RECREATIONAL SCUBA DIVING AND REEF CONSERVATION IN SOUTHERN MOZAMBIQUE

by

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ABSTRACT

Recreational SCUBA diving has grown tremendously along most of the southern Mozambican coastline in the last eight years. This growth was not accompanied with management actions, largely due to a lack of baseline information and appropriate regulations. A number of aspects of the industry were thus covered in this study to redress this shortfall.

Information was collected on divers and diving pressure in southern Mozambique using questionnaires and dive log sheets distributed through local dive centres. The diving pressure was estimated at 42 500 dives in 2001 and 62 000 dives in 2002, and occurs at about 20 dive sites. More than 50% of the diving occurs on five reefs, three of which were included in the study. Surveys using visual techniques were conducted on six reefs subjected to different diving pressures, ranging from minimal (< 250 dives.year^{-1}) and medium (~ 4 000 dives.year^{-1}) to high (> 6 000 dives.year^{-1}). Divers visiting southern Mozambique were found to be mostly educated South African males in their 30s. They are experienced and committed divers, satisfied with their diving experiences in the area and sensitive to reef conservation issues.

The reefs differed in benthic composition, with three main reef groups identified through multivariate analysis. All were typified by prolific soft corals but one included an abundance of branching *Acropora* and the other an abundance of foliose hard corals, thus differentiating the three groups. Reef fish communities also differed among the reefs. While prey species diversity was generally similar on all the reefs, two included high densities of piscivorous species.

The present levels of SCUBA diving appeared to be having no deleterious effects on the reef communities, especially when compared to other disturbances such as storms and fishing. The sustainable diving capacity was estimated to be 7000 dives/year/dive site. The overall effects of recreational diving activities in southern Mozambique are discussed, along with future research needs and the management implications of the study.

PREFACE

The experimental work described in this dissertation was carried out in southern Mozambique from February 2001 to December 2002 under the supervision of Prof. Michael H. Schleyer, using the Oceanographic Research Institute, School of Life and Environmental Sciences, University of Natal, Durban as an occasional research base.

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use was made of the work of others, it has been duly acknowledged in the text.

Durban, 12 September 2003

(Marcos A M Pereira)

DEDICATION

This dissertation is dedicated to
my parents Iolanda and Santos Pereira…
my brother Sérgio…
… and to my wife Micaela.

TABLE OF CONTENTS

LIST OF UNITS, ABBREVIATIONS AND ACRONYMS

CORDIO	Coral Reef Degradation in the Indian Ocean
Cr	Creche
DANIDA	Danish International Co-operation Agency
FC	Futi Corridor
KL	Kev's Ledge
LSDI	Lubombo Spatial Development Initiative
LTFCA	Lubombo Trans-Frontier Conservation Area
m	Metre
MCRMP	Mozambique Coral Reef Management Programme
MER	Maputo Especial Reserve
MICOA	Ministério para a Coordenação da Acção Ambiental (Ministry for the Co-ordination of Environmental Affairs)
ORI	Oceanographic Research Institute
SM	Shallow Malongane
SCUBA	Self-contained underwater breathing apparatus
SDC	Sustainable diving capacity
Te 1	Techo 1
Te 2	Techo 2
Tx	Texas
UPGMA	Unweighted pair-group method using arithmetic averages
WWF	World Wide Fund for Nature

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In Mozambique

My family. For all the support and encouragement throughout these years. My father was the first to get me in the water when I was still a little boy and sowed in me an eternal fascination for the sea. Thank you for all your support, especially when the dream was turning into a nightmare (you know what I'm talking about)! My mother was a pillar in all of this, even though she seldom realized it. Her belief and encouragement were crucial… whenever things went wrong you were there for me… as always! Thanks, mom. To my brother I owe hours of philosophical discussions about religion, soccer, politics, … life.

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Last but definitely not least, Micaela my partner for life... I thank you for all your love, belief and tireless encouragement throughout these years… there are not enough words to express it all. You're, truly all my reasons!

In South Africa

I would like to address a profound and heartfelt word of gratitude to my supervisor Prof. Michael H. Schleyer. Thank you for your support, enthusiasm and patience. You are a constant source of inspiration and your deep passion for every living creature is very contagious! I look forward to enjoy more dives with you and maybe share a bottle or two of *Dão*. Thanks are also due to Margie Schleyer for making me feel at home in Durban and for showing me that the mountains can be as exciting and dynamic as the sea.

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CHAPTER 1

GENERAL INTRODUCTION

Man has been interacting with coral reefs for thousands of years (Hodgson 1999). These highly diverse (Kohn 1997; Ormong & Roberts 1997; Reaka-Kudla 1997) and extremely productive (Odum & Odum 1955; Kohn & Helfrich 1957; Sorokin 1990) ecosystems have been primarily used by different human cultures as a source of curios, jewellery and food (Hodgson 1999). Reef resource use has been rather limited through time, but the rapidly increasing human population and the technological advances of the 20th century have had significant effects on the ecology and integrity of coral reefs worldwide (Craik *et al*. 1990). Inboard and outboard motors that have simplified access to remote reef areas, mono-filament plastics that have provided more efficient and durable fishing nets, the combination of agricultural, industrial and domestic pollutants, and engineering and military activities are some examples (Craik *et al*. 1990; Wilkinson 1999). Nowadays, the demand for reef resources is much higher and the diversity of uses and their effects on coral reefs is quite remarkable (Craik *et al*. 1990; Grigg *et al*. 1990). Coral reefs support millions of people in tropical areas and reef resources are of nutritional, socio-cultural, pharmaceutical and recreational importance (Spalding *et al*. 2001).

Broadly speaking, modern uses of reefs include extractive (i.e. fishing and mining) and non-extractive activities, such as tourism and research. These activities, to a varying degree, have caused reef deterioration through over-exploitation (Chou & Yamazato 1990; McClanahan & Obura 1995, 1996), increased sedimentation (Chou 1988; Acevedo *et al*. 1989; Brown *et al*. 2002), pollution (revisions by Johannes 1975; Endean 1976; Wilkinson 1999), alteration of physical and ecological processes (Hay & Taylor 1985; McClanahan & Shafir 1990; Roberts 1995; McClanahan *et al*. 1996), physical damage (Woodland & Hooper 1976; Davis 1977; Hawkins & Roberts 1992, 1993; Öhman *et al*. 1993; Allison 1996; Lutz 1997; Schleyer & Tomalin 2000) and, in some cases, permanent degradation of reef areas (Hodgson 1999). Together with some natural phenomena (e.g. global warming and crown-of-thorns-starfish, *Acanthaster planci*, outbreaks), the above have had a direct negative effect on the dynamics, biodiversity and, ultimately on the very existence of coral reefs (Hoegh-Guldberg 1999; Wilkinson 1999).

The nature and intensity of recreational activities have been increasing in coral reef areas throughout the last 50 years (Craik *et al*. 1990; Price *et al*. 1998). Recreational fishing, boating, reef walking, shell collecting, underwater photography, snorkelling and SCUBA diving are the most popular (Kenchington 1993). As outlined by Tilmant (1987), Wells & Price (1992) and Harriott *et al*. (1997), these activities, especially underwater photography, snorkelling and SCUBA diving, have generally been perceived as recreational activities entirely compatible with the sustainable use of marine resources. That perception has gradually changed as various popular dive sites have lost their attractiveness and reef degradation has become evident (e.g. Ward 1990; Wells & Price 1992; Hawkins & Roberts 1993; Roberts & Harriott 1995).

Recreational SCUBA diving is a relatively new form of reef resource use and has become popular only in the last 35 years (Ditton & Baker 1999). The ecological effects of this activity on coral reef communities have only been studied more recently. However, there is already a considerable body of literature on the effects of recreational SCUBA diving on coral reefs (reviewed by Tilmant 1987; Davis & Tisdell 1995 and Price *et al*. 1998) but the physical and ecological effects of this activity on reef communities are, as yet, poorly understood. Most of this work has been carried out on Australia's Great Barrier Reef (e.g. Davis 1993; Rouphael & Inglis 1995, 1997, 2001; Plathong *et al*. 2000) and the Caribbean/Florida region (e.g. Davis 1977; Tilmant & Schmahl 1981; Talge 1990, 1993; Dixon *et al*. 1993; Shivlani & Suman 2000; Tratalos & Austin 2001). More recently, however, further coral reefs subjected to recreational damage have been studied in the Red Sea (e.g. Riegl & Velimirov 1991; Medio *et al*. 1997; Jameson *et al* 1999; Zakai & Chadwick-Furman 2002), Maldives (Allison 1996; Price *et al*. 1998), Hawaii (MacDonald *et al*. 1999; Rodgers & Cox 2003) and southern Africa (Schleyer & Tomalin 2000; Bjerner & Johansson 2001; Walters & Samways 2001).

In general, these studies have shown that divers are potentially harmful to benthic reef communities, especially when the diving intensity exceeds a threshold of 5000 to 6000 dives.year^{-1}.dive site^{-1} (Hawkins & Roberts 1997; Zakai & Chadwick-Furman 2002). Evidence of the effects of SCUBA diving on other communities, especially fish, is less well documented and rather contradictory (Chapman *et al*. 1974; Cole 1994; Stanley & Wilson 1995; Bohnsack 1998; Hawkins *et al*. 1999; Tratalos & Austin 2001).

The southern Mozambique coastline between Ponta do Ouro and Cabo Santa Maria has been a focus of coastal tourism development since the end of the civil war in 1992 (Hatton 1995; Massinga & Hatton 1996). Around 115 000 tourists visit southern Mozambique annually (A. Saia 2003, Ministry of Tourism, pers. comm.). Of these, approximately 10 000-13 000 visit the Ponta do Ouro and Ponta Malongane region (Bjerner & Johansson 2001) to dive, fish and camp, the majority (60–72%) being certified SCUBA divers (Bjerner & Johansson 2001; Abrantes & Pereira 2003).

The high fish diversity in the area (Robertson *et al*. 1996; Pereira *et al*. 2002) contributes to the beauty and attractiveness of the reefs. Further, the occurrence of large, resident fishes such as potato bass (*Epinephelus tukula*), several species of sharks and marine turtles has resulted in specific localities such as 'Bass City' and 'Pinnacles' near Ponta Malongane becoming popular with divers (Robertson *et al*. 1996). Most diving takes place around Ponta Malongane at about 16-20 diving sites (Bjerner & Johansson 2001; Chapter 3). The dive pressure in 1995 was estimated at 30 000-40 000 dives.year^{-1} and Robertson *et al*. (1996) stated that this dive rate was high considering the size of the reefs. Unconfirmed reports claimed that in 1998 this number increased to around 80 000-90 000 dives.year^{-1} (Rodrigues & Motta in prep) and it was suggested that the diving pressure was approaching unsustainable levels (H. Motta 2001, WWF Mozambique, pers. comm.). Bjerner & Johansson (2001) estimated the diving intensity in the area to be approximately 63 000 dives.year^{-1} and stated that '…divers should therefore be considered as a threat to the coral reefs of Ponta d'Ouro, even though the amount of dives per dive site has to be high to inflict permanent damage'. As highlighted by Wells & Price (1992), although it is very important to developing countries, such as Mozambique, to be able to exploit their reefs commercially, these activities need to be carefully managed to ensure the reefs are not damaged.

Despite the remarkable growth and economic importance of recreational diving in southern Mozambique (Bjerner & Johansson 2001), its regulation and management are deficient and the existing legislation is obsolete (dating back to the late 1960s) and poorly enforced. Two surveys in the area have dealt with the subject (Robertson *et al*. 1996; Bjerner & Johansson 2001), but further baseline information was needed for the proper management of this activity in southern Mozambique. Information on diving intensity was generally lacking and there have been reports of reef over-use (Bjerner & Johanson 2001; H. Motta 2001, WWF Mozambique, pers. comm.). The objectives of this study were thus to assess the effects of recreational SCUBA diving on the reef communities and formulate management guidelines for the sustainable use and conservation of the reefs of southern Mozambique. Specific aims were to:

- Collect and analyse information on recreational SCUBA diving on the southern Mozambican reefs, especially with regard to the diving intensity on the reefs and the demographic characteristics, perceptions and attitudes of the divers;
- Describe and compare reef communities subjected to different levels of diving activity;

- Estimate the sustainable diving capacity of the reefs in southern Mozambique; and
- Propose management guidelines for their sustainable use and conservation.

This dissertation includes five further Chapters. A description of the area is given in the next chapter, providing information on the physical and biological characteristics of southern Mozambique in general and the study sites in particular. The recreational SCUBA diving survey is dealt with in Chapter 3. In Chapter 4, the coral and fish communities of selected reefs subjected to different levels of diving pressure are described and compared. Chapter 5 deals with the effects of recreational SCUBA diving activities on the reef communities and provides an estimate of the sustainable diving capacity of the southern Mozambican reefs. The final chapter comprises a general discussion and conclusions, dealing with the overall effects of recreational SCUBA diving on the southern Mozambican reef communities, management implications and future research needs.

CHAPTER 2
DESCRIPTION OF THE STUDY AREA

2.1 GENERAL DESCRIPTION OF THE SOUTHERN MOZAMBIQUE AREA

For the purpose of this study, southern Mozambique comprises the stretch of 86 km of coastline between Cabo de Santa Maria (26°05’ S; 32°58’E) in the north and Ponta do Ouro (26°51’S; 32°58’E) in the south (Figure 1), located in the Matutuíne district of Maputo province. Matutuíne is about 5500 km^2 in area and has a population of about 35 000 (Instituto Nacional de Estatística 2000).

The climate of southern Mozambique is tropical to subtropical, being humid in the coastal zone. Rainfall is recorded in all months, but the peak rainy season is from October to April. The annual mean rainfall is between 900 and 1000 mm and the annual mean temperature on the coast is between 22–24°C (Hatton 1995). The prevailing winds blow parallel to the coast with the southerly component being the strongest and most frequent, occasionally reaching gale force (> 65 $km.h^{-1}$; Robertson *et al*. 1996).

The area is characterized by a rich plant biodiversity and high levels of endemism. It was previously included in the Tongoland-Pondoland Regional Mosaic (White 1983) and more recently in an Indian Ocean centre of endemism, the Maputaland-Pondoland Region (van Wyk 1994). The vegetation is relatively well known and consists of forest (‘undifferentiated’ coastal forest, sand forest, dune forest and swamp forest), woodland/bushland, grassland and swamps (Hatton 1995). Myre (1964) describes the composition and structure of these plant communities in more detail. The associated fauna of the area is interesting and rich in diversity (Hatton 1995), although the megafauna (large herbivores) were decimated during the civil war (de Boer *et al*. 2000; Parker & de Boer 2000). Almost 375 bird species were recorded in the Maputo Elephant Reserve and surrounding areas (Tello 1973; Parker & de Boer 2000). There is a small population of elephants (*Loxodontha africana*) and various species of antelopes are still common (de Boer & Baquete 1998; de Boer *et al*. 2000; Parker & de Boer 2000).

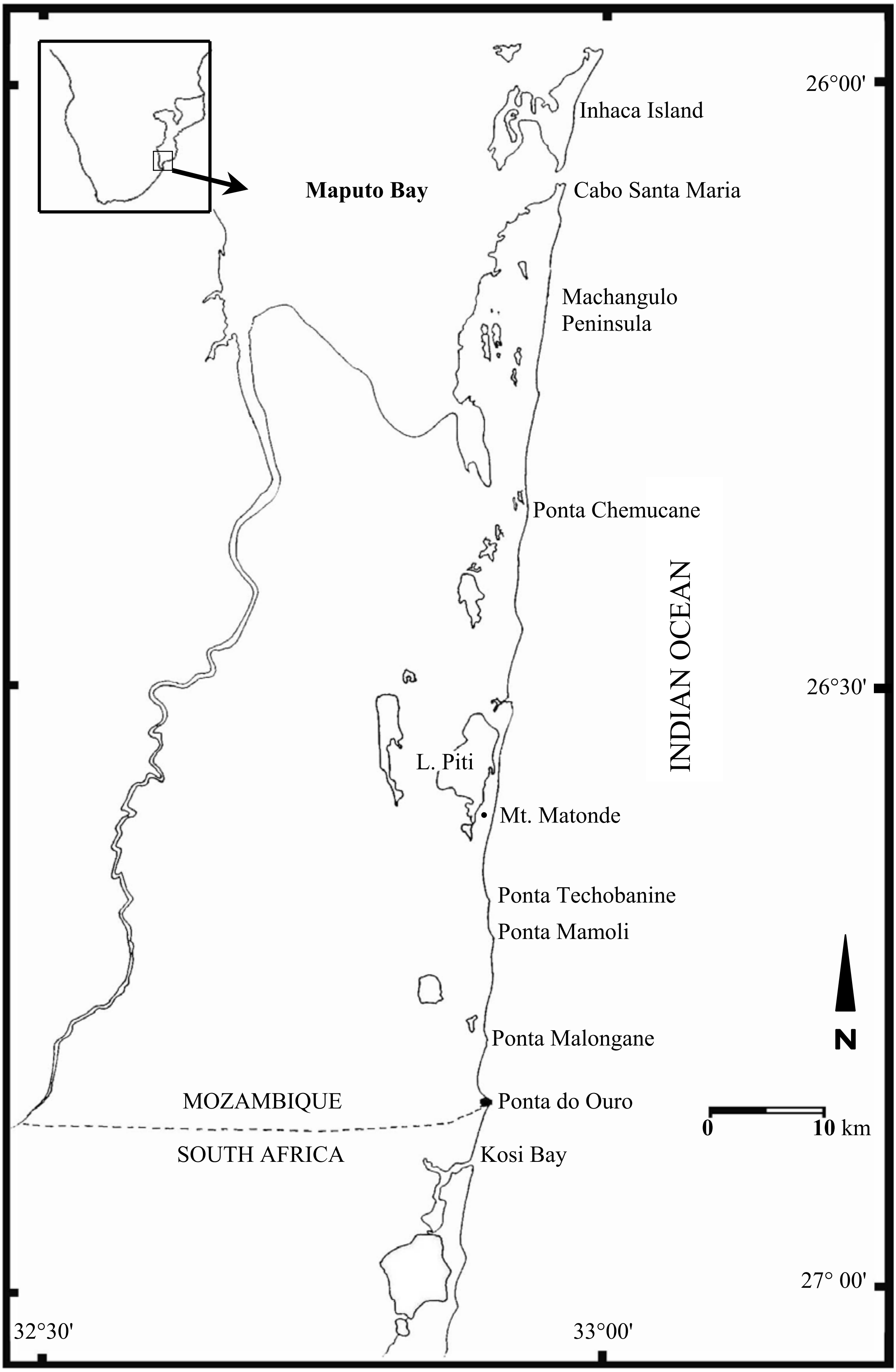


Figure 2.1. Location of the southern Mozambique area and sites mentioned in the text.

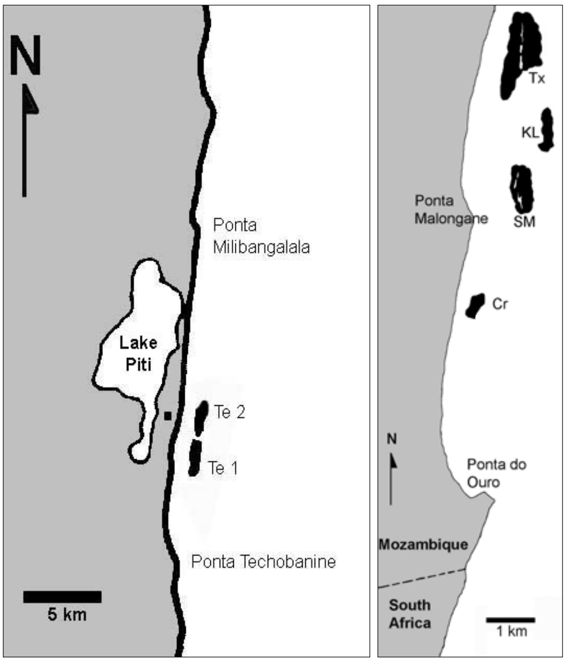
The coast is straight and without the shelter of large bays, consisting primarily of extensive sandy beaches with well-vegetated sand dunes, and is thus exposed to the full force of the elements (Robertson *et al*. 1996). The sandy beaches are interspersed with occasional rocky headlands (Hatton 1995; Robertson *et al*. 1996).

The general physical oceanography of the area is relatively well documented. Saetre & da Silva (1982, 1984) and Saetre (1985) investigated the water masses, currents and water circulation patterns of the Mozambique Channel, while Carvalho (1973) studied shore dynamics at Ponta Dobela (see also revisions by Harris 1978; Schumman 1988). The continental shelf narrows in the study area, and extends only few kilometres offshore. It is strongly influenced by the warm Agullhas Current, which flows in a southerly direction, reaching mean peak velocities of 1,4 $m.s^{-1}$ (Lutjeharms & Ruijter 1996). Inshore counter-currents flowing to the north are also common (Saetre & da Silva 1982) but tend to flow at less than 0,25 $m.s^{-1}$ (Schumman 1988). The prevailing long-shore winds blow with the current or against it, generating large waves in the latter case; southerly swells are predominant, attaining a height in excess of 5 m (Schumman 1988). The annual mean sea surface temperature for the area is 24°C, ranging from 22,5°C in winter to 26,4° C in summer, the tidal cycle is semi-diurnal and the tidal range is between 1,8 and 2,4 m (Robertson *et al*. 1996). The terrestrial input is minimal, as no major rivers enter the sea in the area (Schumman 1988).

Two species of marine turtles, the loggerhead turtle (*Caretta caretta*) and leatherback turtle (*Dermochelys coriacea*) nest in the area (Magane & João 2002). Ghost (*Ocypode* spp.) and mole crabs (*Emerita austroafricana*) are the dominant benthic macrofauna in the surf zone (Robertson *et al*. 1996). The majority of the fish and coral species in the area are widely distributed throughout the Indo-Pacific region, but some are endemic to southern Africa (van der Elst 1988; Chater *et al*. 1995; Riegl *et al*. 1995; Robertson *et al*. 1996; Schleyer 1999a; Turpie *et al*. 2000). There has been only one comprehensive biodiversity study in the area (Robertson *et al*. 1996), which lists around 150 species of reef fish, 19 genera of hard and 10 of soft corals, 9 genera of sponges and 5 of tunicates. Major reef-fish families include butterflyfishes (Chaetodontidae), wrasses (Labridae), surgeonfishes (Acanthuridae), damselfishes (Pomacentridae), triggerfishes (Balistidae) and rockcods (Serranidae). Mid-water predatory species (i.e. kingfishes – Carangidae and jobfish *Aprion viriscens* – Lutjanidae) are occasionally encountered (Robertson *et al*. 1996; pers. obs.).

2.2 THE STUDY SITES

The study sites are located between Ponta do Ouro (26°51'S; 32°58'E) in the south and Mt. Matonde (26°37'S; 32°54'E) in the north (Figure 1). Six reefs were studied at Ponta Malongane (Creche, Kev's Ledge, Shallow Malongane and Texas) as well as the major reef at Ponta Techobanine (Techo 1 and Techo 2). The location of the study reefs is shown in Figure 2.2.



Reef	Latitude	Longitude
Cr	26° 48.371' S	32° 53.622' E
KL	26° 46.673' S	32° 54.268' E
SM	26° 46.784' S	32° 53.993' E
Te 1	26° 37.770' S	32° 54.736' E
Te 2	26° 37.806' S	32° 54.873' E
Tx	26° 46.275' S	32° 54.105' E

Figure 2.2 Schematic map of the location of the study reefs. Cr=Creche; KL= Kev's Ledge; SM=Shallow Malongane; Te1=Techo 1; Te2=Techo 2; Tx=Texas .

The reefs can be classified as patch reefs. The coral communities grow as a thin veneer on late Pleistocene sandstone, which originated from submerged coastal sand dunes (Ramsay 1994, 1996); they are thus not derived from biogenic accretion. The reefs run parallel to the coastline 1 to 2 km offshore. As in Kwazulu-Natal (Riegl *et al*. 1995), the reefs do not reach the surface and lack most geomorphological traits typical of true coral reefs. None of the usual features (reef crest, or steep reef slopes) are thus present, resulting in homogenous topographic conditions over most of the hard bottom area. The major topographic features are gullies and associated small drop-offs, perpendicular to the dominant direction of the swells. The reefs are generally smaller (~200 m) than those in Kwazulu-Natal (Schleyer 1995, 1999a; Bjerner & Johansson 2001); the width varies between 10 to 600 m and the length between 50 to 1500 m. The structure and bathymetry of the reefs is thus variable. Creche ranges in depth from 10-14 m and is a doughnut-shaped reef with a sand path in the middle. It is about 1 km from the Ponta Malongane launch site and has a diameter of about 120 m. Kev's Ledge is 5 km from the launch site at Ponta Malongane and consists of two ledges approximately 150 m in length that run parallel to the coastline, in about 18 to 22 m of water, with some drop-offs from 18 m to the sea floor at 27 m. Shallow Malongane is the closest reef to the launch site (~700 m) and is shallow (14-16 m) and flat with sandy patches interspersed along its length. It is approximately 1000 m in length. Texas is a large (~1500 m), flat shallow reef (12-18 m) that is actually comprised of two ledges: an inner- and outer reef, and is located 3 km offshore. Only the inner-reef was surveyed in the present study, this being the one frequented by divers. In the northern section of the reef, overhangs, gullies and drop-offs of about 5 m are common. The Techobanine reefs are part of a long chain of reefs that start at a depth of 5 m opposite Ponta Techobanine and run northwards some 10 km parallel to the coast. The most extensive reefs in southern Mozambique occur in this complex (Robertson *et al*. 1996). The reefs are flat and are about 25 km from the Ponta Malongane laun site, with a depth range of 16-27 m.

Riegl (1995) reported maximum sedimentation levels in high surge conditions ($>0{,}7\ m.s^{-1}$) of $107\ mg.cm^{-2}.h^{-1}$ in sandy gullies and $43\ mg.cm^{-2}.h^{-1}$ in elevated parts of the reefs at Sodwana Bay in Kwazulu-Natal. The reefs in southern Mozambique may well experience similar conditions, especially the shallower ones which are frequently subjected to intensive sand movement resulting from strong surge action. This often results in poor horizontal visibility (< 10 m; pers. obs.).

The coral communities of southern Mozambique, along with those in northern Kwazulu-Natal, are the most southerly in Africa (Riegl & Cook 1995; Riegl *et al*. 1995; Schleyer 1995, 1999a). The structure and nature of the former have not been thoroughly studied but appear to be similar to the Kwazulu-Natal reefs (pers. obs.; M. H. Schleyer 2002, ORI, pers. comm.). Riegl *et al*. (1995) conducted thorough quantitative studies on the Kwazulu-Natal reefs and found that two main community-types were present. The first was dominated by the alcyonacean soft corals *Sinularia* and *Lobophytum* and occurred in areas of low sedimentation on the shallow reefs. The second was a hard (Scleractinia) coral-dominated 'gully' community with sediment-resistant massive corals (mainly *Montipora* and Faviidae). This differentiation was mainly influenced by a depth and sediment gradient. However, recent work by Schleyer & Celliers (in press), has shown that soft corals are tolerant of sedimentation as well as their previously recognised domain of turbulence on the reef tops (Schleyer 1999a). They thrive in, and dominate, the turbulent reef tops and the reef-sediment interface and the coral communities in the area are thus more complex than previously expected.

CHAPTER 3

DEMOGRAPHY, PARTICIPATION AND ATTITUDES OF RECREATIONAL SCUBA DIVERS AND AN ASSESSMENT OF THE DIVING INTENSITY IN SOUTHERN MOZAMBIQUE

3.1 INTRODUCTION

In the last three decades, the management and conservation of marine resources has changed substantially. From the user's point of view, a passive and reactive attitude has given place to one more active and participatory. Nowadays, information on the demography, participation and attitudes of recreational users of natural resources is considered extremely important for the design, implementation, and in several cases, the success of sustainable management programmes (e.g. Swanson 1971; Milon 1989; Pollock *et al*. 1994; Wells & White 1995; Beaumont 1997; Ditton & Baker 1999).

The demographic and socio-economic statistics of recreational SCUBA divers and their attitudes towards reef management were thoroughly studied in Texas by Ditton & Baker (1999) and Thailing & Ditton (2001). Westmacott *et al*. (2000a; 2000b) also studied the demography and tourism-related attitudes of SCUBA divers in Zanzibar and Mombasa. In general, the results of these studies indicate that recreational SCUBA divers are environmentally aware, educated and committed to their sport and quite capable of participating in reef management and conservation actions. Examples include the participation of recreational divers in surveys and monitoring programs on coral bleaching, crown-of-thorns starfish (*Acanthaster planci*) outbreaks and other fisheries management related issues (e.g. Pattengill-Semmens & Semmens 1998; Schleyer 1998; Hodgson 1999; Uwate & Al-Meshkhas 1999; Seaman *et al*. 2003).

Important demographic and socio-economic information on divers visiting the southern Mozambique reefs is generally lacking and management actions have been partially hindered by the lack of knowledge on the current diving pressure in the area. Bjerner & Johansson (2001) have studied the economics of the diving industry in Ponta do Ouro but very few data were collected on the divers *per se*. They also estimated the diving pressure to be between 50 000 and 63 000 dives, but these estimates were based on data collected during relatively short sampling periods (two weekends).

This Chapter presents aspects of the demography, participation and attitudes of recreational SCUBA divers visiting southern Mozambique. Estimates of the diving pressure during the study period (February 2001 - December 2002) are also provided.

3.2 MATERIALS AND METHODS

3.2.1 Demography, Participation and Attitudes of Recreational SCUBA Divers

An 8-page, 30-question, self-administered questionnaire was developed to collect data from recreational divers (Appendix 3.1). The questionnaires were distributed to the dive centres operating in Ponta do Ouro and Ponta Malongane (namely The Whaler, SCUBA Adventures, Simply SCUBA, Planet SCUBA and Malongane Holiday Resort) and collected throughout the study period. Before distribution, the questionnaire was pre-tested with various divers from Maputo city; several questions were modified as a result.

The questionnaire grouped questions into four sections. In the first section a demographic profile of the recreational scuba divers was sought with questions regarding gender, age, nationality and education level. The next section covered diver experience, activities and qualifications. The last two sections were directed at collecting information on specific diving activities and experiences in southern Mozambique, with several aspects related to the condition and management of diving in southern Mozambique.

3.2.2 Assessment of the Diving Pressure in Southern Mozambique

Two sampling strategies were adopted to estimate the number of recreational dives done during the study period. Initially, pre-prepared log sheets were handed to the dive centres and collected as regularly as possible. The initial results were not very satisfactory, as most of the dive centres seldom logged their dives and the contact persons were constantly on the move, disturbing the continuity of the process.

A second approach was then adopted. Data were extracted from resort log sheets and several hundred boat launches from three dive centres were analysed (number of divers, reef visited and dive time) to assess the diving pressure on each reef. Data for launches made from Malongane Holiday Resort were extracted for high (November -December and mid April) and low (rest of the year) seasons booking this way and were used to estimate the total number of dives made through this dive centre for the whole study period (February 2001 - December 2002). The Malongane Resort Holiday uses three (low season) and five (high season) boats for their diving operations (J.-J. Serraventoso 2002, Malongane Resort Holiday, pers. comm.). Estimates of the total number of dives made through the dive centres at Ponta do Ouro were made on the basis of this data relative to the number of boats operating from each dive centre in both low and high seasons. An estimated of number of dives undertaken on each reef during the study period was then calculated from the estimated number of dives at all dive centres and the proportional diving pressure on each reef obtained from the Malongane data.

3.3 RESULTS

3.3.1 Demography, Attitudes and Participation of Recreational SCUBA Divers

Demography

A total of 108 questionnaires were filled in and returned. The demographic data is summarized in Table 3.1. Most (57,9%) of the recreational SCUBA divers that answered and returned the questionnaires were South African males. Interestingly, only three Mozambicans, of which two were females, responded to the questionnaire (representing only 2,8% of the divers). A total of nine nationalities were represented.

Generally, female divers (average age = 31,3 years, S.D. = 8,5) were younger than male divers (average age = 36,5 years, S.D. = 8,5). Altogether, the average age was 34,9 years (S.D. = 8,8), with most (73%) between 21 and 39 years of age. The youngest and oldest divers were males (14 and 57 years of age, respectively). Female divers had a slightly narrower range in age (15-51 years).

All divers had completed, at least, their secondary level of education (high school) and the majority (36,4% of females and 50,0% of male divers) had completed their tertiary education at university (B.A / B.Sc.). A number of female (27,3%) and male divers (21,6%) had undergone post-graduate education (B.A. / B.Sc. (Hons), M.Sc., PhD.).

Table 3.1 Nationality, age and highest education level of recreational SCUBA divers visiting southern Mozambican reefs.

Country	Females		Males		Total	
	N	%	N	%	N	%
Australia	0	0,0	1	1,4	1	0,9
Germany	0	0,0	1	1,4	1	0,9
Mozambique	2	6,1	1	1,4	3	2,8
Netherlands	0	0,0	1	1,4	1	0,9
Norway	1	3,0	0	0,0	1	0,9
Portugal	0	0,0	1	1,4	1	0,9
South Africa	24	72,7	62	83,8	86	80,4
United Kingdom	5	15,2	7	9,5	12	11,2
United States	1	3,0	0	0,0	1	0,9
Total	33	100	74	100	107	100
Age						
20 or less	3	9,1	2	2,7	5	4,7
21-29	15	45,5	13	17,6	28	26,2
30-39	11	33,3	39	52,7	50	46,7
40-49	3	9,1	17	23,0	20	18,7
50-59	1	3,0	3	4,1	4	3,7
Total	33	100	74	100	107	100
Education						
Primary (grade school)	0	0	0	0	0	0
Secondary (high school)	11	33,3	20	27,0	31	29,0
Graduate (B.A./B.Sc.)	12	36,4	37	50,0	49	45,8
Post-graduate (B.A./B.Sc (Hons), M.Sc., Phd.)	9	27,3	16	21,6	25	23,4
Total	32	100	73	100	106	100

Experience and Participation in Overall Diving Activities in Southern Mozambique

Divers visiting southern Mozambican reefs had been certified for 5,8 years on average, the range being 0-27 years. The majority had been certified for at least 4 years and more than half of them had completed 51 or more dives. Generally, male divers were more experienced than females. This is was attributable to the number of years they had been certified (6,5 as opposed to 4,4), the average number of dives completed (females = 77,7 dives; males = 287,1 dives) and the highest diving qualification attained (Table 3.2). Although a considerable proportion (35,0%) of divers were 'newcomers' ('have dived for one year or less in southern Mozambique'), divers that have visited southern Mozambique for the past 2 to 5 years totalled 48,5%. A number of divers (16,5%) have been visiting these reefs for longer than 5 years (Table 3.2). The majority of respondents (63,0%) stated that they have also dived at other locations in Mozambique, most notably Inhambane (31,3%) and Inhaca Island (19,3%; Figure 3.1).

Table 3.2 Level of experience of recreational SCUBA divers visiting southern Mozambican reefs.

Years spent diving	Females		Males		Total	
	N	%	N	%	N	%
1 or less	7	21,2	14	19,2	21	19,8
1-3	8	24,2	13	17,8	21	19,8
4-5	10	30,3	9	12,3	19	17,9
6-10	4	12,1	26	35,6	30	28,3
11-15	4	12,1	6	8,2	10	9,4
16-20	0	0,0	3	4,1	3	2,8
21 or more	0	0,0	2	2,7	2	1,9
Total	33	100	73	100	106	100
Average (S.D.)	4,4 (3,6)		6,5 (5,4)		5,8 (5,0)	
Range	0 – 14		0 – 27			
Number of logged dives						
20 or less	12	36,4	14	19,7	26	25,0
21-50	10	30,3	12	16,9	22	21,2
51-100	3	9,1	19	26,8	22	21,2
101-200	5	15,2	5	7,0	10	9,6
200 or more	3	9,1	21	29,6	24	23,1
Total	33	100	71	100	104	100
Average (S.D.)	77,7 (107,8)		287,1 (518,0)		220,6 (442,2)	
Range	4 – 520		0 – 3000			
Highest diving qualification						
Basic pen water	13	40,6	16	21,6	29	31,5
Advanced open water	14	43,8	32	43,2	46	50,0
Specialty (wreck, etc.)	1	3,1	0	0,0	1	1,1
Dive master	4	12,5	12	16,2	16	17,4
Dive instructor	0	0,0	14	18,9	14	15,2
Total	32	100,0	74	81,1	92	100,0

Years visited southern Mozambique	N	%
1 year or less	36	35,0
2-3 years	26	25,2
4-5 years	24	23,3
6 years or more	17	16,5
Total	103	100
Average (S.D.)	3,0 (2,5)	
Range	0- 10	

Other Mozambican locations visited (Some divers chose more than one)	N	%
Bazaruto Archipelago	14	16,9
Bilene	12	14,5
Inhaca Island	16	19,3
Inhambane	26	31,3
Xai-Xai	9	10,8
Other	6	7,2
Total	83	100

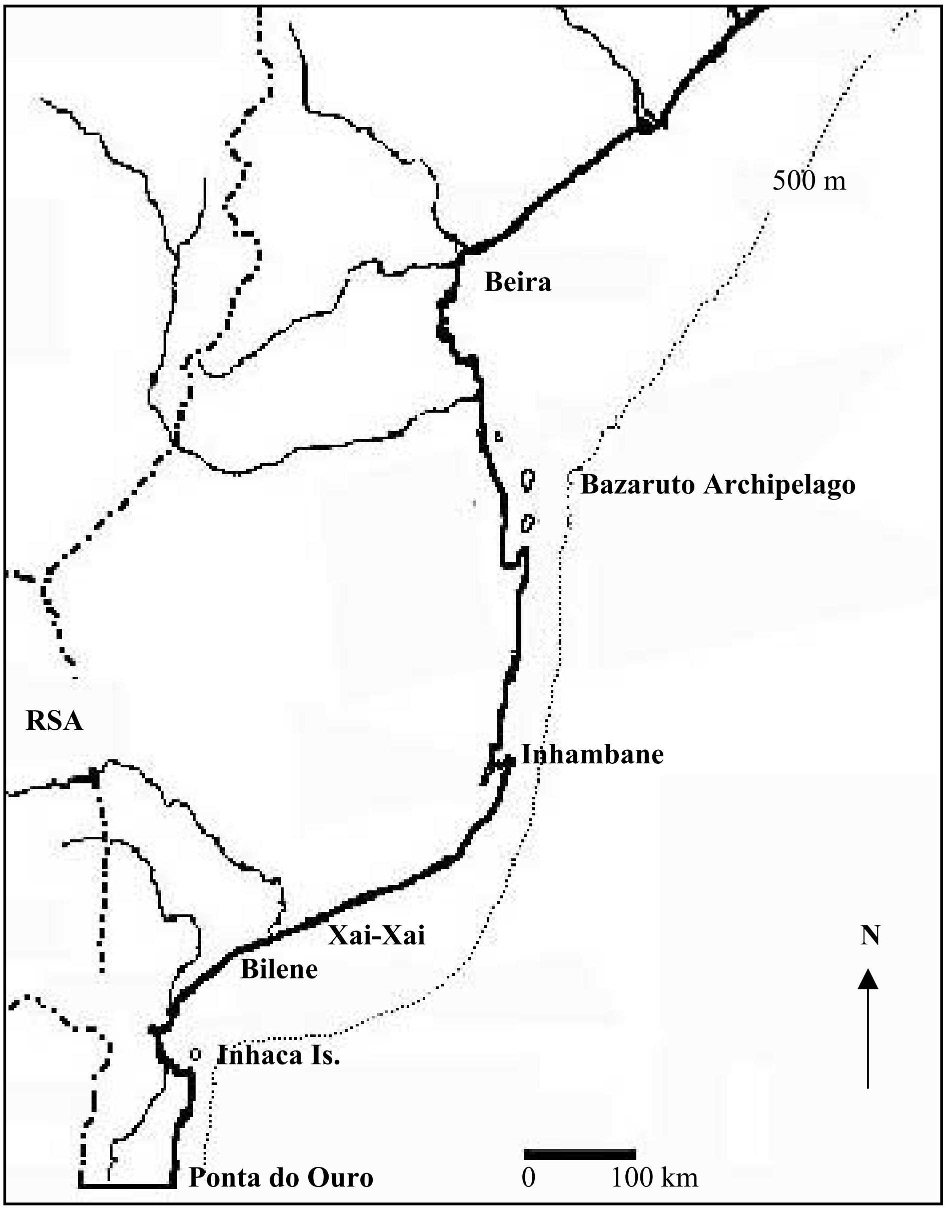


Figure 3.1 Map showing other Mozambican sites visited by the divers responding to the questionnaire.

Almost half (48,8%) of the divers were certified by PADI, with NAUI certifying another third (Table 3.3). The divers tended to diversify their diving activities with underwater photography, decompression/NITROX diving and night and wreck diving, the latter two being particularly popular. A minority (6,5%) of divers responded that they participated in spear fishing (Table 3.4).

Table 3.3 Certification of recreational SCUBA divers visiting southern Mozambican reefs. Some divers chose more than one agency.

Certifying Agency	N	%
PADI	59	48,8
NAUI	41	33,9
YMCA	1	0,8
BSAC	1	0,8
SSI	7	5,8
Other	12	9,9
Total	121	100

Table 3.4 Most frequently recorded activities of recreational SCUBA divers visiting southern Mozambican reefs. Some divers chose more than one activity.

Activity	N	%
Underwater photography	23	13,7
Spear fishing	11	6,5
Marine life research	11	6,5
Decompression/NITROX diving	24	14,3
Cave diving	4	2,4
Night diving	26	15,5
Wreck diving	27	16,1
Other	42	25,0
Total	168	100

The majority of divers (65,1%) considered SCUBA diving to be their most important or second most important outdoor activity (Table 3.5), but most of them (63,2%) do not subscribe to diving magazines.

Table 3.5 Index of importance SCUBA diving relative to other outdoor activities recorded by recreational SCUBA divers visiting southern Mozambican reefs.

Comparison	N	%
Most important	49	46,2
Second most important	20	18,9
Third most important	6	5,7
Only one of many outdoor activities	31	29,2
Total	106	100

The great majority of divers (91,6%) rated 'look at fish and other marine life' as a very important or extremely important reason why they came to dive in southern Mozambique. This was the highest ranked reason (4,7 on a scale of 1-5). Another important reason, with an average rank of 4,4 (83,7% of the divers), was ‘to experience unpolluted surroundings’ (Table 3.6). The least important reason given for diving in southern Mozambique was ‘for the exercise’ with an average rank of 2,7 (47,2 % of the divers).

Table 3.6 Reasons and the importance given by recreational SCUBA divers for diving on southern Mozambican reefs. 1=not important; 2=slightly important; 3=moderately important; 4=very important; and 5=extremely important.

Reasons why people dive	**1**		**2**		**3**		**4**		**5**		**Total**	**Mean rank**
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**		
Look at fish and other marine life	1	1,0	0	0,0	3	3,0	24	23,8	73	72,3	101	4,7
Experience unpolluted surroundings	1	1,0	2	1,9	14	13,5	22	21,2	65	62,5	104	4,4
Experience tranquillity underwater	3	2,9	5	4,8	13	12,5	24	23,1	59	56,7	104	4,3
For relaxation	3	2,9	2	1,9	17	16,2	23	21,9	60	57,1	105	4,3
Learn about the marine environment	1	1,0	6	5,9	18	17,8	33	32,7	43	42,6	101	4,1
To be outdoors	2	1,9	3	2,9	20	19,4	33	32,0	45	43,7	103	4,1
To experience adventure	2	1,9	8	7,8	16	15,5	25	24,3	52	50,5	103	4,1
Experience new and different things	2	1,9	6	5,8	20	19,4	25	24,3	50	48,5	103	4,1
Get away from regular routine	6	5,8	8	7,7	15	14,4	30	28,8	45	43,3	104	4,0
Get away from demands of others	10	9,6	7	6,7	17	16,3	35	33,7	35	33,7	104	3,8
Develop diving skills and abilities	7	6,7	6	5,7	13	21,9	33	31,4	36	34,3	105	3,8
To be with friends	2	2,0	7	7,1	29	29,3	28	28,3	33	33,3	99	3,8
For family recreation	21	21,0	14	14,0	22	22,0	16	16,0	27	27,0	100	3,1
For the excercise	22	21,2	27	26,0	28	26,9	12	11,5	15	14,4	104	2,7

Divers recorded that, on average, they had been diving for 4,9 days (S.D. = 7,6) during the trip that they responded to the questionnaire (range 1-30 days). During this period, they had dived 5,3 times (S.D. = 4,3) with a maximum of 30 dives and a minimum of one dive. The answers to the question ‘on which reefs have you dived during this trip?’ revealed that about 20 reefs are regularly dived, Doodles, Creche, Bass City, Texas and Kev’s Ledge being the five most dived reefs (Table 3.7). These reefs are within the depth range in which the majority (73,5 %) of divers prefer to dive (i.e. between 11 and 24 meters) (Table 3.8). Divers also prefer to use their own personal diving gear; only 17,6% of them used hired gear.

Table 3.7 Diving pressure on southern Mozambican reefs derived from the questionnaire data.

Reef	Frequency dived	%	Rank
Doodles	47	15,4	1
Creche	38	12,4	2
Bass City	29	9,5	3
Texas	27	8,8	4
Kev's Ledge	24	7,8	5
Pinnacles	19	6,2	6
Paradise Ledge	16	5,2	7
Three Sisters	16	5,2	7
Shallow Malongane	12	3,9	8
Lego’s Atlantis	11	3,6	9
Checkers	11	3,6	9
Breadloaf	10	3,3	10
Riana's Arch	10	3,3	10
Steps	9	2,9	11
The Ridge	9	2,9	11
Malongane Ledge	7	2,3	12
Anchor	4	1,3	13
Others	3	1,0	14
Finger's	2	0,7	15
Steve's	2	0,7	15
Total	306	100	

Table 3.8 Preferred diving depth category SCUBA divers visiting southern Mozambican reefs. Some divers chose more than one depth category.

Depth category	N	%
Less than 10 m	5	2,9
11 – 15 m	43	24,9
16 – 24 m	84	48,6
25 – 30m	24	13,9
31 – 40 m	13	7,5
More than 41 m	4	2,3
Total	173	100

Many outdoor recreational activities are primarily family-orientated, and recreational SCUBA diving in southern Mozambique does seem to be one of these activities. Most divers practised their sport frequently with friends (47,1 %) or a combination of friends and family (42,4%; Table 3.9).

Table 3.9 Preferred diving partners of recreational SCUBA divers visiting southern Mozambican reefs.

Social group	N	%
Friends	40	47,1
Family	5	5,9
Family and friends together	36	42,4
Dive Centre's Buddies	4	4,7
Total	85	100

Divers were asked to rate the marine biota they considered most important for their diving experience in southern Mozambique. A summary of their responses is presented in Table 3.10. Marine megafauna were clearly the highest in rank. Dolphins, whales and whale shark were particularly popular (average rank of 4,6 on a scale of 1-5), with 92,1% of the divers declaring that these species were very important or extremely important.

Reef fishes and corals seem to elicit similar interest in divers. Hard and soft corals, and most of the reef fish categories, had an equal rank of 4,0 (excepting tropical reef fishes i.e. damsels, angels and butterflyfishes, which had an average rank of 4,1). However, the number of divers that recorded that hard and soft corals were very or extremely important (totalling 70,9% of the respondents) is lower than those that valued tropical reef fish (77,2%), other reef fish (74,2%) and small reef fish (72,9%) in the same terms. Furthermore, 10,7% of the divers considered hard and soft corals to be unimportant or slightly important as opposed to only 7% for large reef fish or 6,9 % for small reef fish, which declared that these reef fish categories were unimportant for their diving experience. Few divers mentioned other reef organisms (though nudibranchs were the most cited) but, those who did, showed special interest in their group with the great majority of these divers (average rank of 4,5) considering these organisms to be very or extremely important.

The diving in southern Mozambique ranks very well when compared to other dive sites, as 84,2% of the divers considered the diving in southern Mozambique slightly or much better than other diving sites they have visited (Table 3.11). The perception that southern Mozambique offers good quality diving is also reflected in the overall diving satisfaction expressed by the respondents (Table 3.12). The great majority (93,4%, average rank of 4,5 on a scale of 1-5) stated that they were very or extremely satisfied with their diving experience in southern Mozambique, with none of them dissatisfied or slightly satisfied.

Table 3.10 The importance of various marine organisms to recreational SCUBA divers recoded in the southern Mozambique questionnaire. 1=not important; 2=slightly important; 3=moderately important; 4=very important; and 5=extremely important.

Marine life	1		2		3		4		5		Total	Mean
	N	%	N	%	N	%	N	%	N	%		
Dolphins, whales & whale shark	1	1,0	2	2,0	5	5,0	25	24,8	68	67,3	101	4,6
Other	1	3,4	0	0,0	2	6,9	7	24,1	19	65,5	29	4,5
Marine turtles	0	0,0	4	3,9	15	14,7	39	38,2	44	43,1	102	4,2
Sharks and rays	1	1,0	6	6,1	18	18,2	24	24,2	50	50,5	99	4,2
Tropical reef fish (damsels, angels, butterflyfishes)	0	0,0	6	5,9	20	19,6	32	31,4	44	43,1	102	4,1
Large reef fish (rockcods, snappers)	1	1,0	6	6,0	23	23,0	35	35,0	35	35,0	100	4,0
Small reef fish (blennies, gobies)	2	2,0	5	4,9	21	20,6	36	35,3	38	37,3	102	4,0
Other reef fish (triggerfish and surgeonfish)	0	0,0	7	6,9	19	18,8	38	37,6	37	36,6	101	4,0
Hard and soft corals	1	1,0	10	9,7	19	18,4	28	27,2	45	43,7	103	4,0
Large pelagic fish (barracuda, kingfish)	3	2,9	9	8,8	25	24,5	27	26,5	38	37,3	102	3,9
Sponges, sea squirts, algae	6	6,0	21	21,0	21	21,0	24	24,0	28	28,0	100	3,5
Crustaceans & molluscs	7	7,0	22	22,0	23	23,0	24	24,0	44	24,0	100	3,4
Sea stars, sea cucumbers & sea urchins	9	9,2	24	24,5	20	20,4	20	20,4	25	25,5	98	3,3

Table 3.11 Rating of the diving in southern Mozambique compared to other sites visited by recreational divers responding to the questionnaire.

Comparison scale		N	%
1	Much worse	0	0,0
2	Worse	1	1,0
3	Same	15	14,9
4	Slightly better	63	62,4
5	Much better	22	21,8
Total		101	100
Average (S.D.)		4,0 (0,62)	

Table 3.12 Satisfaction rating of their diving experience by recreational SCUBA divers visiting southern Mozambican reefs.

	Scale of Satisfaction	N		%
1	Not satisfied	0		0,0
2	Slightly satisfied	0		0,0
3	Moderately satisfied	7		6,9
4	Very satisfied	38		37,3
5	Extremely satisfied	57		55,9
Total		102		100
Average (S.D.)			4,5 (0,6)	

Reef Condition and Management Attitudes

The last section of the questionnaire was on the condition and management of the reefs and their communities and aimed directly at more experienced divers that have dived in southern Mozambique before 1999 (divers that potentially witnessed the effects of the 1998 bleaching event; Schleyer *et al*. 1999). More than half of the divers (55,3%) stated that the reefs appeared the same and no changes were noted in the reef environment (Table 3.13). Most divers also considered that the coral cover and the abundance of small reef fish had not changed. When asked about the abundance of large reef fish (rockcods, kingfishes), divers were not in agreement; the majority of them (44,4%) considered that there were less rockcod and kingfish, while 36,1% felt that the abundance of these fish had not changed (Table 3.14). A closer examination of the experience of the respondents to these questions (Appendix 3.2) revealed that those that noted changes in the overall reef environment were more experienced divers (highest level of diving qualification and mean number of logged dives). The more experienced divers also declared that both the coral cover and abundance of small reef fishes had remained the same, while they were unsure if the large reef fishes had decreased in abundance.

Table 3.13 Number and percentage of recreational SCUBA divers that noted any change in the environment on the visiting southern Mozambican reefs.

Change in the reef environment	N	%
Yes	17	44,7
No	21	55,3
Total	38	100

Table 3.14 Number and percentage of recreational SCUBA divers that noted any change in selected groups of reef fauna on southern Mozambican reefs such as coral cover, small reef fish (including damsels and butterflyfishes) and large reef fish (rockcods and kingfishes).

Reef fauna	Decreased		Did not change		Increased		Did not notice		Total
	N	%	N	%	N	%	N	%	N
Coral cover	9	24,3	18	48,6	4	10,8	6	16,2	37
Small fish	9	24,3	16	43,2	9	24,3	3	8,2	37
Large fish	16	44,4	13	36,1	3	8,3	4	11,1	36

Attitudes towards reef conservation and the management of diving activities varied according to the nature and context of statements in the questionnaire (Table 3.15). For example, the majority of respondents disagreed (average rank 2,3 on a 1-5 scale; 1 being strong disagreement) with the deployment of mooring buoys or with the idea that there is excessive diving in southern Mozambique (54,5% of the divers strongly disagreed or disagreed with the statement ‘The reefs in southern Mozambique are too crowded’). Most divers agreed that excessive diving might damage reef communities (64,5%) and that a pre-dive briefing should emphasize environmentally-friendly diving practices (96%), emphasising the 3T’s (‘do not Touch, do not Tease, and do not Take’). A clear-cut picture could not be drawn from responses regarding two management statements on restrictions on the number of dives per site and the deployment of artificial reefs, thus suggesting that these were not very popular among the respondents.

Only 35,2 % (38 out of 108) of the divers who responded to the questionnaires provided their opinions in the last general question field. The resulting comments were grouped in 4 categories. More than half the comments addressed issues related to SCUBA diving in southern Mozambique and the condition and conservation of the reefs. An important proportion of the respondents that provided comments (26,3%) paid special attention to the development of the tourism industry in southern Mozambique, highlighting issues such as pollution and coastal dune conservation among others. All these comments are presented in Appendix 3.3.

Table 3.15 Agreement or disagreement of recreational SCUBA divers visiting southern Mozambican reefs with attitude statements concerning management of the reefs. 1=Strongly disagree; 2=disagree; 3=neutral; 4=agree; 5=Strongly agree.

Southern Mozambican reefs	1		2		3		4		5		Total	Mean
	N	%	N	%	N	%	N	%	N	%		
Pre-dive briefings should emphasize 3Ts	2	2,0	0	0,0	2	2,0	17	17,2	78	78,8	99	4,7
Can be damaged by excessive diving	5	5,1	10	10,2	19	19,4	27	27,6	37	37,8	98	3,8
Designated for specific uses	8	8,2	14	14,4	16	16,5	23	23,7	36	37,1	97	3,7
Artificial reefs should be deployed	19	19,4	7	7,1	20	20,4	27	27,6	25	25,5	98	3,3
The number of dives should be restricted	10	10,1	18	18,2	29	29,3	22	22,2	20	20,2	99	3,2
Mooring buoys should be provided	33	34,4	15	15,6	25	26,0	7	7,3	16	16,7	96	2,6
Are too crowded	22	22,2	32	32,3	36	36,4	7	7,1	2	2,0	99	2,3

3.3.2 Assessment of the Diving Pressure in Southern Mozambique

A total of five dive centres operated continuously throughout the study period (February 2001 to December 2002). Four of them were based in Ponta do Ouro and the fifth in Ponta Malongane. Two new operations initiated their activities in April (one based in Ponta do Ouro) and May 2002 (one based in Ponta Mamoli). The total number of dives during the 22-month study period was estimated at 104 500, with considerably more dives being executed in 2002 (62 000) when compared to 2001 (42 500).

A total of 1526 launches (13 661 dives) were logged during the study period. Of the 23 reefs dived (Figure 3.2), four (Doodle, Creche, Kev's Ledge and Texas) were used the most, hosting more than 44% of the dives (Table 3.16). This means that each of these four reefs was dived more than 7000 times during the study period (February 2001 to December 20002). In this group, Doodles was the most dived reef, with more than 12 000 dives in 2002. Diving intensities are not presented for the reefs at Ponta Techobanine as they were not commercially dived for most of the study period due to the great distance from the Ponta do Ouro and Ponta Malongane dive centres. However, a small-scale dive operation that uses these reefs was established at Ponta Mamoli in April/May 2002. The number of dives that were undertaken from this base is unknown but, according to a local operator (D. Wagner 2002, Malongane

Holiday Resort, pers. comm.), the number of dives conducted on Techobanine from April/May to December 2002 was less than 500.

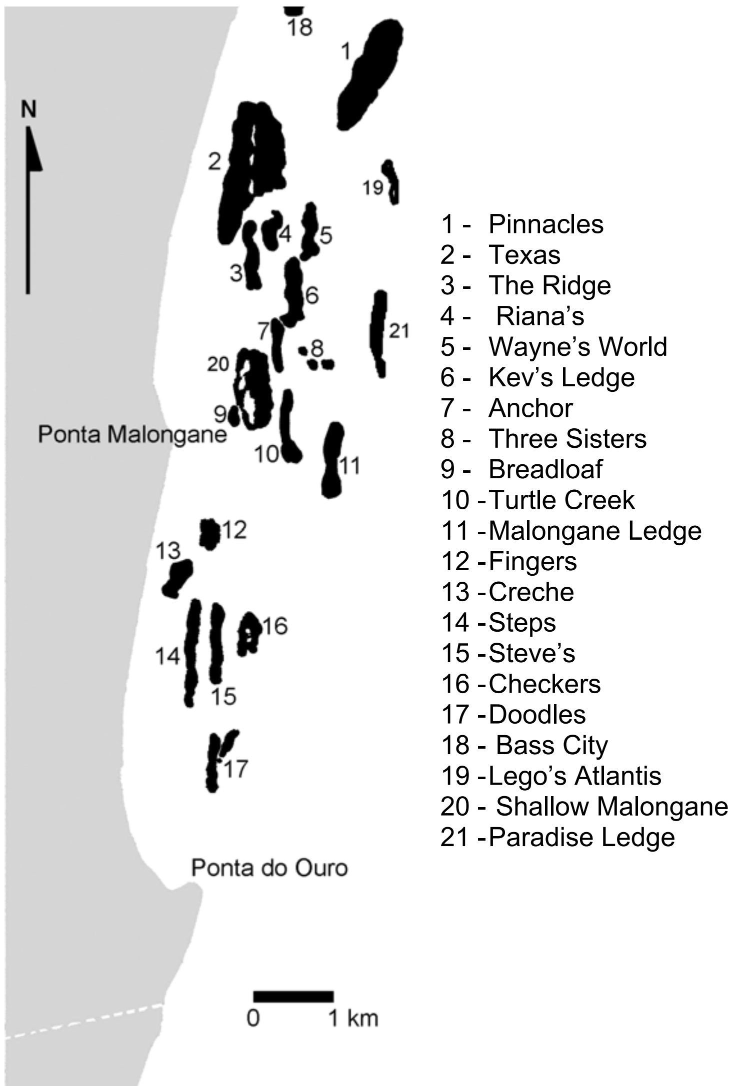


Figure 3.2 Schematic map of the most frequently dived reefs in southern Mozambique.

Table 3.16 Recreational dives conducted on southern Mozambican reefs during the study period. NA=refers to launches in which the number of divers was recorded but not the reef.

Reef	Dives logged	%	Estimated dives 2001	Estimated dives 2002	□	Rank
Doodles	2706	19,81	8419	12282	20700	1
Creche	1414	10,35	4399	6417	10816	2
Kev's Ledge	980	7,17	3047	4445	7497	3
Bass City	937	6,86	2916	4253	7168	4
Texas	928	6,79	2886	4210	7099	5
NA	818	5,99	2546	3714	6257	6
Steps	817	5,98	2542	3708	6250	7
Three Sisters	751	5,50	2338	3410	5745	8
Anchor	699	5,12	2176	3174	5347	9
Paradise Ledge	628	4,60	1955	2852	4804	10
The Ridge	520	3,81	1619	2362	3978	11
Breadloaf	461	3,37	1432	2089	3526	12
Shallow Malongane	454	3,32	1411	2058	3473	13
Checkers	419	3,07	1305	1903	3205	14
Pinnacles	403	2,95	1254	1829	3083	15
Malongane Ledge	244	1,79	761	1110	1866	16
Lego's Atlantis	215	1,57	667	973	1645	17
Aquarium	92	0,67	285	415	704	18
Riana's Arch	88	0,64	272	397	673	19
Wayne's World	26	0,19	81	118	199	20
Padi	20	0,15	64	93	153	21
Fingers	15	0,11	47	68	115	22
Turtle Creek	14	0,10	43	62	107	23
Steve's	12	0,09	38	56	92	24
Total	13661	100,00	42500	62000	104500	

3.4 DISCUSSION

Divers visiting southern Mozambique were mostly educated males in their 30s. These demographic characteristics do not differ substantially from those reported for divers from Zanzibar and Mombasa (Westmacott *et al*. 2000a) or Texas (Ditton & Baker 1999; Thailing & Ditton 2001). Virtually all the divers on the southern Mozambican reefs were South Africans. This is not surprising as the great majority of tourists (> 95%) visiting the area originate from South Africa (Abrantes & Pereira 2003; Bjerner & Johansson 2001). Surprising, however, was the fact that a minimal number of Mozambicans nationals participate in this recreational activity. This may be due to two factors:

- SCUBA diving is not very popular in Mozambique as a sport or recreational activity.
- The costs of training and diving are high. For example a PADI open water diver course costs about 300 U$ (~ R 2 250) and a dive at Ponta do Ouro R135 (~18U$). This is clearly too expensive for the majority of Mozambicans.

In either event, of the limited number of Mozambicans that actually dive, only three bothered to respond to the questionnaire.

The diving qualifications and experience were of a high standard and comparable to those previously found at Ponta do Ouro (Bjerner & Johansson 2001), Texas (Ditton & Baker 1999; Thailing & Ditton 2001) or higher than those reported in Zanzibar and Mombasa (Westmacott *et al*. 2000a) and Australia (Roberts & Harriot 1995; Rouphael & Inglis 1995; Harriot *et al*. 1997). Divers were also committed to their sport, considering it an important outdoor activity. Again, it might be argued that only experienced and more conscientious divers responded to the questionnaire (Table 3.2), but similar proportions of experienced and novice divers responded to the questionnaire, suggesting that the survey data is representative of the recreational diving population of southern Mozambique. Diving experience in reef users is an important asset as far as the management and conservation of coral reefs is concerned. There is evidence that novice divers (< 100 logged dives) cause more physical damage to corals than more experienced and conscientious ones (> 100 logged dives; Bjerner & Johansson 2001; Davis *et al*. 1995).

When divers make their choice as to where they will dive, many factors are considered. Excluding the travelling distance and cost, which were not considered here, the attractiveness of the site, the quality of diving, and other social and psychological benefits (e.g. family recreation) are of particular importance. 'Family recreation' was given as a moderately important reason for diving in southern Mozambique but more divers dive with friends than with family members (Table 3.9). Abrantes & Pereira (2003) reported that children accounted for only 21% of the tourists crossing the Ponta do Ouro border to southern Mozambique for the summer holidays. Therefore, SCUBA diving *per se* cannot be considered as a family attraction for vacations in southern Mozambique.

'To look at fish and other marine life' was identified as the most important reason why divers chose to dive in southern Mozambique (Table 3.6). When questioned about which species were more interesting, the majority of recreational divers responded that marine mammals (dolphins and whales), cartilaginous fish (sharks and rays) and marine turtles were actually the ones that caught their attention. This is not surprising, as most species mentioned enjoy world-wide popularity, being flag species for a number of marine conservation campaigns. Divers prefer reef fish (large or small tropical reef fish) when compared to benthic species (e.g. corals, sponges). Divers interviewed in Zanzibar and Mombasa by Westmacott *et al*. (2000a) and

Williams & Polunin (2000) in the Caribbean, also regarded the variety and abundance of fish as the most important reef feature. The wide range of colours, shapes and smoothness of movement that reef fish display may explain the divers' preferences. This may be an important issue to consider if diving pressure and fishing restrictions or zoning schemes are to be implemented.

Southern Mozambique seems to attract a loyal diver clientele. The percentage of the respondents that have been visiting these reefs for more than four years totalled almost 40% (Table 3.7). Despite the fact that tourism, and SCUBA diving in particular, were badly affected by the February 2000 floods, new divers are still attracted to this destination. This is also reflected in the levels of satisfaction expressed by the respondents. Divers found southern Mozambique to be a good-quality diving destination and they were very or extremely satisfied with their diving experience.

This study also assessed divers' perceptions on reef condition and changes in coral cover and fish abundance. Although their expertise and skills may be questionable, their observations may be important indicators of changes in reef condition and community structure. Various studies and conservation programs have employed recreational divers' observations and participation with relative success (e.g. Hodgson 1999, Seaman *et al*. 2003; Uwate & Al-Meshkhas 1999). Another important issue is that divers' personal perceptions as to whether reefs are changing or undergoing degradation may have an influence on the local economy. For example, Westmacott *et al*. (2000a, 2000b) reported that coral bleaching, influenced the choice of destination in 39% of the instances of divers visiting Mombasa who were aware of the 1998 bleaching event. They also noted that coral bleaching affected tourists' holiday satisfaction (with 47% of them considering dead corals the most disappointing experience), thus causing financial losses to the economies of Sri Lanka and the Maldives. Graham *et al*. (2001) recorded similar results in Palau, Micronesia.

In the present study, divers were in agreement regarding changes in the overall reef environment, with the majority of them noting no changes before 1999 or during the study period. Even though more experienced divers (divemasters, dive instructors and divers with a higher number of logged dives; > 100) may have better judgement skills as to whether a reef has changed or not, caution is needed when interpreting these results. The more experienced divers may have opinions contrary to the majority of divers (for example the majority of divers thought that no changes had occurred) but this was not always the case, with the most experienced disagreeing as to whether coral cover or small reef fish remained the same. It is quite worrying that the majority of divers (44%; Table 3.14) stated that the large reef fishes (rockcods, kingfishes) had decreased since 1999. This could probably be attributed to fishing activity in the area. Divers noted the occurrence of bottom fishing or over-fishing on the reefs in their general comments (Appendix 3.3). Additionally, local dive operators (G. Beukes 2001, The Whaler - Ponta do Ouro, pers. comm.), declared that '...[illegal] large industrial vessels have been seen quite commonly, around the reefs (even the shallow ones) and this may explain the high amount of damage on some reefs with broken coral, less fish, etc.'.

Some of the divers' attitudes towards the management of SCUBA diving and reef conservation in southern Mozambique were similar to those of divers in Texas (Ditton & Baker 1999) and Bonaire Marine Park (Dixon *et al*. 1993). They disagreed with the statement that the reefs were too crowded and agreed that the reefs should be designated for specific uses. On the other hand, Texan divers agreed with the deployment of mooring buoys and artificial reefs (sunken ships). However, the last two appeared not to be very popular with divers in southern Mozambique. The SCUBA diving industry in southern Mozambique is largely driven by and for South Africans (Bjerner & Johansson 2001) and the methods and practices used on the southern Mozambican reefs are the same as those used in South Africa. Artificial reefs are infrequently deployed and not very popular with divers in South Africa due to the rough sea conditions and relatively high costs. It is thus not surprising that mooring buoys and artificial reefs were similarly unpopular with respondents to the survey. The fact that divers strongly agreed with the 3Ts (do not Touch, do not Tease and do not Take) suggests that they would accept and welcome awareness campaigns and pre-dive briefings (Medio *et al*. 1997) on environmentally-friendly diving practices. This is an indication of their openness and reveals a sense of responsibility and sensitivity to reef conservation issues.

Divers did not accept that southern Mozambican reefs are too crowded. The relatively high number of dive sites in Ponta do Ouro and Malongane, which in a certain sense spreads the load across all the reefs, probably explains this. Dispersal of the diving pressure has prevented a loss in 'sense of place' occurring as the divers do not feel crowded. However, considering that the reefs are not very extensive (the most frequently dived reefs are smaller than 200 m^2; Bjerner & Johansson 2001; pers. obs.) and more than 50% of the dives are made on only five reefs (Tables 3.7 and 3.16), it can be concluded that overuse has been occurring to some extent.

Recreational SCUBA diving in southern Mozambique is poorly documented and has often been associated with anecdotal confusion and exaggeration, especially regarding diving pressure (number of dives) and overuse. Previous estimates on the number of dives were made in 1996, when Robertson *et al*. (1996) reported that the dive rate on the reefs was high relative to their size, being between 30 000 and 40 000 dives a year. Rodrigues & Motta (in prep) reported that this number increased to 80 000 - 90 000 dives.year^{-1} in 1999 and suggested that the diving pressure was approaching an unsustainable level. In early 2000, a small-scale study was conducted by Bjerner & Johansson (2001) who estimated that 50 000 to 63 000 dives were made per year. In the present study, the diving pressure was estimated at 42 500 dives in 2001 and 62 000 dives in 2002. These figures clearly show that the industry grew quite fast, although the 1999 figure cited by Rodrigues & Motta (in prep) seems to be exaggerated. The decline registered in 2001 is indicative of the impact of massive floods that occurred throughout southern Mozambique in February 2000. These caused widespread destruction in the basic infrastructure with consequent bad publicity that resulted in a decline in tourism. In 2002, the number of dives increased due to better marketing and a decline in value of the South African Rand, causing more South Africans divers to dive 'locally' rather than travel overseas for their diving vacations.

It thus appears that the diving pressure in southern Mozambique is not as high as was previously thought, especially if one compares it with other areas (for example in Sodwana Bay, South Africa, where 120 00 dives.year^{-1} are dispersed over four large reefs; Schleyer & Tomalin, 2000). However, the diving activity seem to have reached its 'carrying capacity' and it is likely that it will not increase, as the present tourism facilities such as accommodation, roads, electricity and medical facilities appear to be saturated.

Most of the recreational SCUBA diving activity in southern Mozambique takes place on about 20 reefs with more than 50% of the dives being concentrated on five of them (Tables 3.7 and 3.16). This represents a high diving load on these reefs, especially considering their size. Reef features such as the abundance and diversity of fish, distance from the shoreline and depth are some of the most important factors in the selection of dive sites by both dive operators (skippers, divemasters) and divers. A similar situation was reported in Sodwana Bay, South Africa (Schleyer & Tomalin 2000; Walters & Samways 2001) where 85% (68 000 dives.year^{-1}) of the dives are carried out on Two-mile Reef (the closest of four reefs). This has resulted in measurable damage on reefs. There is evidence that reef areas near launching sites (e.g. Schleyer & Tomalin; 2000) or close to mooring buoys (e.g. Hawkins *et al*. 1999) are subjected to more diver-caused damage. There is thus a need to alleviate the diving pressure on the southern Mozambican reefs through a more balanced distribution of the diving intensity and perhaps the deployment of artificial reefs (Wilhelmsson *et al*. 1998; van Treeck & Schuhmacher 1999).

CHAPTER 4
STRUCTURE OF CORAL AND REEF-FISH COMMUNITIES IN SOUTHERN MOZAMBIQUE

4.1 INTRODUCTION

The coral reefs of the western Indian Ocean provide a valuable resource base for the livelihood of many coastal communities (Kimani 1995; McClanahan & Obura 1996; Muhando 1999; Rodrigues *et al*. 2000). In Mozambique, reef resource use includes fishing and the collection of edible invertebrate species, recreational diving and snorkelling, coral mining, and the collection of corals, shells and fish for the ornamental trade (Rodrigues *et al*. 2000; Whittington *et al*. 2000; Marshall *et al*. 2001).

In Mozambique, coral reefs occupy an estimated area of 1860 km^2 (Spalding *et al*. 2001) and represent one the country's main marine assets for both coastal communities (Pacule *et al*. 1996; Ruy *et al*. 1997; Loureiro 1998) and the growing coastal tourism industry (Rodrigues *et al*. 2000; Bjerner & Johansson 2001).

Limited studies have been undertaken on the community structure and diversity of Mozambique's coral reefs. Studies have been conducted in the Quirimbas Archipelago (Rodrigues 1996; Whitington *et al*. 1998), Primeiras Archipelago (Schleyer 1999b), Bazaruto Archipelago (Benayahu & Schleyer 1996) and at Inhaca Island (Salm 1976; Gonçalves 2000; Pereira 2000a; Perry 2003; see also revisions by Rodrigues *et al*. 2000 and Pereira 2002). The biodiversity of the Mozambican reefs was found to be high with almost 900 species of reef associated fishes recorded (Pereira 2000b) and 151 species of hermatypic corals (Riegl 1996).

The paucity of baseline information on the structure of reef communities in southern Mozambique prompted the present study. The structure of fish and coral communities of six reefs subjected to different diving intensities is described and compared, providing quantitative information for future comparisons.

4.2 MATERIALS AND METHODS

4.2.1 Benthic Community Structure

Benthic community structure was studied using the video technique described by Carleton & Done (1995), Aronson & Swanson (1997) and Page *et al*. (2001). This technique offers a wide range of advantages, the most important for the present study being that it (i) can be used in adverse diving conditions; (ii) permits rapid data acquisition when dive time becomes limited; and (iii) it provides a permanent record, which can be referred to for re-analysis.

Surveys were undertaken with a Sony Hi-8 Handycam video camera in an underwater housing fitted with a spacer bar, to maintain a working distance of 110 cm from the reef, thus ensuring that a frame size of 0,5 x 0,5 m was filmed. The photography was undertaken at right angles to the reef and transects were filmed in a straight line within a depth contour or zone of the reef by a SCUBA diver swimming at a velocity of ±0,25 $m.s^{-1}$. The number of video transects filmed on each reef is presented in Table 4.1.

Table 4.1 Survey dates and number of video transects (VT), fish belt transects (BT; 250 m^2) and point counts (PC; 154m^2) undertaken on each reef. Cr=Creche; KL=Kev's Ledge; SM=Shallow Malongane; Te 1= Techo 1; Te 2=Techo 2 and Tx=Texas.

Reef	February 2001			August 2001			June 2002			December 2002			Total		
	VT	BT	PC	VT	BT	PC	VT	BT	PC	VT	BT	PC	VT	BT	PC
Cr	2	1	0	0	2	0	5	0	11	6	0	14	13	3	25
KL	2	1	0	0	4	0	5	0	9	2	0	16	9	3	27
SM	0	0	0	0	0	0	4	0	8	4	0	15	8	0	23
Te 1	2	2	0	0	0	0	0	0	0	4	0	14	6	2	14
Te 2	2	2	0	0	0	0	0	0	0	2	0	11	4	2	11
Tx	2	0	0	0	0	0	4	0	17	4	0	12	10	0	29

The Hi-8 footage was transferred to VHS tape for on-screen analysis, which was done by pausing the videotape in every new field. The life form categories (English *et al*. 1994; Appendix 4.1) of the substratum below four randomly placed points within each quadrant of the screen were recorded. Percent cover estimates were determined from the proportion of the total number of sampling points for each category.

4.2.2 Fish Counts

Reef fish diversity and abundance was estimated by SCUBA diving using visual techniques. Initially, fish counts were made using a modification of Brock's (1954) belt transect (BT; English *et al*. 1994) covering 250 m^2 (50 × 5 m). However, due to limited dive time, the Point Count (PC) technique was later adopted (Bohnsack & Bannerot 1986). Fishes encountered within a 7 m radius and up to 5 m above the substratum were counted. Altogether, 51 species groups in nine families were included in the surveys (Appendix 4.2). Each PC took three minutes. The number of randomly located BT and PC surveys (spaced 30-50 m apart) on each reef is presented in Table 4.1. Fish counts were made between 0700 and 1700 hours, as recommended by Halford & Thompson (1994), so as to avoid the diurnal-nocturnal fish community shift. Recess periods of ten minutes were allowed after diver entry, prior to fish counts, to allow the fishes to resume normal behaviour (Carpenter *et al*. 1981).

The fish species were divided into two groups: piscivorous (those whose main diet consists mainly of fish) and prey (common small- to medium-sized species that serve as food to piscivores) according to the literature (Hiatt & Strasburg 1960; Hobson 1974; Branch *et al*. 1995; van der Elst 1995; King 1997; Lieske & Myers 1999). The total length of piscivorous species was estimated and assigned to one of three size classes: small (5-30 cm), medium (31-50 cm) and large (> 51 cm). The abundance of prey species that manifested shoaling behaviour (i.e. *Chromis dimidiata* and *Pseudanthias squamipinnis*) was recorded in ten $\log_2$ abundance categories (1, 2, 3-4, 5-8, 9-16, 17-32, 33-64, 65-128, 129-256 and 257-512; Williams 1982; Öhman *et al*. 1997).

4.2.3 Data Analysis

Benthic data were arcsine-transformed prior to analysis. Differences in the percentage cover of benthic categories (soft, hard and total coral and rock and algae) were investigated between sites using one-way ANOVA. Data were checked for homoscedasticity in variance using Bartlett's chi-squared test. *Post hoc* multiple comparison tests (Unequal N HSD) were used to assess which reefs differed significantly. Cluster analysis (UPGMA - unweighted pair-group method using arithmetic averages) was performed on double square root-transformed data using the Bray-Curtis dissimilarity index. Only data collected in December 2002 were used in the cluster analysis and for comparison of the reefs because this was the only period in which the benthic communities could be surveyed on all the reefs due to logistical constraints (Table 4.1).

Fish data collected using both methods (belt transect and point counts) were standardized to an area of 1 m^2 and tested for similarity between the two methods (Man-Whitney *U*-test). No significant differences were found ($p < 0,05$) and the data were pooled. The Kruskal-Wallis ANOVA by ranks test was used to test for differences in fish density (i.e. number of individuals or the mid point of abundance categories) and other parameters pertaining to reef fish distribution and abundance between reefs. Non-parametric, *post hoc* multiple comparison tests were performed to assess which reefs had significantly different fish communities.

Benthic (arcsine-transformed) and fish (double square-root transformed) data were also analysed using a nested ANOVA procedure. Spearman rank correlation tests were used to analyse the relationship between soft and hard coral cover and between the fish communities. Differences in benthic community structure were further studied by means of ANOSIM (analysis of similarities) and SIMPER (similarity percentages) routines (Clarke & Warwick 1994).

All univariate tests were performed according to Zar (1999) using a Statistica 6.0 software package (StatSoft 2001). The ANOSIM and SIMPER routines were performed using the PRIMER software developed by the Plymouth Marine Laboratory (Car 1997).

4.3 RESULTS

4.3.1 Benthic Communities

Multivariate Analysis

Significant differences in benthic community structure (ANOSIM, R = 0,72; $p < 0,05$) were found. The cluster analysis performed on the benthic data (Figure 4.1) identified 3 groups of reefs at a dissimilar level of 20% (80% similarity): group I comprised Creche and Kev's Ledge; group II includes Techo 1, Shallow Malongane and Texas; and group III, consisted solely of Techo 2. The dominant benthic categories and those responsible for the separation into the groups are given in Table 4.2.

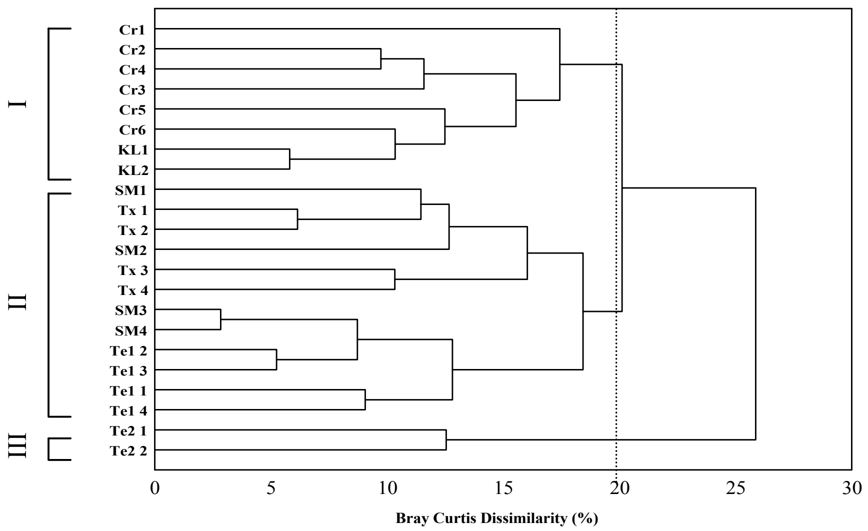


Figure 4.1 Clustering (UPGMA) of reefs obtained by classification of benthic data collected in December 2002. The Bray-Curtis dissimilarity index was applied to double square-root transformed data. Cr=Creche; KL=Kev's Ledge; SM=Shallow Malongane; Te 1=Techo 1; Te 2=Techo 2; Tx=Texas.

Table 4.2 Benthic categories causing within group similarity and between group dissimilarity resulting from the SIMPER (similarity of percentages) procedure. The benthic categories are listed in descending order according to their percentage contribution to average Bray-Curtis similarity within groups or dissimilarity between groups. Percentages are cumulative values for contribution to average Bray-Curtis similarity or dissimilarity.

Group I (Average similarity = 85,52%)		Differences between Groups I & II (Average dissimilarity = 20,11%)	
Rock and algae	22,52%	*Acropora* branching	19,54%
Soft corals	43,05%	Dead coral and algae	31,89%
Encrusting hard corals	58,45%	*Acropora* tabular	44,14%
Massive hard corals	70,40%	Sand	54,21%
Acropora tabular	81,67%	Rubble	62,04%
Group II (Average similarity = 84,48%)		**Differences between Groups I & III (Average dissimilarity = 29,22%)**	
Soft corals	21,80%	Foliose hard coral	15,09%
Rock and algae	41,23%	Rubble	28,26%
Encrusting hard corals	53,61%	*Acropora* branching	39,34%
Acropora branching	65,82%	Dead coral and algae	49,70%
Massive hard corals	76,47%	*Acropora* tabular	59,01%
Group III (Average similarity = 87,45%)		**Differences between Groups II & III (Average dissimilarity = 23,64%)**	
Due to the small number of samples in this group (N=2), the SIMPER procedure failed to discriminate within-group similarities		Foliose hard coral	19,74%
		Mushroom hard coral	30,85%
		Rubble	41,25%
		Dead coral and algae	50,38%
		Encrusting hard coral	58,87%

Groups I (Creche and Kev's Ledge) and II (Shallow Malongane, Techo 1 and Texas) were the most similar (average similarity 79,89; Table 4.2) and shared four of the benthic categories: soft corals, rock and algae, encrusting and massive hard corals. The benthic categories contributing to the separation of these two groups were branching and tabular *Acropora*, dead coral and algae, and sand, which accounted for more than 50% of the dissimilarity between these two groups (20,11%). Group III (Techo 2) was characterised by foliose and mushroom hard corals, which occurred nowhere else (Tables 4.2 and 4.3).

Table 4.3 Hard coral sub-categories on each of the study reefs expressed as percentage cover of the area surveyed in December 2002. Numbers in brackets = standard error.

Reef	Cr	KL	SM	Te 1	Te 2	Tx
Acropora branching	0,4 (0,1)	0,4 (0,2)	13,0 (0,7)	4,9 (0,5)	7,2 (1,2)	6,7 (0,4)
Acropora tabular	4,3 (0,2)	1,6 (0,2)	0,6 (0,2)	2,8 (0,3)	0,6 (0,4)	0,5 (0,2)
Coral branching	0,2 (0,1)	0,3 (0,0)	0,0 (0,0)	0,1 (0,1)	0,1 (0,1)	0,2 (0,1)
Coral encrusting	12,3 (0,3)	9,5 (1,3)	3,6 (0,3)	10,7 (0,6)	23,5 (1,3)	5,5 (0,2)
Coral foliose	0,1 (0,1)	0,0 (0,0)	0,0 (0,0)	0,0 (0,0)	5,3 (0,9)	0,0 (0,0)
Coral massive	4,7 (0,2)	2,8 (0,7)	4,9 (0,4)	5,4 (0,4)	3,4 (0,1)	2,2 (0,3)
Coral mushroom	0,0 (0,0)	0,0 (0,0)	0,0 (0,0)	0,0 (0,0)	0,5 (0,2)	0,0 (0,0)
Coral submassive	0,0 (0,0)	0,0 (0,0)	0,1 (0,1)	0,0 (0,0)	0,8 (0,5)	0,0 (0,0
Total hard coral	22,0	14,6	22,2	23,9	41,4	15,1

The reef groups identified by multivariate analysis were further tested for differences in benthic characteristics (i.e. percentage cover of hard, soft and total coral and rock and algae cover). All of the groups differed significantly with regard to these benthic parameters (nested ANOVA, hard and soft corals, $p < 0,005$; total coral and rock and algae cover, $p < 0,001$; Appendix 4.3).

Univariate Analysis

Soft corals were, throughout the study, the dominant benthic biota on most of the reefs, the exceptions being Techo 1 and Techo 2. In fact, soft corals were always dominant on Creche, Kev's Ledge, Shallow Malongane and Texas while on Techo 1 and Techo 2 temporal shifts in dominance were observed. In February 2001, soft corals comprised about 30% of the cover on Techo 1 and rose to more than 45% in December 2002. The opposite was observed on Techo 2, the soft coral cover decreasing from 50,4% in February 2001 to less than 30% in December 2002 (Figure 4.2).

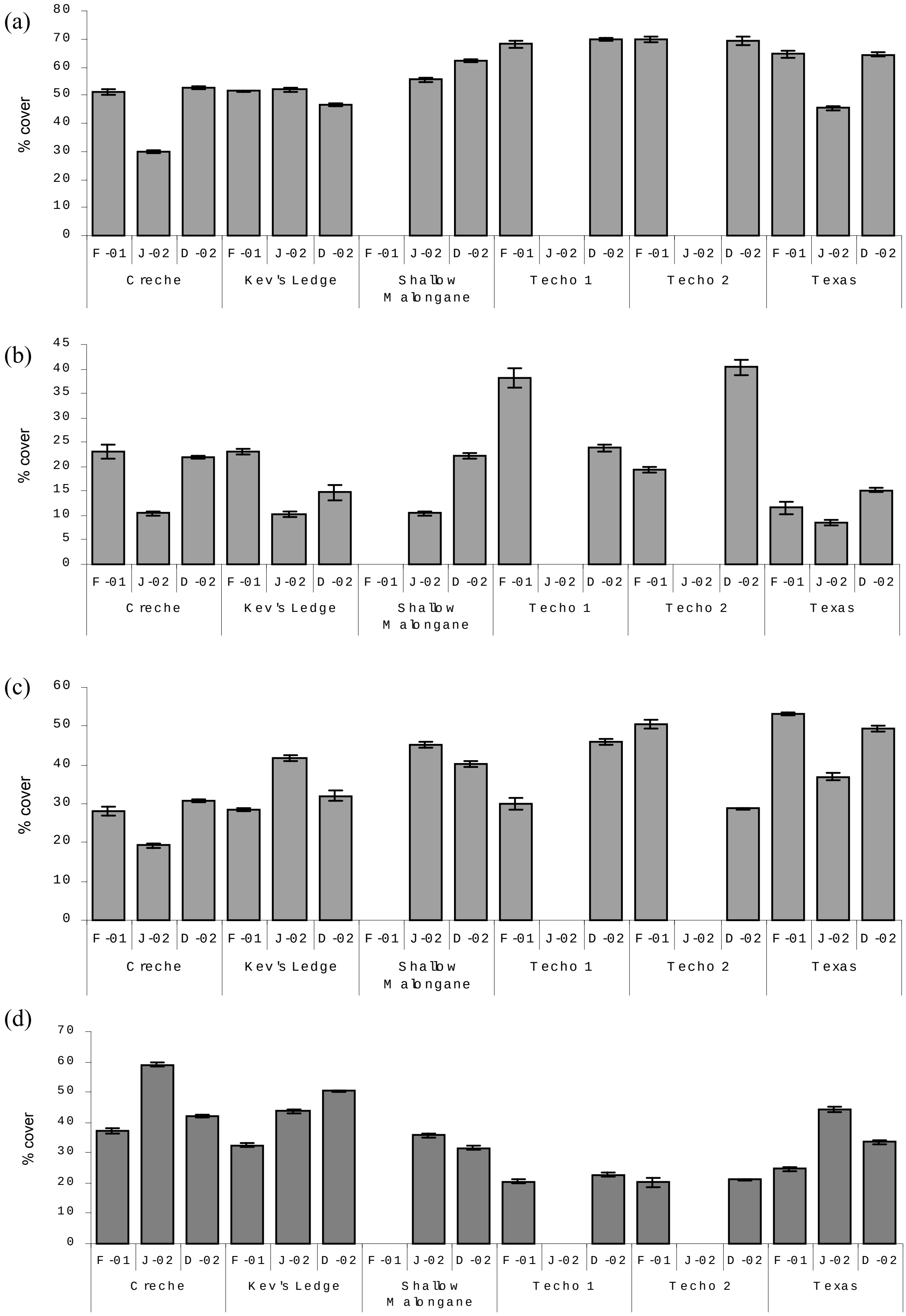


Figure 4.2 Variation in major benthic categories during the study period (bars = standard error); (a)= total coral cover; (b)=hard coral cover; (c)=soft coral cover=; and (d)=rock and algae cover. The sampling dates were F-01=February 2001; J-02=June 2002 and D-02=December 2002.

A comparison of the percentage soft coral cover on the reefs (December 2002 data only) revealed that they varied significantly (One-way ANOVA, $p < 0{,}05$). A multiple comparison *post hoc* test (Unequal N HSD) revealed that the soft coral cover on Creche and Texas were responsible for the observed difference between the reefs.

A significant negative correlation was found between soft and hard coral cover (Spearman rank correlation, $R_s = -0{,}599$, $p < 0{,}005$). A general pattern that emerged was that transects dominated by soft corals (say > 35% cover) had less than 20 % hard coral cover. The inverse was also true: areas with high hard coral cover had a much lower soft coral cover (Figure 4.3). Hard coral cover was consistently higher than soft coral cover on deeper reefs (Figure 4.2). Techo 1 (February 2001) and Techo 2 (December 2002) thus had higher hard coral cover. The hard coral cover differed significantly between reefs (One-way ANOVA, $p < 0{,}01$); *post hoc* multiple comparisons identified the following pairs of reefs as being significantly different in this regard: Techo 2 and Kev's Ledge as well as Techo 2 and Texas.

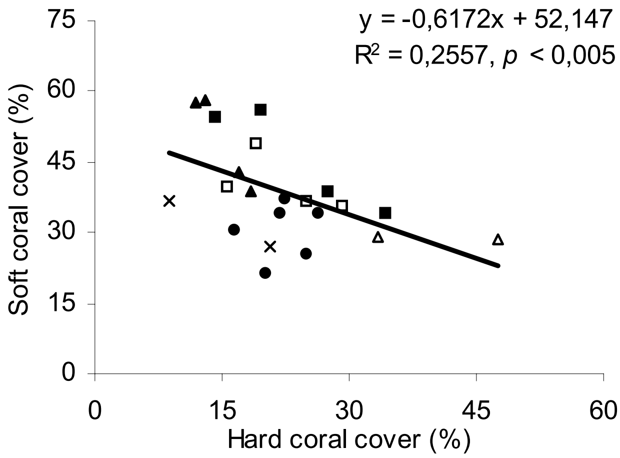


Figure 4.3 Correlation between soft and hard coral cover on the study reefs. Each point represents a video transect collected in December 2000. ●=Creche; x=Kev's Ledge; □=Shallow Malongane; ■=Techo 1; △=Techo 2 and □=Texas.

The total percentage cover of corals was significantly different between the reefs (One-way ANOVA, $p < 0{,}005$). The Unequal N HSD *post hoc* test indicated that the following reefs were significantly different: Kev's Ledge and Techo 1; Kev's Ledge and Techo 2 and Creche and Techo 1. The two Techo reefs had more coral cover when compared to the other reefs (with values > 65%), while Creche (~ 30% in June 2002) and Texas (45% in June 2002) had the lowest values for total coral cover (Figure 4.2).

Encrusting and massive life forms were the most important hard coral sub-categories on the reefs, contributing, for instance, as much as 77% of the total hard coral cover on Creche (Table 4.3). Branching *Acropora* was also an important sub-category at specific sites (Shallow Malongane, Techo 2 and Texas), contributing e.g. almost 60% of the total hard coral cover at Shallow Malongane (Table 4.3).

There was a similar inverse relationship between the rock and algae category and total coral cover: higher values were found in the former wherever the total coral cover was low (e.g. Creche and Texas in June 2002; Figure 4.2). Creche and Kev's Ledge were significantly different from Techo 1 and Techo 2 in this regard (One-way ANOVA, $p < 0{,}001$; Figure 4.2).

4.3.2 Fish Communities

Total Fish Density and Diversity

In the present study, a total of 89 new fish species were recorded for the area, including eight families not previously recorded (Appendix 4.4), bringing the total species count for the southern Mozambican reefs to 239. Total fish density and diversity varied between reefs for both predator and prey species ($p < 0{,}001$, Kruskal-Wallis ANOVA by Ranks; Figure 4.4). Kev's Ledge had the highest total fish density (1,1 fish.m^{-2}). This reef had five times more fish than Techo 1, where the lowest density was observed (0,2 fish.m^{-2}; Figure 4.4a). A non-parametric multiple comparison test revealed that Creche had significantly more fish than Techo 1 and Texas, while Kev's Ledge had significantly more fish than Techo 1, Techo 2 and Texas. Shallow Malongane was also statistically different to Techo 1 (Figure 4.4 a). The average total fish diversity (average number of species recorded per transect) was generally around 0,07 species.m^{-2} (Figure 4.4 b). Creche had the highest total fish diversity (0,08 fish.m^{-2}) while Shallow Malongane (0,02 species.m^{-2}) had the lowest ($p < 0{,}05$; Kruskal-Wallis non-parametric multiple comparison test).

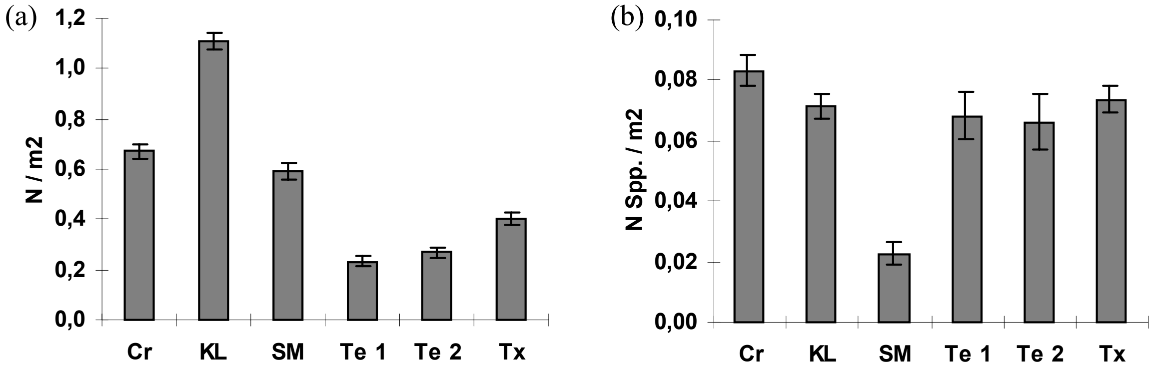


Figure 4.4 Average fish density (a) and fish diversity (b) on each of the study reefs. Bars=standard error. Cr=Creche; KL=Kev's Ledge; SM=Shallow Malongane; Te 1=Techo 1; Te 2=Techo 2; Tx=Texas.

Piscivore Density, Diversity and Size Structure

Total piscivore density varied significantly within and between the reefs (Kruskal-Wallis ANOVA, $p < 0,05$; Figure 4.5a). Kev's Ledge (0,023 fish.m^{-2}) had by far the highest density of piscivores, followed by Shallow Malongane and Creche (0,015 and 0,013 fish.m^{-2}). The rest of the reefs had piscivore densities below 0,010 fish.m^{-2}. The non-parametric *post hoc* multiple comparison test failed to identify significant differences between pairs of reefs, as the variability in the piscivore density was considerable.

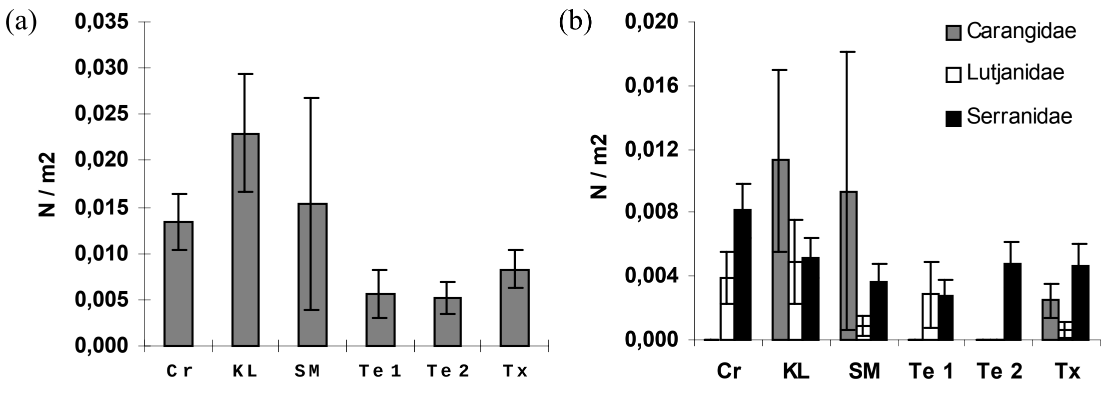


Figure 4.5 Average densities of piscivorous fish (a) and piscivorous fish families (b) on each of the study reefs. Bars=standard error. Cr=Creche; KL=Kev's Ledge; SM=Shallow Malongane; Te 1=Techo 1; Te 2=Techo 2; Tx=Texas.

Rockcods (Serranidae) were commonly observed on all the reefs (Figure 4.5b), being particularly abundant on Creche, but there were no significant differences between reefs (Kruskal-Wallis ANOVA, $p > 0,05$). Snappers (Lutjanidae) were not as common, with none recorded on Techo 2, resulting in great variability within and between reefs. No significant differences were detected between reefs (Kruskal-Wallis ANOVA, $p > 0,05$). Kingfishes were observed only on three of the reefs (Kev's Ledge, Shallow Malongane and Texas). They were observed either in large shoals or singly in mid-water, resulting in great variability between the reefs. The reefs were significantly different in terms of kingfish density (Kruskal-Wallis ANOVA, $p < 0,005$) but the non-parametric *post hoc* test failed to discriminate between these differences.

Creche and Kev's Ledge had higher piscivore diversity (0,076 and 0,074 species.m^{-2} respectively) when compared to the other reefs (Figure 4.6). However, this difference was not statistically significant (Kruskal-Wallis ANOVA, $p > 0,05$).

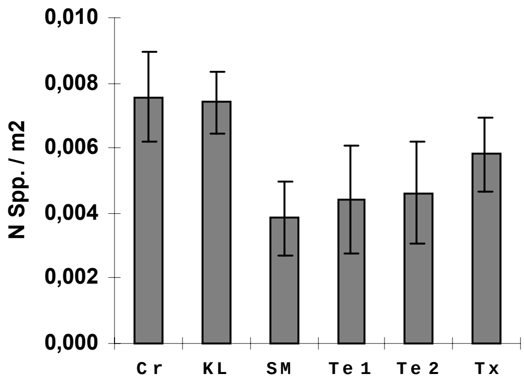


Figure 4.6 Average diversity of the total piscivores fish on each of the study reefs. Bars=standard error. Cr=Creche; KL=Kev's Ledge; SM=Shallow Malongane; Te 1=Techo 1; Te 2=Techo 2; Tx=Texas.

The size class structure of the piscivorous fish is presented in Figure 4.7. There were significant differences between reefs in terms of the density of small (5-30 cm) piscivorous fish (Kruskal-Wallis ANOVA, $p < 0,01$), although a non-parametric *post hoc* multiple comparison test failed to establish significant differences between the reefs. Kev's Ledge and Techo 2 had the highest densities of small piscivores (predominantly rockcods).

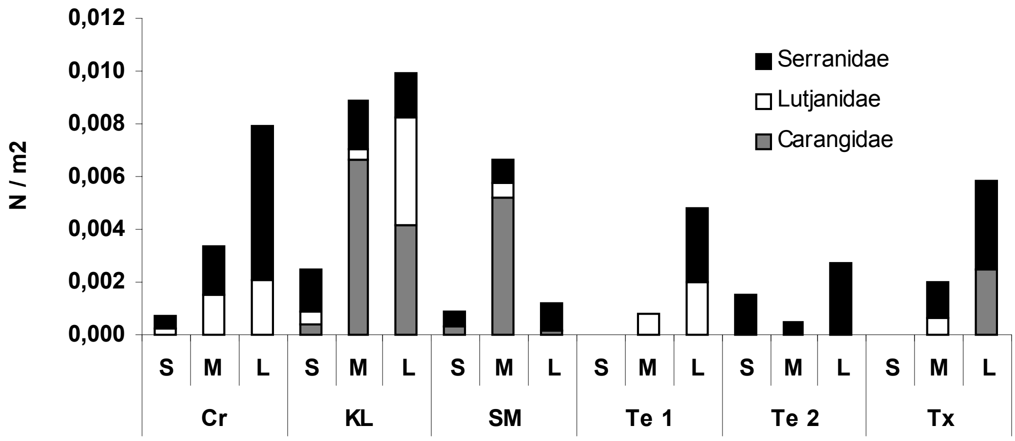


Figure 4.7 Size class structure of piscivorous families on each of the study reefs. Bars=standard error. Cr=Creche; KL=Kev's Ledge; SM=Shallow Malongane; Te 1=Techo 1; Te 2=Techo 2; Tx=Texas.

The density of medium-sized (31-50 cm) piscivorous fish was highly variable. Kev's Ledge and Shallow Malongane had the highest density of mid-sized piscivores (mainly kingfishes), which contrasted with the low values observed on Techo 1, Techo 2 and Texas. These differences, however, were not significant (Kruskal-Wallis ANOVA, $p > 0{,}05$). Large fish (>51 cm) were the dominant size class on almost all of the reefs except on Shallow Malongane. Kev's Ledge and Creche had the highest densities of large piscivores. Most of these were rockcods, except on Kev's Ledge where the contribution of other piscivorous families was higher.

Prey Density and Diversity

The reefs differed significantly in their density of fish prey species (Kruskal-Wallis ANOVA, $p < 0{,}001$). Kev's Ledge had the highest density (1,1 fish.m^{-2}), while Techo 1 had the lowest (0,2 fish.m^{-2}; Figure 4.8 a). The following reefs were paired by non-parametric *post hoc* multiple comparison tests as being significantly different ($p < 0{,}05$) in their total prey density: Creche had a higher density than Techo 1 and Texas; Kev's Ledge was higher than Techo 1, Techo 2 and Texas; and finally Shallow Malongane was higher than Techo 1.

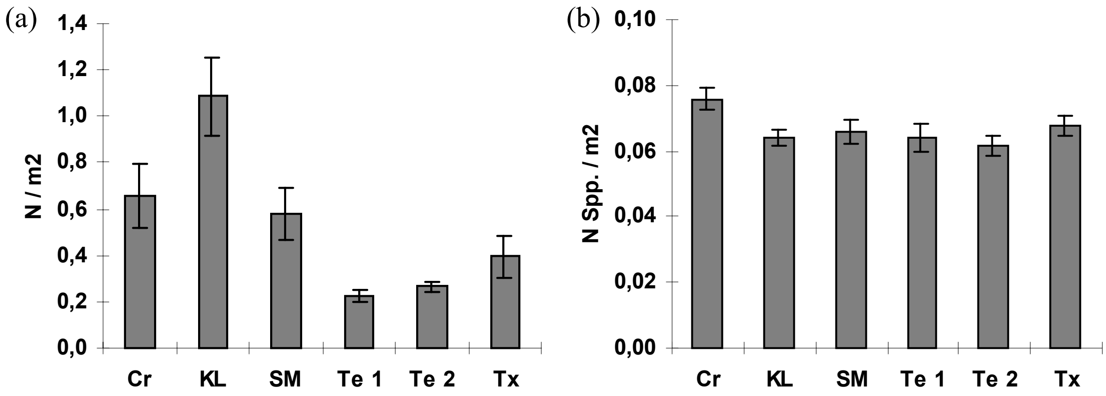


Figure 4.8 Average density of fish prey species (a) and diversity (b) on each of the study reefs. Bars = standard error. Cr=Creche; KL=Kev's Ledge; SM=Shallow Malongane; Te 1=Techo 1; Te 2=Techo 2; Tx=Texas.

The fish prey species diversity (Figure 4.8 b) was found to be statistically different between reefs (Kruskall-Wallis ANOVA, p = 0,047) although further testing with non-parametric multiple comparison tests failed to reveal which reefs differed significantly. The mean number of fish prey species was around 0,064 species.m^{-2} on all reefs, Creche being the exception with 0,076 species.m^{-2}. At family level, fish prey density also differed between reefs (Figure 4.9). Kruskal-Wallis ANOVA tests were performed on each family and significant differences were found in all but butterflyfishes (Chaetodontidae) and emperors (Lethrinidae). Butterflyfishes were common on all the reefs and their density showed little variation within and between reefs while emperors (Lethrinidae) varied considerably, being absent on Techo 2. Kev's Ledge had a significantly lower density of wrasses (Labridae) when compared to the other reefs (Kruskal-Wallis ANOVA; p < 0,0005; Figure 4.9; Table 4.4).

Angelfish density (Pomacanthidae) was significant higher on Techo 2 when compared to Kev's Ledge, Shallow Malongane and Texas (p < 0,0001, Kruskal-Wallis ANOVA; Figure 4.9). The last two reefs were also different compared to Creche. The damselfish family (Pomacentridae represented solely by the chocolate dip, *Chromis dimidiata*) were more abundant on Shallow Malongane and less so on Techo 1 and Techo 2. Finally, Creche and Kev's Ledge had significantly more prey fish of the family Serranidae (sea goldies - *Pseudanthias squamipinnis*) when compared to all the other reefs (Figure 4.9; Table 4.4).

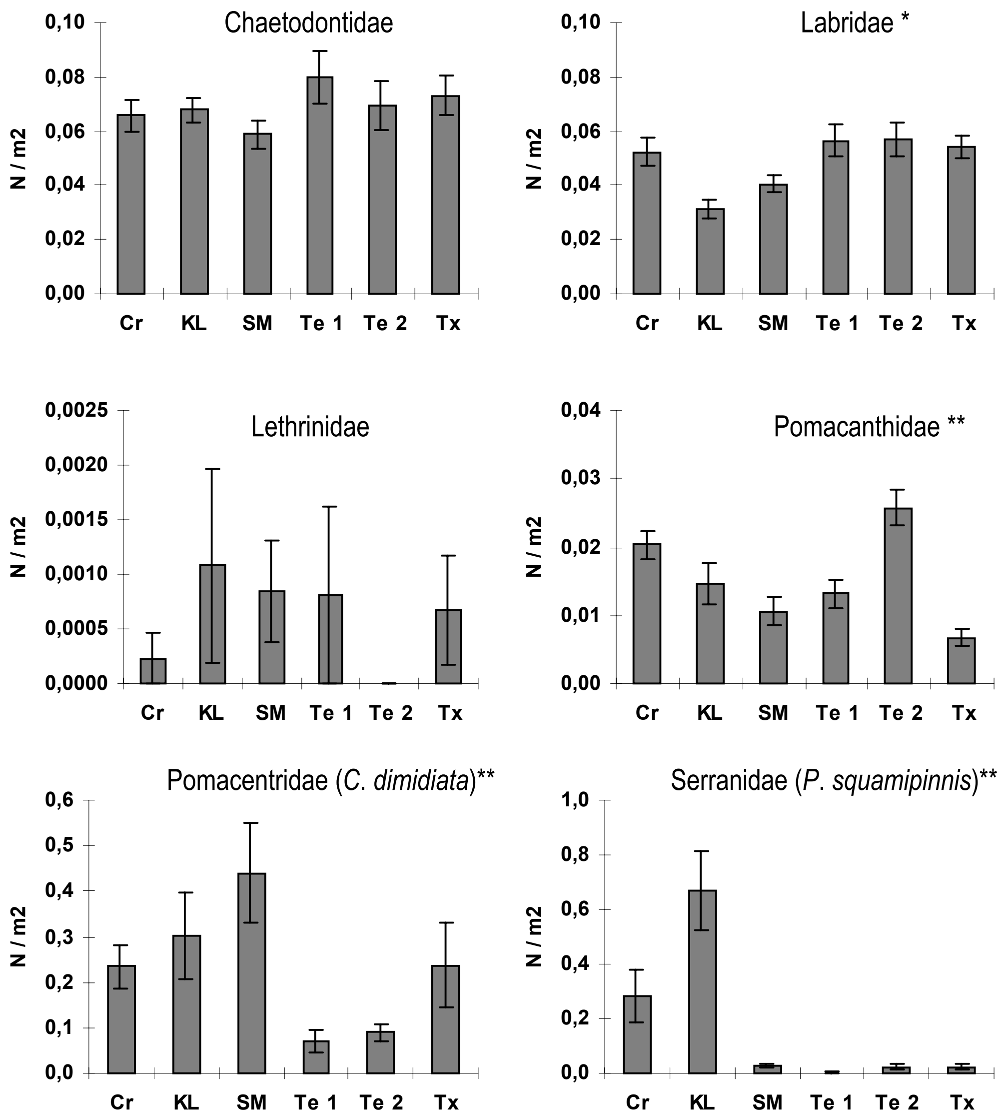


Figure 4.9 Average densities of fish prey families on each of the study reefs. Bars=standard error. Cr=Creche; KL=Kev's Ledge; SM=Shallow Malongane; Te 1=Techo 1; Te 2=Techo 2; Tx=Texas. Significant differences between reefs are indicated as * $p < 0,0005$; ** $p < 0,0001$; Kruskal-Wallis ANOVA.

Table 4.4 Results of the non-parametric *post hoc* multiple comparison tests on fish prey family densities between reefs (all significantly different at $p < 0,05$).

Family	Reefs
Labridae	Kev's Ledge (Creche, Techo 1, Techo 2, Texas)
Pomacanthidae	Creche (Shallow Malongane, Texas) Techo 2 (Kev's Ledge, Shallow Malongane, Texas)
Pomacentridae	Shallow Malongane (Techo 1, Techo 2, Texas) Creche (Techo 1)
Serranidae	Creche (Shallow Malongane, Techo 1, Texas) Kev's Ledge (Shallow Malongane, Techo 1, Techo 2, Texas)

Within the fish prey species, the butterflyfish regarded as being strictly corallivores (i.e. *Chaetodon meyeri*, *C. trifascialis*, *C. trifasciatus* and *C. xanthocephalus*) were analysed in more detail (Figure 4.10). Corallivore density was highly variable both within and between reefs, being generally more abundant on reefs that had higher hard coral cover. Techo 1 and Techo 2 were, respectively, the reefs with the highest and lowest density estimates. The differences were not significant (Kruskal-Wallis ANOVA, $p > 0,05$).

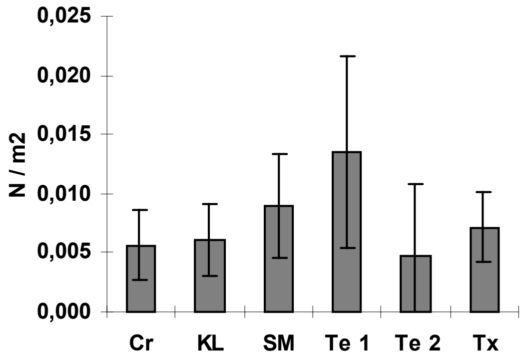


Figure 4.10 Average corallivore density on each of the study reefs. Bars=standard error. Cr=Creche; KL=Kev's Ledge; SM=Shallow Malongane; Te 1=Techo 1; Te 2=Techo 2; Tx=Texas.

Analysis of Fish Communities within Reef Groups

The groups of fish communities identified by multivariate analysis were tested for differences between reefs, the results of which are presented in Appendix 4.5 and summarized in Table 4.5. Total fish density and diversity were significantly different between reef groups (nested ANOVA, $p < 0,0001$). Piscivore parameters were also different (except the densities of rockcods - Serranidae and kingfishes - Carangidae). The total prey density was significantly higher in Group 1 (Creche and Kev's Ledge; $p < 0,05$). The only fish prey parameters that were not significantly different between reef groups were the densities of butterflyfishes (Chaetodontidae), emperors (Lethrinidae) and damselfishes (Pomacentridae).

Table 4.5 Summary of results of nested ANOVA performed on fish data obtained on southern Mozambican reefs after multivariate analysis. n.s.- not significant.

Fish Parameter	Significance of differences among reef groups
All species	
Total fish density	$p < 0,0001$
Total fish diversity	$p < 0,0001$
Piscivores	
Total piscivore density	$p < 0,05$
Total piscivore diversity	$p < 0,05$
Carangid density	n.s
Lutjanid density	$p < 0,05$
Serranid density	n.s
Prey	
Total prey density	$p < 0,0001$
Total prey diversity	n.s
Corallivore density	$p < 0,05$
Chaetodontid density	n.s
Labrid density	$p < 0,01$
Lethrinid density	n.s
Pomacanthid density	$p < 0,005$
Pomacentrid density	n.s
Serranid density	$p < 0,0001$

4.4 DISCUSSION

4.4.1 Benthic Communities

The reefs of southern Mozambique resemble the South African reefs to the south and are different from true coral reefs. They lack the composition and morphological features of true coral reefs (Riegl *et al*. 1995; Schleyer 1995, 1999a; Schleyer & Celliers 2000). As noted by Riegl *et al*. (1995), these reefs are very flat and uniform, changing along a gentle depth gradient. Despite this, these authors found different communities on the reefs and in different reef zones. The results of the present study, using multi- and univariate analysis, also revealed different benthic communities on the southern Mozambican reefs. Three main reef groups were identified based on their benthic composition, the amount of hard corals (*Acropora* branching and foliose hard corals) being the most important benthic categories differentiating the reefs (Table 4.3). In general, soft corals were most common and abundant on all the reefs, leaving the hard corals in a minor yet differentiating role. This proved especially the case with the foliose hard corals, which occurred in abundance on Techo 2 (Group 3), thus acting as a 'perfect indicator' (Field *et al*. 1982).

Soft corals were the dominant biota on most of the reefs throughout the study period. This is in accordance with the results published by Robertson *et al*. (1996) working in the same area (southern Mozambique) and Riegl *et al*. (1995), Riegl & Riegl (1996) and Walters & Samways (2001) working on the Sodwana reefs (South Africa). Notably, soft corals were dominant on reefs that were shallow and exposed to swell-generated turbulence (Creche, Texas and Shallow Malongane; Figures 4.2 and 4.3). Similar findings were reported for exposed high-energy reefs in Zanzibar (Bergman & Öhman 2001), the Great Barrier Reef (Dinesen 1983; van Woesik & Done 1997), including Lord Howe Island (Harriot *et al*. 1995), and Sodwana (Riegl & Cook 1995; Riegl *et al*. 1995; Riegl & Riegl 1996; Schleyer & Celliers in press).

According to Schleyer (1999a), the unusual dominance of soft corals on the southern African reefs may be attributed to the prevailing low to moderate swell-generated turbulence and sedimentation in the area, of which soft corals are more tolerant (Dai 1991; Fabricius 1997; Schleyer & Celliers in press). In fact, an experimental study conducted by Lin & Dai (1996) showed that different soft coral species of the genus *Sarcophyton* employ different morphological, mechanical and behavioural properties to reduce water drag, enabling them to colonise habitats with relatively strong currents and water turbulence. On the other hand, hard corals (especially the branching and foliaceous life forms) are more sensitive to turbulence and sedimentation, which restricts their large-scale occurrence and dominance in southern Mozambique to deeper areas (Schleyer 1999a).

The benthic categories proved highly variable during the study (Figure 4.2), especially on Creche and Texas where radical changes in benthic cover were observed when the coral cover fell and was temporarily replaced by rock and algae. According to INAM (Instituto Nacional de Metereologia - National Institute of Meteorology), there were approximately 440 cyclones and tropical depressions along the Mozambique coast from 1951-1994. Most of these occurred in the summer months between November and April, with an average of 10 per year. During the study period, in late April 2002, a particularly strong storm with 6-7 m swells hit the southern Mozambique region. According to local dive operators (J.-J. Serraventoso 2002, Malongane Holiday Resort, pers. comm.), this had a considerable effect on the coral communities and large branching and tabular *Acropora* colonies were dislodged and overturned. The storm probably contributed to the changes in benthic cover in June 2002. Coral damage by storms and cyclones occurs primarily as a result of the mechanical forces exerted by the storm-induced swells and currents (Harmelin-Vivien 1994). Indirect mechanical damage caused by rolling debris, especially massive coral colonies, abrasion by sand blasting and burial under new sediment also affects the coral communities, especially those on shallow reefs (revisions by Endean 1976; Harmelin-Vivien 1994). However, on the other hand, one must bear in mind that the observed patters may also result from sampling variation.

Techo 1 and Techo 2 are considered the best reefs in the region, both in extent and condition (M. H. Schleyer 2003, ORI, pers. comm.). In the survey carried out in 1996, Robertson *et al*. (1996) reported a high coral cover on the Techobanine reefs, despite being subjected to the ravages of crown-of-thorns starfish *Acanthaster planci* (Schleyer 1998). For example, Robertson *et al*. (1996) recorded a total coral cover of 82 % (53% hard coral and 29% soft coral cover) on Techo 1. These figures compare well with the data collected in February 2001 (Figure 4.2). It seems that the April 2002 storm also had an effect on the benthic communities of this reef, causing a dominance shift from hard to soft corals. On the other hand, Techo 2, a deeper reef, seemed less affected by the storm and the soft corals were displaced to some extent by hard corals. These results and other anecdotal records suggest that this reef is recovering from previous disturbances such as the 1998 bleaching and a crown-of-thorns starfish outbreak (Schleyer 1998) but at a slower recovery rate than the successional path of disturbance:soft corals:hard corals already mentioned for the other reefs (Kev's Ledge and Shallow Malongane). Further monitoring is thus needed to measure succession changes and community shifts in the biota on this reef, which could serve as a model for other marginal reefs subjected to similar environmental conditions, along the southern Mozambican coast.

4.4.2 Fish Communities

The fish fauna in the area is composed of widely distributed Indo-Pacific species (van der Elst 1988; Chater *et al*. 1995). New records were added during the present study, bringing the total of fish species to 239 in 71 families (Appendix 4.4). The previous total was 150 (Robertson *et al*. 1996). This number is expected to increase to that closer to the 399 species recorded further south on the South African reefs (Chater *et al*. 1995) in subsequent surveys. The number of fish species occurring in southern Mozambique may actually be higher, given the decrease towards South Africa in species richness due to the subtropical subtraction effect (Turpie *et al*. 2000).

No differentiation of fish communities within reef zones could be made in the present study. A more appropriate sampling design involving temporal replication was planned but could not be implemented during this study due to logistical constraints. These two factors certainly contributed to the high variability found in the fish community parameters that were studied.

Reef fish communities commonly show zonation patterns, with a varying number of zones and habitats on different reefs (Öhman *et al*. 1997) that are highly variable in time (Sale 1980, 1991).

The reef fish communities differed between reefs and reef groups. This is not surprising, as the reefs themselves were clearly different in substratum composition and structure. In general, reef groups identified through multivariate analysis based on their benthic structure had similar fish communities (e.g Creche and Kev's Ledge). Reef fishes are strongly influenced by habitat features such as reef rugosity (= habitat complexity), substratum composition diversity, live coral, and depth, among others (e.g. Bell & Galzin 1984; Carpenter *et al*. 1981; Chabanet *et al*. 1997; Friedlander & Parrish 1998; Luckhurst & Luckhurst 1978; McClanahan 1994; McCormick 1994; Öhman & Rajasuriya 1998; Öhman 1999; Pereira 2000a). It would thus be expected that fish communities would differ among reefs. According to the review by Williams (1991), reefs may have different fish communities due to a distinct combination of habitat characteristics. The flatness of Shallow Malongane, for instance, could probably explain the low fish diversity recorded there (Figures 4.4b and 4.6). Elsewhere, reef fish diversity has been reported to increase with reef rugosity (Luckhurst & Luckhurst 1978; McClanahan 1994; McCormick 1994, Öhman & Rajasuriya 1998; Pereira 2000a).

It has been proposed that fishes of the butterflyfish family (Chaetodontidae) may be used as biological indicators of disturbance on coral reefs due to their corallivorous feeding habitats (Reese 1981; Öhman *et al*. 1998). Despite their considerable variability (Figure 4.10), corallivorous butterflyfish were typically more abundant on reefs with higher a percentage cover of hard corals, suggesting that they may also be used in Southern Mozambique as indicators of reef condition (Pereira 2000a). Further research is needed to refine this assessment and establish which species would be the best indicators.

Creche and Kev's Ledge consistently had higher densities of total fish, prey and piscivorous species (Figures 4.4a, 4.5a and 4.8a), the sea goldies (*Pseudanthias squamipinnis*) being particularly abundant on these reefs (Figure 4.9). Although the difference in depth between the two reefs is considerable, they were found to be quite similar in substratum and morphology (Figure 4.1, Table 4.3). A possible reason for the higher densities of fish on these reefs may be attributable to similarities in their extent and function. They are both surrounded by sand, and in the case of Creche, the nearest reef is more than 1 km away. It appears that the reefs are concentrating small fish; hence the name Creche (nursery in Portuguese), and larger predatory species come to feed on the smaller prey species. The main evidence suggesting this is that:

- Positive significant correlations (Spearman rank correlation test, $p < 0,05$) were found between total prey and piscivore density on these reefs.
- On more than one occasion, blacktip sharks (*Carcharinus wheelerii*), potato bass (*Epinephelus tukula*), barracudas (*Sphyraena* spp.) and king mackerel (*Scomberomorus commerson*) were seen at Creche and Kev's Ledge. These species were seen nowhere else.
- The piscivorous fish distribution pattern on the reefs was different. On the one hand, the more site-specific and territorial rockcod family (Serranidae) (Heemstra & Randall 1993; Jory & Iversen 1989; Sadovy & Eklund 1999; Samoilys 1997) was found on almost all reefs in similar densities while, on the other hand, pelagic and semi-pelagic families, i.e. kingfishes (Carangidae) and snappers (Lutjanidae), were observed cruising past the reefs, thus using the area as a feeding ground.
- Finally, the size structure of the piscivorous species (Figure 4.7) revealed that Creche and Kev's Ledge had higher densities of large-sized piscivores.

One of the main processes regulating the structure of reef fish communities is predation (Hixon 1991; Hixon & Beets 1993; Carr & Hixon 1995; Beets 1997). No clear-cut picture could be drawn from the present study on the role that predators may be playing in structuring the fish communities in southern Mozambique. Generally, reefs with a higher total density of piscivorous species and large-sized piscivores also had a high species richness in prey species (Figure 4.5a, 4.7 and 4.8b), thus, suggesting that predation may be influencing the diversity in fish prey communities. This needs a more detailed study as no statistical significance was found in the results. Again, the high variation in fish data undoubtedly influenced the findings.

Reefs furthest away from the Ponta Malongane launching site (Techo 1 and Techo 2) had significantly less piscivorous fish (Figure 4.5), especially those families subjected to high recreational fishing pressure such as carangids and lutjanids (David *et al*. 1996). This can be explained by the fact that these reefs are more heavily fished than reefs closer to Ponta Malongane. Increased mortality and reduced fish densities are an expected consequence of fishing either through direct targeting of predator species or the indirect effects of habitat degradation caused by destructive fishing techniques (Russ 1991). Illegal fishing by large industrial vessels has been reported to occur on the reefs in southern Mozambique (G. Beukes 2001, The Whaler–Ponta do Ouro, pers. comm.). In addition, skiboat angling and spear fishing activities are focused on these reefs, as the SCUBA diving traffic is concentrated on the reefs closer to Ponta Malongane. Recreational angling is an important attraction in the area (David *et al*. 1996) and illegal trawling a national issue; both definitely need stronger management and law enforcement, especially in view of the proposed new limits of the Maputo Especial Reserve (MER), which will incorporate the Techobanine reefs.

One may conclude that the reef fish community structure on the studied reefs is not affected by recreational diving at this stage but regulated rather by habitat characteristics of the reefs themselves. Interactions between species (predation) and disturbances such as fishing may also be important in structuring these communities. These and other factors known to influence reef fish community structure (i.e. recruitment and settlement, post-recruitment processes, availability of food and space) were not given attention during this study but need to be addressed to provide an understanding of the factors regulating the reef fish fauna in southern Mozambique.

CHAPTER 5

EFFECTS OF RECREATIONAL SCUBA DIVING AND THE SUSTAINABLE DIVING CAPACITY OF REEF COMMUNITIES IN SOUTHERN MOZAMBIQUE

5.1 INTRODUCTION

Compared to other anthropogenic impacts (e.g. pollution, over-fishing), the effects of recreational activities on coral reef areas, especially SCUBA diving, are the least documented in the literature (Tilmant 1987). Until very recently, SCUBA diving was generally perceived to be non-destructive and entirely compatible with the sustainable use of marine resources (Wells & Price 1992; Roberts & Harriott 1995; Harriott *et al*. 1997). For example, in a paper published in the late 1980s, Kinsey (1988) stated that '… it is clear that the chronic stress of non-extractive tourism alone is likely to be withstood by a normal coral reef system, for a very extended time, if not indefinitely'. That perception has gradually changed worldwide, as recreational SCUBA diving popularity has increased enormously and various popular dive sites have lost their attractiveness as reef degradation became evident (e.g. Ward 1990; Wells & Price 1992; Hawkins & Roberts 1993; Roberts & Harriott 1995).

SCUBA divers may disturb benthic reef communities in several ways. Reef areas dominated by branching and foliose corals are of particular concern as the fragility of their delicate skeleton makes them more susceptible to damage than other more massive coral forms (Hawkins & Roberts 1992; Riegl & Cook 1995; Rouphael & Inglis 1995). Direct damage includes trampling (Woodland & Hooper 1976; Liddle & Kay 1987; Liddle 1991; Hawkins & Roberts 1993; Rodgers & Cox 2003), coral abrasion and breakage due to poor buoyancy control (Chadwick-Furman 1997; Hawkins & Roberts 1992; Rouphael & Inglis 1995; Zakai & Chadwick-Furman 2002), and boat grounding and anchor damage (Davis 1977; Tilmant & Schmahl 1981; Tilmant 1987; Lutz 1997). Divers also disturb benthic communities by stirring up sediments, smothering corals and other sessile invertebrates (Rogers 1990). Studies conducted both in temperate and tropical areas have shown that SCUBA diving and divers may have detrimental effects on a wide range of sessile benthic communities including hard and soft reef corals (Chadwick-Furman 1997; Schleyer & Tomalin 2000; Zakai & Chadwick-Furman 2002), bryozoans (Sala *et al*. 1996; Garrabou *et al*. 1998), sponges and gorgonians (Roberts & Harriot 1995; Chadwick-Furman 1997) and kelp forests (Schaeffer & Foster 1998). Indirect damage to coral reefs includes pollution and development, causing the deterioration of water quality through increased sedimentation, turbidity and nutrient input (Johannes 1975; Hawkins & Roberts 1994) and increased fishing pressure (Tilmant 1987; van der Knaap 1993; Hawkins & Roberts 1994; Price *et al*. 1998).

Special attention has been paid to benthic communities in the great majority of studies on the effects of recreational diving and there has been a general perception that the effects of SCUBA diving on fish communities are minimal. One of the recreational activities that has raised some concern is fish feeding, an issue that has been surrounded by some controversy but little research. This popular activity may alter the natural composition of reef fish communities (Tratalos & Austin 2001), adversely affecting certain fish populations while favouring others. However, studies conducted by Sweatman (1996) and Hawkins *et al*. (1999) yielded no evidence to support this. The only concern pointed out by Cole (1994) and Hawkins *et al*. (1999) was that fish feeding could also change natural fish feeding behaviour causing them to behave aggressively toward divers in anticipation of food.

Beside fish feeding, no other SCUBA diving impacts on fish communities have been anticipated. Actually, some authors maintain that reef fishes perceive divers as passing clouds (Bohnsack 1998) and that their presence does not disturb or have any long-term effect on reef fish communities. However, anecdotal evidence from South African reefs suggests that SCUBA diving does affect reef fish communities (M. H. Schleyer 2001, ORI, pers. comm.). A shift in species composition and abundance of certain species with a decrease in large predators (e.g. barracudas, rockcods, etc.) and an increase in small planktivorous species, such as damselfishes has been observed. Thus, it is believed that divers are perceived as schools of large predators, ‘extra competition’, which drives the other predators away (M. H. Schleyer 2001, ORI, pers. comm.). In a study using hydro-acoustic techniques, Stanley & Wilson (1995) found that the mean density of fishes decreased by 60% around an oil rig when SCUBA divers were present and the size distribution of fishes also changed with the most abundant size classes and the larger specimens exhibiting the greatest avoidance and leaving the area.

Some of the potential factors that may cause fishes to avoid divers include (i) noise; (ii) the continuous release of air bubbles; (iii) the vivid colour patterns of wetsuits and other diving gear; (iv) the presence of "bulky" diving equipment; and (v) the behaviour of the divers themselves, i.e. rapid and jerky movements, and the tendency to attempt to touch and chase fish. All these factors may alter the natural feeding, social and reproductive behaviour of fishes, especially if the diving pressure is high, ultimately causing fish to abandon an area. Although many reef fishes are territorial, diel migrations from resting places to feeding areas have been reported in many species and distances travelled may range from a few meters to at least several kilometres, especially in the larger species (see review by Williams 1991). Following Stanley & Wilson's (1995) input and the fact that larger fish may secure larger territories and thus travel further, it is quite logical and acceptable to assume that larger fishes may abandon an area whenever the cumulative effect of disturbance (SCUBA diving) reaches an unbearable threshold.

The most used management tool for SCUBA diving is the concept of diving carrying capacity (Davis & Tisdell 1995; Hawkins & Roberts 1997), or the more recent concept of sustainable diving capacity (SDC) proposed by Schleyer & Tomalin (2000), which incorporates fisheries stock assessment concepts such as the precautionary approach (FAO 1995; Garcia 1996). Introduced in the mid 80s, the concept of carrying capacity for recreational diving has been advocated as a useful management tool (Dixon *et al*. 1993; Davis & Tisdell 1995; Hawkins & Roberts 1997; Schleyer & Tomalin 2000), especially for marine protected areas. It implies that there is some level of use (usually expressed as number of dives.year^{-1}.dive site^{-1}) below which the reef and its communities can cope with the amount of disturbance or stress, but above which degradation becomes evident and the reef starts losing its aesthetic appeal (Dixon *et al*. 1993; Davis & Tisdell 1995; Hawkins & Roberts 1997; Ammar 2001). Despite its limitations, especially its practical implementation, carrying capacity is still one the most popular management tools constituting the first step in establishing a management programme for SCUBA diving and recreational reef use.

Given the steady increase of recreational diving activity in southern Mozambican reefs during the last decade, there was concern (Bjerner & Johansson 2001; H. Motta 2001, WWF Mozambique, pers. comm.) that reef communities (both corals and fish) were stressed and the overall diving activity was reaching an unsustainable level. In this Chapter, the effects of recreational SCUBA diving in southern Mozambique are assessed, providing results on the underwater behaviour of SCUBA divers, and the relationship between SCUBA diving and coral and reef fish communities. An estimation of the SDC of the southern Mozambican reefs is provided.

5.2 MATERIALS AND METHODS

5.2.1 Underwater Behaviour of Recreational SCUBA Divers

Individual divers (n = 25) were followed by the author for 10 minutes and their behaviour in relation to the substrata was recorded following the methodology described by Harriot *et al.* (1997), Rouphael & Inglis (1995) and Zakai & Chadwick-Furman (2002). Quantitative observations were made on: (i) the number of times individual divers came into contact with the substratum and whether these contacts resulted in coral breakage, abrasion or sediment re-suspension; (ii) type of contact, whether it was caused by hand, knee, or diving gear; and (iii) the type of substratum (in the case of hard corals, the growth form of damaged coral colonies was also recorded). Divers were observed at a safe distance of 4-6 m so as not to influence their behaviour. In the pre-diving briefing, it was announced by the divemaster that the author would be doing some sort of 'marine biological research on the reef' and divers were generally not aware that they were the study subjects. Information on gender, number of logged dives and highest diving level attained was obtained from individual divers later in the boat after the dive was completed.

5.2.2 Data Analysis

Data on diving pressure (Chapter 3) and reef fish and benthic communities (Chapter 4) were used to study the impacts of recreational SCUBA diving on these communities. The relationships between fish and benthic communities and diving pressure (estimated number of dives per reef during the study period; Chapter 3) were investigated by means of the non-parametric Spearman rank correlation (Zar 1999). Benthic and fish community data collected in December 2002 were used for this purpose, comprising the only full data set of surveys at all the study sites. The percentage cover of damage susceptible indicator corals (i.e. grouped branching, tabular and foliose hard corals; Hawkins & Roberts 1992; Riegl & Cook 1995; Rouphael & Inglis 1995; Schleyer & Tomalin 2000) was used as a diving damage indicator (Table 4.3) and subjected to regression analysis (Draper & Smith 1981; Zar 1999) against diving pressure (estimated number of dives made at each reef during 2002). Diving pressure was used as the dependent variable and the percentage cover of indicator corals as independent variables in order to predict the number of dives (with standard errors), which would result in a decrease of 5, 10, 15, 20, 25 and 50% of the cover of the indicator corals. The variance about the mean for each increase was calculated using the standard equation for linear regressions

(Draper & Smith 1981). The results were used as parameters for the calculation of normal distribution probability functions from which cumulative probability curves of diving intensities causing decreases in coral cover were plotted using the MS-Excel 2000 and Statistica 6.0 software packages (StatSoft 2001).

5.3 RESULTS

5.3.2 Impacts on Reef Fish Communities

Fish community parameters were, in general, positively correlated with diving pressure. Contrary to total density (R_s = 0,86; p < 0,05), total fish diversity was not significantly correlated with diving pressure (R_s = 0,75; p > 0,05). Other fish parameters that significantly correlated with diving pressure were prey species density and diversity, and piscivorous species diversity (Figure 5.1).

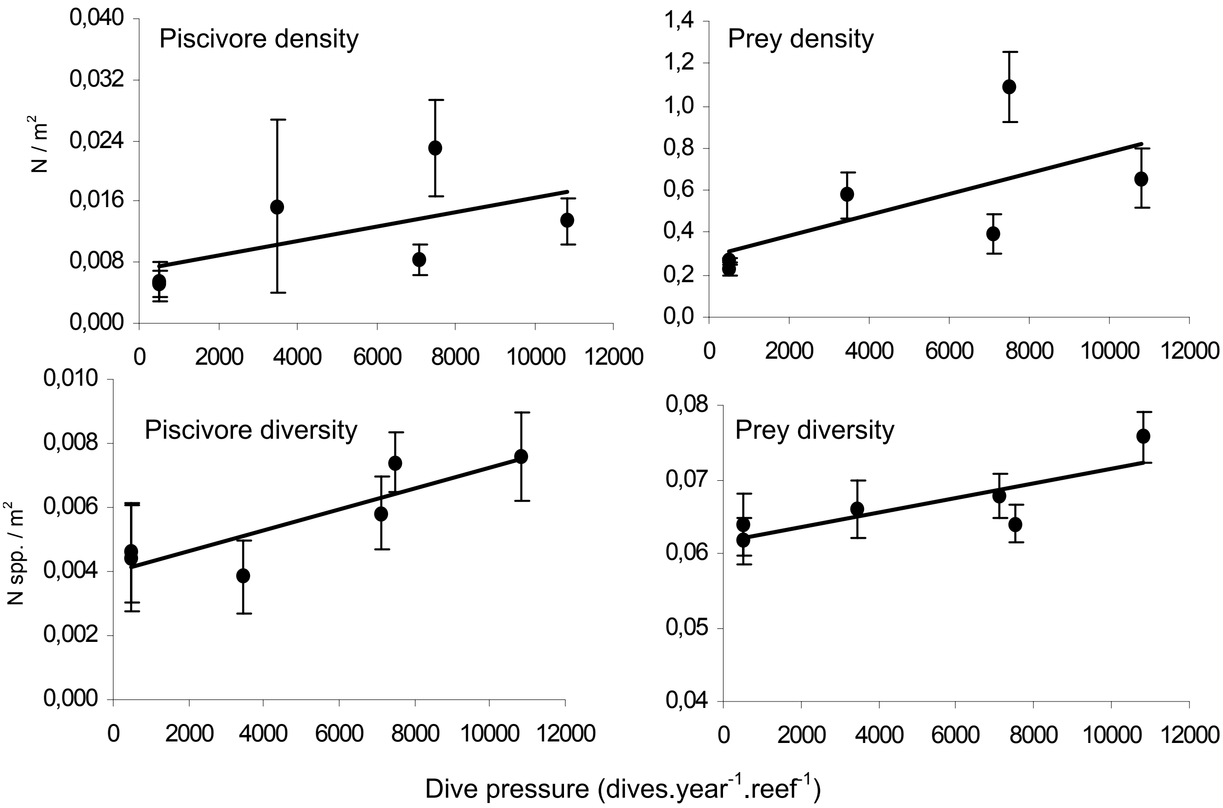


Figure 5.1 Relationship between fish community criteria and recreational SCUBA diving pressure (dives per reef during the study period) in southern Mozambique (N = 6). Bars=standard errors. Spearman Rank Correlation tests: piscivorous fish density (R_s = 0,70; p > 0,05), prey density (R_s = 0,87; p < 0,05), piscivorous diversity (R_s = 0,81; p < 0,05) and prey diversity (R_s = 0,81; p < 0,05).

The piscivore density/total fish density ratio was also tested against diving pressure and no significant correlation was found (R_s = – 0,14; $p > 0,05$). When analysed at family level, fishes showed no significant correlations with diving pressure, including strictly corallivorous species of the family Chaetodontidae (Table 5.1). Prey species density was found to be positively and significantly correlated with piscivore density (R_s = 0,89; $p < 0,05$).

Table 5.1 Results of the Spearman Rank Correlation tests performed on fish family densities ($N.m^{-2}$) and recreational SCUBA diving pressure (estimated total number of dives per reef during the study period) in southern Mozambique (N = 6).

Fish Parameter	**R_s**	***P***
Piscivore family		
Carangidae	0,34	0,511
Lujanidae	0,64	0,173
Serranidae	0,75	0,084
Prey family		
Chaetodontidae	-0,493	0,321
Corallivores	-0,290	0,577
Labridae	-0,696	0,125
Lethrinidae	0,174	0,742
Pomacanthidae	0,000	1,000
Pomacentridae	0,464	0,354
Serranidae	0,725	0,103

5.3.2 Impacts on Coral Communities

Reefs subjected to higher diving pressure had significantly less total coral and hard coral cover. No significant correlation was found between the number of dives and soft coral cover (Figure 5.2). Diving pressure was also tested against the percentage cover of various hard coral life form categories, being negatively correlated (but not significantly) with massive/encrusting (R_s = – 0,41; $p > 0,05$) and branching/tabular/foliose (R_s = – 0,75; $p > 0,05$) hard corals. Finally, the diving pressure was negatively correlated with depth (R_s = – 0,35). However, this correlation did not prove to be significant ($p > 0,05$; Figure 5.3).

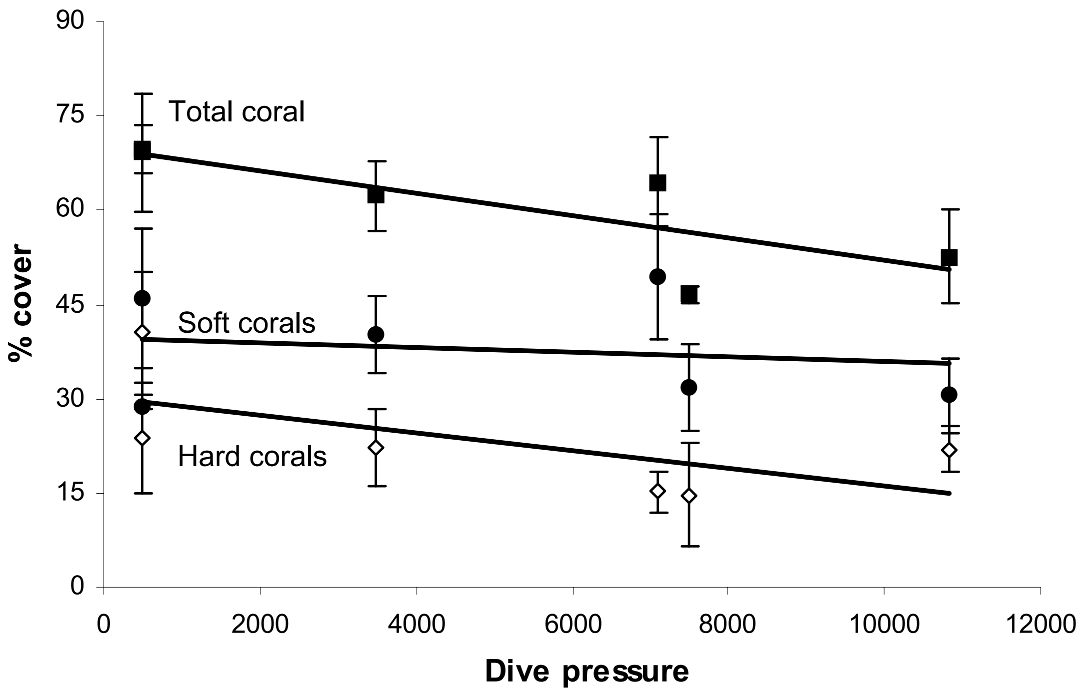


Figure 5.2 Relationship between diving pressure (estimated number of dives per reef during the study period) and percentage cover of total coral, soft and hard coral in December 2002 (N = 6). Bars=standard deviation. Spearman Rank Correlation test: total coral ($R_s = -0,87$; $p < 0,05$), soft corals ($R_s = -0,09$; $p > 0,05$) and hard corals ($R_s = -0,81$; $p < 0,05$).

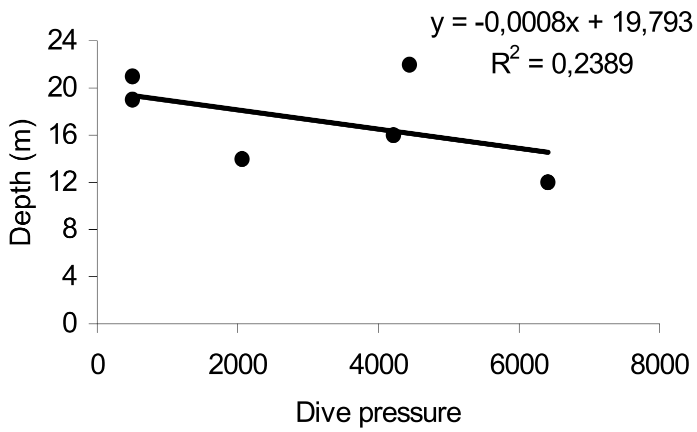


Figure 5.3 Relationship between diving pressure (estimated number of dives per reef during the study period) and depth (N = 6). Spearman Rank Correlation test: total coral ($R_s = -0,35$; $p > 0,05$).

Divers were observed to make contact with the substrata on average 20,16 (S.E. = 7,68) times per 35-minute dive, with female divers making twice the number of contacts than male divers. No significant relationship was found between diving experience (number of logged dives) and number of contacts with the substrata (R^2 = 0,0014; slope = 0,0016; SE = 11,397; p > 0,05). Fins accounted for 53% of the contacts, while 32,1% were made by hand. The majority of the contacts were on sand and other substrata (e.g. rock, algae). Approximately 25% of the contacts occurred on corals, with more contacts on soft corals (14,2%; Figure 5.4).

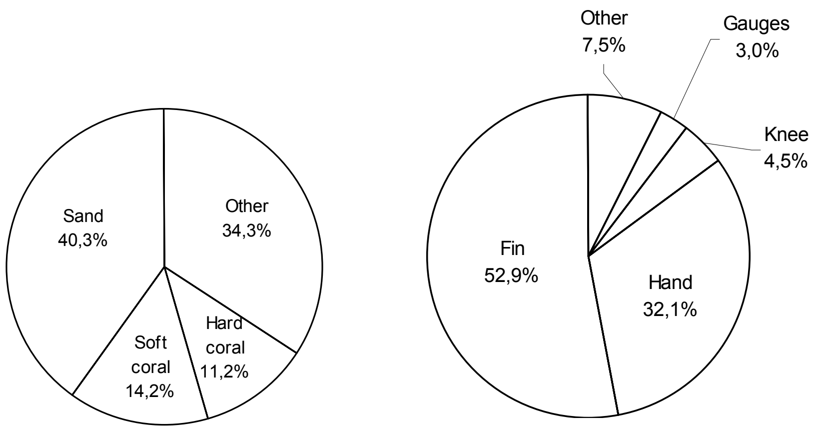


Figure 5.4 Contacts made by recreational SCUBA divers with different substrata per 35-minute dive.

Only 2,2% (0,44) of the contacts resulted in breakage of coral colonies with the remaining 97,8% causing tissue abrasion. It is estimated that in 2002 (when 62 000 dives were made; Chapter 3), divers touched corals 312 480 times, causing breakage of 6 875 of them.

The regression analysis performed on diving pressure and percentage cover of branching/tabular/foliose hard corals revealed that diving was responsible for almost half the variation in percentage cover of these diving-susceptible corals (R^2 = 0,483, slope = – 0,0013, SE = 1923,40) even though it was not statistically significant (p > 0,05; Figure 5.5).

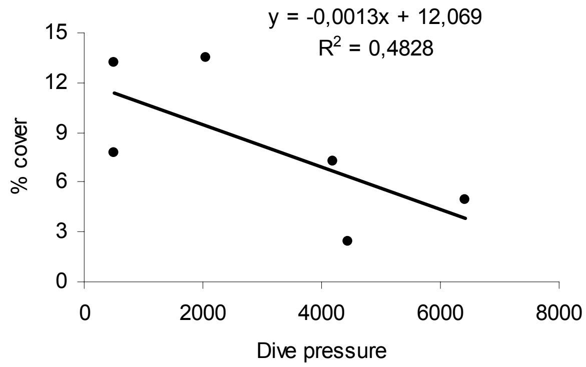


Figure 5.5 Relationship between diving pressure (estimated number of dives per reef during the study period) and percentage cover of branching/tabular/foliose hard corals measured in December 2002 (N = 6).

The probability curves of six limits of decrease in percentage cover of indicator hard corals (branching, tabular and foliose forms) being exceeded at different diving intensities is presented in Figure 5.6. These curves provide the probability of a given diving intensity resulting in a specified level of diver damage expressed as a percentage decrease in fragile corals. For example, at a diving intensity of 3000 dives.year^{-1}.dive site^{-1}, the probability of decreasing the percentage cover of indicator corals by 5% is approximately 30% (Figure 5.6a). On the other hand, there is a 20% probability that, at this diving intensity, the corals decrease by about 20% (Figure 5.6d). If the diving pressure were to increase to 7000 dives.year^{-1}.dive site^{-1}, there would be *ca* 90% probability of a decrease of 50% in percentage cover of indicator corals (Figure 5.6f).

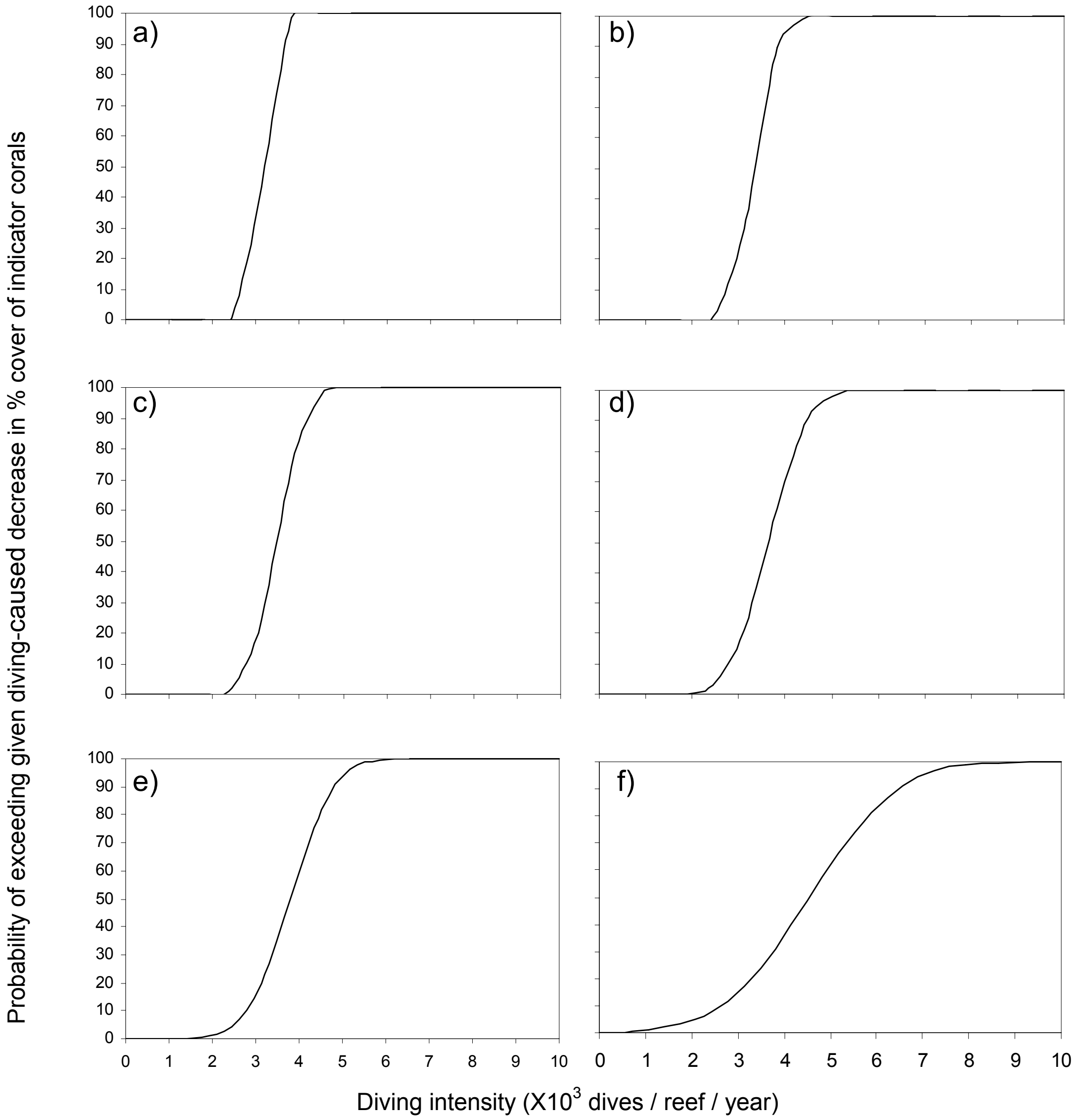


Figure 5.6 Probability curves of a a) 5%; b) 10%; c) 15%; d) 20%; e) 25% and f) 50% decreases in percentage cover of indicator hard corals (branching/tabular/foliose forms) at different diving intensities.

The percentage cover of coral indicator species was also subjected to regression analysis against the total percentage cover of live coral (R^2 = 0,538; p > 0,09) and used to estimate the likely decrease in total coral cover. The results are summarized in Table 5.2.

Table 5.2 Decrease in total coral cover following the reduction in percentage cover of indicator corals.

Reduction in indicator corals (%)	5	10	15	20	25	50
Corresponding reduction in total coral cover (%)	1,0	2,1	3,1	4,1	5,2	10,3

5.4 DISCUSSION

The effects of recreational SCUBA diving on fish communities are, at present, still unnoticeable. In fact, the results show that the most dived reefs are the ones with the highest fish density and diversity (for both piscivorous and prey species).

There are two possible explanations for this, the first one being that SCUBA diving is beneficial to fish communities increasing both fish diversity and density. At present, no fish feeding takes place as part of the diving activities in southern Mozambique and there is no indication, whatsoever, that diving might be positively affecting fish communities. The second, more likely reason, is that SCUBA diving at present levels is not affecting fish communities and the observed results are merely coincidental, as divers prefer to dive on reefs with abundant fish life (See Chapter 3). The most dived reefs are relatively small and shallow and attract baitfish and piscivorous species that come to feed on them (Chapter 4). In addition, sport fishing (Chapter 4) and illegal fishing activities by large industrial vessels (G. Beukes 2001, The Whaler–Ponta do Ouro, pers. comm.) on the more distant reefs (i.e. Techobanine) target mainly large piscivorous species, causing some inconsistencies in the results. The fact that some species (especially game fish, which are sought by spear fishermen) are quite wary of divers, may indicate that recreational activities do have some influence on the fish communities.

It seems that the diving pressure is still low at the moment (actually, for most reefs it is below the critical threshold reported for other reef areas; i.e. between 5 000 - 6 000 dives.year^{-1}.reef^{-1}) and it is not directly affecting the fish communities. Studies conducted by Chater *et al*. (1995) in Sodwana Bay (South Africa) yielded similar results at higher diving intensities, suggesting that recreational diving has had no effect on the fish population there, either (Schleyer 1999a). In fact, it is more likely that fishing (i.e. illegal trawling, spear fishing and boat angling), habitat structure (Luckhurst & Luckhurst 1978; Carpenter *et al*. 1981; Choat & Ayling 1987; Chabanet *et al*. 1997; Friedlander & Parrish 1998; Öhman & Rajasuriya 1998; Pereira 2000a) and other biological factors such as predation (Hixon 1991; Hixon & Beets 1993; Carr & Hixon 1995; Beets 1997) and larval dispersal, settlement and recruitment (Jones 1991; Leis 1991; Caley 1993) play more important roles in structuring these communities.

Reefs subjected to higher diving pressures had significantly less total and hard coral cover. This may be due to the fact that these reefs are shallow and closer inshore and are, hence, subjected to heavy damage caused by cyclonic storms, constant surge and swells, and siltation as reported elsewhere (Tilmant & Schlmahl 1981; Muthiga & McClanahan 1997). Only a handful of coral species can thrive under such conditions. Also, because they are close to the shore and relatively shallow, these reefs are the most used by diving operators to introduce novice divers to their sport. It is thus possible that the lower coral cover on the most intensively dived reefs is due to natural causes and the significantly negative relationship between diving intensity and coral cover is coincidental and not the result of a cause and effect relationship. Additionally, the soft corals and encrusting and massive hard corals dominant on these reefs (Chapter 4) are more resistant to physical damage (Bak & Steward-van Es 1980; Lin & Dai 1996). Furthermore, these reefs are relatively shallow, where coral recovery is much faster (Nagelkerken *et al*. 1999), making these coral communities quite resilient to physical stress. Here, where storm damage would be greatest, diver damage could be construed as irrelevant. However, one must take into account that cyclonic storms are periodic and natural events while diving damage is unnatural and persistent. This has important implications for reef recovery as highlighted by Connell (1997); heavily-dived reefs are subjected to chronic stress and recover more slowly and to lesser degree than those suffering acute, short-term disturbances caused by storms.

Divers in southern Mozambique made comparable or fewer contacts with the substratum and broke less corals than found elsewhere (e.g. Roberts & Harriot 1995; Harriot *et al*. 1996; Rouphael & Inglis 2001; Zakai & Chadwick-Furman 2002). Bjerner & Johansson (2001) found similar results working in the same area. This is probably due to the prevalence of soft corals and massive and encrusting hard corals (Chapter 4; Robertson *et al*. 1996), more resistant to physical damage. Additionally, the diving conditions in southern Mozambique are much rougher than those found in the Caribbean or Australia, with strong surge and swells being common (Schleyer 1995, 1999a; Schleyer & Tomalin 2000; Chapter 2) making divers more aware of the danger of diving too close to the reef and resulting in fewer contacts with the reef biota.

The great majority of contacts were made by fins and hands, which may indicate poor buoyancy control. In fact, novice divers made the majority of contacts (90% of the total fin contacts and 60% of the hand contacts). Secondly, underwater photography is quite popular in the area with a number of underwater photography competitions every year. In this study, one particular underwater photographer was responsible for 28% of the total hand contacts. As shown by Rouphael & Inglis (2001), underwater photographers may cause more damage than other divers whilst hanging on to get the "perfect picture".

The results reported in this study, show that divers are not, as yet, having deleterious effects on the reef communities in southern Mozambique. Managers can use the probability curves shown in Figure 5.6 to determine the risk of several levels of diving intensity to limit diver damage to levels they consider acceptable. For example, a reduction of 50% of indicator corals would result in a 10,3% decrease in total coral cover (Table 5.2). There is a probability of about 90% of this happening at a diving intensity of 7000 dives.year^{-1}.dive site^{-1}. This is probably the SDC of the southern Mozambican reefs as it is close to the level of 5000-6000 dives.year^{-1}.dive site^{-1} recently proposed for reefs in Australia (Harriot *et al*. 1997), the Caribbean (Hawkins *et al.* 1999), Egypt (Hawkins & Roberts 1997) and Israel (Zakai & Chadwick-Furman 2002), despite the latter reefs being different from those in southern Mozambique both in nature and extent. Schleyer & Tomalin (2000) also obtained an SDC of similar value (7000 dives.year^{-1}.dive site^{-1}) for the southern African reefs off Sodwana Bay. This is not surprising as the nature, extent and community structure of the Sodwana Bay reefs are similar to the southern Mozambican reefs, being largely dominated by soft corals. Additionally, the limit they proposed would cause a decline of about 10% in total coral cover, which they reported (Schleyer & Tomalin 2000) to be the threshold at which divers start complaining that diver damage is affecting the aesthetics of the reefs.

In selecting this SDC level, one must bear in mind that it is below the present diving intensity, except on Doodles and Creche (Table 3.16). This means that there is a potential for a two-fold growth in the recreational diving industry in southern Mozambique. If expansion is considered, it must nevertheless be accompanied by other management efforts that will encourage environment-friendly diving practices, the establishment of codes of conducts and awareness and education programmes. Such expansion should either be concentrated in the Machangulo Peninsula, where present diving activities are limited, or be thoroughly managed and regulated. A rotation scheme should be developed (see Chapter 6) and strictly followed. It is also recommended that no new licences for commercial diving operations be issued, at least for operations based at Ponta do Ouro-Ponta Malongane. Finally, the implementation of monitoring programmes on the reefs as well as of diver behaviour, perceptions and attitudes towards reef damage and conservation will be imperative.

CHAPTER 6
GENERAL DISCUSSION

The work presented in this dissertation constitutes the first of its kind in Mozambique, both in nature and extent. It is intended to fulfil a long recognized gap in the baseline information needed for the management of the recreational SCUBA diving activities in southern Mozambique. In this chapter, a general discussion will address the effects of these activities on the reef communities, their management implications and future research directions.

Most of the southern Mozambique coastline adjoins rocky reefs colonized, to a varying degree, by coral communities. There are three main reef-types based on their structure and nature (Chapter 4; Robertson *et al*. 1996):

- *Type A: massive, barren rocky reefs*. These have very low live coral cover (< 25%) and are intensively surge-scoured or have been seriously affected by crown-of-thorns starfish (*Acanthaster planci*; Schleyer 1998). Examples include Doodles (Ponta do Ouro), Pinnacles and Bass City (Ponta Malongane) and some reefs off Ponta Mamoli, Milibangalala and Baixo de São João. These reefs range in depth from 14–35 m and are not necessarily without interest to divers as they provide a refuge for many fish including large predators such as sharks and potato bass.
- *Type B: flat, shallow-ledges*. Clearly dominated by soft corals, these reefs are presently the main attraction for divers visiting the area. The fish are diverse and abundant (especially prey species) and the reefs are typically located in depths between 12–18 m. The majority of reefs dived in the area are included in this category, such as Creche, Texas and Shallow Malongane.
- *Type C: flat, deep-ledges*. Although dominated by soft corals, these reefs include extensive areas covered by branching and foliose hard corals. They are deeper (18–25 m) and their fish are not as prolific or diverse as on the other reef types. Kev's Ledge, Techo 1 and Techo 2 fall in this category.

The results of the diving intensity analysis (Table 3.16; Chapter 3) show that all three reef types are extensively dived in the Ponta do Ouro–Malongane area and that, at present levels, recreational SCUBA diving appears to have had no deleterious effects on either the coral or fish communities (Chapter 5). This may be attributed to the following:

- The diving intensity has not reached the critical threshold level of 7000 dives.$year^{-1}$ (except on Doodles and Creche) found to be deleterious on reefs immediately to the south in South Africa (Schleyer & Tomalin 2000) (Chapter 3).
- Results from the questionnaires reveal that divers visiting southern Mozambique seem to be responsible in pursuing their sport and aware of the damage they can cause to the reefs (Chapter 3), resulting in less diver-damage to the benthic communities (shown by the underwater diver observations; Chapter 5) when compared to reefs elsewhere (Roberts & Harriot 1995; Harriot *et al*. 1996; Rouphael & Inglis 2001; Zakai & Chadwick-Furman 2002).
- Boat anchoring is not a common practice due to local conditions (depth, current and swells), thus avoiding anchor damage encountered elsewhere (Davis 1977; Tilmant & Schmahl 1981; Tilmant 1987).
- The reefs are dominated mainly by soft corals and encrusting and massive hard corals (Chapter 4), which have been reported to be more resistant to physical damage (Bak & Steward-van Es 1980; Lin & Dai 1996).

This has important management implications, as southern Mozambique has been identified as a priority area for coastal tourism development (Hatton 1995) and several new developments are already taking place. It is expected that the diving industry will continue to grow (Bjerner & Johannson 2001) following development in the area. As stressed by Robertson *et al*. (1996), it is important to include management strategies as early as possible in such developments rather than to introduce them later. Additionally, as highlighted by Salm *et al*. (2000), if the use of the marine environment for tourism (including SCUBA diving) is to be sustainable, tourism interests must be given early warning that resource use may have to be limited at some stage. In this particular case, it would be important to cap the diving capacity at an early stage of the development on the basis of preliminary assessments and to refine the diving carrying capacity later.

Although the present study was conducted mainly on the most southerly reefs (where the diving industry is based), the SDC model developed here can be applied to the whole southern area of Mozambique. Despite limitations in its effectiveness (due to variability in diver awareness, experience and behaviour; reef conditions; resilience in the coral communities; stresses on the reef communities), the SDC concept remains an important management tool, incorporating both the concepts of acceptable levels of use (the diving carrying capacity approach) and acceptable levels of ecological change (Limits of Acceptable Change; Oliver 1995). Nevertheless, the

SDC tool should be implemented simultaneously with other management actions such as those related to diver education and the formulation of appropriate legislation and zoning schemes for effective reef conservation (Tratalos & Austin 2001; Mous 2001; Zakai & Chadwick-Furman 2001).

It is thus proposed that a dive limit of 7000 dives.year^{-1}.dive site^{-1} site should be implemented in southern Mozambique, as well as the following actions (largely derived from Schleyer & Tomalin 2000):

- Pre-dive briefings should be undertaken by dive operators prior to all diving operations, emphasizing environmentally friendly diving practices;
- A unified code of conduct (common to all dive centres) should be developed and implemented;
- The use of gloves during diving activities should be strictly prohibited;
- Awareness and education campaigns should be regularly undertaken, paying especial attention to photographers;
- A system of dive site rotation should be developed, in order to evenly distribute the diving intensity among the reefs.

It is often difficult to accommodate all the interests and needs of local communities, tourism development and conservation within MPAs (Salm *et al*. 2000) and other areas where natural resource utilization need management. One of the most effective ways in which support and an understanding of management programmes have been achieved with good results is through user-integrated zoning schemes, especially when the process involves public consultation (Laffoley 1995). Zoning schemes should be drafted and implemented at two spatial scales in southern Mozambique: a macro-zonation plan on a regional scale as proposed by Robertson *et al*. (1996) and Direcção Nacional de Áreas de Conservação (2002), and a micro-zoning plan for local reef development and conservation (Figure 6.1).

In the first, the northern (Machangulo Peninsula) and southern (Ponta do Ouro–Ponta Mamoli) sections could be developed for tourism, keeping the central area (Ponta Chemucane–Ponta Techobanine) in as natural a state as possible as a sanctuary. Tourism in the south is already concentrated at Ponta do Ouro and Ponta Malongane, with a recent development in Ponta Mamoli, and is primarily based on tourism from South Africa and Swaziland.

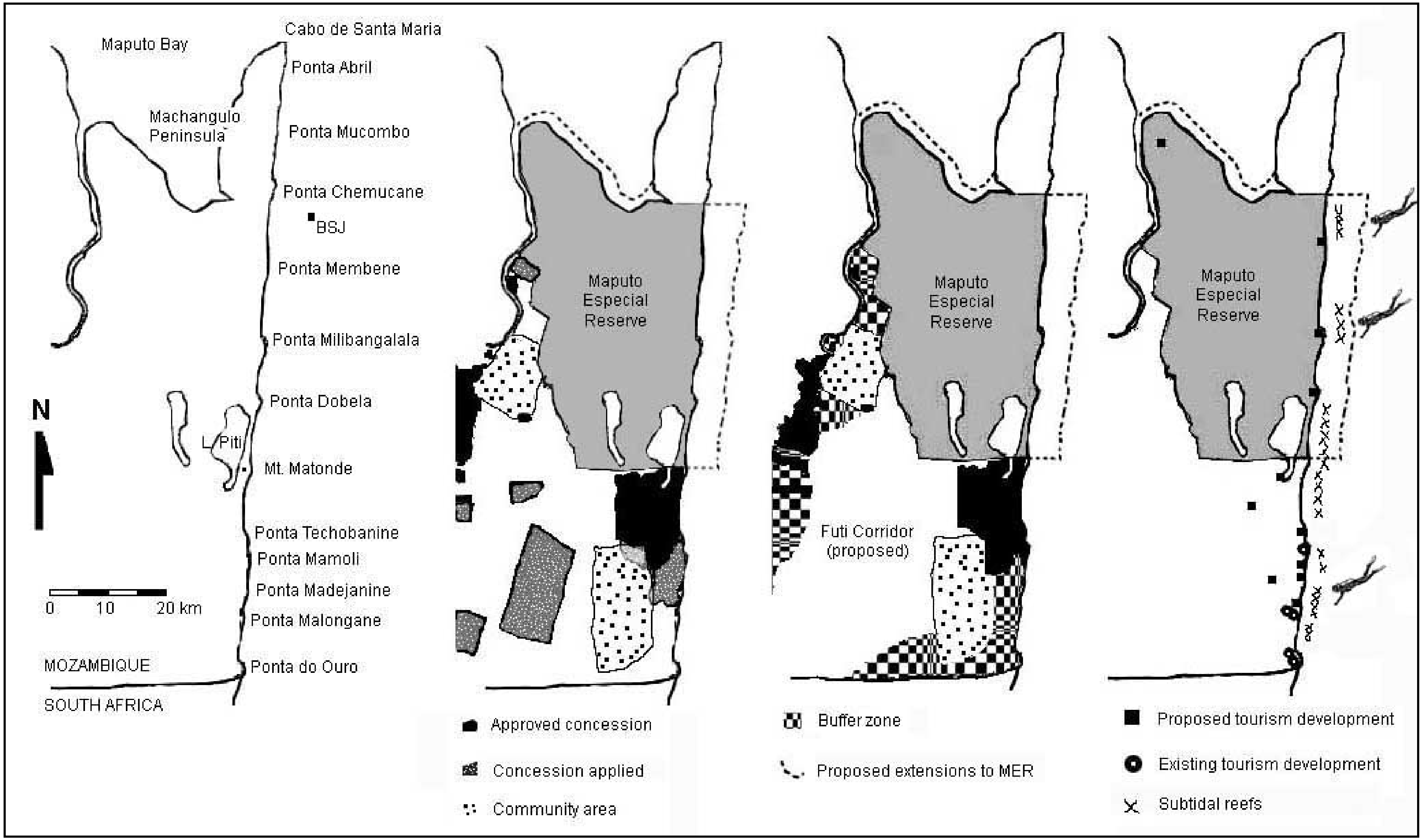


Figure 6.1 Location of sites mentioned in the text, existing and proposed concessions and tourism developments (as of July 2002), and the proposed zoning plan for the Futi Corridor (adapted from Direcção Nacional de Áreas de Conservação 2002). The proposed micro-zoning scheme for the recreational SCUBA diving activities is also shown. BSJ=Baixo São João.

Robertson *et al*. (1996) further proposed that the northern section could be developed primarily for domestic tourism. The central area, encompassing the Maputo Especial Reserve (MER) and Ponta Techobanine, could cater for international tourists at high value, low impact developments. This has been proposed in the Futi Corridor (FC) Zoning and Management Proposal, as part of the Lubombo Transfrontier Conservation Area (LTFCA; Direcção Nacional de Áreas de Conservação 2002). There is, however, uncertainty about the extent to which development will take place in the area. Several claims, concessions and tourism development projects have been submitted within the proposed Futi Corridor (Figure 6.1), some of which (such as the proposed deep-water port at Ponta Techobanine) are incompatible with existing national interventions and protocols such as the LTFCA, and the national marine and coastal protection programmes of MICOA. In addition, the area from Portuguese Island to Ponta do Ouro, incorporating the Maputo Special Reserve and Inhaca Island, is the subject of a World Heritage Site application being prepared with support from UNESCO under the supervision of a national committee (Direcção Nacional de Áreas de Conservação 2002).

New boundaries were proposed for the MER and should be approved (H. Motta 2003, WWF Mozambique, pers. comm.), encompassing an area extending from the current terrestrial reserve boundaries into a marine zone extending three nautical miles eastwards into the Indian Ocean. This was based on the need to provide (i) protection to important coral and rocky reef communities and Baixo de São João; and (ii) to facilitate appropriate tourism development in the area (Direcção Nacional de Áreas de Conservação 2002). It is expected that this will 'safeguard the marine resources of the area, ensure the protection of the richest hard coral communities in the sub-region, allow proper zonation of the reefs and help prevent inshore trawling (currently prevalent) and illegal SCUBA diving from Ponta do Ouro' (Direcção Nacional de Áreas de Conservação 2002). The proposed macro-zoning plan, jointly drafted and implemented by MICOA, the Navy, the Maritime Authority, Ministry of Tourism and other interested parties, will thus ensure that the reefs opposite Mt. Matonde, which include Techo 1 and Techo 2, the largest and richest reefs in the best condition in southern Mozambique (Robertson *et al*. 1996; M. H. Schleyer 2003, ORI, pers. comm.), will be subjected to reduced stress from tourism activities (including fishing, diving and pollution).

A key consideration in the preparation of a zoning scheme is the basis on which zoning will be developed and options can range from a purist approach of zoning based entirely on the ecological sensitivity of habitats, to zoning related purely to human activities (Laffoley 1995). In reality practice zoning schemes fall somewhere between these two extremes, both habitat sensitivity and user requirements into account (Laffoley 1995; Salm *et al*. 2000). Zoning schemes may be composed of several areas with different degrees of protection, but generally they include a core area or sanctuary (Laffoley 1995), which is strictly protected and generally encompasses the one of highest conservation value.

According to Salm *et al*. (2000), the size of the area, its biodiversity, distance from human settlements and levels of use in terms of human dependence are some of the most important factors to consider in designating sanctuary areas. The proposed micro-zoning scheme is based on three important characteristics: reef biodiversity and sensitivity to damage (Riegl & Cook 1995; Riegl & Riegl 1996), diver safety and isolation:

- The reef complex located in the central area (Ponta Dobela - Ponta Techobanine), including Techo 1 and Techo 2, is considered the best in southern Mozambique (M. H. Schleyer ORI 2002, pers. comm.) and the most extensive (Robertson *et al*. 1996) with a high live coral cover (including delicate branching and foliose hard corals; Robertson *et al*. 1996; Chapter 4), and diverse fish life (Pereira, unpublished data).
- The reefs are quite deep. Due to their relative distance from existing tourism developments and despite the recent technological advances in SCUBA equipment, there is a risk of a diving accident occurring in the area, especially at the deeper sites.
- The reefs are relatively inaccessible and isolated, being far from existing launch sites or human habitation.

As highlighted by Saila *et al*. (1993), the maintenance of healthy coral communities is crucial for the maintenance of general reef biodiversity. As this is the major reef complex in southern Mozambique, its conservation is important in its own right and as a breeding refuge and source of reproductive recruits for the southern reefs (Robertson *et al*. 1996) given the southward flow of the Agulhas Current (Schumman 1988). It is thus proposed that the reefs from Ponta Techobanine–Ponta Dobela (Figure 6.1) be designated a sanctuary area.

No recreational activities (including diving and fishing) should be allowed in the sanctuary area, the only human activity permitted would be strictly controlled scientific research and monitoring. The MER staff and the Maritime Authorities would be responsible for the daily management of the sanctuary.

Additionally, selected dive sites should be allocated for advanced diving only on the deeper and more damage-susceptible reefs (Figure 6.1), the reasons being the depth of the reefs (diver safety) and high percentage cover of delicate branching and foliose hard corals (reef sensitivity). Examples of such reefs are Texas and Kev's Ledge. This would prevent the better dive sites from being unnecessarily damaged, while maintaining their attractiveness and avoiding the divers 'loving the reefs to death'. The selection of dive sites could be facilitated, for practical reasons, by using the reef type system provided in Table 6.1. Riegl & Cook (1995) and Schleyer (1999a) proposed a similar zoning scheme for the Kwazulu-Natal reefs, based primarily on coral community and growth form analysis.

Table 6.1 Reef types (based on reef sensitivity and diver safety) to be used in zoning diving activities on reefs in southern Mozambique.

REEF TYPE	**DEPTH**	
	14 – 18 m	**> 18 m**
Type A (total live coral cover low; abundant fish life, especially predators)	Novice + advanced divers	Advanced divers only
Type B (soft-coral dominated, high coral cover; prolific fish life including predators and prey)	Novice (starting their dives on sandy areas) + advanced divers	Advanced divers only
Type C (mixed coral community of soft corals + hard branching/foliose corals; high coral cover; diverse fish life although not as abundant as in other reef types	Advanced divers only	Advanced divers only

The implementation of this system, along with the recommended SDC (7000 dives.year^{-1}.dive site^{-1}) and other management actions proposed for diving, should be promoted and coordinated by the Maritime Authorities based in Ponta do Ouro in close collaboration with the dive centres and other interested parties. It is worth mentioning that, although it may seem that the type A reefs would probably accommodate a higher diving intensity due to their lower coral cover, a precautionary approach is advised as the effects of SCUBA diving on fish communities are still under debate (see discussion in Chapter 5). There is evidence that they are adversely affected if diving reaches a certain level of intensity (Stanley & Wilson 1995; M. H. Schleyer 2002, ORI, pers. comm.). Therefore, it is proposed that the diving intensity on these reef types should also not exceed the recommended SDC.

There may be some degree of conflict between diving and fishing activities, especially at the more advanced dive sites with abundant fish life (e.g. Pinnacles, Baixo de São João) given their popularity amongst sport fishermen (David *et al*. 1996; Massinga & Hatton 1996). Results of the dive surveys (Table 3.15; Chapter 3) show that at least 60% of the divers agree that the reef should be designated for specific uses and should be incorporated in the zoning scheme. These aspects warrant further attention, as user-related zoning schemes are predominantly about managing how people use or do not use an area (Laffoley 1995).

Further research is needed on the reefs and should include detailed reef surveys and mapping, not only to refine the proposed zoning scheme, but also to provide a better picture of the nature, extent, biodiversity and condition of the reefs. Coral reproduction, larval dispersal patterns and reef connectivity are largely unknown in the area (but see Schleyer *et al*. 1997; Ridgway *et al*. 2001) and need further study to provide different improved management and conservation strategies. Reef recovery after damage by the crown-of-thorns starfish (*Acanthaster planci*) recorded in the mid 1990s (Robertson *et al*. 1996; Schleyer 1998) and its management deserve further attention, finally, the monitoring programme initiated as part of the Mozambique Coral Reef Monitoring Programme (Rodrigues *et al*. 1999; Motta *et al*. 2002; Pereira *et al*. in prep), should be continued, and expanded to provide information on the effects of global climate change on the reefs in southern Mozambique.

The conservation measures and research needs outlined above are considered essential in view of the increasing use and pressure anticipated on southern Mozambique's valuable reefs. As stressed before, this is urgent as they should be implement at an early stage before tourism development and reef deterioration. Similar reefs are found in Mozambique from Inhambane southwards and the findings of this study will also find application between this centre and Inhaca Island.

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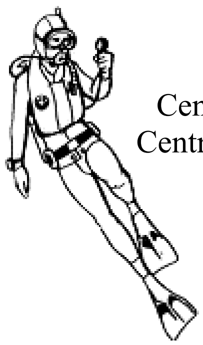
APPENDICES

Appendix 3.1 The self-administered bilingual (English and Portuguese) questionnaire used to collect information on the demography, participation and attitudes of recreational SCUBA divers in southern Mozambique.

Southern Mozambique Recreational Diving Survey

Estudo sobre o Mergulho Recreativo no Sul de Moçambique

2001-2002



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Diver's Questionnaire
Questionário para o Mergulhor

This survey was designed to help the Center for the Sustainable Development of Coastal Zones (CDS-ZC) know more about your diving activities and the extent to which you use the reefs in southern Mozambique waters (Pta. Ouro - Pta. Malongane). The information you are about to provide is an important part of a wider project, that aims to achieve a better use and sustainable management of the recreational diving industry in Southern Mozambique.

Please answer all questions to the best of your ability. Your responses will be confidential; no names will be identified with the information provided. Thank you and enjoy your dive!

Este estudo foi desenhado com o objectivo de ajudar o Centro de Desenvolvimento Sustentável das Zonas Costeiras (CDS-ZC) a obter mais informação sobre as suas actividades de mergulho e a extensão com que você usa os recifes de coral no Sul de Moçambique (Pta. Ouro - Pta. Malongane). A informação que irá a fornecer, será parte importante de um estudo mais abrangente, que tem como objectivo um uso melhor e a gestão sustentável da indústria de mergulho recreativo no Sul de Moçambique.

Por favor, responda o melhor que puder. As suas respostas são confidenciais. Nenhum nome será identificado e ligado à informação providenciada. Muito obrigado e aprecie o seu mergulho!

The first section of this questionnaire will help us know more about divers who use Southern Mozambique reefs.
A primeira secção deste questionário irá ajudar-nos a conhecer melhor os mergulhadores que usam os recifes do Sul de Moçambique.

1. Are you:
Qual é o seu sexo?

Female / Feminino ☐ Male / Masculino ☐

2. What is your age?
Qual é a sua idade? ☐ *years* / *anos*

3. Nationality:
Nacionalidade: ☐

4. What is your academic background?
Qual é a sua formação académica?

Primary / Ensino Primário ☐ Secondary / Ensino Secundário ☐ Graduate / Universitário ☐ Post-graduate / Pós-graduação ☐

In the following questions please tell us about your overall scuba diving activity and experience.
As questões à seguir estão relacionadas com as suas actividades e experiência em mergulho scuba.

5. How many years have you been certified as a scuba diver?
Há quantos anos é um mergulhador certificado? ☐

6. How many dives have you done after being certified?
Quantos mergulhos já fez depois ser certificado? ☐

7. Where did you get your certification? (Please check all that apply)
Onde obteve o seu certificado? (Marque todos os casos que se lhe apliquem)

PADI ☐ NAUI ☐ YMCA ☐
BSAC ☐ SSI ☐ Other (Please specify):
Outro (Por favor especifique): ☐

8. What is your highest level of certification?
Qual é o seu nível mais alto de graduação?

Basic open water ☐ Advanced open water ☐ Divemaster ☐ Dive instructor ☐
Specialty (cave, wreck, conservation, navigation, photography, etc.) ☐

9. Which of the following diving activities do you participate in most often? (Please tick all that are acceptable)
Em qual das seguintes actividades de mergulho tem participado com mais frequência (Por favor marque todos os casos que se lhe apliquem)

Underwater photography / Fotografia subaquática ☐
Spear fishing / Caça submarina ☐
Marine life research / Estudo da vida marinha ☐
Decompression/NITROX diving / Mergulho de descompressão/NITROX ☐
Cave diving / Mergulho em cavernas ☐
Wreck diving / Mergulho em destroços ☐
Night diving / Mergulho nocturno ☐
Other / Outras ☐

10. Compared to your other outdoor recreation activities (such as golf, tennis, fishing, soccer, etc.) would you rate scuba diving as: (Please tick only one)
Comparado com as suas outras actividades recreativas (como golf, ténis, pesca, futebol, etc.) classificaria o mergulho como sendo (Por favor marque apenas uma):

Your most important outdoor activity / A sua actividade recreativa mais importante ☐
Your 2nd most important outdoor activity / A sua 2ª actividade recreativa mais importante ☐
Your 3rd most important outdoor activity / A sua 3ª actividade recreativa mais importante ☐
Only one of many outdoor activities / Apenas uma das suas actividades recreativas ☐

11. Below is a list of reasons why people dive in coral reefs. Please circle the number that indicates how important each item was to you as a reason for diving in Southern Mozambique.
Em baixo encontrará uma lista de razões pelas quais se mergulha em recifes de coral. Por favor marque com um círculo o número que indica quão importante cada item é para si, como razão para mergulhar no Sul de Moçambique.

	Not important / Não importante				Extremely important / Muito Importante
For family recreation Recreação familiar	1	2	3	4	5
To learn more about the underwater world Aprender mais sobre o mundo submarino	1	2	3	4	5
To experience unpolluted natural surroundings Experimentar uma área natural sem poluição	1	2	3	4	5
To look at fish and other marine life Olhar para os peixes e outra vida marinha	1	2	3	4	5
To be outdoors Para estar for a	1	2	3	4	5
For relaxation Para relaxar	1	2	3	4	5
To experience adventure and excitement Para viver uma aventura excitante	1	2	3	4	5
To get away from the demands of other people Para estar longe das exigências de outras pessoas	1	2	3	4	5
To experience tranquility undewater Para viver a tranquilidade submarina	1	2	3	4	5
To be with friends Para estar com os amigos	1	2	3	4	5

For the exercise Para fazer exercício	1	2	3	4	5
To develop your diving skills and abilities Para melhorar a sua abilidade a mergulhar	1	2	3	4	5
To get away from the regular routine Para fugir à routina	1	2	3	4	5
To experience new and different things Para experiementar coisas novas e diferentes	1	2	3	4	5

12. Do you subscribe to diving magazines?
É assinante de alguma revista de mergulho?

In the next section we want to ask you specifically about your diving activities in Southern Mozambique.
Na próxima secção, iremos perguntar-lhe sobre as suas actividades de mergulho no Sul de Moçambique.

13. For how long have you been diving in Southern Mozambique (years)?
Há quanto tempo mergulha no Sul de Moçambique (anos)?

14. Which other sites in Mozambique have you dived? (Please check all that apply)
Em que outros locais já mergulhou em Moçambique? (Por favor marque todos os casos que se lhe apliquem)

Inhaca ☐ Bilene ☐ Xai-Xai ☐ Inhambane (Barra, Tofo, etc.) ☐ Bazaruto ☐

Others (Please specify):
Outros (por favor especifique):

15. How many DAYS did you go scuba diving in Southern Mozambique, during this trip:
Quantos DIAS mergulhou no Sul de Moçambique, durante esta viagem:

16. How many DIVES have you done during this trip in Southern Mozambique?
Quantos MERGULHOS fez no Sul de Moçambique, durante esta viagem?

17. Which reefs have you dived in Southern Mozambique during this trip?
Em que recifes mergulhou no Sul de Moçambique durante esta viagem?

18. Please rank ONLY the 5 reefs you have dived most in Southern Mozambique (1 - most dived; 5- least dived).
Por favor, ordene APENAS os cinco recifes em que mais mergulhou no Sul de Moçambique (1- mais mergulhado; 5 - menos mergulhado).

Anchor __ Checkers __ Creche __ Doodles __ Fingers __ Kev's Ledge __ Paradise __ Bass City __

Malongane Ledge __ Pinnacles __ Riana's __ Shallow Malongane __ Steps __ Atlantis __ Steve's __

Texas __ The Ridge __ Three Sisters __ Turtle Creek __ Wayne's World__

19. At what water depth do you prefer to dive in Southern Mozambique? (Please tick all that are acceptable)
A que profundidade prefere mergulhar no Sul de Moçambique? (Por favor marque todos os casos que se lhe apliquem)

- 10 m □ 11-15 m □ 16-24 m □ 25-30 □ 31-40 m □ + 41 m □

20. Do you use hired or your own diving gear?
Aluga ou usa o seu próprio equipamento?

Own / Próprio □ Hired / Alugado □

21. What type of group do you dive with in Southern Mozambique most often? (Please tick only one)
Em que tipo de grupo você mergulha mais frequentemente no Sul de Moçambique? (Por favor marque apenas uma)

Friends / Amigos □ Family / Família □ Family & friends together / Família & amigos □ Centre's Buddies / Buddies da Escola de Mergulho □

22. From your experiences in other parts of the world, how would you rate the diving in Southern Mozambique?
A partir da sua experência em outros locais do mundo, como classificaria o mergulho no Sul de Moçambique?

Much worse Pior				Much better Melhor
1	2	3	4	5

23. Please rate the importance of the listed marine life to your diving experiences in Southern Mozambique.
Por favor classifique a importância dos organismos marinhos listados abaixo para as suas experiências de mergulho no Sul de Moçambique.

	Not important Não importante				Extremely important Muito Importante
Dolphins, whales & whale shark Golfinhos, baleias & tubarão baleia	1	2	3	4	5
Turtles Tartarugas	1	2	3	4	5
Sharks & rays Tubarões & raias	1	2	3	4	5
Larger pelagics (barracuda, kingfish) Grandes pelágicos (barracuda, xaréus)	1	2	3	4	5
Large reef fish (snapper, grouper) Grandes peixes de recife (ladrões, garoupas)	1	2	3	4	5
Small reef fish (blennies, gobies) Pequenos peixes de recife (cambotas, góbios)	1	2	3	4	5
Other reef fish (triggerfish, surgeonfish) Outros peixes de recife (peixe-porco, cirugiões)	1	2	3	4	5
Tropicals (angels, damsels, butterflies) Tropicais (lebres, castanhetas, borboletas)	1	2	3	4	5
Hard & Soft Corals Corais duros & moles	1	2	3	4	5
Sponges, Sea squirts, algae Esponjas, ascídias, algas	1	2	3	4	5
Crustaceans & mollusks Crustáceos & moluscos	1	2	3	4	5
Seastars, sea cucumbers & sea urchins Estrelas do mar, pepinos do mar, ouriços	1	2	3	4	5
Other (please specify): Outro (por favor especifique):	1	2	3	4	5

24. Overall, how satisfied were you with you diving in Southern Mozambique?
No geral, quão satisfeito está com o mergulho no Sul de Moçambique?

Not satisfied Não satisfeito				Extremely satisfied Muito satisfeito
1	2	3	4	5

This is the last section of the questionnaire. It relates to the condition and management of the diving in Southern Mozambique. If you have not dived in Southern Mozambique before 1999 jump to Question 29.
Esta é a última secção do questionário. Relaciona-se com o estado e gestão do mergulho no Sul de Moçambique. Se não mergulhou no Sul de Moçambique antes de 1999, salte para a Pergunta 29.

25. Have you noticed any changes in the overall reef environment?
Notou alguma alteração nos recifes em geral?

26. Have you noticed any changes in the coral cover?
Notou alguma alteração na quantidade de coral?

Drecreased / Diminuiu ☐ Did not change / Não se alterou ☐ Increased / Aumentou ☐ Haven't noticed / Não notei ☐

27. Have you noticed any changes in the abundance on small reef fish (butterflies, damsels)?
Notou alguma alteração na quantidade de pequenos peixes de recife (borbolestas, castanhetas, etc.)?

Drecreased / Diminuiu ☐ Did not change / Não se alterou ☐ Increased / Aumentou ☐ Haven't noticed / Não notei ☐

28. Have you noticed any changes in the abundance on large reef fish (groupers, kingfishes)?
Notou alguma alteração na quantidade de grandes peixes de recife (garoupas, xáreus)?

Drecreased / Diminuiu ☐ Did not change / Não se alterou ☐ Increased / Aumentou ☐ Haven't noticed / Não notei ☐

29. Please indicate whether you agree or disagree with the following statements about the management of Southern Mozambique reefs.
Por favor indique se concorda ou não, com as seguintes afirmações sobre a gestão dos recifes no Sul de Moçambique.

	Strongly disagree Discordo				Strongly agree Concordo
The reefs in Southern Mozambique are crowded Os recifes no Sul de Moçambique estão superlotados de mergulhadores	1	2	3	4	5
Scuba diving at excessive levels, damages reef communities O mergulho scuba a níveis excessivos, degrada as comunidades dos recifes	1	2	3	4	5
The number of dives per year per site should be limited to a certain level O número de mergulhos anuais por cada recife deveria ser limitado a um certo nível	1	2	3	4	5
Certain reefs should be designed for specific uses (diving only or fishing only) Alguns recifes deveriam ser designados para usos específicos (apenas para mergulho ou apenas para pesca)	1	2	3	4	5
Pre-dive briefings should emphasize the 3 T's: "don't Touch, don't Tease, don't Take" Os *briefings* antes de cada mergulho deveriam enfatizar: "não tocar, não provocar, não levar".	1	2	3	4	5
Mooring buoys (for tying off) should be provided at all reefs Deveriam ser providenciadas bóias de ancoragem em todos os recifes	1	2	3	4	5
Artificial reefs should be deployed to diversify the diving and reduce the pressure on natural reefs Recifes artificiais deveriam ser estabelecidos para diversificar o mergulho e reduzir a pressão sobre os recifes naturais	1	2	3	4	5

30. Is there anything else you would like to share with us?
Há mais alguma coisa que gostaria de nos dizer?

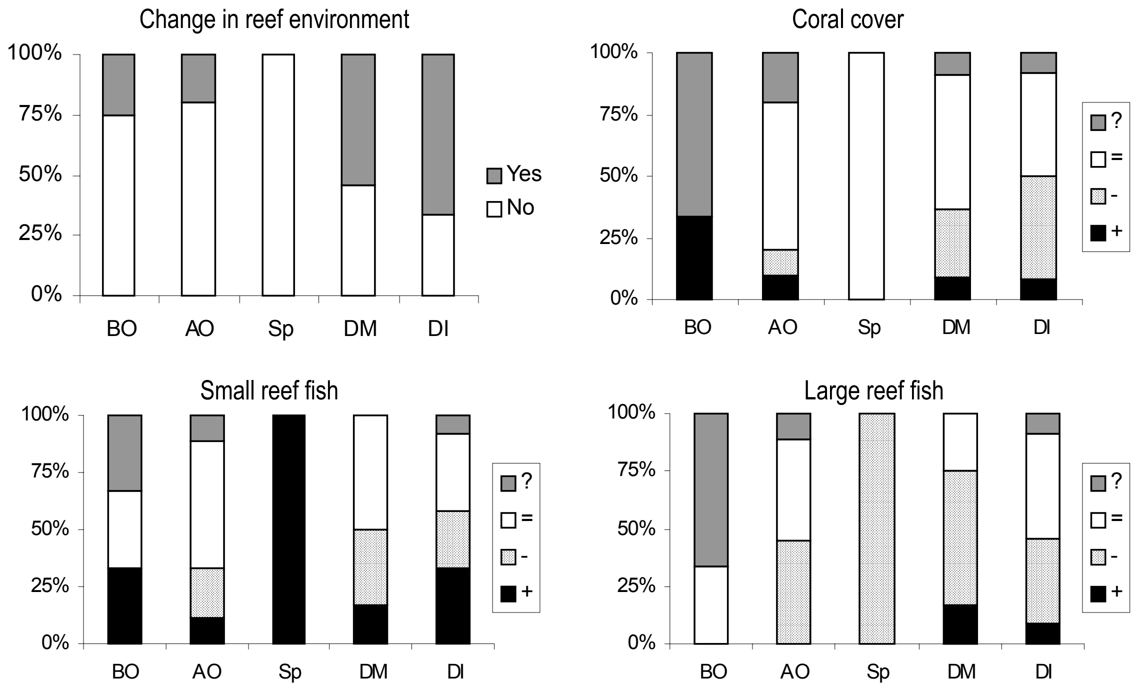
___

___

___

Your contribution to this study is greatly appreciated. Please leave your completed questionnaire at the dive centre or hand it to the divemaster in charge. Thank you.
A sua contribuição para este estudo é muito apreciada. Por favor deixe o seu questionário preenchido na escola de mergulho ou entregue ao instrutor responsável. Muito Obrigado.

Appendix 3.2 Divers' perceptions of various reef characteristics on southern Mozambican reefs. Diver qualifications: BO=Basic openwater; AO=Advanced openwater; Sp=Specialty; DM=Divemaster; DI=Dive instructor. Perceptions: ?, did not notice; =, did not change; –, decreased; +, increased.



	No change		Change	
Reef environment	354,9		685,4	
	Decreased	**Increased**	**Did not change**	**Did not notice**
Coral cover	569,6	352,3	592,8	234,3
Small reef fish	504,4	745,1	428,3	176,7
Large reef fish	621,0	277,7	506,1	274,0

Appendix 3.3 General comments provided by recreational SCUBA divers visiting southern Mozambique. The comments are presented in their original format. With the exception of correcting obvious spelling mistakes and substituting references to specific individuals with ###, they have not been edited or changed.

Category 1: The Survey

- Thank you for looking into this. Go further and protect!
- Question 29. Artificial reefs - Wreck diving (…increase…).
- Having little legislation concerning latter it is good to see preventing and awareness measures being implemented. To preserve the environment more laws should be pushed, juxtaposed with education of tourists and local population. Penalties should be imposed on improper use. Fiscalization should follow penalties.

Category 2: General Tourism and Development in Southern Mozambique

- The use of jet-skis and 4 wheelers on the beaches may ruin a lot of the positive aspects of diving in Southern Mozambique. Strict control should take place. Protection of the sand dune is important, no building activity in the dune should be allowed.
- Border control is negatively influencing all SCUBA and fishing activities in the whole of Mozambique!
- The use of Jet-skis and Quad bikes should be banned due to the negative impact they have on the environment and other people. The roads should be improved to reduce the multiple tracks that are ruining the landscape. Stop development, like "#####", taking place in the primary dunes.
- Do not develop at all costs. Some things (reefs) are not replaceable.
- More attention to keep surrounding hills pristine. Some litter seen there.
- Pollution – emphasis to local population and visitors to protect the fragile environment (land and sea). Tourism – have potential for the economy but must be managed appropriately.
- This is a country with great potential – can the government now turn it into what it can be?
- The general cleanness i.e. rubbish needs to be addressed.
- Border post should open earlier and close later over holidays and long weekends.
- The general environment in Ponta do Ouro has became increasingly more polluted. Seem to be on downward spiral.

Category 3: SCUBA diving in Southern Mozambique: Reef Condition and Conservation

- Stricter rule on reef protection "No gloves". No touching or taking shells to be emphasised by Dive leader. Students to watch for buoyancy.
- Have dived a lot at Sodwana, in comparison the reefs have a lot of sand covering them in Malongane. If DMs and instructors are effective and enforce good, environmentally friendly diving, then diving shall not damage the reefs.
- No bottom fishing should be allowed. Inexperienced divers should not be allowed to dive off coral reefs. Rocky reefs are available for them.
- Knowledgeable skippers and DM's must always be encouraged and suitably rewarded for their efforts. Large dive groups should be avoided - 14 divers is too many for a single dive. I disagree with

allowing independent/outside DMs leading dives. Not only do they lack local knowledge, but also don't care enough since there are not permanently here.

- Dive schools should not allow beginner divers or students dive on certain coral reefs. There are plenty of rock reefs on which they can dive.
- Stop people from touching and taking natural things from the reef.
- There should be a certain reef for o/w (open water) students doing diving courses as they do sometimes tend to crash in reef with their unstable buoyancy.
- Natural reefs should be protected against inexperienced, ignorant and stupid people… take them to areas where they can't touch, can't tease and shoot them when they take!!
- Note: you have got the honour to dive, not the right to dive!! Be the seas guest not their intruder!
- DM's dive numbers should be worn on wetsuits and be clearly visible underwater. Should one of their divers ruin/touch the reef a witness and the person who saw the reef being damaged should be able to report the offence to the resort/dive school. An appropriate fine/ban should be imposed.
- As a serious wreck diver, a few ships should be sunk, not only to provide natural reefs but give wreck divers the opportunity to dive them as there are none at Ponta do Ouro or Malongane.
- Close reefs & good visibility.
- Mooring buoys on sandy areas for openwater student (as in Sodwana) but not in all reefs. Stop bottom fishing!! Lots of hooks and sinkers on reef!! STOP fish feeding!! Declare National Marine Park from Malongane to Dobela!!
- Too many divers holding on to the reef. No check on DM done at present. They don't seem to care about the reef.
- Limit the number of dive charters to the area to keep the tranquillity.
- Diving in southern Mozambique is great. I do believe in [high] season you should control the diving a lot more otherwise it gets crowded.
- These dive sites are still well preserved. Try to keep it like this.
- A board with sightings on the different reefs on the day of the day.
- 3 T's – Very important!
- Much prettier diving in Mozambique to Sodwana or Aliwal. Easier to get here, better sea life, better operators and more comfort. Do not like camping.
- People bringing their own boats and launching should have to be lead by a local divemaster to ensure safety on both the divers and reef environment and better first aid is required in the way of on boat availability of oxygen and other emergency items especially when a boat trip back is more than 20 minutes.

Category 4: Remaining Comments

Would have enjoyed a night dive.

- I think there are over-fishing and too little appreciation of the underwater world. Too many predators are slaughtered unnecessarily. Due to misunderstanding and lack of knowledge towards most ocean creatures.
- Awaiting to experience a great time!
- Great place!

Appendix 4.1 Benthic life-form (following English *et al*. 1994) categories used in the present study.

Benthic categories	Code
Hard coral	HC
Acroporids	
Acropora branching	ACB
Acropora tabular	ACT
Acropora digitate	ACD
Non-Acroporids	
Coral branching	CB
Coral foliose	CF
Coral massive	CM
Coral encrusting	CE
Soft coral	SC
Other invertebrates (sea urchins, sponges, sea anemones, etc)	OT
Dead coral	DC
Dead coral and algae	DC/A
Dead coral and coralline algae	DC/CA
Sand	S
Rock	RCK
Rock and algae	RCK/A
Rock and coralline algae	RCK/CA
Rubble	R

Appendix 4.2 The 51 fish species in the trophic groups recorded in the present study.

PISCIVORES	PREY	
Carangidae	**Chaetodontidae**	*Gomphosus caeruleos*
Caranx melampygus	*Chaetodon auriga*	*Halichoeres hortulanus*
Caranx spp.	*Chaetodon blackburnii*	*Labroides dimidiatus*
	Chaetodon guttatissimus	*Thalasoma hardwicke*
Lutjanidae	*Chaetodon interruptus*	*Thalasoma hebraicum*
Aprion virescens	*Chaetodon kleinii*	*Thalasoma lunare*
Lutjanus bohar	*Chaetodon lunula*	
	Chaetodon mertensii	**Lethrinidae**
Serranidae	*Chaetodon meyeri*	*Gnathodentex aurolineatus*
Aethaloperca rogaa	*Chaetodon trifascialis*	*Monotaxis grandoculis*
Cephalopholis argus	*Chaetodon trifasciatus*	
Cephalopholis miniata	*Chaetodon vagabundus*	**Pomacanthidae**
Epinephelus spp.	*Chaetodon xanthocephalus*	*Centropyge bispinosus*
Epinephelus fasciatus	*Forcipiger flavissimus*	*Centropyge multispinis*
Epinephelus tukula	*Hemitaurichthys zoster*	
Variola louti	*Heniochus acuminatus*	**Pomacentridae**
	Heniochus monoceros	*Chromis dimidiata*
	Labridae	**Serranidae**
	Anampses caeruleopuntactus	*Pseudanthias squamipinnis*
	Anampses lineatus	
	Coris caudimacula	

Appendix 4.3 Results of nested ANOVA performed on benthic parameters of the reef groups, previously identified by the multivariate analysis. Significance at $p < 0,05$ is shown in **bold**.

Hard Coral	DF	SS	MS	F	p
Intercept	1	13391,03	13391,03	735,6488	0,000000
Reef Groups	2	326,90	163,45	8,9792	**0,002429**
Reefs within reef groups)	3	130,28	43,43	2,3857	0,107321
Error	16	291,25	18,20		
Total	21	729,53			
Soft Coral					
Intercept	1	21842,97	21842,97	991,7363	0,000000
Reef Groups	2	358,67	179,33	8,1423	**0,003639**
Reefs (within reef groups)	3	94,26	31,42	1,4265	0,271845
Error	16	352,40	22,02		
Total	21	830,12			
Total Coral					
Intercept	1	42236,40	42236,40	3078,737	0,000000
Reef Groups	2	339,92	169,96	12,389	**0,000562**
Reefs (within reef groups)	3	136,38	45,46	3,314	**0,046897**
Error	16	219,50	13,72		
Total	21	680,11			
Rock And Algae					
Intercept	1	17399,47	17399,47	921,0786	0,000000
Reef Groups	2	465,05	232,52	12,3091	**0,000580**
Reefs (within reef groups)	3	276,25	92,08	4,8746	**0,013551**
Error	16	302,25	18,89		
Total	21	1009,26			

Appendix 4.4 Cumulative species list of fish in southern Mozambique derived from this study, Robertson *et al.* (1996), sport angler catches, underwater observations on coral reefs, rock pool hand-net collections and interviews with local dive operators. New family and species records are respectively marked with # and *.

FAMILY / SPECIES

Acanthuridae
Acanthurus blochii
Acanthurus dussumieri
Acanthurus leucosternon
Acanthurus lineatus
Acanthurus nigrofuscus
Acanthurus tennenti
Acanthurus thompsoni
Acanthurus triostegus
Acanthurus xanthopterus
*Naso brevirostris**
Naso lituratus
Naso unicornis
*Paracanthurus hepatus**
*Zebrasoma gemmatum**
Zebrasoma scopas
Apogonidae
Apogon aereus
Apogon taeniophorus
Atherinidae
Atherinomorus lacunosus
Aulostomidae#
*Aulostomos chinensis**
Balistidae
Balistapus undulatus
Balistoides conspicillum
*Balistoides viridescens**
Melichthys indicus
Odonus niger
Pseudobalistes rectangulus
Sufflamen bursa
Sufflamen chrysopterus
Sufflamen fraenatus
Blenniidae
Exallias brevis
*Istiblennius edentulous**
*Pereulixia kosiensis**
Plagiotremus tapeinosoma
Unidentified spp.
Bothidae#
*Bothus mancus**
Caesionidae
Caesio caerulaureus
Caesio teres

FAMILY / SPECIES

Carangidae
Caranx ignobilis
Caranx melampigus
Caranx papuensis
Caranx sem
*Caranx sexfasciatus**
*Decapterus macarellus**
*Gnathanodon speciosus**
Scomberoides sp.
Trachinotus botla
Carcharhinidae#
*Carcharhinus amblyrhynchos**
*Carcharhinus leucas**
*Galeocerdo cuvier**
*Triaenodon obesus**
Chaetodontidae
Chaetodon auriga
Chaetodon blackburnii
*Heniochus diphreutes**
Chaetodon dolosus
Chaetodon guttatissimus
Chaetodon interruptus
Chaetodon kleinii
Chaetodon lunula
Chaetodon mertensii
Chaetodon meyeri
*Chaetodon trifascialis**
*Chaetodon trifasciatus**
Chaetodon vagabundus
Forcipiger flavissimus
Hemitaurichthys zoster
Heniochus acuminatus
Cirrhitidae
Cirrhitichthys oxycephalus
Paracirrhites arcatus
Paracirrhites forsteri
Coracinidae
Coracinus multifasciatus
Cynoglossidae
Cynoglossus sp.
*Parapaglusia bilineata**
Dasyatidae
Dasyatis kuhlii
*Himantura gerrardi**
Urogymnus asperrimus

Appendix 4.4 Continued.

FAMILY / SPECIES
Dinopercidae
Dinoperca petersi
Diodontidae
Diodon liturosus
Echeneidae
Echeneis naucrates
Ephipidae
Platax sp.
*Platax teira**
*Tripterodon orbis**
Exocoetidae
Unidentified spp.
Fistularidae
*Fistularia commersonii**
Fistularia petimba
Gerreidae
Gerres acinaces
Gobiidae
Nemateleotris magnifica
Ptereleotris evides
Unidentified spp.
Grammistidae
Grammistes sexlineatus
Haemulidae
Plectorhinchus chubby
Plectorhinchus flavomaculatus
Plectorhinchus gaterinus
Plectorhinchus playfairi
Plectorhinchus schotaf
Pomadasys commersonnii
Pomadasys furcatum
Hemiramphidae
Hyporhamphus affinis
Holocentridae
Myripristis murdjan
Sargocentron diadema
Istiophoridae#
*Makaira indica**
Khuliidae
Khulia mugil
Kyphosidae
Kyphosus bigibbus
Labridae
Anampses caeruleopunctatus
Anampses lineatus
*Bodianus anthioides**
Bodianus axillaries
Bodianus bilunulatus

FAMILY / SPECIES
Bodianus Diana
*Bodianus perditio**
Coris aygula
Coris caudimacula
Coris Formosa
Coris gaimard africana
Gomphosus caeruleus
*Halichoeres cosmetus**
Halichoeres hortulanus
Halichoeres nebulosus
*Hemigymnus fasciatus**
Labroides dimidiatus
*Labroides bicolor**
Stethojulis albovittata
Stethojulis interrupta
Sthethojulis strigiventer
Thalassoma amblycephalum
*Thalassoma genivittatum**
Thalassoma hebraicum
Thalassoma lunare
Thalassoma purpureum
Thalassoma trilobatum
Lethrinidae
Gnathodentex aureolineatus
Gymnocranius griseus
Lethrinus crocineus
Lethrinus harak
Lethrinus nebulosus
Monotaxis grandoculis
Lutjanidae
Aprion virescens
Lutjanus argentimaculatus
Lutjanus bohar
Lutjanus fulviflama
Lutjanus gibbus
Lutjanus kasmira
Lutjanus russellii
*Macolor niger**
Malacanthidae
Malacanthus sp.
*Malacanthus latovittatus**
Mobulidae
Manta birostris
Monacanthidae
Cantherhines pardalis
Monodactylus argenteus
Mugilidae
Mugil cephalus

Appendix 4.4 Continued.

FAMILY / SPECIES

Mugilidae (cont.)
Valamugil buchanani
Mullidae
Mulloides vanicolensis
Parupneus bifasciatus
*Parupneus cyclostomus**
Parupneus indicus
Parupneus rubenscens
Muraenidae
*Echidna nebulosa**
*Gymnomuraena zebra**
Gymnothorax favagineus
*Gymnothorax meleagris**
Siderea grisea
Myliobatidae
Aetobatus narinari
Nemipteridae
Scolopsis vosmeri
Notocheiridae
Iso natalensis
Odontaspididae#
*Eugomphodus taurus**
Oplegnathidae
Oplegnathus robinsoni
Orectolobidae
Stegostoma fasciatum
Ostraciidae
Ostracion cubicus
Ostracion meleagris
Pempheridae
Pempheris adusta
Pinguipedidae#
*Parapercis exophthalma**
Parapercis robinsoni
Plotosidae
Plotosus lineatus
Pomacanthidae
Apolemichthys trimaculatus
Centropyge acanthops
Pomacanthus imperator
Pomacanthus rhomboides
Pomacanthus semicirculatus
Pomacentridae
Abudefduf natalensis
Abudefduf notatus
Abudefduf sexfasciatus
Abudefduf sordidus
Abudefduf sparoides

FAMILY / SPECIES

Abudefduf vaigiensis
Amphiprion akallopisos
Amphiprion allardi
Chromis dasygenys
Chromis dimidiata
Chromis nigrura
Chrysiptera unimaculata
Dascyllus trimaculatus
Plectroglyphidodon leucozonus
Pomacentrus caeruleus
*Pomacentrus trichouros**
Priacanthidae
Priacanthus hamrur
Pseudochromidae
Pseudochromis dutoiti
Rhincodontidae
Rhincodon typus
Scaridae
Scarus ghobban
Scarus rubroviolaceus
*Scarus tricolor**
Sciaenidae
Argyrosomus japonicus
Umbrina canariensis
*Umbrina ronchus**
Scombridae#
*Thunnus albacares**
Scorpaenidae
Pterois miles
*Scorpaenopsis venosa**
Scorpidadae
Neoscorpis lithophilus
Serranidae
*Aethaloperca rogaa**
*Anthias evansi? **
Cephalopholis argus
Cephalopholis miniata
Cephalopholis nigripinnis
Epinephelus flavocaerulus
Epinephelus malabaricus
Epinephelus marginatus
Epinephelus rivulatus
Epinephelus tukula
Nemanthias carberryi
Pseudanthias sqamipinnis
Variola albimarginata
Variola louti

Appendix 4.4 Continued.

FAMILY / SPECIES

Siganidae
Siganus stellatus
Siganus sutor
Sparidae
Diplodus cervinus hottentotus
Lithognathus mormyrus
Rhabdosargus sarba
Acanthopagrus bifasciatus
Diplodus sargus capensis
Rhabdosargus holubi
Rhabdosargus thorpei
Sphyraenidae
Sphyraena sp.
Sphyrnidae#
Sphyrna sp.*
Synodontidae
Synodon variegatus
Teraponidae
Terapon jarbua
Tetraodontidae
Amblyrhynchotes honckenii
*Arothron meleagris**
*Arothron nigropunctatus**
Canthigaster ambionensis
Torpedinidae
Torpedo sinuspersici
Tripterygiidae
Unidentified spp.
Zanclidae
Zanclus canescens

Appendix 4.5 Results of nested ANOVA performed on fish parameters in the reef groups, previously identified by multivariate analysis. Significance is shown in **bold**.

Total Fish Density	DF	SS	MS	F	p
Intercept	1	65,80978	65,80978	2918,069	0,000000
Reef Groups	2	0,91425	0,45712	20,269	**0,000000**
Reefs (within reef groups)	3	0,44824	0,14941	6,625	**0,000332**
Error	133	2,99948	0,02255		
Total	138	4,34250			
Total Fish Diversity					
Intercept	1	25,56418	25,56418	26289,44	0,000000
Reef Groups	2	0,08953	0,04476	46,03	**0,000000**
Reefs (within reef groups)	3	0,26849	0,08950	92,04	**0,000000**
Error	133	0,12933	0,00097		
Total	138	0,48784			
Total Piscivore Density					
Intercept	1	4,146486	4,146486	130,2096	0,000000
Reef Groups	2	0,290354	0,145177	4,5589	**0,012162**
Reefs (within reef groups)	3	0,092412	0,030804	0,9673	0,410258
Error	133	4,235345	0,031845		
Total	138	4,600347			
Total Piscivore Diversity					
Intercept	1	3,327283	3,327283	144,0012	0,000000
Reef Groups	2	0,145088	0,072544	3,1396	**0,046525**
Reefs (within reef groups)	3	0,057562	0,019187	0,8304	0,479388
Error	133	3,073091	0,023106		
Total	138	3,262142			
Carangidae Density					
Intercept	1	0,126714	0,126714	7,973834	0,005476
Reef Groups	2	0,042030	0,021015	1,322429	0,269968
Reefs (within reef groups)	3	0,250361	0,083454	5,251568	**0,001865**
Error	133	2,113528	0,015891		
Total	138	2,405639			
Lutjanidae Density					
Intercept	1	0,193091	0,193091	13,06340	0,000426
Reef Groups	2	0,105715	0,052858	3,57604	**0,030709**
Reefs (within reef groups)	3	0,018289	0,006096	0,41245	0,744329
Error	133	1,965881	0,014781		
Total	138	2,099846			
Serranidae Density					
Intercept	1	2,328875	2,328875	90,93522	0,000000
Reef Groups	2	0,085431	0,042716	1,66791	0,192562
Reefs (within reef groups)	3	0,030857	0,010286	0,40163	0,752057
Error	133	3,406165	0,025610		
Total	138	3,512141			

Appendix 4.4 Continued.

Total Prey Density	DF	SS	MS	F	p
Intercept	1	65,00561	65,00561	2861,177	0,000000
Reef Groups	2	0,89910	0,44955	19,787	**0,000000**
Reefs (within reef groups)	3	0,45001	0,15000	6,602	**0,000342**
Error	133	3,02174	0,02272		
Total	138	4,35202			
Total Prey Diversity					
Intercept	1	26,19157	26,19157	26283,17	0,000000
Reef Groups	2	0,00308	0,00154	1,54	0,217439
Reefs (within reef groups)	3	0,00680	0,00227	2,28	0,082686
Error	133	0,13254	0,00100		
Total	138	0,14200			
Corallivore Prey Density					
Intercept	1	0,005232	0,005232	59,38947	0,000000
Reef Groups	2	0,000614	0,000307	3,48496	**0,033483**
Reefs (within reef groups)	3	0,000419	0,000140	1,58701	0,195519
Error	133	0,011716	0,000088		
Total	138	0,012600			
Chaetodontidae Density					
Intercept	1	25,93473	25,93473	6685,740	0,000000
Reef Groups	2	0,00044	0,00022	0,056	0,945185
Reefs (within reef groups)	3	0,01237	0,00412	1,063	0,367165
Error	133	0,51592	0,00388		
Total	138	0,52860			
Labridae Density					
Intercept	1	21,45512	21,45512	4388,731	0,000000
Reef Groups	2	0,05117	0,02558	5,233	**0,006490**
Reefs (within reef groups)	3	0,08179	0,02726	5,577	**0,001236**
Error	133	0,65019	0,00489		
Total	138	0,78560			
Lethrinidae Density					
Intercept	1	0,026729	0,026729	4,432271	0,037146
Reef Groups	2	0,008620	0,004310	0,714700	0,491208
Reefs (within reef groups)	3	0,006098	0,002033	0,337057	0,798562
Error	133	0,802074	0,006031		
Total	138	0,816986			
Pomacanthidae Density					
Intercept	1	9,624581	9,624581	474,7287	0,000000
Reef Groups	2	0,257963	0,128981	6,3620	**0,002298**
Reefs (Reef Groups)	3	0,274143	0,091381	4,5073	**0,004800**
Error	133	2,696423	0,020274		
Total	138	3,284750			
Pomacentridae Density					
Intercept	1	31,34729	31,34729	477,5244	0,000000
Reef Groups	2	0,31657	0,15828	2,4112	0,093621
Reefs (within reef groups)	3	1,16460	0,38820	5,9136	**0,000809**
Error	133	8,73084	0,06565		
Total	138	10,15535			
Serranidae Density	DF	SS	MS	F	p
Intercept	1	10,43025	10,43025	143,3468	0,000000
Reef Groups	2	8,99562	4,49781	61,8150	**0,000000**
Reefs (within reef groups)	3	1,32938	0,44313	6,0900	**0,000648**
Error	133	9,67740	0,07276		
Total	138	20,07338			