coral bleaching. Coral reefs constitute an important biological resource in terms of their complex biodiversity and are the basis for tropical reef fisheries and marine ecotourism. They represent one of Mozambique's main coastal assets and its coastal communities and growing tourism industry rely mainly on reef-based resources. Mozambican artisanal fisheries are largely centred on reefs and are responsible for about 70% of the total catch, highlighting their importance. Most tourism similarly occurs along the coast where the best infrastructure is established, especially near the coral reefs of Pemba, Mozambique Island, the Bazaruto Archipelago, Inhaca Island and Ponta do Ouro.

Reefs along the Mozambican coast consist of fossilized dune and beach rock, colonized by corals to a varying degree. The shoreline has been successively exposed and submerged during the millennia and the reefs fall in three regions: (1) the northernmost section, which extends over 770 km from the Rovuma River in the north to Pebane in the south (17º20'S), mainly coraline; (2) the central section, between Pebane (17º20'S) and Bazaruto Island (21º10'S), a distance of about 950 km, which is classified as a swamp coast, and (3) the southern section, which stretches for 850 km from Bazaruto Island southwards to Ponta do Ouro (26º50'S), comprising mainly patchy reefs.

As the extent of reef loss during the 1997 – 1998 El Nino phenomenon was unknown in Mozambique, the current survey was undertaken to:

1. Assess the consequences of coral bleaching in Mozambican waters.
2. Train Mozambican scientists in this specialized field to increase the scientific capacity of the country.

The survey of coral bleaching was undertaken from March 24 to April 8, 1999 at the end of summer. Evidence of bleaching was sought for the present and past year in six localities, these being tabulated below in order from north to south. Dives were executed on a total of 17 reefs and a visual assessment was made of reef type, faunistic cover and the extent of reef damage attributable to bleaching and crown-of-thorns starfish (COTS). Quantitative measurements using transect techniques proved inappropriate due to the sea conditions, the nature and condition of the reefs, and the fact that most of the work was done using snorkel rather than SCUBA. However, it proved possible to record random video-photo quadrats at ten of these stations for later analysis. The reefs surveyed were:

Locality Reefs

- Pemba Wimbe Beach, Quilalulia Channel, Quilalulia, Pemba Bay
- Nacala Fernao Veloso Bay
- Angoche Baixo St. Antonio, Mafamede Island
- Bazaruto Is. Inner Two-mile Reef, Coral Garden, Lighthouse Reef
- Inhambane Mike's Cupboard, Coral Garden, Anchor Bay (all at Ponta da Barra), Cabo dos Correntes (Paindane)
- Inhaca Island Pta Torres, Pta Torres Channel, Barreira Vermelha

The effects of El Nino bleaching in Mozambique were most extensive on exposed reefs in the

north (up to 99%) and this diminished further south except at Inhaca Island where serious recent bleaching (90%) was encountered. Extensive COTS damage was also found at Bazaruto (80%) and Inhambane (95-98%). The COTS outbreaks commenced in 1995-1996 and, as sufficient time has elapsed for reef erosion and collapse to occur, the damage on these reefs was more pronounced. The consequences of the El Nino bleaching are going to be even more serious as coral mortality on the northern reefs was as high as 99%; a similar progression in the collapse of reef structure on the seriously bleached reefs is anticipated. The biodiversity of these sites will be impaired as only low coral recruitment was observed at the Bazaruto COTS site. The fish populations on the damaged reefs, the basis of many of Mozambique's valuable artisanal fisheries, were also poor. Both the fisheries and the tourism value of these sites will thus be affected, parameters that will have to be quantified.

Further work and monitoring at three localities in the north of Mozambique and three in the south was thus proposed. Bleaching, COTS and control sites will be included to:

1. Establish whether further bleaching occurs.

2. Monitor and compare reef recovery at bleaching and COTS sites.

3. Consider appropriate procedures for intervention if reef recovery proves unlikely or slow e.g. the artificial propagation and transplantation of corals.

4. Develop a management plan for Mozambique's coral reefs.

Further development of Mozambican staff was planned during the survey to deal with the situation. MICOA and CORDIO will fund a course later in 1999 to train MICOA, UEM and IIP staff and students in the identification of reef fauna, appropriate methods for the work and the principles of reef management. Monitoring will commence immediately after the course. Two students will register for M.Sc. degrees through ORI and execute the programme under the joint supervision of MICOA and ORI. Similar studies are currently being undertaken at ORI, including groundwork on coral culture, and collaboration between these organizations will provide added impetus to the Mozambique-South African coral research programme.

ACRONYMS

CORDIO	Coral Reef Degradation in the Indian Ocean
COTS	Crown-of-Thorns
ENSO	El Nino Southern Oscillation
INE	Instituto Nacional de Estatistica (Statistics Department)
IIP	Instituto de Investigação Pesqueira (Fisheries Research Institute)
MICOA	Ministério para a Coordenação da Acção Ambiental
MSY	Maximum Sustainable Yield
ORI	Oceanographic Research Institute
SADCO	Southern Africa Data Centre for Oceanography
UEM	Universidade Eduardo Mondlane

BACKGROUND

General

The 1997-1998 El Nino southern oscillation (ENSO) caused elevated sea temperatures that resulted in global coral bleaching. Coral reefs constitute an important biological resource in terms of their complex biodiversity and are the basis for tropical fisheries and marine ecotourism. They represent one of Mozambique's main coastal assets and coastal communities and the growing tourism industry rely mainly on reef-based resources. Today, about 6.6 million people live within Mozambique's 48 coastal administrative districts. This represents 42% of the current population of Mozambique (15.7 million) which is expected to grow at 3% p.a. (INE, 1998). While the population density in coastal districts was 28 persons/km^2 in 1994, densities have been recorded in the coastal cities as high as 1,525 persons/km^2 in Maputo, 625 persons/km^2 in Beira and 409 persons/km^2 in Nacala (Lopes, 1996). Coral reefs are thus of paramount to Mozambique and its economy.

Sea surface temperatures and oceanography

Sea surface temperatures vary seasonally along the coast of Mozambique. In general, high surface water temperatures (26º C-30º C) are found from November to May, while lower values (21º C-26º C) occur from June to October (SADCO data, 1960 to 1997). The 1997 and 1998 sea surface temperatures are presented for the areas studied during this survey in Fig. 1. While it is evident in these that the sea surface temperatures along the north coast are normally 1 to 2 º C higher than those observed along the south coast, the temperature difference between 1997 and 1998 is far more apparent. The elevated temperatures in the 1997-1998 summer were certainly due to the ENSO event.

The Mozambique Current which transports the warm water is part of the anti-cyclonic sub-tropical gyre that consists of the South Equatorial Current, the Agulhas Current system and the eastward flow to the north of the sub-tropical convergence. According to Saetre & da Silva (1984), the circulation of the Mozambican Current along the Mozambican coast includes three anti-cyclonic cells within the Beira, Inhambane and Maputo bights, as well as some smaller cyclonic eddies.

Reef type and distribution of coral reefs

Reefs along the Mozambican coast consist of fossilized dune and beach rock colonized by corals to a varying degree. The shoreline has been successively exposed and submerged during the millennia, forming a compound shoreline (Tinley, 1971; Rodrigues et al., in press) in which the coral reefs are distributed in three regions (Fig. 2.).

The northernmost section of the coast extends for 770 km from the Rovuma River in the north to Pebane in the south (17º20'S). It is characterized by numerous small islands that form the Quirimba archipelagos and the Primeiras and Segundas Islands. Coral reefs form an almost continuous fringing reef on the eastern shores of the islands and the more exposed sections of the mainland coast.

The graphs were extracted from South African Weather Bureau remote sensing data.

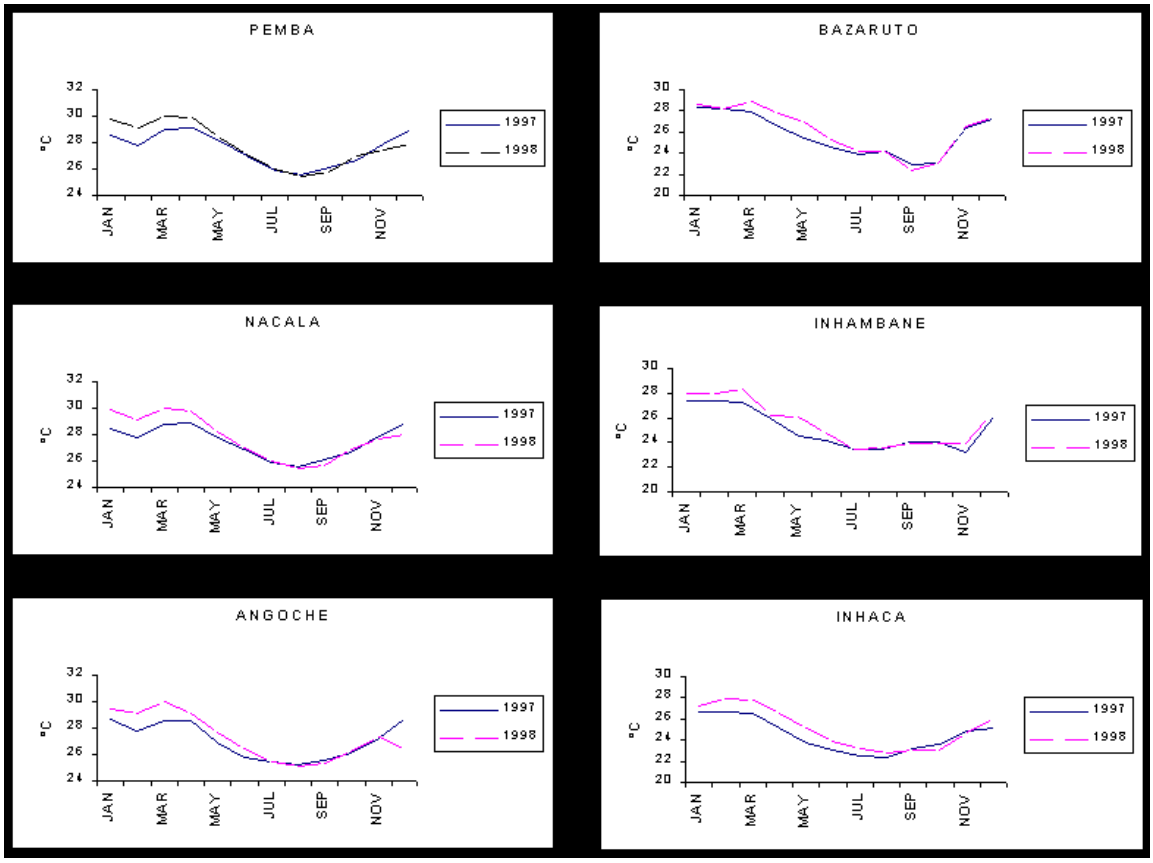

Fig. 1. The 1997 and 1998 sea surface temperatures for the areas studied during the survey.

The central section of the coast between Pebane (17º20'S) and Bazaruto Island (21º10'S), a distance of about 950 km, is classified as a swamp coast. Twenty-four

rivers discharge into the Indian Ocean along this section, each with an estuary supporting well-established mangrove stands. The coastal waters are shallow and this, combined with the sediment loading from the rivers, causes high turbidity levels. Coral reef formation in this area is consequently severely limited.

The southern section stretches for 850 km from Bazaruto Island southwards to Ponta do Ouro (26º50'S). The coastline is characterized by high dunes, north facing bights and barrier lakes. The dune systems attain heights of 120 m and are considered to be the highest vegetated dunes in the world. The distribution of reefs along the coast and nearshore islands is patchy and the reefs are more sparsely inhabited by corals.

Fisheries

There are three types of fisheries in Mozambique, comprising industrial, semi-industrial and artisanal fisheries. These three sectors land about 90,000 tons/year from an estimated MSY of about 300,000 tons/year (Palha de Sousa, 1996). The industrial and semi-industrial fleets currently earn 40% of Mozambique's foreign revenue, gained largely from prawn fisheries dependent on mangroves and estuaries for their productivity.

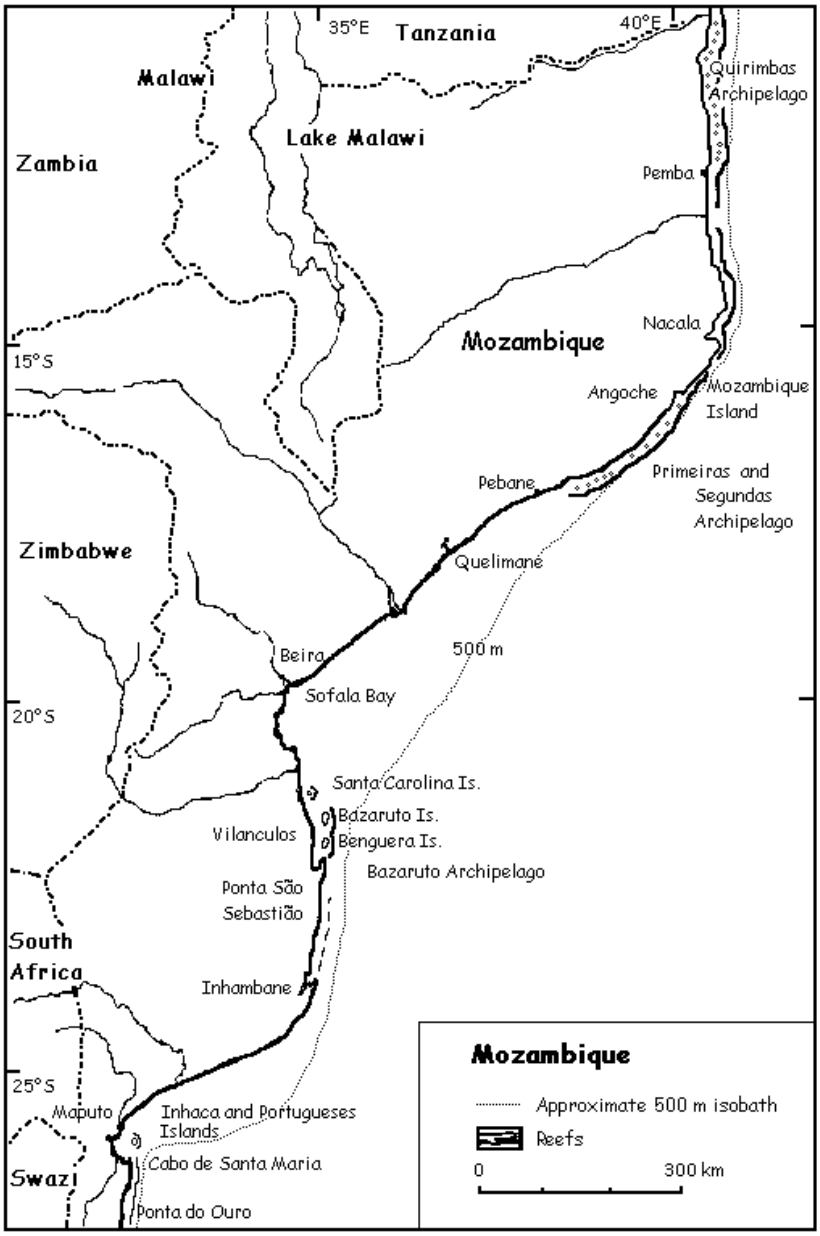

Fig.2. Map of the Mozambican coastline depicting reef distribution and the localities studied in the survey.

The artisanal fishery, on the other hand, is responsible for about 70% of the total catch, representing an average production per unit area of 4.6 tonnes/km^2 in the fishing grounds which extend up to 5 km offshore (Sanders, 1988). Very little information is available on the artisanal fisheries and resource assessments have only been undertaken in Maputo Bay. These fisheries are largely centred on the reefs and are clearly important to the coastal communities and Mozambican economy.

Tourism

Coral reefs represent one of the main attractions for the tourists industry in Mozambique. Most tourism occurs along the coast where the best infrastructure for tourism is established, especially near the coral reefs of Pemba, Mozambique Island, Bazaruto Archipelago, Inhaca Island and Ponta do Ouro. The industry has been growing since the end of the civil war in 1992 and is increasing in importance, both in the employment sector and the Mozambican economy.

OBJECTIVES

As the extent of reef loss during the 1997 – 1998 El Nino phenomenon was unknown in Mozambique, the current survey was undertaken to:

1. Assess the consequences of coral bleaching in Mozambican waters.

2. Train Mozambican scientists in this specialized field to increase the scientific capacity of the country.

PRELIMINARY SURVEY

Methods

The survey of coral bleaching was undertaken from March 24 to April 8, 1999, at the end of summer. Evidence of bleaching was sought for the present and past year in six localities, these being tabulated below in order from north to south. It was executed by MICOA and IIP staff and post-graduate students, accompanied throughout by staff from the ORI and CORDIO. Dives were executed on a total of 17 reefs and a visual assessment was made of reef type, faunistic cover and the extent of reef damage attributable to bleaching and crown-of-thorns starfish (COTS). Quantitative measurements using transect techniques proved inappropriate due to the sea conditions, the nature and condition of the reefs, and the fact that most of the work was done using snorkel rather than SCUBA. However, it proved possible to record random video-photo quadrats at ten of these stations for later analysis.

Results

Co-ordinates of the study sites are listed in Table 1. The basic findings of the survey are summarized in Table 2 and the list of species recorded on the reefs is tabulated in Table 3 (Appendix).

Table 1. GPS co-ordinates (WGS 84) of the reef sites surveyed during the study. Where applicable, co-ordinates of the start and end of long dives are presented.

LOCALITY	REEF	LATITUDE (start)	LONGITUDE (start)	LATITUDE (end)	LONGITUDE (end)
Pemba	Wimbe Beach	12 57'42"	40 33'10"		
	Quilaluia	12 29'36"	40 37'27"	12 29'51"	40 37'31"
	Quilaluia Channel	12 29'00"	40 34'44"		
	Pemba Bay	12 55'31"	40 30'04"	12 55'14"	40 29'54"
Nacala	Fernao Veloso Bay	±14 26'56"	±40 42'04"		
Angoche	Baixo St Antonio	16 12'46"	40 08'05"		
	Mafamede Island	16 20'57"	40 03'19"		

Bazaruto Island	Inner Two-mile Reef	21 48'32"	33 30'05"		
	Coral Garden	±21 48'	±35 33'		
	Lighthouse Reef	21 31'22"	35 29'44"		
Inhambane	Mike's Cupboard (Ponta da Barra)	23 48'44"	35 32'30"		
	Coral Garden (Ponta da Barra)	23 47'13"	35 31'27"		
	Anchor Bay (Ponta da Barra)	23 46'37"	35 30'38"		
	Cabo dos Correntes (Paindane)	21 31'21"	35 21'44"		
Inhaca Island	Pta Torres Channel	26 03'51"	32 57'12"		
	Pta Torres	26 04'27"	32 57'07"	26 04'19"	32 57'14"
	Barreira Vermelha		26 01'19"	32 53'59"	

Table 2. Summary of the results of the survey.

LOCALITY	REEF	DESCRIPTION	RESULTS
Pemba	Wimbe Beach	Patch reef of beach/dune rock at 3.5-7 m in sheltered bay; subject to eutrophication and sedimentation. Prominent species: Porites rus, P. nigrescens, P. lutea and Diploastrea heliopora. Fish community poor.	Reef cover 30-40%; coral cover 0-60%, mean ~30-40%. Mortality ~30% from bleaching. Also COTS and COTS scars.
	Quilalulia Channel	Sparse patch reef of coral rubble in 1.5-2.5 m channel between Quilaluia and Sencar Islands. Corals consisted of a sparse mix of soft and hard corals. Fish community poor.	Reef cover 40-60%; coral cover <1%. Heavy mortality from bleaching in 1998.
	Quilalulia	Fringing reef of excellent profile on seaward edge of island, depth ranging from 3-7.5 m onto sand. Near total mortality from bleaching. Previous coral population rich and diverse. Fish population poor, possibly heavily fished.	Solid reef cover with 1% survival of corals from 1997-1998 El Nino event.

	Pemba Bay	Excellent reef on beach rock in sheltered bay, dropping steeply from 3-8 m onto sand. Reef subject to eutrophication and turbidity from the bay but little evidence of bleaching. Heavily colonized by Porites rus and P. nigrescens; also considerable Stylophora pistillata and plate Montipora sp. Large numbers of Diadema. Fish well represented.	Near solid reef and coral cover with a maximum of 30% mortality from bleaching in 1998.
Nacala	Fernao Veloso Bay	Patch reef developing into fringing reef 2-7 m deep in sheltered entrance to lagoon. Coral cover low in inshore region, improving offshore. Mixed community of Porites and Acropora and a diversity of other corals. Relatively little bleaching. Fish community poor.	Reef cover variable with commensurate variability in coral cover. The latter ranged from 0-90%, the mean cover on the fringing reef being 50-70%. Bleaching of ~30% in 1998.
Angoche	Baixo de St. Antonio	Fringing reef subject to considerable surge and surf at 3-7 m depth with marked spur and groove formations manifesting the original dune rock structure. Evidence of bleaching in 1998 and the current year. Mixed but not prolific fish community.	Substantial reef with 30-40% coral cover, 25% of this being soft coral. Mortality from past bleaching ~20%; some evidence (<2%) of current bleaching.
	Mafamede Island	Reef similar to above but more consolidated. Evidence of bleaching in 1998 and the current year. Mixed but not prolific fish community.	Hard and soft coral cover each ~20%. Mortality from El Nino bleaching ~20%, little (<2%) in current year.
Bazaruto Island	Inner Two-Mile Reef	Partially sheltered mixed coral community 1-3.5 m deep on the landward side of a fringing rock reef between Benguera and Bazaruto Islands. A COTS outbreak commenced on this reef in 1995, 80% of which has been destroyed. The post-COTS deterioration of the reef has continued with reef collapse and erosion; largely rubble was found. Evidence of some coral recruitment was	Coral cover used to be high (~80%) with high species diversity; the reef has suffered 80% mortality.

		only found at the inner periphery of the reef. Fish community poor.	
	Coral Garden	A coral garden protected within two northern projections of Two-mile Reef. Depth: surface to 8 m. Coral community rich and diverse, dominated largely by staghorn and tabular Acropora spp. Little evidence of current and past bleaching; some mortality from COTS, boat and diver damage. Fish community diverse and abundant.	Coral cover high, ~80-90% in parts of the reef. Mortality ~20% in parts due to the causes listed.
	Lighthouse Reef	Partially sheltered mixed coral community, 1-3.5 m deep, on the landward side of a fringing rock reef north of Bazaruto lighthouse. Coral cover and community structure variable according to degree of exposure and sedimentation on the reef. This ranged from monospecific outcrops of large staghorn corals to a sparse cover of sediment tolerant faviids and soft corals. Little present or past bleaching. Fish community commensurately rich and abundant.	Coral cover 5-90% depending on position on the reef. El Nino bleaching in tidal gullies 10-20%. Current bleaching ~1%.
Inhambane	Mike's Cupboard (Ponta da Barra)	Fossilized dune rock of substantial profile at 16 m depth with gullies and potholes. Coral cover low due to swell-generated turbulence, turbidity and sedimentation; mainly sediment tolerant soft corals and faviids with Pocillopora and Stylophora. No evidence of COTS or bleaching. Good fish community but few coral fish.	Coral cover 2-10%.
	Coral Garden (Ponta da Barra)	A wave cut beach rock platform exposed to surge and surf at 1-5 m. Dominated by tabular staghorn and soft corals. Some El Nino and current bleaching. Poor fish community.	Coral cover 5-60%; El Nino bleaching ~5-15%; current bleaching <1%.

	Anchor Bay (Ponta da Barra)	Small, low profile reef in the sea at 9 m depth. Evidence of a previously rich coral community decimated by COTS. COTS and recent feeding scars were observed and a local report of the destruction of the reef over the last three years confirmed our finding. Pocillopora and a few Acropora clathrata are the main survivors. Little evidence of recent coral recruitment. Fish community surprisingly good; mainly snappers and herbivores.	Coral cover ~2-5%.
	Cabo das Correntes (Paindane)	Coral garden at 1-5 m on the landward side of a largely submerged rocky reef exposed to strong currents and surf. Coral community dominated by a diverse and extensive cover of soft corals. Scant evidence of bleaching. Fish community good in the deeper water, largely snappers and goatfish with very few chaetodons.	Coral cover 0-90%; mean ~60%; almost exclusively soft corals. Three colonies of digitate Acropora were bleached and encrusted with coralline algae.
Inhaca Island	Pta Torres Channel	Shallow reef of Porites bommies, faviids and a few Acropora spp. fringing a sand bank channel. The reef top is exposed at low tide and the reef extends to a depth of 2 m. It is clearly subject to a tidal race, turbidity and eutrophication. Fish were sparse, mainly herbivores, half-beaks and sand-dwelling species.	Little evidence of bleaching in 1998 but ~40% of the corals were undergoing recent bleaching. A further 40% of the bommie tops were dead from (natural) tidal exposure.
	Pta Torres	A reef consisting of an emergent dune rock wall dropping to a depth of 6 m. Sparsely inhabited by corals tolerant of a tidal race, turbidity and sedimentation. Stylophora pistillata, faviids and Pocillopora verrucosa were the most abundant in that order. Recent bleaching had caused near total mortality; quantitative assessment was difficult	Coral cover 2-5%. Mortality from recent bleaching ~90%. The only unaffected genera were Pocillopora, Goniopora, Goniastrea, Astreopora, Pavona and Leptoseris.

		due to turbidity. Fish were sparse.	
	Barreira Vermelha	Mixed Acropora community 2-5 m deep on flat bottom with a few small Porites bommies. Sheltered location inshore of Inhaca Island. Poor visibility (0.5 m) limited quantitative assessment but extensive beds of Palythoa, evidence of El Nino bleaching and current bleaching indicated that this was an affected reef. No fish were seen.	No assessments were possible.

Discussion

The effects of El Nino bleaching in Mozambique were most extensive on exposed reefs in the north and this diminished further south except at Inhaca Island where serious recent bleaching was encountered. Extensive COTS damage was also found at Bazaruto and Inhambane. The COTS outbreaks commenced in 1995-1996 and, as sufficient time has elapsed for reef erosion and collapse to occur, the damage on these reefs was more pronounced. The consequences of the El Nino bleaching are going to be even more serious as coral mortality on the northern reefs was as high as 99%; a similar progression in the collapse of reef structure on the seriously bleached reefs is anticipated. The biodiversity of these sites will be impaired as low coral recruitment was only observed at the Bazaruto COTS site.

The fish populations on the damaged reefs, the basis of many of Mozambique's valuable artisanal fisheries, were also poor. Impaired reefs had proportionately more herbivorous fish, being more heavily colonised by algae. Both the fisheries and the tourism value of these sites will thus be affected, parameters that will have to be quantified.

The reefs least affected by bleaching were those in sheltered embayments. Such bays are characterized by a level of nutrient enrichment and turbidity from terrestrial runoff, as well as natural heating from insolation in their shallower reaches. Considerable bleaching in embayments should thus be expected, particularly if the rate of water exchange is low. However, the coral communities which have survived on these reefs generally consist of species that are tolerant of these parameters. The reef in Pemba Bay was most typical of this environment (see Tables 2 & 3) and manifested little bleaching.

CONCLUSIONS AND RECOMMENDATIONS

The extent of bleaching encountered during the survey is a cause for concern. The biodiversity of the affected reefs has been seriously impaired in terms of both the coral and fish communities. Further work and monitoring at three localities in the north of Mozambique and three in the south is thus proposed. Bleaching, COTS and control sites should be included to:

1. Establish whether further bleaching occurs.

2. Monitor and compare reef recovery at bleaching and COTS sites.

3. Consider appropriate procedures for intervention if reef recovery proves unlikely or slow, e.g. the artificial propagation and transplantation of corals.

4. Develop a management plan for Mozambique's coral reefs.

Further development of Mozambican staff was planned during the survey to deal with the situation. MICOA and CORDIO will fund a course later in 1999 to train MICOA, University and IIP staff as well as students in the identification of reef fauna, appropriate methods for the work and the principles of reef management. Monitoring will commence immediately after the course. Two students will register for M.Sc. degrees through the ORI in Durban and execute the programme under the joint supervision of MICOA and ORI. Similar studies are currently being undertaken at ORI, including groundwork on coral culture, and collaboration between these organizations will provide added impetus to the Mozambique-South African coral research programme.

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The authors would like to express their gratitude to SIDA/SAREC for funding this survey, especially Dr. Olof Lundin who took the initiative and made the funds available.

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