Journal of Coastal Research	6	4	829-852	Fort Lauderdale, Florida	Fall 1990

Development of a Type Zoning Model for Zululand Coral Reefs, Sodwana Bay, South Africa

P. J. Ramsay and T. R. Mason

Joint Geological Survey
University of Natal
Marine Geoscience Unit

Department of Geology and
Applied Geology
University of Natal
King George V Ave.
Durban 4001, South Africa

ABSTRACT

RAMSAY, P.J. and MASON, T.R., 1990. Development of a type zoning model for Zululand coral reefs, Sodwana Bay, South Africa. *Journal of Coastal Research*, 6(4), 829-852. Fort Lauderdale (Florida). ISSN 0749-0208.

The coral patch reefs of the northern Natal coast are unique, being some of the most southerly in the world, and relatively unspoilt. Two-Mile Reef at Sodwana Bay has been used to develop a physiographic and biological zoning model for Zululand coral reefs which has been applied to other reefs in the region. The Zululand reefs are formed by a thin veneer of Indo-Pacific type corals which have colonized a submerged, late Pleistocene sandstone outcrop. The sedimentary facies beneath the corals were formed as a regressive coastal dune and beach sequence. Two-Mile Reef is a windward reef, and the zones are parallel to the north-northeast south-southwest reef/coast trend. Eight distinct zones can be recognized and differentiated on the basis of physiographic and biological characteristics. The reef fauna is dominated by an abundance of alcyonarian (soft) corals, which constitute 60 to 70% of the total coral fauna. The Two-Mile Reef zoning model has been successfully applied to larger reefs such as Red Sands Reef, and smaller patch reefs: Four-Mile and Seven-Mile Reefs which are in the same general area.

ADDITIONAL INDEX WORDS: *Alcyonarian corals, physiographic and biological zoning, reef-base, southwestern Indo-Pacific faunal province, thin veneer reefs, three-dimensional reef models.*

INTRODUCTION

Two-Mile Reef (27°31.2′ S; 32°41.3′ E) was chosen as the type physiographic and biological zoning model for Zululand coral reefs because of its large size, varied reef fauna and topography, and accessible geographical location (Figure 1). Two-Mile Reef lies in 9 to 34 m of water, 1.3 km north-northeast of Jesser Point at Sodwana Bay (Zululand), on the southwestern margin of the Indo-Pacific faunal province. CROSSLAND's (1948) intertidal study of Natal corals, noted that the fauna was typical of a marginal belt and was characterized by the almost complete absence of the great reef-builder *Acropora*. BOSHOFF (1958) states that the southern-most coral reefs in the southwestern Indian Ocean occur at Inhaca Island (26°10′ S; 32°58′ E) off Mozambique and an annotated checklist of Scleractinia is available for the area (BOSHOFF, 1981).

89078 received 6 December 1989; accepted in revision 19 February 1990.

Two-Mile Reef is parallel to the coast and consists of a thin veneer of Indo-Pacific type corals which have colonized a submerged, late Pleistocene dune and beach sequence (= reef-base). A fossil coral fragment (*Favia* sp.) found in an intertidal beachrock sequence 35 km north of Sodwana Bay gave a ^{14}C-age of 3780 +/ − 60 BP (laboratory analysis no. Pta-5052); the authors assume that this represents a minimum age for the Zululand patch reef assemblages. Similar patch and platform reefs consisting of thin veneers of coral, capping calcareous sandstone foundations, are found on the Natal-Recife coastline of Brazil (GUILCHER, 1988) and on the western, northwestern and southern Australian shelf area (FAIRBRIDGE, 1950). The Brazilian reefs are colloquially known as "arrecifes", a Portuguese term which means sandstone (GUILCHER, 1988). The reefs are founded on submerged Holocene beachrocks and have been dated at between 7000 and 2000 BP (FLEXOR & MARTIN, 1979). The Australian patch reefs described above are truncated benches in Pleis-

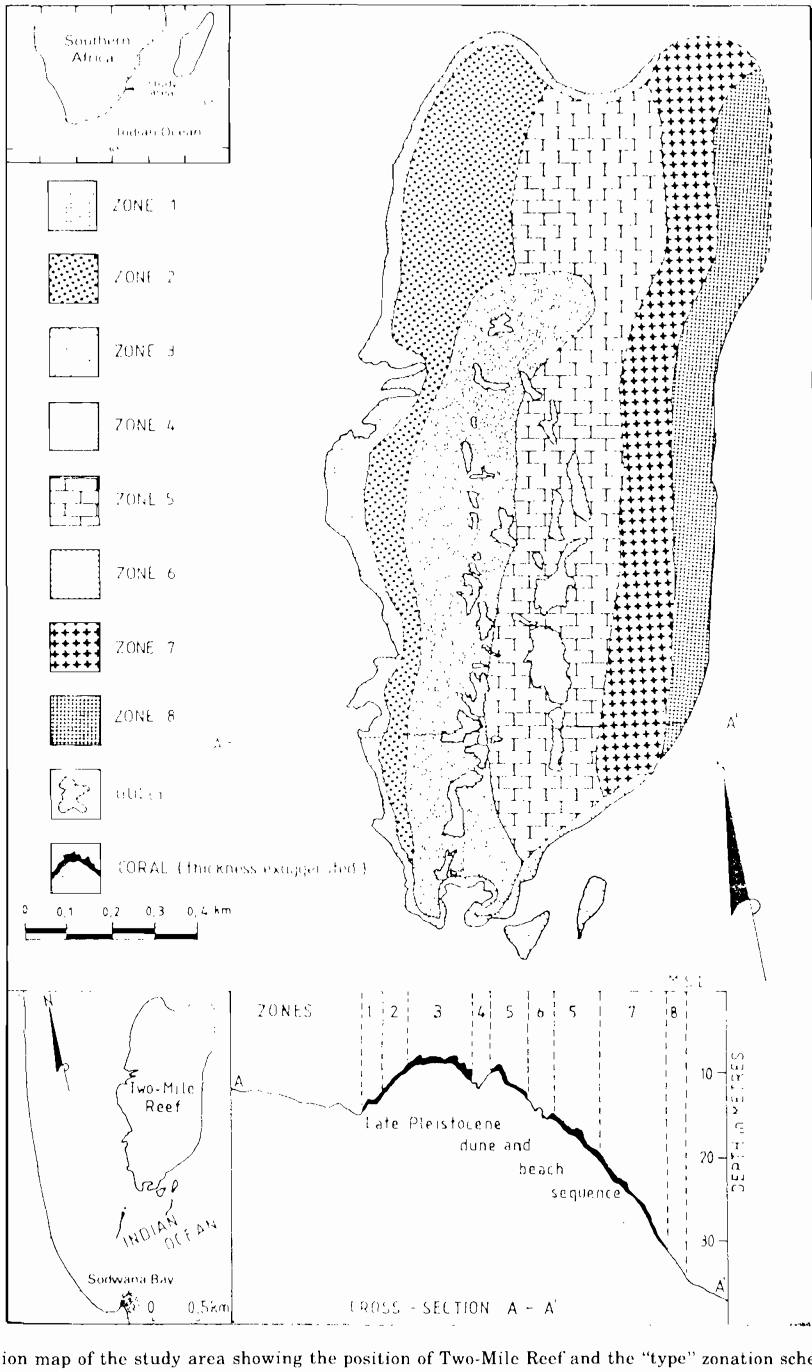

Figure 1. Location map of the study area showing the position of Two-Mile Reef and the "type" zonation scheme for Two-Mile Reef.

tocene aeolianites, which formed as coastal sand dunes in parallel ridges during various sea-level lows (FAIRBRIDGE, 1950). BLOOM (1974) described modern reef complexes as thin veneers of late Pleistocene and Holocene limestone deposited on older reefs and lithified dune fields that were exposed to subaerial weathering during a low sealevel of the Wisconsin glaciation.

REEF SETTING

The Zululand coral reefs are some of the most southerly coral reefs in the world, and owe their existence to clear, subtropical water carried southward by the warm Agulhas Current and the absence of silt-carrying rivers in the coastal hinterland. HUBBARD & POCOCK (1972) demonstrated the ability of isolated corals to survive under considerable sediment cover. VERWEY (1931) states that the effect of suspended sediment on reef corals is overrated; suspended sediment basically restricts light penetration. Since decrease in light is a major cause for the decline in coral growth rates with depth (HUSTON, 1985), reduced water transparency reduces carbonate productivity by corals. KANWISHER & WAINWRIGHT (1967) note that very little coral growth occurs below surface light levels of about 4%, but other workers (CHALKER *et al.*, 1986) state that corals are common down to about the 1% light level. This information can be used to predict how coral zonation will change if water transparency changes.

Two-Mile Reef is a patch reef (GUILCHER, *personal communication*, 1988) which is always submerged. The reef lies 1 km offshore and parallels the coastline for 2.1 km: its maximum width is 0.9 km. Water depths vary from 9 m over the shallow central axis of the reef to 34 m along the deep reef-front environment. The coral thickness reaches a maximum of 30 cm on the reef platform, but is thinner and patchily developed at the reef margin (RAMSAY, 1988). The depth to which significant coral cover extends is 25 m; below this depth only scattered coral colonies exist, probably owing to the reduced light intensity at this depth. The euphotic zone, below which little or no photosynthesis occurs, occurs at a depth of 30 m along this section of coastline. Similar light intensity/depth coral growth criteria in other coral reef regions in the world have been observed by AGASSIZ (1898); YONGE (1940); JAUBERT and VASSEUR (1974); MERGNER and SCHEER (1974); MONTAGGIONI (1974); REISS and HOTTINGER (1984); JAAP (1984); TOMASCIK and SANDER (1985), and CHALKER *et al.* (1986).

The continental shelf is narrow in northern Zululand, approximately 3 km wide (FLEMMING 1981; MARTIN & FLEMMING, 1986), and the Agulhas Current flows close to shore. Coastal conditions for the Natal coast are summarized in HYDRAULICS RESEARCH UNIT report (1968). The tidal range in the area averages 2 m (SCHUMANN & ORREN, 1980) and the coast is therefore microtidal (DAVIES, 1964) or low mesotidal (HAYES, 1979). The coast is dominated by persistent high-energy waves and prevailing large-amplitude swells from the southeast, as indicated by VOS (voluntary observing ships) data (SWART & SERDYN, 1981). This leads to a net northward longshore drift. Littoral drift is predominantly toward the north and intertidal sandstone ledges serve to trap beach sediments on their southern or updrift side while allowing erosion on the downdrift side (ORME, 1973).

METHODS

The primary survey involved mapping the extent of Two-Mile Reef and other Zululand coral reefs using panchromatic aerial photographs. These photographs were enlarged to a scale of 1:11500 and shading techniques were employed to enhance the visual impact of the underwater reef on the photograph. The deeper reef margins could not be observed on the photograph, but were mapped using sextant bearings taken from three coordinated landmarks on the shore and from coordinated echo-sounding traverses. Selected west-east underwater traverses were undertaken on Two-Mile Reef using SCUBA to collect physiographic and biological zoning data. Similar traverses undertaken on the other reefs were used to apply the test zoning method. A team of three divers and backup in an inflatable craft or ski-boat collected data and coordinated the underwater traverse lines accurately using sextant bearings. On each traverse the divers: photographed and identified corals; noted and measured coral cover/density and topographic features;

recorded depth measurements; sampled the reef-base to determine the sedimentary facies. These data were supplemented by extensive snorkel-diving observations and sampling (to depths of 25 m) along the entire reef system. Sediment grain size statistics were computed using a settling tube.

Seven echo-sounding traverses, two in a north-south direction, and five in an east-west direction, were used to produce a three-dimensional model of Two-Mile Reef to help visualize the morphology of the reef (Figure 2). The instrument used was a Furuno FE-4000 chart-record echo-sounder. The echo-sounding data were supplemented by extensive, coordinated, spot-depth readings taken on various SCUBA dives over a period of three years. Each echo-sounding traverse was coordinated (using a sextant) at the start and finish and the traverses undertaken at a constant speed so that each sounding could be reduced to a common horizontal scale using an Apple Macintosh II computer and graphics software. Each sounding profile was digitized with a computerized scanning device ("Thunderscan") and the resulting bitmapped image was transferred into a graphics programme ("Superpaint") which incorporated a facility of scale enlargement or reduction. In this way all the sounding profiles were reduced to a common horizontal scale of 1:11 500. A total of 232 X, Y, and Z coordinates on Two-Mile Reef were read off the coordinated echo-sounding traverses and entered into a three-dimensional surface-generating programme called Surfer; this facilitated the development of a model of Two-Mile Reef which can be viewed from any orientation and tilt angle (RAMSAY, *in press*). It is possible to plot a topographic map from the same set of X, Y, and Z data. This is especially useful in visual-

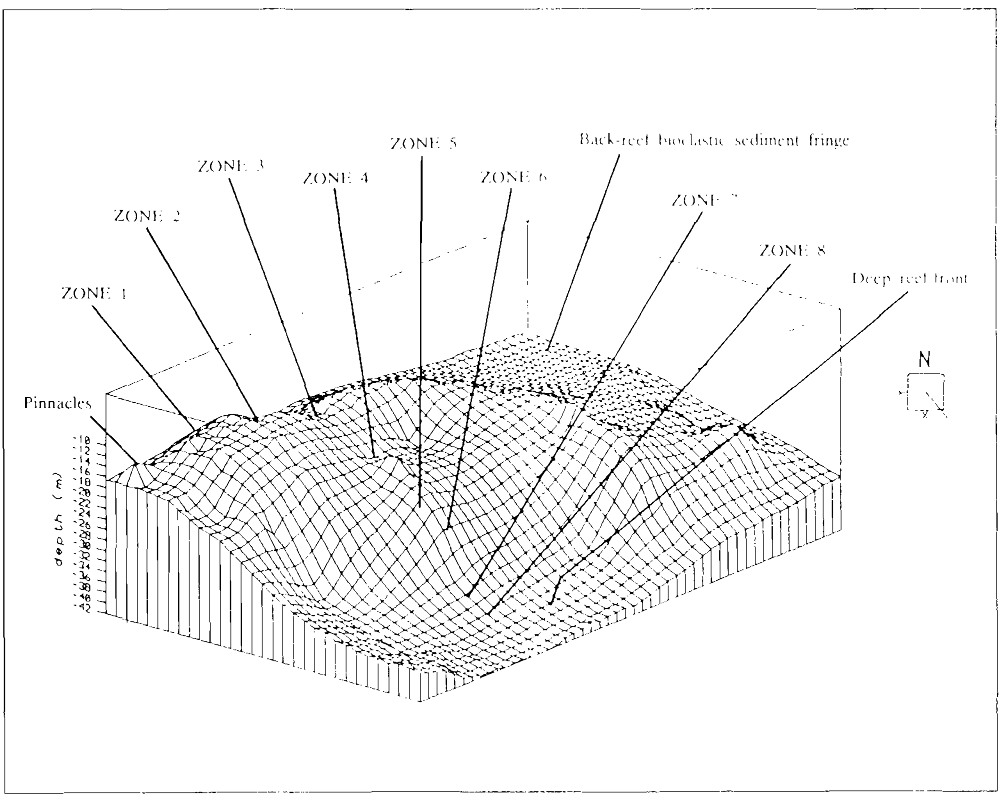

Figure 2. Computer-generated, three-dimensional surface model of Two-Mile Reef viewed from the southeast at a tilt angle of 20° above horizontal. The small legend next to the plot indicates the direction of view.

izing the bathymetry of the reef system (Figure 3).

REEF ZONING

Earlier investigations on coral reefs viewed reef dynamics in terms of geomorphology (BARNES *et al.*, 1971; GUILCHER, 1971; STODDART, 1969) or the biology of the reef system (ROSEN, 1971; SCHEER, 1971; TAYLOR, 1971). Regional variation, formation type and structural zonation of each reef are primarily caused by its geological history and its position in the open sea (MERGNER & SCHEER, 1974). Coral species distribution is influenced more by light exposure and light intensity than by other abiotic factors (MERGNER & SCHEER, 1974). Corals are the dominant animals on flourishing coral reefs and these determine the character of the physiographic zones within the reef by their horizontal or vertical sequence which results from the influence of changing abiotic factors (MERGNER, 1971).

The physiographic and biological investigation of Two-Mile, Four-Mile, and Seven-Mile Reefs were made using coral sociological methods similar to those described by MERGNER & SCHEER (1974). The "zurich-montpellier" phytosociological method of coral abundance and sociability (surface coverage) described by VASSEUR (1974) is too complex for large reef tract investigations. The extreme difficulty of applying current coral classification meant that the reef corals were only identified to generic level. Underwater observations of the coral genera abundance/cover were either (a) r = rare, very few specimens in the study area; the value of dominance or cover is insignificant; (b) p = present, coverage is poor; (c) c = common, a large number of specimens significantly contributes to reef cover; (d) a = abundant, many specimens and the value of dominance or cover is very significant.

In the absence of quantitative data, reefs are best compared using descriptive schemes based on physiographic and biological distribution patterns. The method is best suited to reefs

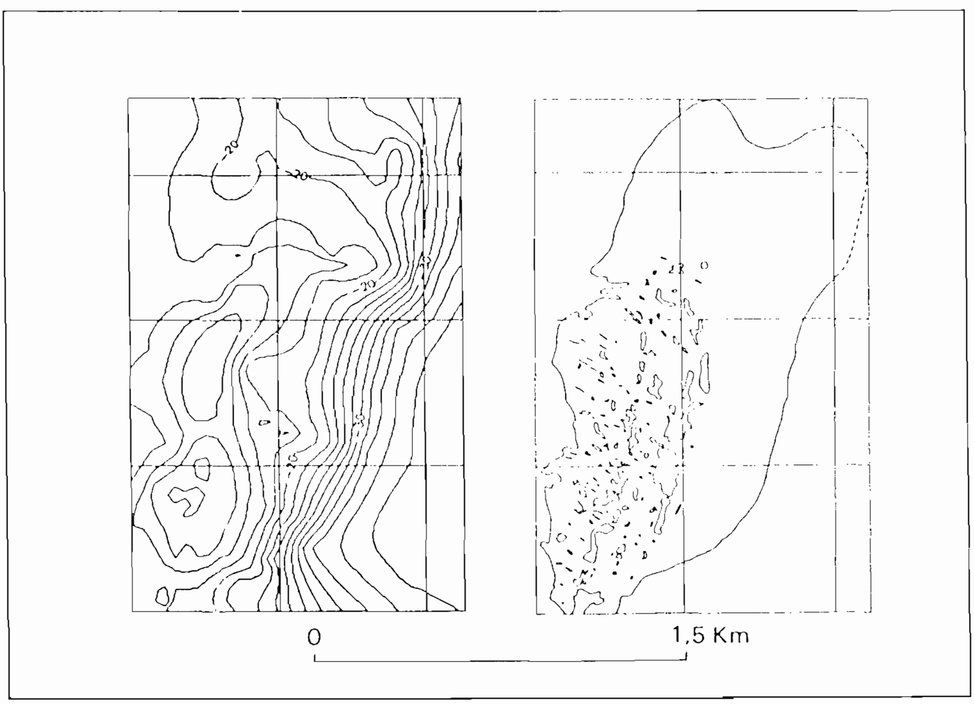

Figure 3. Bathymetric map and plan of Two-Mile Reef reduced to the same scale. Bathymetric contour interval is 2 metres.

showing pronounced zonation parallel to the reef edge, *i.e.* windward reefs (STODDART, 1973). The Sodwana Bay reefs are windward reefs, and the criteria mentioned above were adopted to define eight distinct zones on the type area, Two-Mile Reef (Figures 1, 2, 4 & Table 1).

Corals belong to the Phylum Cnidaria (CLARKSON, 1979) and Zululand reefs host members of the two main orders: Scleractinia (hard corals) and Alcyonacea (soft corals). The other two subordinate anthozoan orders present are Gorgonacea (sea fans) and Antipatharia (black corals). The dominant alcyonarian corals comprise 60 to 70% of the total reef coral fauna and include the genera *Lobophytum, Sinularia, Sarcophyton,* and *Dendronephthya*. FAURE (1974) noted a similar abundance of alcyonarians in the "Passe" Grand Bassin on Rodriguez Island and FAIRBRIDGE (1950) quotes that patch and platform reefs in the outer parts of the Buccaneer Archipelago are dominated by

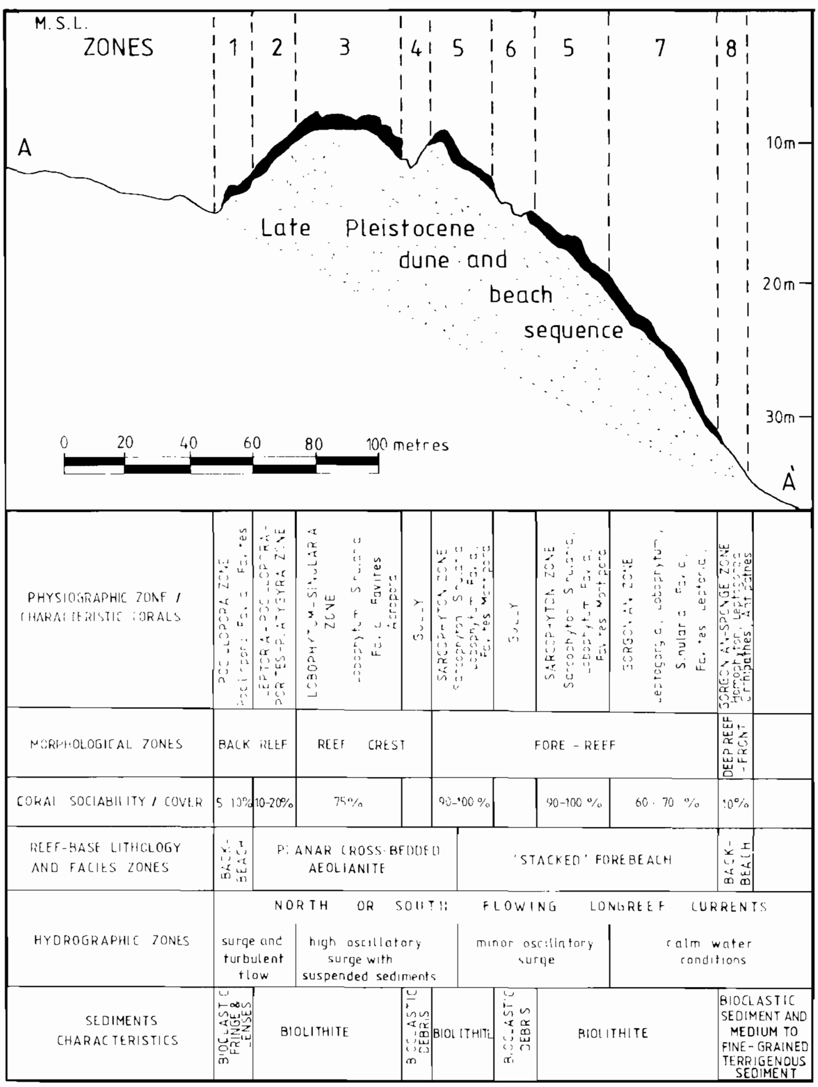

Figure 4. Reef cross-section A-A' on Two-Mile Reef indicating relationships of the physiographic, morphological, sociability, reef-base facies, hydrographic and sediment zones.

bryozoans and alcyonarians. WILLIAMS (1989a&b) states that the alcyonarian contribution on Zululand reefs is typical of Indo-Pacific coral reef assemblages, and is dominated by the three genera *Sinularia, Sarcophyton,* and *Lobophytum,* with a relatively minor contribution being made by genera such as *Dendronephthya, Nephthea, Alcyonium, Clavularia, Cladiella, Anthelia, Rumphella, Menella* and *Leptogorgia*. WILLIAMS (1989a) also noted that the Zululand coral reef fauna is scanty compared to other Indo-Pacific areas such as the Red Sea. The most important Zululand scleractinian genera, in descending order of abundance, are *Favia, Favites, Montipora, Acropora, Leptoria, Echinopora, Turbinaria, Pocillopora, Porites, Platygyra, Astreopora, Symphyllia, Goniapora, Galaxea, Lobophyllia, Stylophora, Fungia, Anomastrea, Oxypora, Pavona, Pachyseris, Dendrophyllia, Coeloria, Hydnophora, Goniastrea, Oxyphyllia,* and *Oulophyllia* (Table 1).

The eight defined physiographic and biological zones on Two-Mile Reef occur from the landward margin of Two-Mile Reef to the deep reef front zone (Figures 1, 3 & 4).

Zone 1

Zone 1 is the landward margin of the reef and occasional "spur and groove" topography is developed. These ridges strike perpendicular to the shore and have a maximum height of 40 cm. Within 20 m of the reef margin they disappear under the fringe of bioclastic sediment which surrounds the reef (Figure 5). Water depth varies from 15 to 21 m and coral growth is sparse (approximately 5% coral cover or sociability), due to dynamic sediment movement on the reef fringe. The reef-base in this zone is generally broken, covered in coral rubble, and comprises a carbonate-cemented, backbeach, sedimentary facies. Soft alcyonarian corals are not as common in this zone as on other areas of the reef. The only abundant coral genus is the hard coral *Pocillopora, Favia* and *Favites* are however common; defining the zone as the "*Pocillopora* Zone". The reef is fringed by skeletal biogenic carbonate sediment, mainly of molluscan origin, derived from the reef environment (RAMSAY, 1988). The mean grain size of the reef-derived, carbonate fringe is between 0.894 to 0.139 mm. Subtidal ladderback ripples often form in this sediment after a strong northeasterly wind (RAMSAY *et al.*, 1989).

Zone 2

Zone 2 is a flat, low-relief zone with scattered coral colonies covering 10% of the area, though in some places the coral cover is much greater (Figure 5). Depths vary from 12 to 14 m and less coral debris occurs here compared to Zone 1. Alcyonarian corals are less common in Zones 1 and 2 than on the rest of the reef. The most abundant corals are the scleractinian genera *Leptoria, Pocillopora, Porites,* and *Platygyra;* a suitable name for the zone is the "*Leptoria—Pocillopora—Porites—Platygyra* Zone." Rocky outcrops in this zone tend to be covered by brown algae. Zones 1 and 2 form the back-reef environment which dips at 3° to the west.

Zone 3

Zone 3 is a shallow, high energy, and high relief central region of the reef which is parallel to the shore. This is the reef-crest zone, closest to the ocean surface, with numerous deep gullies, overhangs, and pinnacles, and depths varying from 9 to 13 m (Figures 6 & 7). The zone resembles the "spur and groove zone" described by PICHON (1974) on the fringing reefs of southwest Madagascar. The rock foundation of the reef in this zone is an ancient aeolian sandstone facies which overlies a backbeach sandstone facies at a depth of 13 m. Corals are abundant in this zone with a total coral cover of about 75%. It is a stressful environment with a relatively high sediment load, and where the erosive effects of wave, surge, and tidal action are concentrated. Individual alcyonarian coral colonies tend to be larger, and species diversity is lower than in the deeper, seaward zones. According to WILLIAMS (1989a), these corals produce great quantities of mucus as an adaptation against the abrasive action of the high suspended sediment load in the water, and the mucus is an important nutrient source in coral reef food webs (MEANS and SIGLEO, 1986). Other workers (DAVIES, 1984; MITCHELL and CHET, 1975) have related excess mucus production to an excess in available nutrients within the surface waters. The reason for excess production of mucus by Zululand corals still needs to be investigated. The stressful condi-

Table 1. *Distribution of coral genera in the eight "type" zones of Two-Mile Reef.*

	TWO-MILE REEF					
	ZONE 1	ZONE 2	ZONE 3	ZONE 5	ZONE 7	ZONE 8
ALCYONARIANS						
Lobophytum sp.	c/p	p	a	a/c	a	p
Sinularia sp.	c/p	p	a	a	a	
Sarcophyton sp.	p/r	p	c	a	c	p
Dendronephthya sp.	r	r	p	p	p	
SCLERACTINIANS						
Favia sp.	c	p	c	c	c	p
Favites sp.	c	p	c	c	c	
Montipora sp.			p	c	p	
Leptoria sp.	p	a	c	c	c	r
Acropora (plate)	r	p	c	c	c/p	p
Acropora sp.	p	p	c	c/p	p	
Echinopora sp.		p	c	c	c/p	r
Turbinaria sp.	p	p	p	p	p	
Pocillopora sp.	a/c	a	p	p	r	
Porites sp.	p	a	p	p		
Platygyra sp.	p	a	p/c	p		
Astreopora sp.		p	p	p		
Symphyllia sp.		p				
Goniapora sp.			p	r	r	r
Galaxea sp.			r	p/r		
Lobophyllia sp.			r	p/r	p	
Stylophora sp.			p	p/r		
Fungia sp.			p	p		
Anomastrea sp.	p		p/r			
Oxypora sp.			r			
Pavona sp.			r	r		
Pachyseris sp.						
Dendrophyllia sp.						
Coeloria sp.			p/r	r		r
Hydnophora sp.						
Goniastrea sp.						
Oxyphyllia sp.						
Oulophyllia sp.			r	r	r	
ANTIPATHARIANS						
Antipathes sp.			p/c	p	r	p
Cirrhipathes sp.					r	c/p
GORGONIANS						
Leptogoria sp.			p	p	c/p	a
Homophyton sp.			p	p		a

tions on the reef-crest result in alcyonarian colonies displaying a low profile with short and compact lobes on the upper surface as opposed to having elongate digitate processes (WILLIAMS, 1989a). The most common coral genera include the dominant alcyonarians *Lobophytum, Sinularia, Sarcophyton,* and *Dendronephthya* whilst the most common scleractinians are *Favia, Favites, Acropora, Leptoria, Echinopora,* and *Montipora*. Antipatharians are represented by *Antipathes*. This high energy reef-crest zone has been named the "*Lobophytum—Sinularia* Zone." The lower part of the spur or gully sidewall is usually devoid of coral growth owing to dynamic sediment scouring in this area. Antipatharians and gorgonians such as *Rumphella* tend to congregate on the spur side-walls (WILLIAMS, 1989a): corals are scarce. PICHON (1974) describes a lack of coral growth in similar areas of the reefs of southwestern Madagascar. Reef-derived debris, broken coral, and impact marks on soft and hard corals were observed here. These features were caused by a tropical cyclone which passed over the Zululand

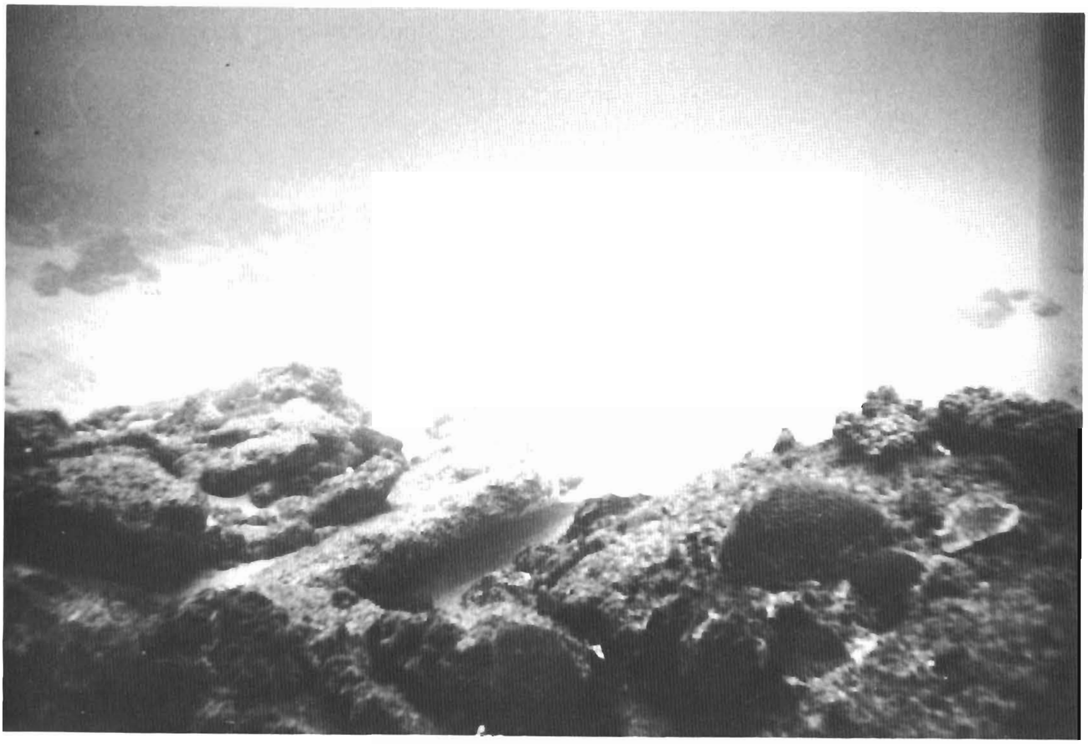

Figure 5. Underwater photograph of Zone 1—Zone 2 (foreground) interface. This illustrates the carbonate sediment fringe on the landward margin of Two-Mile Reef. The foreground field of view is approximately four metres.

coast in January 1988, just before the initial zoning survey was carried out.

Zone 4

Zone 4 consists of 20 to 50 m wide, north-south trending gullies which separate Zone 3 from Zone 5. Skeletal, reef-derived, bioclastic carbonate sediment occurs in the gullies and is underlain in places by medium- to fine-grained terrigenous quartz sand with a minor biogenic component. The bioclastic reef-derived sediment is moderately well-sorted, fine- to coarse-skewed, and has a mean grain size of between 0.885 to 0.682 mm. These gullies may be remnant rock pools or other erosional features incised by tidal action on the consolidated reef-base during periods when sea-level was substantially lower than at present. These larger, north-trending sets of gullies on the reef-crest fore-reef interface probably were formed during a sea-level stillstand at -13 m during the Holocene transgression. MAUD (1968) found evidence of consistent submarine platforms on the Natal continental shelf at -11, -18, and -36 m.

Zone 5

Zone 5 is a flat, low-relief zone with a few pinnacles rising 2-3 m above the average reef level. Depths are between 13 and 20 m. The zone is dominated by regular, narrow, inter-reef gullies striking at approximately 120° (Figure 8). The coral assemblage is diverse and sociability is 90-100%. The corals grow on a reef-base comprising carbonate-cemented, stacked forebeach facies and attain a maximum thickness of 20 cm. This zone is named the "*Sarcophyton* Zone" as it is the dominant genus, often reaching 70 cm in diameter (Figure 9). Alcyonarian genera include *Sarcophyton, Sinularia,* and *Lobophytum,* whilst the common scleractinians are *Favia, Favites, Montipora, Acropora, Leptoria,*

Figure 6. Underwater photograph of an inter-reef gully on the reef-crest. Note the presence of rippled bioclastic debris in the gully.

Echinopora, and *Turbinaria*. Reefal debris is less evident than in the other zones. This can be attributed to less tidal and wave action effecting the zone, thereby defining it as a lower energy regime.

Zone 6

An 80 to 100 m wide set of north-south trending gullies occur within Zone 5 and this has been termed Zone 6 due to a change in physiography. The inter-reef gully sediment is typically reef-derived biogenic material with occasional mounds of dead coral rubble. The sediment is well- to moderately well-sorted and near-symmetrically skewed with a mean grain size between 0.803 and 0.578 mm. The gullies were probably formed by wave and tidal action when sea-level was 17 m lower than at present and the reef-base was eroded.

Zone 7

In Zone 7 there is a marked change in relief compared to Zone 5, with a range of 1,5 m between gully bottom and reef level. Water depths vary from 21 to 28 m on this zone and there are no true inter-gullies developed. Reef-base lithology is that of a stacked forebeach facies comprising carbonate-cemented sandstone, but it is seldom exposed beneath the extensive coral cover. Apart from the common hard and soft coral genera observed in the other zones, the hard coral *Lobophyllia* occurs along with colonies of red gorgonian sea fans (*Leptogorgia* sp.). This has given the zone its name: the "Gorgonian Zone" (Figure 10). A reduction in abundance of *Sarcophyton* is also noted. Zones 5, 6 and 7 comprise the forereef environment which dips at an average of 3.5° to the east.

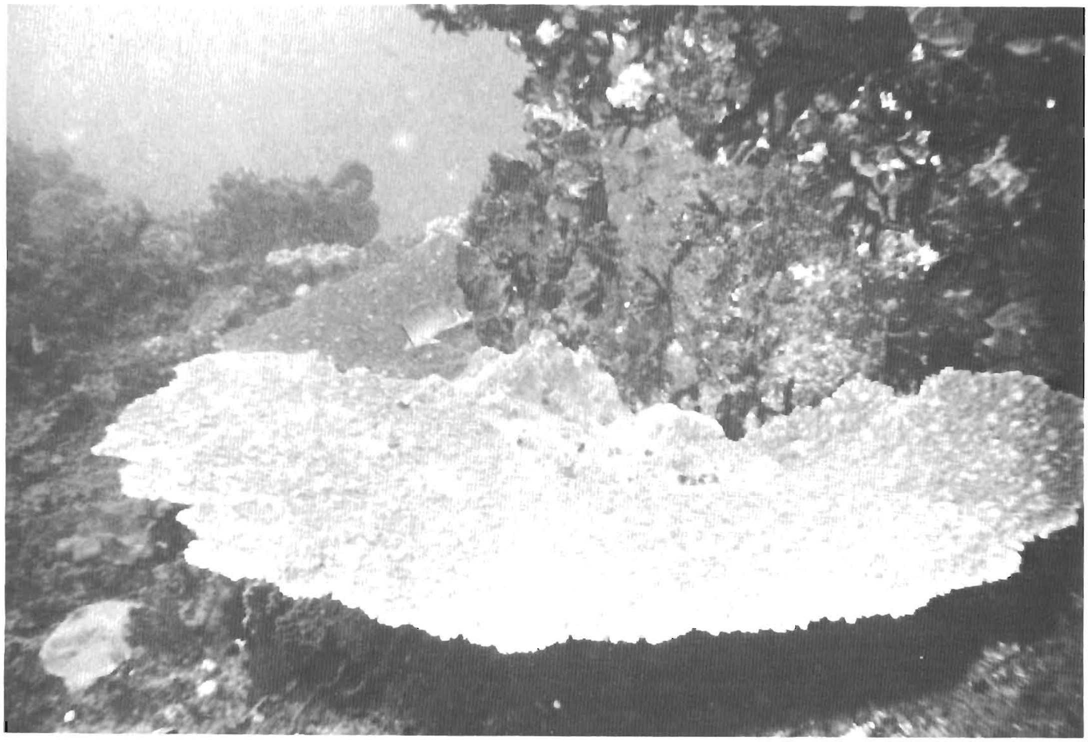

Figure 7. A large *Acropora* sp. plate coral (1 metre diameter) growing at the base of a pinnacle at a depth of 12 m on the reef-crest.

Zone 8

This 29 to 34 m deep zone represents the deepest reef and reef-front environments of Two-Mile Reef. Potholes penetrate about 20% of the zone. Similar potholes, described by COETZEE (1975), exist on the modern wave-cut platform and are formed by pebble grinding and diurnal carbonate solution and dissolution reactions. The underwater potholes at a depth of 32 m may therefore be related to a low sea-level still-stand. The relief is flat and neither true inter-reef gullies nor "spur and groove" topography are well-developed. The reef front grades imperceptibly into terrigenous quartz sand, with a few biogenic grains: no topographic break is observed. Light penetration is poor at this depth, resulting in a low diversity coral assemblage. A sparse fauna of epifaunal algae, numerous sponges, gorgonians, black corals and occasional hard and soft coral varieties cap a coarse-grained, backbeach sedimentary facies. Alcyonarians are usually *Sarcophyton* and *Lobophytum* colonies, scleractinians include *Favia, Acropora, Leptoria, Coeloria,* and *Echinopora*. Cup- and vase-shaped sponges are extremely common, as are gorgonians (*Homophyton* and *Leptogorgia*) and black corals (*Antipathes* and *Cirrhipathes*). A suitable name for this zone is the "Gorgonian-Sponge Zone" (Figure 11).

APPLICATION OF THE TYPE ZONING MODEL

Four-Mile Reef

Four-Mile Reef (27°29.5′ S; 32°41.7′ E) is a patch reef located 5.1 km north-northeast of Jesser Point, Sodwana Bay, along the same strike as Two-Mile Reef (Figure 12). The reef is 1 km long and 300-400 m wide. Depths vary

Figure 8. A narrow, 50 cm wide, sinuous inter-reef gully photographed in Zone 5.

from 15 m over the central reef axis to 27-30 m on the deep reef-front zone (Figure 13). The reef consists of flat ledges with few topographic high areas except on the reef-crest. The topographic highs are formed by resistant, planar cross-bedded aeolianite outcrops dipping at between 15°-30° in a northerly direction. The coral capping the homogeneous, ferruginous aeolianite reef-base reaches a maximum thickness of 30-40 cm with a sociability (surface cover) of 80-100%. A topographic break of 1.5 m occurs between the fore-reef and the deep reef-front boulder tract. This boulder tract extends seaward for approximately 50 m. Inter-reef gullies strike at 108° but are not as well-developed as they are on Two-Mile Reef. This is probably due to lower hydraulic swell dynamics reducing the gully erosion rate acting on this low-relief reef structure.

Corals on the reef have a homogeneous distribution and are scleractinians which comprise 60% of the coral reef fauna and alcyonarian corals make up the 40% balance (Table 2). The dominance of hard corals over soft corals shows that Four-Mile Reef is more like a true Indo-Pacific coral reef than the other Zululand coral reefs studied. The commonest scleractinians are *Acropora* (both branched and plate varieties) (Figures 14 & 15), *Favia, Favites, Montipora,* and *Echinopora*. *Sarcophyton* dominates the soft coral component (Figure 15) with *Sinularia* and *Lobophytum* being important. *Sarcophyton* is almost as abundant as *Acropora;* the name most applicable to the reef zone is "*Acropora-Sarcophyton* Zone". Four-Mile Reef is a mono-zone reef owing to the homogeneous distribution of the corals and the geomorphology of the reef.

If the zoning of Four-Mile Reef and Two-Mile Reef is compared, Four-Mile Reef would fit into Zone 5 ("*Sarcophyton* Zone") on Two-Mile Reef. The major difference between them is the abundance of *Acropora* on Four-Mile Reef.

Seven-Mile Reef

Seven-Mile Reef (27°27.2′ S; 32°42.6′ E) is a small patch reef located 10.1 km north-northeast of Jesser Point (Figure 12). The reef is 240 m long and 80 m wide. Water depths vary from 15 m on the reef-crest to 22 m on the reef-front (Figure 13). The reef coral veneer caps an aeolianite and beachrock ridge lying approximately 800-900 m offshore. Reef coral thickness varies 5-30 cm. Alcyonarian and scleractinian abundance ratios are comparable to those on Two-Mile Reef and the coral sociability (surface cover) is approximately 70%. The reef comprises three geomorphological zones: back-reef, reef-crest, and fore-reef (Figure 13). These define three physiographic and biological zones on Seven-Mile Reef. All three zones have similar abundances of the alcyonarian genera *Lobophytum, Sinularia, Sarcophyton,* and *Dendronephthya* (Table 2).

The back-reef environment (Zone 1) is characterized by a steep, shoreward-dipping slope. Depths in this zone vary from 22 m on the reef margin/sandy sea-bed interface to 18 m at the base of the reef-crest. The zone is distinguished by the lack of antipatharians and branched *Acropora: Acropora* plate varieties are common. Other common scleractinian corals

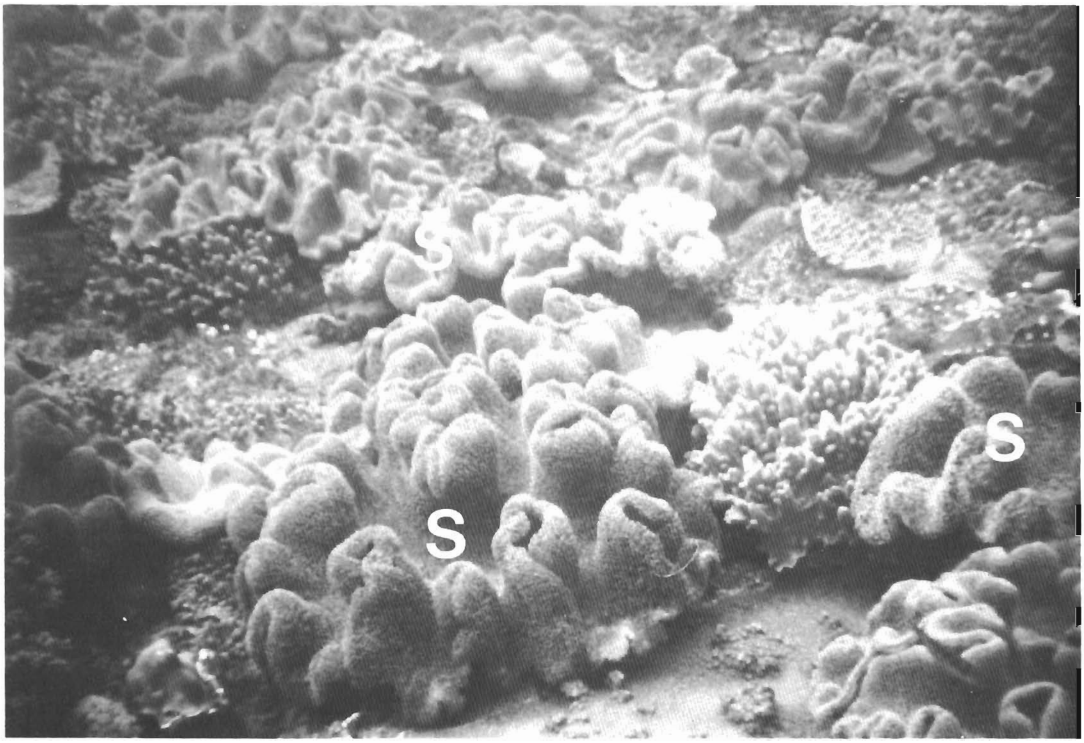

Figure 9. Numerous colonies of the characteristic Zone 5 soft coral *Sarcophyton* sp. (labelled S); photographed at a depth of 18 m. Average colony diameter 30 cm.

include the ubiquitous *Favia, Favites, Montipora,* and *Echinopora.*

The reef-crest zone (Zone 2) has numerous deep gullies, overhangs, and pinnacles, and depths vary from 15 to 18 m (Figure 16). The relief from gully bottom to reef platform is as much as 5 m. This zone is biologically characterized by the appearance of the antipatharians *Cirrhipathes* and *Antipathes* which are recorded as "present." On other Zululand reefs *Cirrhipathes* is much less abundant and is usually recorded as "rare" following the MERGNER & SCHEER's (1974) coral sociology scheme. A good correlation can be made between Zones 1 and 2 on Seven-Mile Reef and Zone 3 on Two-Mile Reef, on the basis of physiographic and biological criteria.

The 19 to 22 m deep seaward margin of the reef is the fore-reef zone (Zone 3). The zone has a flat relief with a few isolated pinnacles rising 1.5 m above the reef level. Besides the common scleractinians that occur elsewhere on the reef, the rare genera *Pavona, Pachyseris,* and *Dendrophyllia* occur in small numbers in the fore-reef zone. The presence of the red gorgonian sea fan *Leptogorgia* is also characteristic of this zone. The geomorphology and coral fauna of the reef-front zone (Zone 3) correlates well with Zone 7 ("Gorgonian Zone") on Two-mile Reef.

Red Sands Reef

Red Sands Reef (27°45.5′ S ; 32°37.9′ E) is a patch reef located 23 km south of Jesser Point, Sodwana Bay (Figure 17). The reef is larger than Two-Mile Reef, being approximately 5 km long, 1 km wide and 1 km from the shore. The topography is very similar to that of Two-Mile Reef with depths varying from 9 m on the reef-crest to 35 m on the reef-front (Figure 13). Inter-reef gullies are orientated in two directions; 000° and 124°. The physiographic and biological zoning of the reef resembles Two-Mile Reef. "Type zones" 1 to 8 occur from the land-

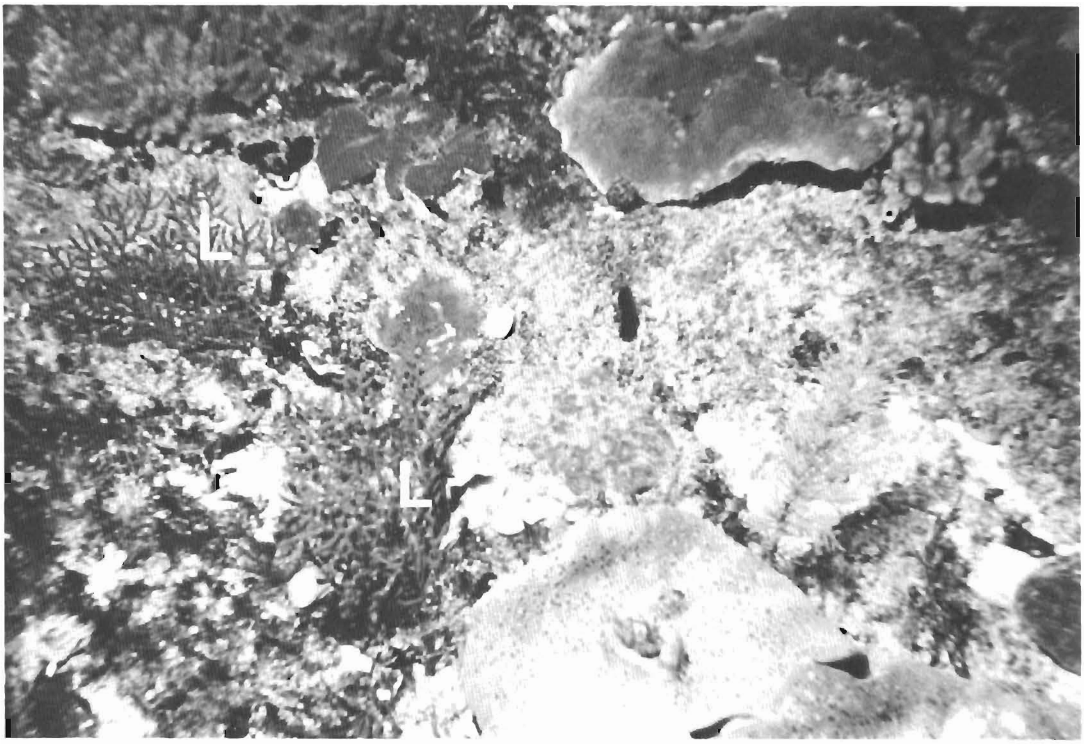

Figure 10. The appearance of numerous colonies of the red gorgonian *Leptogorgia* sp. (labelled L) indicate the Zone 7 coral assemblage.

ward margin of the reef to the deep reef-front and are identical to those on Two-Mile Reef. Zone 1 is developed on the landward margin of the reef in water depths of 15 to 17 m. Between 13 and 14 m depth zone 2 is developed, with the reef-crest (zone 3) occurring at depths of 11 to 13 m. Zone 3 has a more blocky relief than the corresponding zone on Two-Mile Reef. A set of north-south trending gullies at 13 m depth, with an average width of 40 m make up zone 4. The "*Sarcophyton* Zone" (zone 5) is well-developed at a depth of 14 to 19 m and has the same characteristics as Zone 5 on Two-Mile Reef. Zone 6 (gully zone) was not observed on the reef traverse owing to the reconnaissance traverse being located in between two gullies. Zone 7 (20–23 m depth) is populated by the characteristic zone gorgonian, *Leptogorgia,* as on Two-Mile Reef. Minor gully structures are present in this zone and strike at an orientation of 124°. The interface between zone 7 and zone 8 occurs at a depth of 23 m and is marked by the appearance of large vase- or cup-shaped sponges.

CONCLUSION

The "type" zoning scheme on Two-Mile Reef, Zones 1 to 8, is applicable on large Zululand coral reefs such as Red Sands Reef: controlling factors include similar depth controls and reef-base topography. Certain of the Two-Mile Reef "type zones" correlate well with zones on Four-Mile and Seven-Mile Reefs. Four-Mile Reef is a mono-zone reef with similar characteristics to Zone 5 ("*Sarcophyton* Zone") of Two-Mile Reef. A major difference between Two-Mile and Four-Mile Reefs is abundant *Acropora* on Four-Mile Reef. The back-reef (Zone 1) and reef-crest zones (Zone 2) on Seven-Mile Reef are very similar to Zone 3 on Two-Mile Reef with respect to physiographic and biological criteria. The reason why all the "type zones" defined on Two-

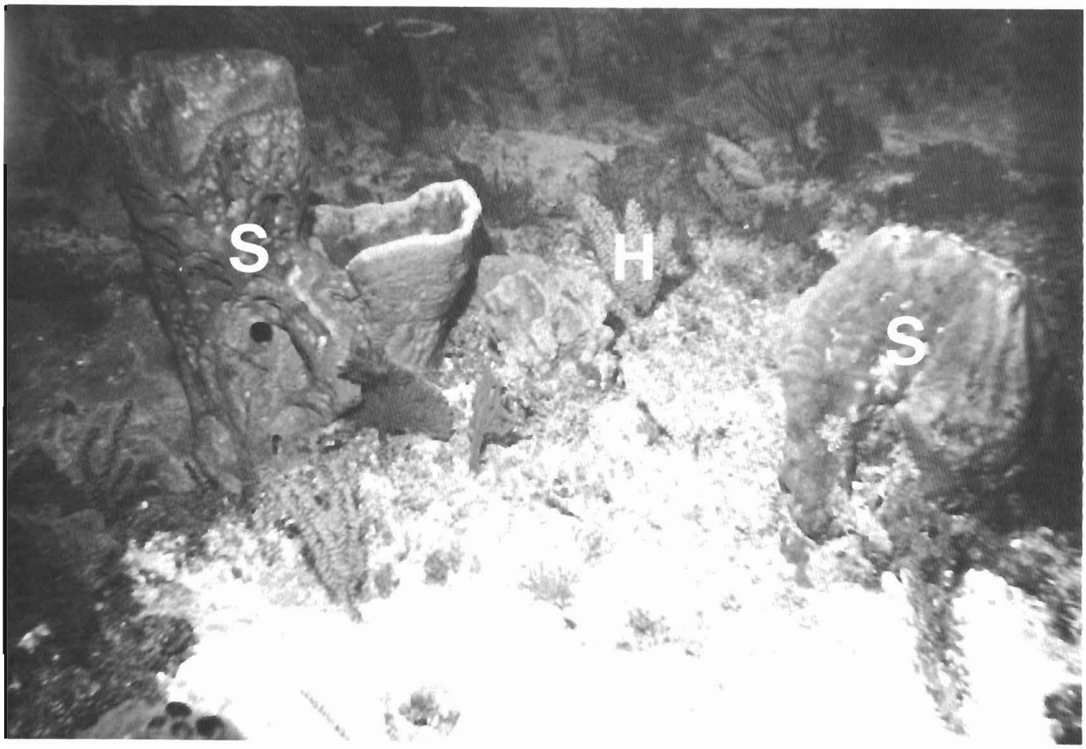

Figure 11. The deep reef-front zone (Zone 8) is characterized by the gorgonians *Homophyton* sp. (labelled H) and *Leptogorgia* sp. (labelled L) together with numerous large vase- and cup-shaped sponges (labelled S).

Mile Reef do not occur on Four-Mile and Seven-Mile Reefs is that these reefs have a compressed or restricted zonation because they are much smaller than the type area, Two-Mile Reef. Other large reefs on the Zululand coast, such as Leadsman Shoal (27°51.7′ S ; 32°36.9′ E) (Figure 18), some 3.5 km south of Red Sands Reef are predicted to have similar zoning characteristics to Two-Mile Reef because they will have similar abiotic factors such as light intensity and exposure, water exchange, and reef-base morphology. Leadsman Shoal is the largest and most southerly reef in the southwestern Indian Ocean; on the other side of the ocean, off southwestern Australia, reefs reach a higher latitude (29° S) (GUILCHER, 1988) owing to the warm Leeuwin current. Because of the location, a further detailed study of Leadsman Shoal would be worthwhile.

The maximum coral thickness found on the four reefs studied is only 30-40 cm because:

(1) Physico-chemical conditions for coral growth are not ideal in this marginal southwestern fringe of the Indo-Pacific faunal province;

(2) Alcyonarians constitute 60 to 70% of the coral fauna on Two-Mile and Seven-Mile Reefs and as they are not reef builders this explains why the reef is merely a thin veneer;

(3) The abundant soft corals, which are ahermatypic, compete for space on the reef with the hard coral varieties. Soft corals release terpenoid chemical compounds into the water which can cause local mortality, tissue necrosis (pathological death), and growth retardation in hard corals (COLL & SAMMARCO, 1986). The large numbers of soft corals, with their chemical defense mechanism, can retard the growth of hermatypic corals, thereby slowing down reef accretion.

The sedimentary facies underlying Zone 1 to Zone 8 of Two-Mile Reef appear to represent a late Pleistocene, regressive coastal aeolianite, backbeach and forebeach sequence. The litho-

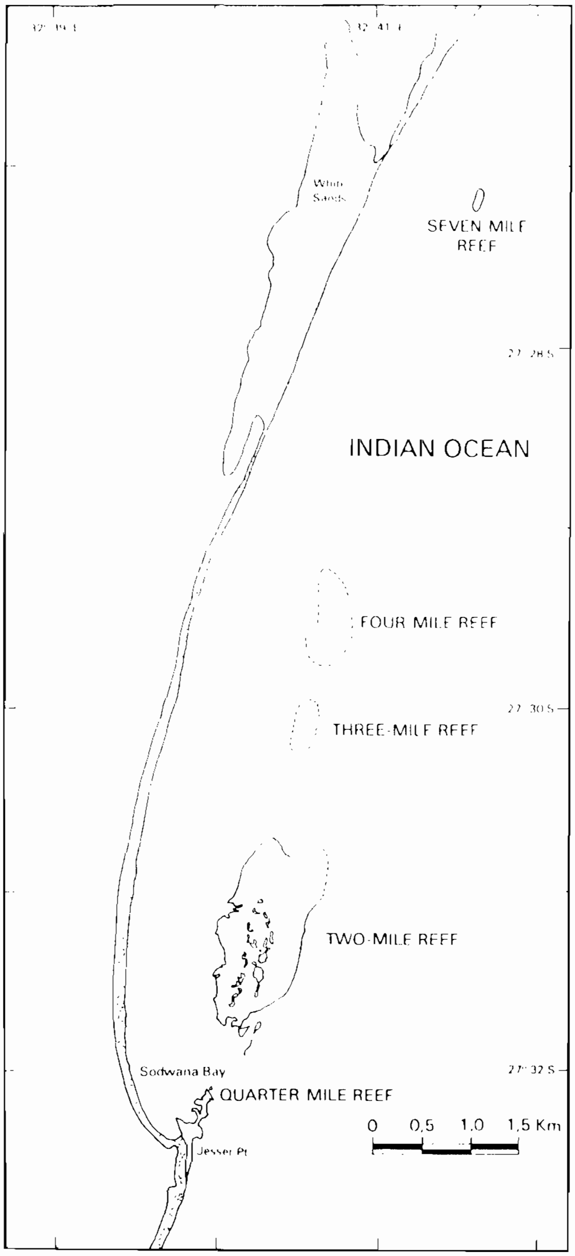

Figure 12. Location map of Two-Mile, Four-Mile and Seven-Mile Reefs in relation to Sodwana Bay.

facies base of Zones 1 and 2 represent part of a backbeach succession which is overlain by a regressive aeolianite (Zone 3). The reef-base of Zones 4, 5, 6 and 7 may be ascribed to deposition in a forebeach environment, whereas Zone 8 probably represents another backbeach facies formed by a lower (30 to 34 m) regressive sea-level stillstand.

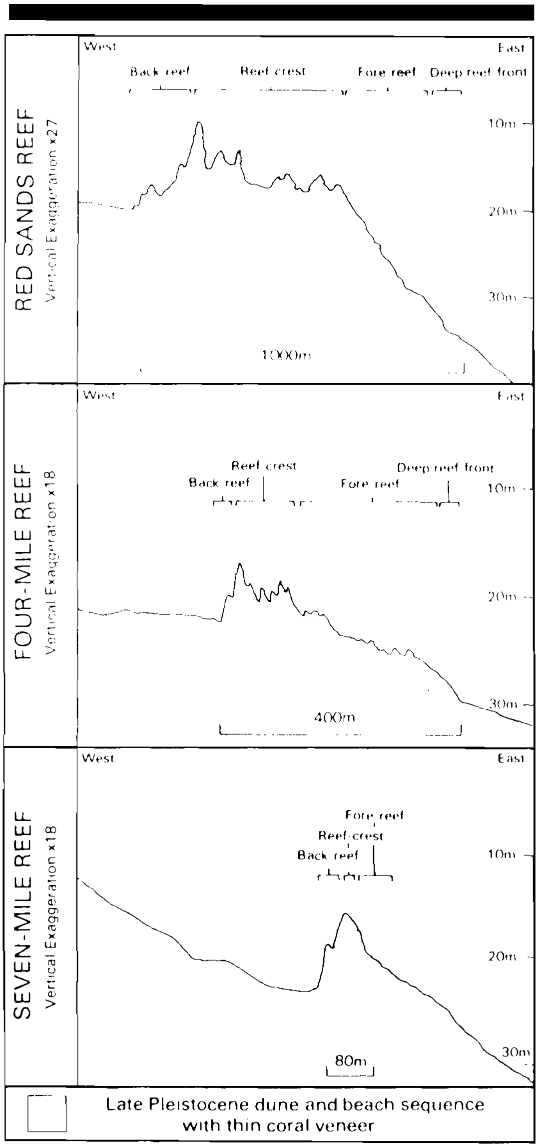

Figure 13. West-east cross-sectional profiles of Red Sands, Four-Mile, and Seven-Mile Reefs. The horizontal scales of the profiles differ.

ACKNOWLEDGEMENTS

This paper is published with the permission of the Chief Director of the Geological Survey of South Africa. The project was initially funded by a South African National Corporation for Oceanographic Research/Estuaries and Coastal Processes Unit (CSIR) grant. Special thanks are due to the Natal Parks Board (NPB) for providing accommodation at Sodwana Bay, and to R. Broker, F. Junor and L. Fearnhead of the NPB who provided invaluable logistic support to the project. In the initial phases of the project Young Yamaha (Durban) loaned us an inflatable and motor and the University of Natal provided a four-wheel drive vehicle. Dr. J. Vogel of the CSIR undertook the ^{14}C-dating. This project would not have been possible without the help of diving companions and surface support team consisting of J.A.G. Cooper, C.I. Wright, R.A. Singh, N.C. Goedhals and W. Kidwell. The authors' wish to thank the referees for the useful and constructive criticism they provided.

LITERATURE CITED

AGASSIZ, A., 1898. A visit to the Great Barrier Reef of Australia in the steamer "Croyden" during April and May, 1896. *Harvard Museum Comparative Zoology Bulletin, 28,* 93-148.

BARNES, J.; BELLAMY, D.J.; JONES, D.J.; WHITTEN, B.A.; DREW, E.A.; KENYON, L.; LYTHGOE, J.N., and ROSEN, B.R., 1971. Morphology and ecology of the reef front of Aldabra. *Symposium Zoological Society London,* 28, 87-114.

BLOOM, A.L., 1974. Geomorphology of reef complexes. *SEPM Special Publication, 18,* 1-8.

BOSHOFF, P.H., 1958. Development and constitution of the coral reefs. *In:* MACNAE, W. and KALK, M., (eds.), *A Natural History of Inhaca Island, Mozambique.* Johannesburg: Witwatersrand University Press, pp. 49-56.

BOSHOFF, P.H., 1981. An annotated checklist of southern African Scleractinia. *Oceanographic Research Institute, Investigational Report 49.* South African Association for Marine Biological Research, Durban, 45p.

CHALKER, B.E.; DUNLAP, W.C., and JOKIEL, P.L., 1986. Light and corals. *Oceanus, 29(2),* 22-23.

CLARKSON, E.N.K., 1979. *Invertebrate Palaeontology and Evolution.* London: Allen and Unwin, 323p.

COETZEE, F., 1975. Solution pipes in coastal aeolianites of Zululand and Mozambique. *Transactions Geological Society South Africa, 78,* 323-333.

COLL, J.C., and SAMMARCO, P.W., 1986. Soft corals: Chemistry and ecology. *Oceanus, 29 (2),* 33-37.

CROSSLAND, C., 1948. Reef corals of the South African coast. *Annals of the Natal Museum,* 11 (2), 169-205.

DAVIES, J.L., 1964. A morphogenic approach to world shorelines. *Zeitschrift fur Geomorphologie,* 8, 27-42.

DAVIES, P.S., 1984. The role of zooxanthellae in the nutritional energy requirements of *Pocillopora eydouxi. Coral Reefs,* 2, 27-35.

FAIRBRIDGE, R.W., 1950. Recent and Pleistocene coral reefs of Australia. *Journal Geology,* 58 (4), 330-401.

FAURE, G., 1974. Morphology and bionomy of the coral reef discontinuities in Rodriquez Island (Mas-

Table 2. *Distribution of coral genera in the zones on Four-Mile and Seven-Mile Reefs.*

		SEVEN-MILE		
	FOUR-MILE	Zone 1	Zone 2	Zone 3
ALCYONARIANS				
Lobophytum sp.	p	a/c	a/c	a/c
Sinularia sp.	c/p	a/c	a/c	a/c
Sarcophyton sp.	a	c/p	c/p	c/p
Dendronephthya sp.	r	p	p	p
SCLERACTINIANS				
Favia sp.	c	c	c	c
Favites sp.	c	c	c	c
Montipora sp.	c	c	c	c
Leptoria sp.	c/p	p	p	p
Acropora (plate)	a/c	c	c/p	c/p
Acropora sp.	a		c/p	p
Echinopora sp.	c	c/p	c/p	c/p
Turbinaria sp.	c/p	p	p	c/p
Pocillopora sp.				
Porites sp.	p	p	p	p
Platygyra sp.	c/p	p	p	
Astreopora sp.	p	p	p	p
Symphyllia sp.	p			
Goniapora sp.	p	p	p	p
Galaxea sp.	p	p	p	p
Lobophyllia sp.	r	p	p	p
Stylophora sp.				
Fungia sp.	c/p	p	p/r	p/r
Anomastrea sp.				
Oxypora sp.				
Pavona sp.	r			r
Pachyseris sp.				p
Dendrophyllia sp.	r			r
Coeloria sp.	p/r	p	p	p
Hydnophora sp.				
Goniastrea sp.			p	p
Oxyphyllia sp.	r			
Oulophyllia sp.	r			
ANTIPATHARIANS				
Antipathes sp.	p/r		p	p
Cirrhipathes sp.	r		p	p/r
GORGONIANS				
Leptogorgia sp.				
Homophyton sp.				

carene Archipelago, Indian Ocean). *Proceedings 2nd International Symposium Corals and Coral Reefs 1973,* 2, 161-172.

FLEMMING, B.W., 1981. Factors controlling shelf sediment dispersal along the southeast African continental margin. *Marine Geology,* 42, 259-277.

FLEXOR, J.M., and MARTIN, L., 1979. Sur l'utilisation des gres coquilliers de la region de Salvador (Bresil) dans la reconstruction des lignes de rivage holocenes. *Proceedings 1978 International Symposium Coastal Evolution Quaternary* (Sao Paulo), pp. 343-355.

GUILCHER, A., 1971. Mayotte barrier reef and lagoon, Comoro Islands, as compared with other barrier reefs, atolls and lagoons in the world. *Symposium Zoological Society London,* 28, 65-86.

GUILCHER, A., 1988. *Coral Reef Geomorphology.* New York: Wiley, 228p.

GUILCHER, A., 1988. *Personal communication.*

HAYES, M.O., 1979. Barrier island morphology as a function of tidal and wave regime. *In:* LEATHERMAN, S.P., (ed.), *Barrier Islands from the Gulf of Mexico.* New York: Academic Press, 3-22.

HUBBARD, J.A.E.B., and POCOCK, Y.P., 1972. Sediment rejection by recent scleractinian corals: a key to palaeoenvironmental reconstruction. *Geologische Rundschau,* 61 (2), 598-626.

HUSTON, M., 1985. Variation in coral growth rates

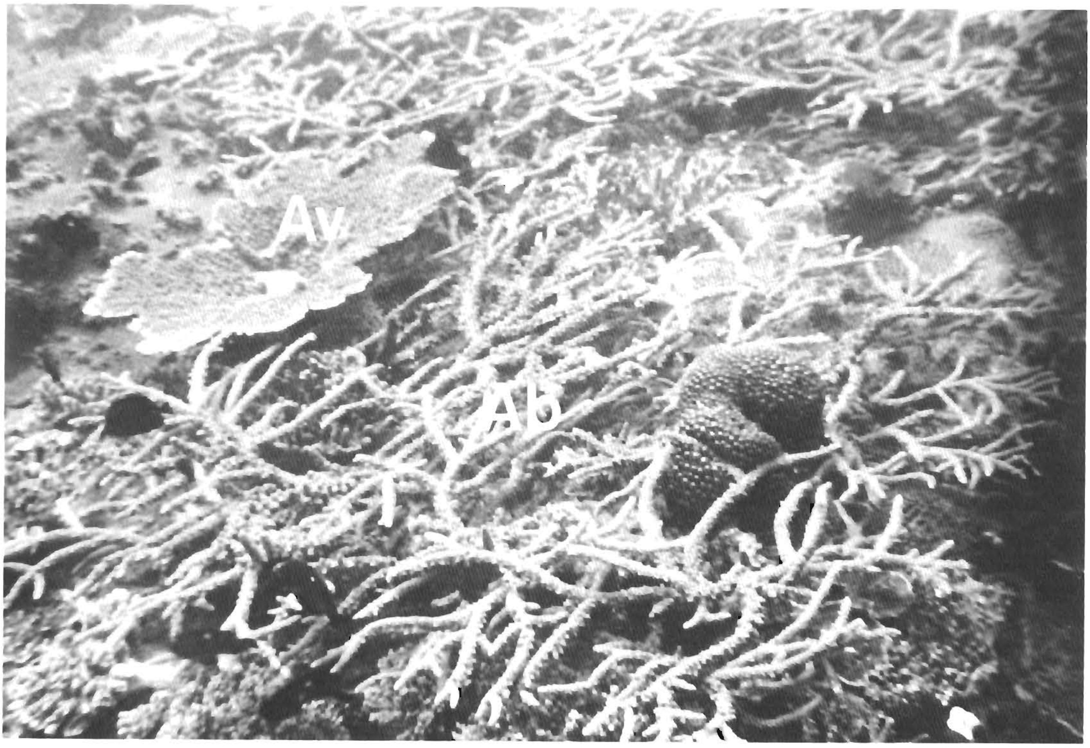

Figure 14. *Acropora brueggemanni* (Brook) and *Acropora vasiformis* (Brook) plate corals (labelled Ab and Av respectively) are abundant on Four-Mile Reef.

with depth at Discovery Bay, Jamaica. *Coral Reefs,* 4, 19-25.

HYDRAULICS RESEARCH UNIT, 1968. Wave and wind conditions for the Natal and Western Cape coastal areas. *CSIR Report MEG 665/1, 665/2*. Pretoria, South Africa.

JAAP, W.C., 1984. The ecology of the south Florida coral reefs: A community profile. *U.S. Fish and Wildlife Service, FWS/OBS-82-08,* 138p.

JAUBERT, J.M., and VASSEUR, P., 1974. Light measurements: duration aspect and the distribution of benthic organisms in an Indian Ocean coral reef (Tulear, Madagascar). *Proceedings 2nd International Symposium Corals and Coral Reefs 1973,* 2, 127-142.

KANWISHER, J.W., and WAINWRIGHT, S.A., 1967. Oxygen balance in some reef corals. *Biological Bulletin,* 133, 378-390.

MARTIN, A.K., and FLEMMING, B.W., 1986. The Holocene shelf sediment wedge off the south and east coast of South Africa. *In:* KNIGHT, R.J. and McLEAN, J.R., (eds.), Shelf Sands and Sandstones. *Canadian Society Petroleum Geology*, Memoir II, pp. 27-44.

MAUD, R.R., 1968. Quaternary geomorphology and soil formation in coastal Natal. *Zeitschrift für Geomorphologie,* 7, 155-199.

MEANS, J.C., and SIGLEO, A.C., 1986. Contributions of coral reef mucus to the colloidal organic pool in the vicinity of Discovery Bay, Jamaica, W.I. *Bulletin Marine Science,* 39 (1), 110-118.

MERGNER, H., 1971. Structure, ecology and zonation of Red Sea reefs (in comparison with south Indian and Jamaican reefs). *Symposium Zoological Society London,* 28, 141-161.

MERGNER, H., and SCHEER, G., 1974. The physiographic zonation and the ecological conditions of some south Indian and Ceylon coral reefs. *Proceedings 2nd International Symposium Corals and Coral Reefs 1973,* 2, 3-30.

MICHELL, R., and CHET, I., 1975. Bacterial attack of corals in polluted seawater. *Microbial Ecology,* 2, 227-233.

MONTAGGIONI, L., 1974. Coral reefs and Quaternary shorelines in the Mascarene Archipelago (Indian Ocean). *Proceedings 2nd International Symposium Corals and Coral Reefs 1973,* 2, 579-593.

ORME, A.R., 1973. Barrier and lagoon systems along the Zululand coast, South Africa. *Office of Naval Research Technical Report 1,* 181-217.

PICHON, M., 1974. Dynamics of benthic communities in the coral reefs of Tulear (Madagascar): succession and transformation of the biotypes through reef

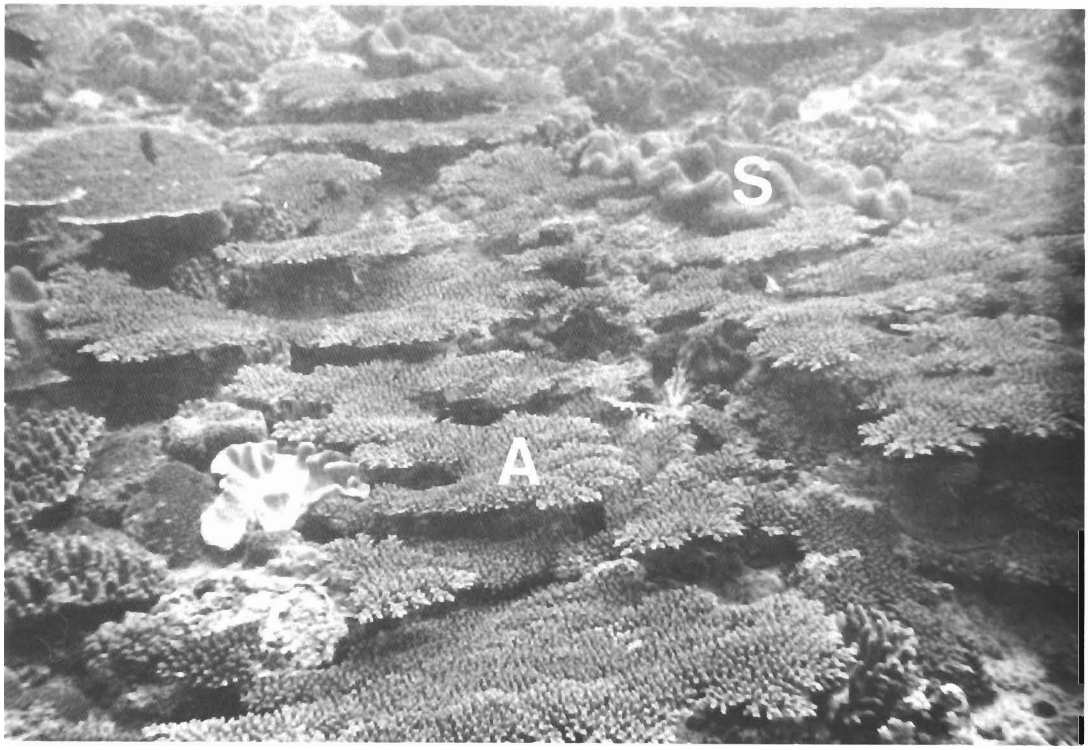

Figure 15. Extensive colonies of *Acropora* sp. (labelled A) and the dominant soft coral, *Sarcophyton* sp. (labelled S).

tract evolution. *Proceedings 2nd International Symposium Corals and Coral Reefs 1973*, 2, 55-68.

RAMSAY, P.J., 1988. Physiographic and biological zoning of Two-Mile Reef, Sodwana Bay. *Extended Abstract: 22nd Earth Science Congress of the Geological Society of South Africa, University of Natal, Durban*, pp. 483-486.

RAMSAY, P.J., *in press*. The use of computer graphics software to produce a three-dimensional morphological and topographical model of a Zululand coral reef. *South African Journal Science*.

RAMSAY, P.J.; COOPER, J.A.G.; WRIGHT, C.I., and MASON, T.R., 1989. The occurrence and formation of ladderback ripples in subtidal, shallow marine sands, Zululand, South Africa. *Marine Geology*, 86 (2/3), 229-235.

REISS, Z., and HOTTINGER, L., 1984. *The Gulf of Aqaba, Ecological Micropalaeontology*. Ecological Studies No. 50. New York: Springer-Verlag, 354p.

ROSEN, B.R., 1971. The distribution of coral reef genera in the Indian Ocean. *Symposium Zoological Society London*, 28, 263-299.

SCHEER, G., 1971. Coral reefs and coral genera in the Red Sea and Indian Ocean. *Symposium Zoological Society London*, 28, 329-367.

SCHUMANN, E.H., and ORREN, M. J., 1980. The physico-chemical characteristics of the south-west Indian Ocean in relation to Maputaland. *In:* BRUTON, M.N. and COOPER, K.H., (eds), *Studies on the Ecology of Maputaland*. Durban: Wildlife Society of South Africa, 8-11.

STODDART, D.R., 1969. Ecology and morphology of recent coral reefs. *Biological Reviews*, 44, 433-498.

STODDART, D.R., 1973. Coral reefs of the Indian Ocean. *In:* JONES, O.A. and ENDEAN, R., (Eds). *Biology and Geology of Coral Reefs*. New York: Academic Press, 51-92.

SWART, D.H., and SERDYN, J. de V., 1981. Statistical Analysis of Visually Observed Wave Data from Voluntary Observing Ships for South African East Coast. Volume 9. *Unpublished CSIR Report*, 141p.

TAYLOR, J.D., 1971. Reef associated molluscan assemblages in the western Indian Ocean. *Symposium Zoological Society London*, 28, 501-534.

TOMASCIK, T., and SANDER, F., 1985. Effects of eutrophication on reef-building corals: I. Growth rate of the reef-building coral *Montastrea annularis*. *Marine Biology*, 87, 143-155.

VASSEUR, P., 1974. The overhangs, tunnels and dark reef galleries of Tulear (Madagascar) and their sessile invertebrate communities. *Proceedings 2nd International Symposium Corals and Coral Reefs 1973*, 2, 143-159.

VERWEY, J., 1931. The depth of coral reefs in rela-

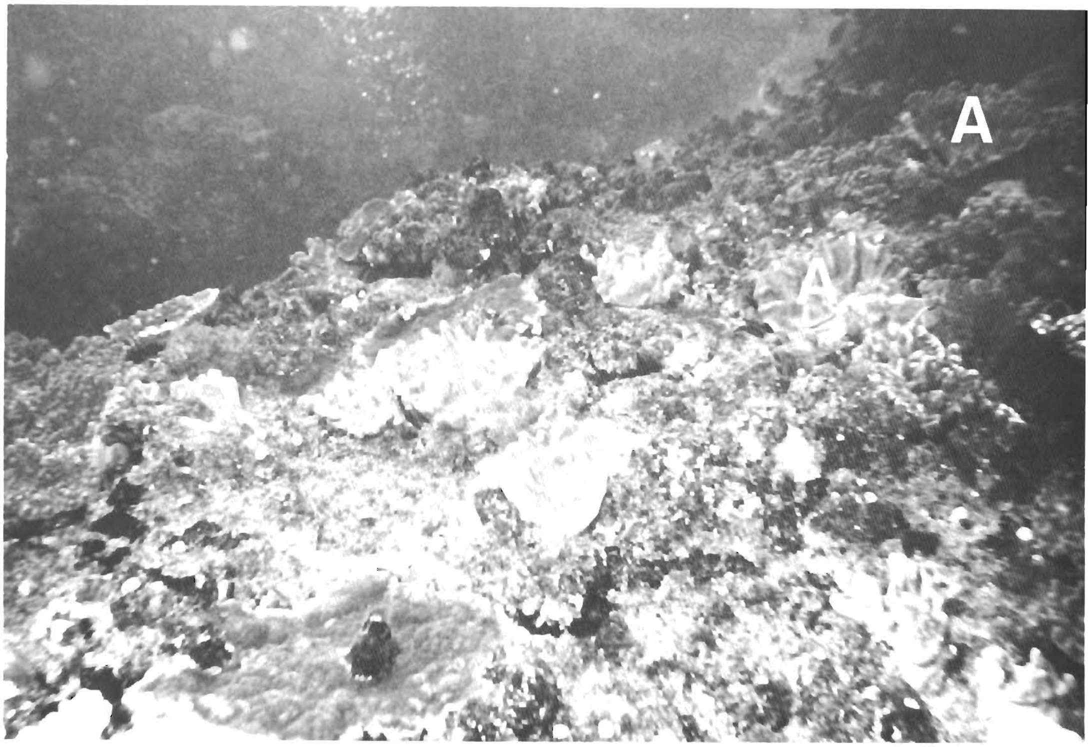

Figure 16. Underwater photograph of the reef-crest on Seven-Mile Reef showing the dominance of alcyonarian corals (labelled A).

tion to their oxygen consumption and the penetration of light in the water: Treubia (Buitenzorg). *Coral Reef Studies,* 13, 169-198.

WILLIAMS, G.C., 1989a. A review of recent research on the sublittoral coral reefs of northern Natal with a provisional assessment of findings regarding the distribution of octocorals on Two-Mile Reef, Sodwana Bay. *South African Journal Science,* 85 (3), 140-141.

WILLIAMS, G.C., 1989b. A provisional annotated list of octocorallian coelenterates occurring on the sublittoral coral reefs at Sodwana Bay and Kosi Bay, northern Natal, with a key to the genera. *South African Journal Science,* 85 (3), 141-144.

YONGE, C.M., 1940. The biology of reef-building corals: Great Barrier Reef Expedition 1928-1929. *British Museum National History Science Reports,* 1 (13), 353-391.

□ RESUMEN □

Los arrecifes de coral de la costa norte de Natal son únicos, tanto por su situación (unos de los más meridionales del mundo) como por su estado de conservación. Con objeto de desarrollar un modelo fisiográfico y biológico para los arrecifes de coral de Zululand se ha estudiado el emplazamiento coralino de "Two-Mile", en la Bahía de Sodwana. Los arrecifes de Zululand están formados por un fino revestimiento de corales del tipo Indo-Pacífico que han colonizado la roca Pleistocena, estando las facies sedimentarias bajo el coral formadas por un regresión de un costa de dunas. En función de características fisiográficas y biológicas, se ha determinado ocho zonas diferentes. La fauna coralina está dominada por la abundancia de Alcyonarian, que constitue el 60%-70% del total. El modelo desarrollado para el arrecife "Two-Mile" ha sido aplicado con éxito tanto a arrecifes mayores como el de "Red Sands", como arrecifes menores: "Four-Mile" y "Seven-Mile".—*Department of Water Sciences, University of Cantabria, Santander, Spain.*

□ ZUSAMMENFASSUNG □

Die Fleckenriffe der Küsten von Nordnatal sind einzigartig, weil sie zu den südlichsten der Erde gehören und relativ ungestört sind. Das Two-Mile Reef in der Sodwana Bay wurde benutzt, um ein physiographisches und biologisches Zonierungsmodell für die Zululandkorallenriffe zu entwickeln, welches auf die übrigen Riffe der Region angewandt werden kann. Die Zululandriffe werden geformt durch eine dünne Kruste indopazifischer Korallen auf einer ertrunkenen Erhebung aus jungpleistozänem Sandstein. Die Fazies unter den Korallen wird von regressiven Dünen und Strand gebildet. Das Two-Mile Riff liegt an der Luvseite und seine Zonen verlaufen parallel mit der Riff- und Küstenerstreckung von NNE nach SSW. Acht verschiedene Zonen werden erkannt und aufgrund ihrer physiographischen und biologischen Eigenschaften differenziert. Die Riff-fauna wird durch Weichkorallen bestimmt, die 60-70% aller Korallen ausmachen. Das Zonenmodell des Two-Mile-Reef wurde erfolgreich angewandt auf größere Riffe, wie das Red Sands Reef und kleinere Fleckenriffe wie Four-Mile und Seven-Mile-Reef in derselben Gegend.—*Dieter Kelletat, Essen, FRG.*

□ RÉSUMÉ □

Les systèmes coralliens de la côte du Nord Natal sont uniques de par leur localisation (la plus au Sud dans le monde) et sont relativement intacts. Le site de Two-Mile Reef à Sodwana Bay a permis de développer un modèle de zonation biologique et physiographique des coraux du Zululand, modèle ensuite appliqué aux autres récifs de la région. Les récifs coralliens du Zululand sont formés par un fin placage de coraux de type indo-pacifique colonisant les affleurements de grès de la fin du Pléistocène. Les faciès sédimentaires sous jacents aux coraux ont été formés au cours d'une séquence dune côtière régressive—plage. Le Two-Mile Reef est un récif au vent, dont la zonation est parallèle à la direction NNE-SSW du récif et de la côte. On a reconnu 8 zones distinctes, différenciées selon des critères physiographiques et biologiques. La faune récifale est dominée par l'abondance des coraux alcyonariens (60 à 70% de la faune totale). Le modèle de zonation de Two-Mile Reef a été appliqué avec succès à des récifs plus vastes, comme celui de Red Sands, et à d'autres plus petits et fragmentés: Four-Mile, Seven-Mile, tous situés dans la même région.—*Catherine Bressolier, Géomorphologie EPHE, Montrouge, France.*

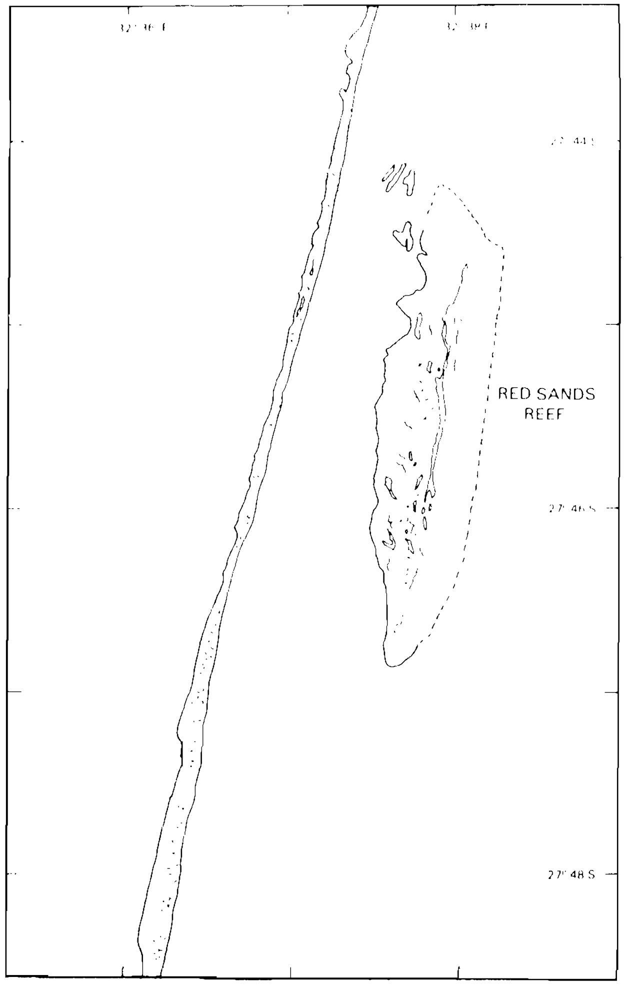

Figure 17. Location map of Red Sands Reef, 23 km south of Sodwana Bay.

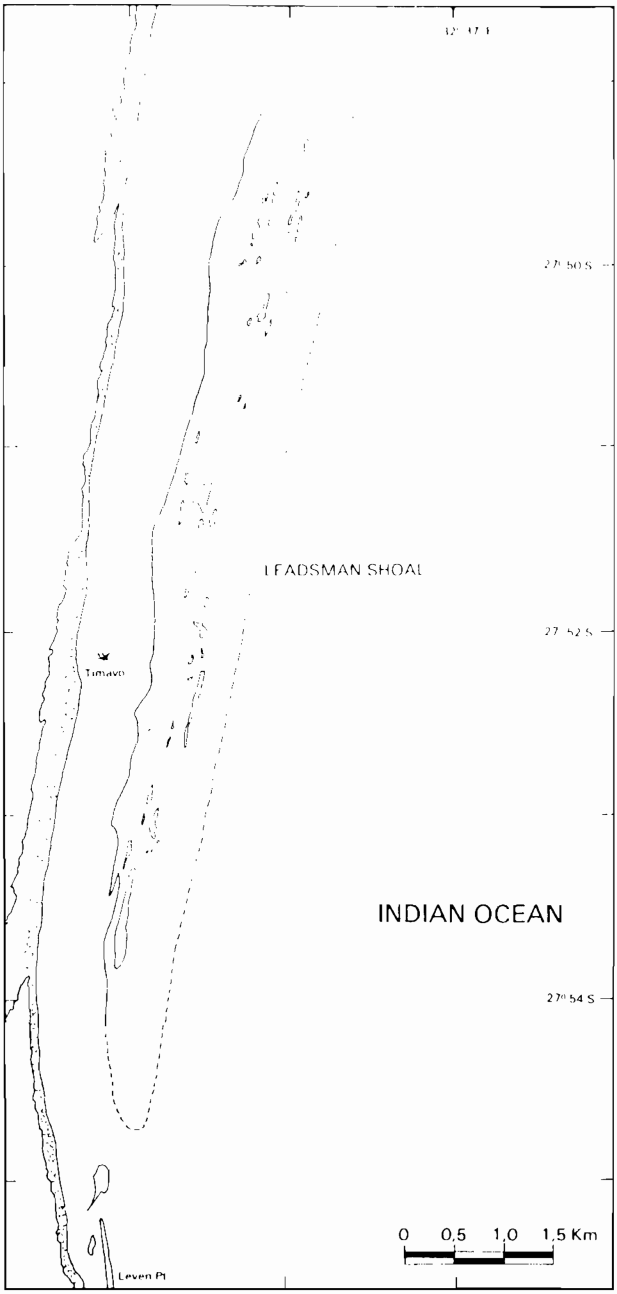

Figure 18. Location map of Leadsman Shoal, 3.5 km south of Red Sands Reef. This is the most southerly coral reef in southern Africa.