Frontier Mozambique Environmental Research

REPORT 1

Introduction and Methods

Marine Biological and Resource Use Surveys of the Quirimba Archipelago

Ministry for Coordination of Environmental Affairs

Frontier Mozambique
1997

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Marine Biological and Resource Use Surveys of the Quirimba Archipelago

Whittington M.W., and Myers, M. (eds)

Ministry for the co-ordination of Environmental Affairs, Mozambique

Darwin Initiative: Department for Environment and Rural Affairs, UK.

Frontier-Mozambique Society for Environmental Exploration

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Frontier-Mozambique
Frontier-Mozambique was initiated in January 1996 when a Memorandum of Understanding was signed between The Society for Environmental Exploration and the Ministry for the Co-ordination of Environmental Affairs (Ministério para a Coordenação de Acção Ambiental), Mozambique. The aim of Frontier-Mozambique was to undertake field research within the Quirimba Archipelago, an area of recognised biological interest and conservation value.

The Ministry for the Co-ordination of Environmental Affairs
The Ministry is a Mozambican government organisation which co-ordinates the sustainable development process, harmonising the activities of different public and private sectors with environmental principles and practises and developing appropriate policies and legislation towards this end. The Ministry also trains the necessary technicians through executive activities and demonstrate models of good practise.

The Society for Environmental Exploration (SEE)
The Society is a non-profit making company limited by guarantee and was formed in 1989. The Society's objectives are to advance field research into environmental issues and implement practical projects contributing to the conservation of natural resources. Projects organised by The Society are joint initiatives developed in collaboration with national research agencies in co-operating countries.

FOR MORE INFORMATION

Ministry for Co-ordination of Environmental Affairs
P.O. Box 2020
Acordo Lusaka Avenue 2115
Maputo,
Mozambique
Tel : 258-68843/51
Fax: 258-4658 49

Society for Environmental Exploration
50-52 Rivington Street, London, EC2A 3QP. U.K.
Tel: +44 20 76 13 24 22
Fax: +44 20 76 13 29 92
E-mail: info@frontier.ac.uk
Internet: www.frontier.ac.uk

Darwin Initiative
Department for Environment, Food and Rural Affairs, 4/CI Ashdown House, 123 Victoria Street, London, SW1E 6DE
Tel: +44 (0) 20 7944 6205
Fax: (0) 20 7944 6239
Email: darwin@defra.gsi.gov.uk

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SECTION 1: INTRODUCTION

1.0 Preamble

Throughout the world, in both developing and developed countries, there has been an increasing awareness over the last 20 years of the importance of the resources that lie in the coastal zone. This zone includes terrestrial and marine areas and can be defined as that area where the terrestrial environment has an influence on the marine environment and vice versa. Coastal zones can be characterised as dynamic and populous areas often with plentiful natural resources and valuable floral and faunal communities. The realisation of the actual and potential contributions of these zones to national economies, and of their vulnerability and degradation in many places, has stimulated efforts for their protection from the United States to Indonesia.

Planners were initially heldback by the limited understanding of physical and biological processes along coasts. In order to legislate for the sustainable management of resources it is vital to have an understanding of how they function. The realisation of the need for such information has led to the conduction of a great amount of scientific work to investigate all aspects of coastal zone systems over the last two decades such that today there is a firmer grasp of the functioning of coastal habitats and the coastal environment and there are also frameworks and management strategies (such as 'Integrated Coastal Zone Management') that aim to clarify the administrative requirements for effective management.

Africa has not been at the forefront of this movement but many African countries, such as South Africa, Kenya, Ghana, Senegal and Mauritania, have taken steps towards recognising the coast as a unique environment requiring a special, non-sectoral approach for its effective management (World Bank, undated).

Mozambique is among those countries now taking measures to improve their coastal management (Hatton, 1995) but it is faced with a familiar range of obstacles including: limited financial resources; shortage of suitably skilled personnel; poor infrastructure - both physical and political, and finally; a lack of information on the existing natural resources and coastal habitats within the country, viz. data on the distribution and status of habitats, patterns and scales of resource utilisation, sustainable rates of exploitation and the location of key areas in terms of biological diversity.

The current programme has been initiated specifically to help overcome some of these obstacles through the provision of data on habitat distributions, biodiversity and resource use, and by a strengthening of in-country expertise through a programme of field training for Mozambican scientists. The area chosen for survey is located within an island chain in the far north of the country. This area has been chosen for its potentially high level of biodiversity (Tinley, 1970), the extreme dearth of information on its natural habitats, and its potential for tourism development.

1.1 The Regional Context

Marine and coastal resources are a significant element in the economies of all the countries in the Eastern African Region[1]. Coastal communities in particular have a high dependence on these resources for animal protein, building materials and firewood and for employment. Kenya, the Seychelles and Mauritius derive significant foreign currency earnings through tourism which depends largely on the maintained integrity of the coastal environments.

Mozambique, with a 2,700 km long coastline (second in the region only to Madagascar), is one of the most marine-resource-dependent nations in East Africa. The estimated population size for the country is 18 million, some 40% of whom live in coastal districts (Lopes, 1996) and 65% within 40 km of the coast. With a per capita income of $94 (1993 figure, cited in Danida, 1995) the economic importance of the sustainable management of all natural resources cannot be overestimated.

The high regional reliance on marine resources notwithstanding, their utilisation in mainland East Africa over the past twenty years has not been sustainably managed (World Bank, undated). Despite the protected status of mangrove trees through much of the region, illegal felling for salt and prawn production, and even agriculture, has caused massive deterioration of the resource. Other critical habitats, such as coral reefs and seagrass beds, have been undermined by destructive methods of exploitation such as dynamite fishing (widespread in Kenya and Tanzania) and seine netting, often in spite of legislation against such activities. Of the eight marine reserves in Tanzania in 1981, only two at Mafia Island now retain intact coral reefs because of the almost total lack of resources available to implement regulations (Ngoile and Horrill, 1993). Fish stocks around the inshore reefs within these reserves are now greatly depleted (Horrill and Ngoile, 1991).

Mozambique has probably enjoyed even less active coastal resource management than its neighbours, though political instability and consequent low levels of economic development may have spared coastal systems from some of the more harmful practices inflicted elsewhere. The danger to foreign tourists and businessmen in visiting a country involved in civil war has impeded the development of coastal tourism and the trade in marine products. (It should be noted that there used to be a high level of coastal tourism before the war and it is likely to return on an even larger scale. Although this should provide a welcome source of income there is a definite risk to the environment unless correctly managed). Moreover, the general absence until now of industrial development and high seas trade in Mozambique has kept marine pollution at low levels. There is, however, a major shipping route down the East African coast used by oil tankers from the Gulf and consequently there exists the potential for acute hydrocarbon pollution in Mozambican waters.

[1]Mozambique is more usually seen as part of the Southern African Region, however, the biology of the northern coastal habitats, which are the subjects of study, is far more closely linked to the East African Region. For the purposes of this document we will therefore speak of Mozambique in the regional context of East Africa.

Since the cessation of war in 1992 the situation has started to change to allow the potential for large scale commercial exploitation of coastal resources and the return of tourism to the coastal areas. In 1994 the authorities drew up a masterplan for the development of the fisheries sector which aims for greatly increased exploitation of fisheries resources (SSF, 1994). Whilst maximisation of catches is an important goal, success requires the adoption of suitable resource monitoring and protection initiatives. Activity in the coastal tourism sector is already growing swiftly in Mozambique, with operators of all sizes from South Africa, Zimbabwe and elsewhere being quick to take advantage of the new political stability.

1.2 The Coastline of Mozambique

The coastline can be divided into three distinct natural regions (Massinga and Hatton, 1996):

i) Coral Coast; the northernmost section extending 770 km south from the Rovuma River (the border with Tanzania) and having a narrow continental shelf (<30 km wide);

ii) Swamp Coast; the central section of nearly 1,000 km stretching from Angoche in the north to Bazaruto Island in the south with high levels of river discharge, high turbidity and a broader continental shelf, and;

iii) Parabolic Dune Coast; the southern section stretching to the South African border and beyond with high dunes enclosing barrier lakes.

Tidal ranges average 3-4 metres but with tides as high as 6.3 m at Beira. The island of Madagascar, some 400-600 km to the east, protects most of the coastline - though not the Cabo Delgado region - from the open ocean and the coast is dominated by the warm, south-flowing Mozambique Current.

1.3 The Current Utilisation and Management of the Coastal Zone in Mozambique

In the National Environmental Management Programme (MICOA, 1996) the coastal zone is identified as one the three areas of critical importance to the nation and so deserving of special attention. Although there are a small number of management projects and protected areas along the coast (see below) the management and current utilisation of the great majority of the coastline can be characterised as follows.

The coastal strip is now home to the majority of the population (approximately 7.5 million). This is in part due to internal migration to the relatively secure coastal areas during the civil conflict and due to the concentration of natural resources within the coastal strip. These resources are consequently under increasing pressure which is exacerbated by the low level of planning that has gone into the occupation and use of land; internal migrants occupied land on the coast before the infrastructures to support them could be put in place. It is also unlikely that the migrants will return to their original

homes towards the centre of the country before a sufficient infrastructure has been rebuilt to support them. Developments towards this restructuring are currently at a relatively low level.

Over half a million coastal dwellers are believed to depend directly on fishing for their livelihoods (MICOA, 1996), not to mention the dependency on other coastal goods and services. High pressures in the coastal zone itself have meant that in certain instances, such as the shrimp fishery in the central zone, the carrying capacity of ecosystems is being exceeded (SSF, 1994). Added to this are activities in the interior such as deforestation and river pollution that also impact on the coastal ecosystems.

Slash and burn agriculture is common throughout Mozambique including on the nutrient-poor sandy soils of the coastal strip (Hatton and Massinga, 1996). Studies have shown recovery of the soil after the land is abandoned is likely to take decades (Serra King, 1995) and natural vegetation succession can take place only slowly. This may lead to increased soil erosion, increased turbidity of coastal waters, and reduced coastal stability.

Other management issues include the degradation of mangroves, coral reefs and seagrass beds and the great lack of information to guide planners in the designation and management of protected areas. The increasing levels of pollution and the lack of infrastructure to deal with it are another concern (Fernandes, 1996) for although, in absolute terms, the level of marine pollution in Mozambique is low it is disproportionately high considering the level of industrial activity in the country.

Land use planning in the coastal zone is complicated by the involvement of multiple local and central government agencies with overlapping and ill-defined mandates. There is also a lack of capacity to enforce planning regulations with the result that developments go ahead before licences have been obtained (Hatton *et al.*, 1996). This institutional confusion is also present at higher levels with many different Ministries and Departments asserting their involvement in coastal zone issues (Massinga and Hatton, 1996). However, MICOA (Ministry for Co-ordination of Environmental Affairs) is now acknowledged as the lead institution for coastal affairs and has the task of co-ordinating the inputs and responsibilities of the other bodies.

1.3.1 Summary of Current Coastal Reserves and Resource Management Initiatives

Coastal Reserves:

As mentioned above, there are a number of initiatives already in place working towards the conservation and sustainable management of coastal habitats in localised areas (Fig. 1) and these are outlined below (after Massinga & Hatton, 1996).

Marromeu Reserve - floodplains and mangroves. Despite being a registered conservation area the reserve so far lacks the necessary conservation measures and investment to fulfil its role. Game populations have been much reduced.

Maputo Reserve - dune forests, floodplains, swamp forests, mangrove and grassland. Under the management of the National Parks and Wildlife Department (DNFFB) with the assistance of the Endangered Wildlife Trust. (The status of this reserve may be radically affected by its assimilation into a new 'ecotourism' venture that has recently been approved).

Pomene Reserve - There is confusion over the demarcation of this supposedly coastal reserve; it could be that the littoral zone may not be included. Conservation measures are so far lacking.

Bazaruto National Park - Two islands and their littoral waters. Conservation measures are the responsibility of DNFFB with the assistance of the World Wide Fund For Nature (WWF).

Inhaca & Portuguese Islands Biological Reserve - Protection of reefs, dune forests and turtle nesting beaches. Situated a short distance from the capital, Maputo, this reserve is managed by the University of Eduardo Mondlane.

Resource management projects:

In addition to the above listed protected areas the following two coastal management projects are also operating.

Mecufi Coastal Zone Management Project - The project is run by the Ministry for the Co-ordination of Environmental Affairs (MICOA) with Norwegian Aid funding. The project aims to reduce the pressure on the natural resource base in Mecufi District in Cabo Delgado Province. To this end they promote improved management and conservation practices through environmental education and community participation (Massinga, 1996).

Xai-Xai - The district of Xai-Xai has been the subject of a coastal profile exercise to assess its development potential and to analyse the land-use conflicts there. There are also plans to establish a National Centre of Coastal Management for Sustainable Development in Xai-Xai. This will be the centre for research and training in coastal management in Mozambique (Mabjaia, 1996).

Management workshops:

The Role of Research in Management of the Coastal Zone - This workshop was held in Maputo in April 1996 and prompted papers outlining the condition of habitats along the Mozambican coast as well as discussions of the research needed for effective CZM (Coastal Zone Management) in the future.

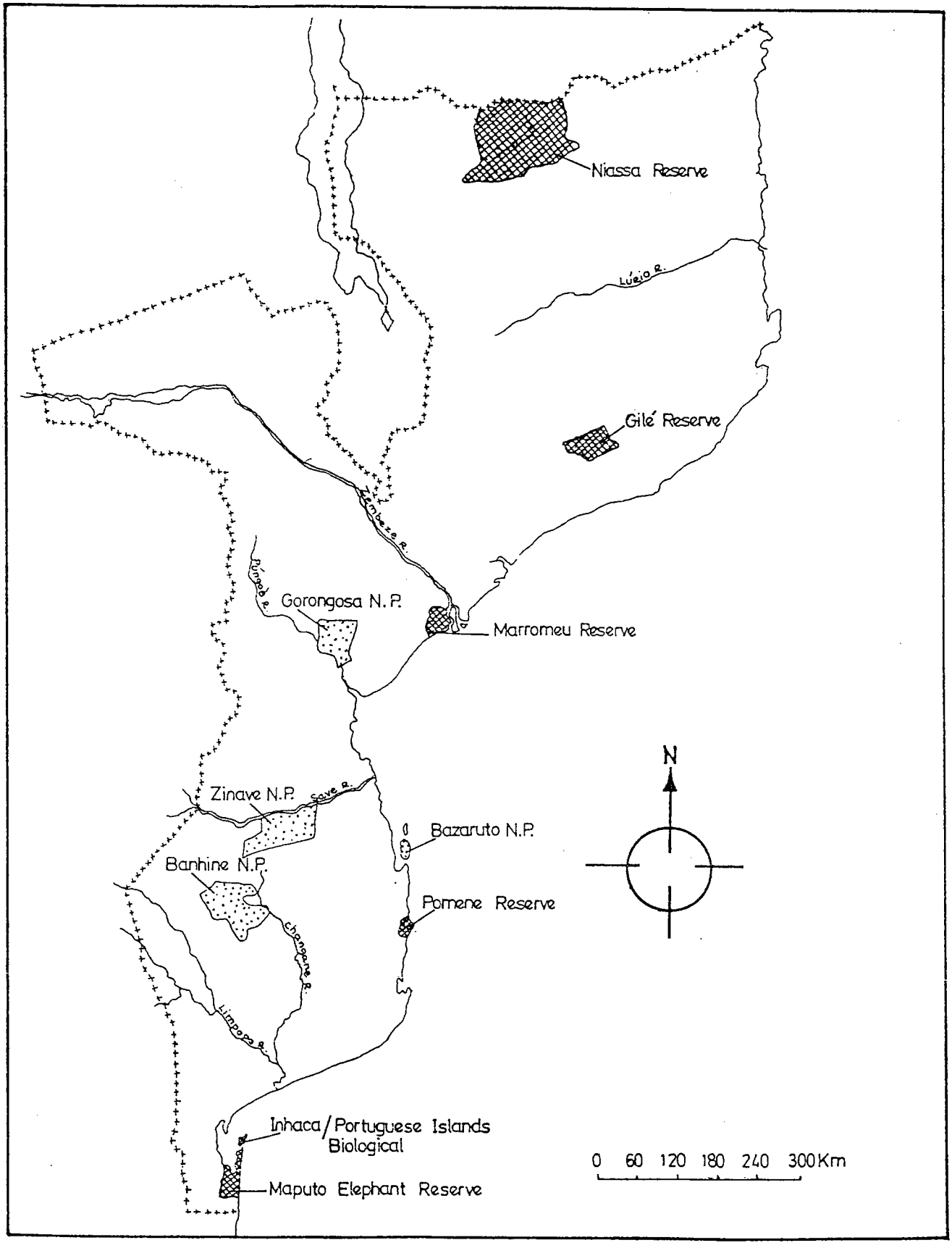

Figure 1. Conservation Areas (National Parks and Reserves) of Mozambique

The Integrated Coastal Zone Management Workshop - This took place on Inhaca Island in May 1996 and was a major forum for involved institutions to discuss the problems of CZM in Mozambique and to share ideas. The workshop generated a large number of written papers.

Formation of the Coastal Zone Working Group - Under MICOA, the lead agency, a group has been formed in 1996 with members from the most involved government ministries, institutes and other organisations. Its role so far is one of information sharing and co-ordination with regards to coastal issues and planning.

At the April workshop in Maputo the following areas were among those identified as priorities for research/action to enable good coastal management decisions to be made:

i) Inventory and classification of coastal habitats (mangrove, coral reef, inter-tidal and estuarine) which so far are little known and understood in Mozambique;

ii) Improved grasp of the socio-economics of the coastal environment and of the impacts of development and resource-use activity on the environment, and;

iii) Greater availability of the information that does exist on coastal zone resources and issues.

In summary, there is a realisation at government level of the importance of coastal habitats which has prompted a considerable amount of activity in the form of workshops and discussions. However, words have yet to be transferred into actions on the ground and there are as yet few operating projects or protected areas.

1.4 The Quirimba Archipelago

The northernmost coastal province, Cabo Delgado, is in the zone classed as Coralline Coast. It has an extensive reef and island system along much of its length known as the Quirimba Archipelago. The oceanic side of the chain is not sheltered by the landmass of Madagascar, as so much of the Mozambican coast is, but is exposed to the Indian Ocean and its South Equatorial Current which splits in the north of the Province to run north to Tanzania and south along the Mozambique coast. There is no significant upwelling in these waters and the tidal range is typically 4 metres (Massinga and Hatton, 1996).

Surveys so far carried out on the Quirimbas are very few, due largely to an imbalance of influence and resources between the north and south of the country, the capital, Maputo is 2,000 km to the south of Pemba. However, Tinley (1970) made a recommendation that the entire chain be designated as a protected area though to date there have been no coastal protected areas demarcated north of Sofala Province (the Marromeu Reserve) (Fig.1).

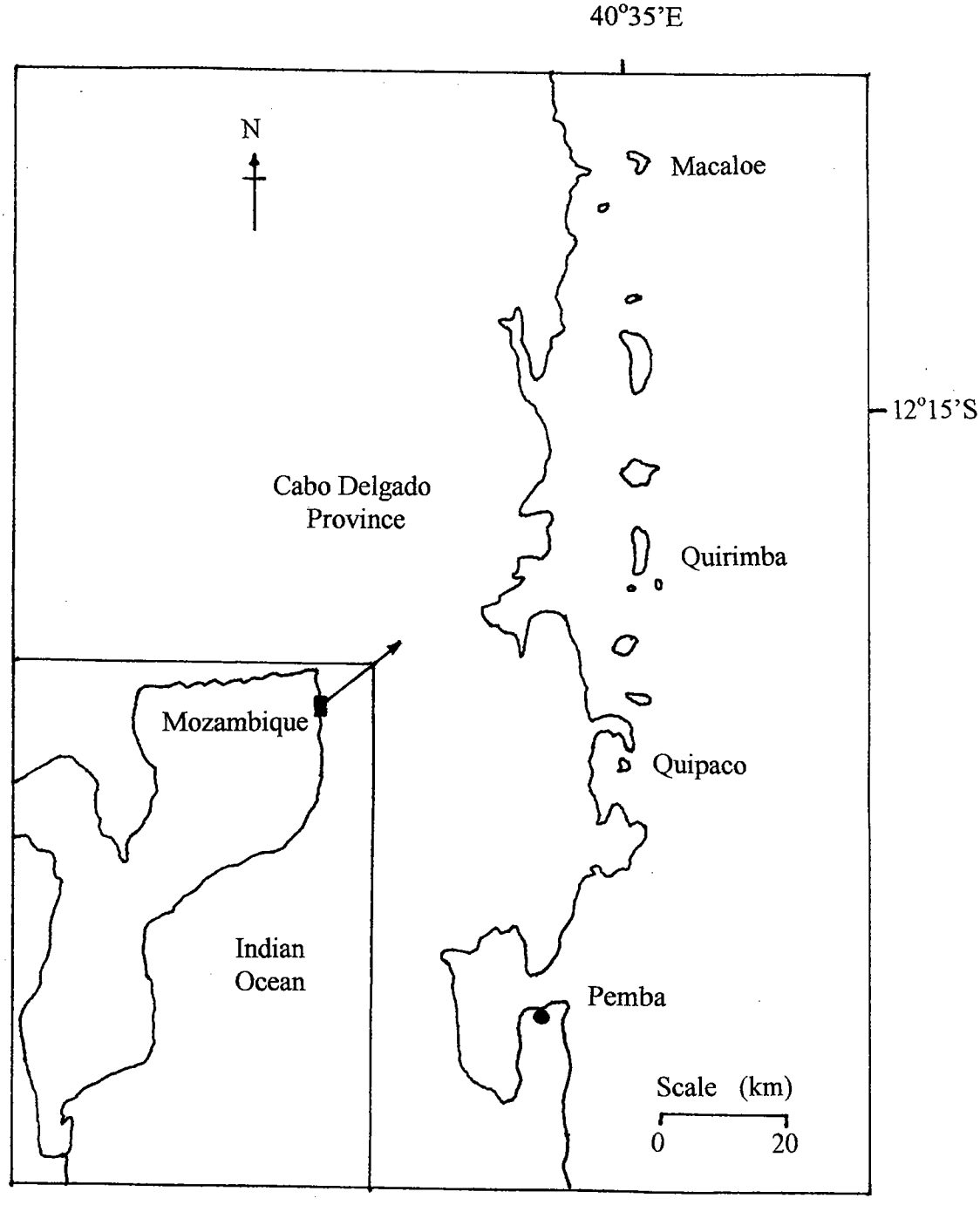

Figure 2. A map indicating the location of the Quirimba Archipelago, Mozambique (inset) and the location of the Programme's study area.

The islands and reefs of the Quirimbas lie on the outer edge of the continental shelf at a maximum distance of 10 km from the mainland. Large areas of the mainland coast and of the islands' western edges are dominated by mangrove stands. These, along with the extensive seagrass beds and the coral reefs, are probably the major nursery areas for the fishery of the islands.

Fishing is the main occupation in the islands. The larger, permanently inhabited islands such as Ibo, Quirimba, Matemo and Mefunvo have fishing-based economies and the temporary camps that spring up on these and other islands are entirely due to fishing activity. Fishing is predominantly for subsistence as there is neither a sufficient market for fish locally nor the infrastructure to preserve and transport the catch to the mainland markets (IDPPE, 1996). The only significant exports are of sun-dried fish.

Other economic and subsistence activities in the islands include gleaning on the intertidal mostly by women and children and cutting of mangrove.

There are few development projects or activities in the islands at present. The Institute for the Development of Small Scale Fisheries (IDPPE) has a presence on Ibo and is collecting catch data around the islands. Also on Ibo is a fish processing co-operative with freezing facilities, however this recently seems to have reduced its turnover. Additionally there are commercial operations fishing holothuria (seacucumbers) and shark fin along much of the northern coast.

The Ministry of Culture and Tourism is seeking funding to have the Quirimbas declared a site of cultural heritage with attendant work planned for the preservation of historical buildings and an assessment of the natural resources and socio-economics of the islands.

1.5 The Darwin/Frontier-Moçambique Quirimba Archipelago Marine Research Programme

The aims of the current Programme are to provide necessary information to assist in the future planning for the sustainable use of resources and the protection of biodiversity in the Quirimba islands through:

(1) describing and mapping the coastal habitats of the islands, identifying areas of notably high biological diversity, and;

(2) determining the current patterns and scale of resource use whilst highlighting any unsustainable or destructive practices.

In recognition of the shortage of skilled personnel in-country to carry out this type of research (and to aid continued monitoring of the resources after the initial survey) the Programme is undertaking training for Mozambican scientists and students in resource-use monitoring techniques and in the use of SCUBA diving equipment. Participants undergo a period of training before practising the techniques under supervision while actually collecting data. This element of the Programme strengthens institutional capacity

in Mozambique and also may help to increase communication and co-ordination among the various involved agencies through the forging of informal and formal links.

The Quirimba Archipelago was chosen as a site for study after consultation between the Society for Environmental Exploration and a range of Mozambican government institutions with an interest in the coastal zone. It is an area ripe for surveying because of the almost total lack of scientific information available for the management of local marine resources and habitats. The early indications are that the islanders have a high dependence on the natural resources of the area and this again makes it an area which stands to benefit from a study such as this. Preliminary surveys also suggest the area to be a site of high biological diversity and, because of the logistical difficulties of working in such a remote region, an area that the national authorities would find problematic to survey.

With the country recently emerging from a long period of civil war into a period of stability it is likely to be a time when institutional roles and powers in resource management will be re-established, industry will develop rapidly, and pressures on the natural resources will increase. Under such conditions the provision of information to aid in the management of coastal resources, such as provided by this programme, is very timely.

The work of the Programme is carried out by Darwin/Frontier-Moçambique, an NGO created by the Society for Environmental Exploration (SEE) in the UK and the Ministry for Co-ordination of Environmental Affairs in Mozambique. These two organisations are the key members of the advisory committee that steers the work of the programme and that also includes government research institutes, the main university and the Provincial Government of Cabo Delgado. Programme funding comes from SEE and the Darwin Initiative - a biodiversity fund of the Department of the Environment in the UK.

In the long term the Programme aims to provide Mozambican government institutions with the information necessary to develop coastal management tools and legislation for the Quirimbas if these are deemed necessary. The contribution of the Frontier-Moçambique project in surveying the Quirimba Archipelago is set in the context of other national and local initiatives that have been mentioned above. The programme adds significantly to the data available on the status of coastal resources in Mozambique and may thus stimulate their effective conservation and sustainable use.

SECTION 2: SURVEY METHODOLOGIES

2.0 Introduction to Methods

Since April 1996, the Darwin/Frontier-Moçambique Marine Research Programme, has conducted scientific survey work based on Quirimba Island (Fig 2), Cabo Delgado Province, Mozambique. During this period, Frontier-Moçambique has conducted a number of biological and resource use surveys using non-specialist volunteers from various countries together with students and personnel from collaborating organisations, departments and institutes in Mozambique.

The following information provides a detailed description of the biological and resource use survey methods employed to collect the data on which the Programme's reports are based. The methodologies, as described in this report, are a development of those employed by the Frontier-Tanzania Marine Research Programme (Darwall *et al.*, 1995), the ReefWatch Project (Tropical Marine Research Unit, York University), and the ASEAN programme (English *et al.*, 1994).

It is intended that this report, whilst forming a complete document in itself, provides an introduction and description of methods to accompany future reports produced by the Darwin/Frontier-Moçambique Marine Research Programme.

2.1 PART I: BIOLOGICAL SURVEYS

2.1.1 Selection of the Study Area and Survey Sites

The study area and the sites for detailed surveying were selected on the basis of information gathered from a variety of sources including: satellite imagery and aerial photography; navigation charts and maps; details of the administrative infrastructure, and; on-the-ground observations. The methods are more fully described below.

2.1.1.1 Selection of the Study Area

The Quirimba Archipelago is made up of 27 islands, numerous reefs, extensive seagrass beds and mangroves, and extends a distance of approximately 300 km alongside the coastline of Cabo Delgado Province, northern Mozambique. The size and complexity of thes archipelago determined that, within the two year timescale of the Programme it was not possible to survey the entire area in enough detail to obtain meaningful data in terms of the construction of a management plan. The Programme therefore selected and concentrated its work on the southernmost 100 km of the archipelago, from Ilha Macaloe in the north to Ilha Quipaco in the south (11°59'S to 12°41'S) (Fig. 2). This study area contains the most heavily populated islands of Ibo and Quirimba and also includes the administrative centre for the islands (Ibo). In addition, the proximity of the southern islands to the town of Pemba, the provincial capital, and to the major population centres in Nampula Province to the south, mean that it is likely that these islands will be subject to

the greatest influence from non-resident peoples (it is envisaged that this will be in the form of resource exploitation and commercial development, e.g. tourism).

Further to this, one of the long-term aims of the Programme is to facilitate the formulation and implementation of a management plan for the archipelago and in order for this to be feasible it is envisaged that there will need to be in-island administration of the plan. The islands in the north of the archipelago have no infrastructure and due to their remoteness are not readily accessible from the province's administrative centre in Pemba. It is therefore likely that any active management of the islands will be more easily achieved and have a better chance of sustained success in the southern islands of the archipelago where the administrative infrastructure is more developed and there is easier access from Pemba.

2.1.1.2 Selection of Detailed Survey Sites

A variety of satellite imagery, aerial photography, nautical charts and maps were obtained and provided the basis for the planning of the Programme's overall survey strategy for the study area and the positioning of the individual survey sites (see Appendix I for listing of reference material consulted). Within the survey area, the extent of the reef systems, seagrass beds and mangroves mean that it is not feasibly possible to survey all the areas in detail. A number of study sites to be surveyed in detail were identified that represent the different habitat types and topographical locations and the results from these sites were combined with the remote sensing information to extend the data to produce a detailed habitat map for the study area.

Many of the sites within the study area are known by a number of names and/or spellings depending on the source consulted. This has arisen from a mixing of Portuguese and the local Kimwani language names together with the often vague boundaries of a named area. For clarity, during the extent of the Programme's survey work, grid references and reference codes were assigned to each survey site and where relevant, all the commonly used site names are provided.

2.1.2 Subtidal Surveys

2.1.2.1 Introduction

The aim of the subtidal surveys was to collect data to provide a baseline for the future management of the subtidal marine resources within the Programme's study area. The surveys concentrated on determining the distribution and composition of the subtidal communities (e.g. coral reef and seagrass beds), their current condition, including evidence of damage, and the diversity and abundance of species within them. The presence and numbers of endangered or commercially important species were also noted.

The majority of the subtidal survey work was carried out by semi-skilled research assistants and due to the nature of underwater work it was not possible to directly supervise the surveys. Therefore the methods devised by the Programme reflect the need for straightforward and easily understood survey techniques and readily identifiable and

recordable data elements (for the purposes of the Programme's survey work, the term 'data element' will refer to a specific component or group of components that form part of the biological or physical structure of the habitat being surveyed e.g. fish species, substrate type, coral form). These should allow the research assistants to gather and produce reliable data. In order to facilitate this, the subtidal surveys were separated into two basic techniques; the 'Horizontal Survey' (Fig. 3) and the 'Vertical Survey' (Fig. 4). In addition, the majority of data elements to be recorded were identical for both survey techniques which further simplified the learning of the subtidal surveys and therefore helped to increase the reliability of the data produced.

2.1.2.2 Survey Strategy

The two basic techniques used for all the subtidal surveys are based on an assessment of transects:

Technique (1) "Horizontal Transect"
The aim of this technique is to gain information on the general structure and composition of the physical and biological features of the study site. Pairs of divers swim along the 'midline' of an imaginary transect 6 m wide along the side of the reef or over the seabed maintaining a constant depth and/or bearing. When conducting the habitat mapping surveys, at intervals of 5 minutes, the substrate and benthic community are summarised for the last 5 minutes swimming; meaning that during a typical survey of 30 minutes, 6 separate assessments are made (All data is recorded onto formatted dive slates, the formats of which are presented in Appendix IIIa-d). For divers carrying out a fish census or assessing the abundance of invertebrates and evidence of 'impacts' on the reef, recording is carried out continuously during each 5 minute period. The exact length of each transect will depend on a number of factors including; speed of swimming of the divers and the presence or absence of current. However, during training the speed of the swimming during surveys is standardised and this is combined with a distance estimate which should ensure that all data collected by the different surveys is comparable. The data once recorded is transfered to preprepared data sheets of the same format.

Technique (2) "Vertical Transect"
The aim of this technique is to gain information on the relatively detailed structure and composition of the physical and biological features of a small area of the study site. This technique is used on reef slopes only. Pairs of divers swim up an imaginary vertical transect, 10 m wide, from the base of the reef slope to the top. The demarcation of the upper and lower limits of the reef slope is not always clear but in general the lower limits of the reef are identified by a marked lessening in the angle of the reef slope and a change to a substrate where sand is the major component and hard coral cover is very low or non-existent (for safety and logistical reasons the surveys are normally limited to a depth of 20 m). The upper limits of the transect are normally

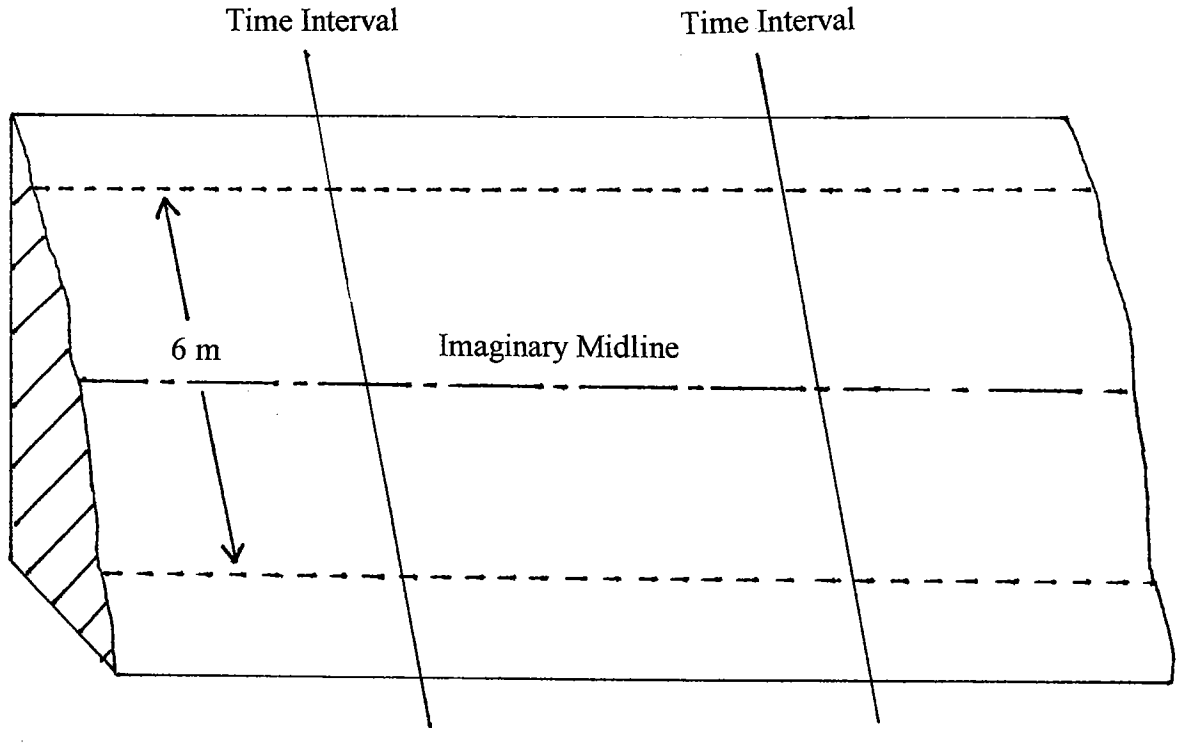

Figure 3. The "Horizontal Transect" survey technique employed by the programme for subtidal surveys

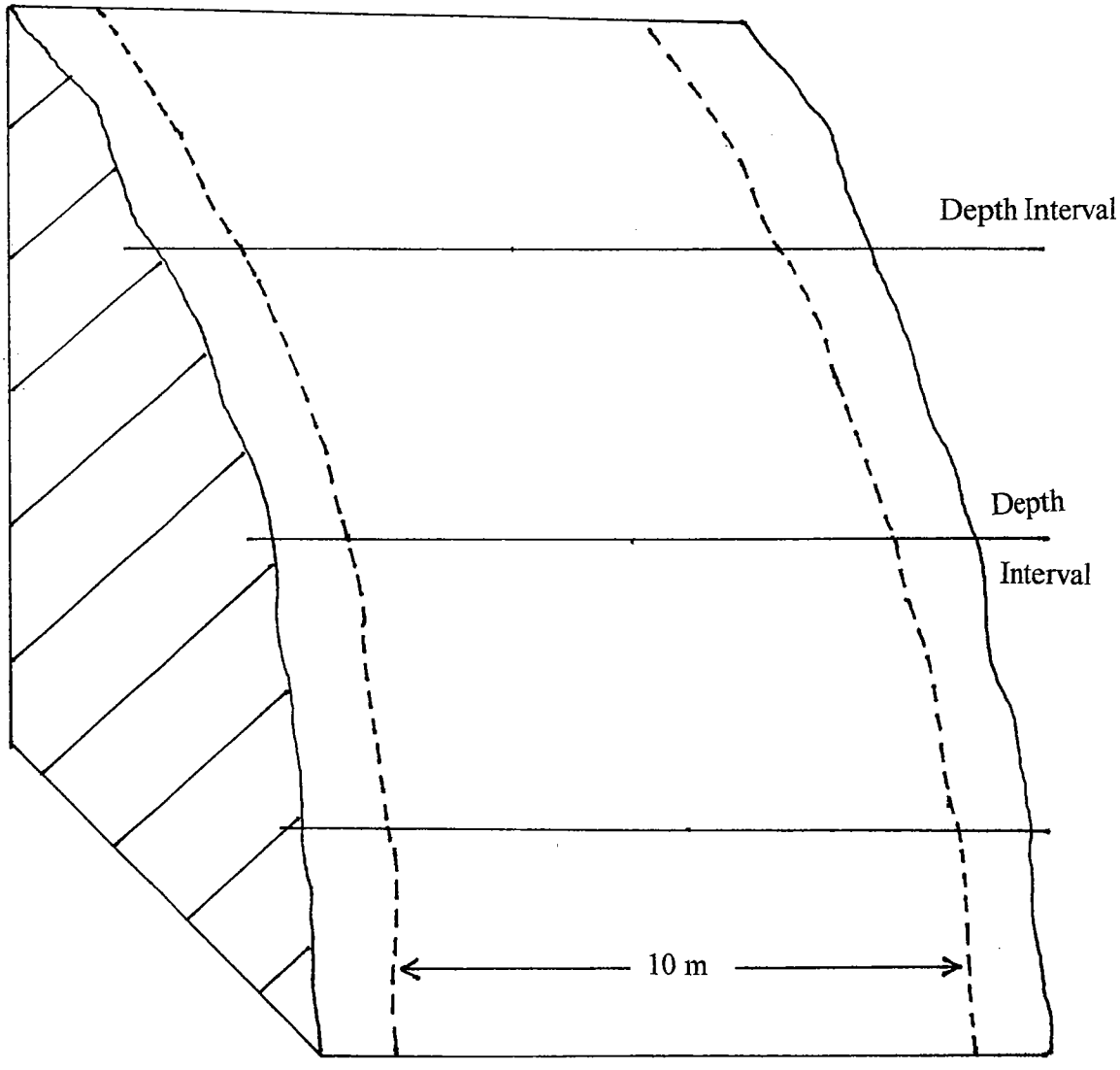

Figure 4. The "Vertical Transect" survey technique employed by the programme for subtidal surveys

marked by extensive areas of rubble found at the base of the reef crest where the waves begin to break. At vertical intervals of 2 m (this may vary depending on the total height of the reef slope and is determined prior to the dive based on depth soundings) the composition of the substrate and benthic communities are summarised and the fish, invertebrates and human and natural impacts (see section 2.1.2.4) data elements are counted.

The two techniques described above are employed to conduct four different types of survey. Presented below are introductions to each survey type combined with a detailed description and justification for the collection of each set of data elements.

As previously mentioned, the above techniques for recording the data have been developed with the aim of producing reliable, relevant results using semi-skilled recorders. The results produced aim to be comparable with data collected on marine biodiversity in other areas of the world e.g. ReefWatch in the Red Sea and Kenya.

To supplement the 'core' data produced by the research assistants using the standard survey techniques, project staff and skilled research assistants also carry out more detailed biodiversity studies on fish, corals, algae, seagrass, crustaceans, gastropods and other fauna and flora groups, depending on available expertise and reference material (Appendix II).

2.1.2.3 Survey 1: Habitat Survey

The 'Habitat Survey' contains data elements that describe features of substrate composition, seabed structure and benthic cover categories and is primarily aimed at habitat mapping.

Substrate composition:

Table 1 presents the data elements recorded to assess substrate composition, the first category of the Habitat survey. For the purposes of this survey, the substrate composition is assessed as if all the benthic cover has been removed to expose the substrate underneath. This is relatively straightforward although an assumption must be made that all substrate 'underneath' hard corals is rock. This is readily justifiable as hard (scleractinian) corals require a stable substrate to colonise due to their slow growth rate and the data element termed 'Rock' covers all stable substrate types. The data elements for substrate composition have been selected on the basis of degrees of stability and consequent suitability for colonisation by benthic organisms.

Table 1. Substrate composition data elements

Data Element	Description and Justification
Rock	All substrate solid and stable to touch. Most commonly bedrock and conglomerated coral rubble (includes larger boulders). It is assumed that all substrate beneath hard corals is rock. Stability allows colonisation of many organisms including the reef-building scleractinian corals.
Rubble	Loose, broken pieces of rock or hard coral (includes smaller boulders). Intermediate in stability, often being colonised by algaes, soft corals and sponges
Sand/Shell	Relatively fine, unstable particles. More stable sand can be colonised by seagrasses. Influences turbidity and sedimentation.
Mud	Compacted, very fine particles with high organic content. More stable than Sand/Shell and can be colonised be seagrass and algae.

In order to quantitatively assess the above data elements, the Programme uses a modified 'P-6' percentage abundance scale to record the percentage cover of each data element.

The scales of percentage cover used are:

Scale	%
0	0
P	<1
1	2-5
2	6-25
3	26-50
4	51-75
5	76-90
6	91-100

This abundance scale was found to be readily understandable by the research assistants, produced reliable results, and has sufficient resolution to distinguish habitats and communities on the scale to which the survey work is carried out. This 'P-6' scale is also used to assess the percentage cover of benthic cover and hard coral forms.

Benthic community composition:

Table 2 presents the data elements recorded to assess the benthic community composition, the second category of the Habitat survey. The data elements were chosen to represent the most commonly important components of the benthic cover found in a variety of subtidal marine habitats. The data elements are straightforward and are therefore only briefly described in Table 2. A data element "Micro-algae" (meaning the very fine, 'hair-like' algal filaments found on much of the hard coral and exposed rock and rubble) was initially proposed for this survey, but was excluded due to difficulties in identifying and accurately quantifying it. It was not felt that this amounted to a serious omission as micro-algae was never a significant component of benthic cover.

Table 2. Benthic Cover data elements

Data Element	Description and Justification
Hard Coral	Scleractinian coral. Main component of reef growth and structure.
Soft Coral	Non-scleractinian coral. Important component on many reefs. Often first to colonise damaged reefs and rubble patches.
Seagrass	Important component of organic production in tropical ecosystems. Found in areas of relatively stable Sand/Shell or Mud and occasionally in patches of irregular coral growth.
Algae-Macro	Plant-like algae.May be an indicator of elevated nutrient levels. Can overgrow dead corals and out-compete reef building organisms.
Algae-*Halimeda* spp.	A large calcareous green algae, found commonly on many reefs. Not associated with elevated nutrient levels.Important in reef building.

Coral growth forms:

Table 3 presents the data elements recorded to assess the diversity and composition of hard coral growth forms, as a subset of the data element `hard coral' within the second category of the Habitat survey. This assessment is time consuming and was thus restricted to surveys using the Vertical transect technique which provides more time for detailed survey. Composition and the proportional representation of growth forms was recorded for each of the individual depth increments independent of the records for total abundance of hard coral present. The 'P-6' scale was used for this measure. The hard coral forms used represent those defined by the ASEAN programme and are listed in Table 3.

Table 3. Hard Coral Forms

Data Element	Description and Justification
Coral Growth Form	e.g. Large Massive (diameter >300 mm) (e.g. genera *Porites*, *Favia* and *Favites*); Small Massive (diameter <300 mm) (e.g. genera *Porites*, *Favia* and *Favites*); Branching (e.g. genera *Acropora* and *Stylopora*); Staghorn (e.g. genus *Acropora*); Table (e.g. genus *Acropora*); Foliose (e.g. genera *Montipora* and *Turbinaria*); Plate (e.g. genera *Montipora* and *Turbinaria*); Encrusting; Mushroom (e.g. genus *Fungia*); Fire (e.g. genus *Millepora*). The diversity and composition of the hard coral forms can be useful in classifying reef types.

Reef structure:

Table 4 presents descriptors for the basic reef structure as contained within the third category of data elements in the Habitat survey. Although under the category of 'reef' structure, the data elements can be used to assess any subtidal marine habitat surveyed.

Table 4. Basic reef structure data elements

Data Element	Description and Justification
Reef Slope	An important descriptor for the general reef form and a determining factor on the overall reef community structure.
Rugosity	Measure of overall reef structure complexity.
Heterogeneity	A general assessment of the dominance of any hard coral form.

The reef slope is assessed in increments of 10^{o}, with 0^{o} taken to be horizontal and 90^{o} as vertical. Research assistants were found to be able to reliably estimate the reef slope to this degree of accuracy after the training period. In order to maintain a standard 'scaling' for all the data elements of the Habitat survey, rugosity and heterogeneity were also assessed on a 0-6 scale. A measure of rugosity was made to give an estimate of the overall complexity of the substrate type and benthic cover that were being surveyed. The scale devised for assessing this is presented in Table 5.

Table 5. Rugosity assessment scale.

Scale	Description
0	Flat surface. No cracks or holes
1	Undulating rock or sand. May have a few stones or pieces of rubble upon it.
2	Broken up substrate with small cracks or holes. May be a flat surface covered with stones or pieces of rubble.
3	Low lying hard corals and/or small boulders that afford a limited number of hiding places for animals.
4	A high percentage cover of hard coral providing extensive bottom cover.
5	Abundant and diverse hard coral forms together with small caves and overhangs providing animals with numerous hiding places.
6	Super abundant and highly diverse hard coral forms coupled with a highly irregular reef structure that affords a multitude of hiding places for both small and large animals

Although it is difficult to assign distinct boundaries within the scale used to assess rugosity it was found that recorders could attain consistent estimates within a short training period.

An assessment of heterogeneity is made to give an estimate of the dominance, if any, of the various hard coral forms present. This information can be useful in classifying the general reef structure. In practical terms, the recorder actually makes an assessment of the homogeneity rather than the heterogeneity and it is purely a matter of preference by the Programme that this data element is referred to by the latter term. Heterogeneity is assessed on the Horizontal surveys only, as detailed information on the composition of coral forms is already collected on the Vertical surveys.

Heterogeneity is based on a scoring system from 0-6 where the composition of coral forms is assessed and summarised for the area covered in one minute of survey. A recorder swimming over a continuous tract of a single hard coral form (e.g. a staghorn coral thicket) for one minute scores a single point. If no hard coral form is dominant for that minute of the survey then the recorder scores it as a zero. This is assessed for each minute of each of the 5 minute survey intervals. Although the maximum for this scoring is obviously 5 per 5 minute survey interval, in order to distinguish between surveying for five minutes where a single hard coral form had been continuously dominant and surveying where different hard coral forms had made up each of the five minute intervals, a continuous '5 minute' tract of the same hard coral form is given an extra point thereby scoring six (in practice it was to be rare to attain high scores for this data element and therefore the assessment of heterogeneity was relatively straightforward).

2.1.2.4 Survey 2: Invertebrate and Impacts Survey

The second survey type, referred to as the Invertebrate and Impacts survey, is split into three categories: Invertebrate Composition; Human Impacts, and; Natural Impacts (coral predators and disease).

Invertebrate composition:

The commonly found invertebrates recorded are presented in Table 6. The invertebrates were selected for recording if they are either significant and distinctive components of the reef fauna, or are exploited (or have a potential as an exploitable resource in the future) by fishermen.

The data elements are recorded on a continuous basis, although split into the appropriate time or depth intervals depending on the survey technique used. To avoid confusion when data elements are seen in large numbers in a short time, the following abundance categories were devised:

Numbers Observed	Recorded As
<20	Actual number (e.g. 1,2,3..)
20-50	Abundant ('A')
50-100	Abundant Plus ('A+')
100+	SuperAbundant ('A++')

The use of these abundance categories speeds up the recording of the more abundant data elements leaving more time to concentrate on recording those which are less common.

Table 6. Invertebrate data elements

Data Element	Description and Justification
Macro Sponges	Any sponge with a overall size greater than 100 mm at the widest point. Sponges can be a major component of the reef and are important in binding substrate.
Sea Whips	*Leptogorgia* spp. Distinctive corals that can be indicative of elevated nutrient levels when occurring in high densities. Relatively tolerant of turbid waters.
Sea Fans	*Gorgonia* spp. Currently being examined for use in the pharmacological industry. Found in areas of significant current.
Lobster (Crayfish)	Important food item and potential target for fisheries development in the archipelago.
Sea Cucumbers	
- *Holothuria* spp	A common genus of seacumbers of the intertidal and shallow sub-tidal zones. Currently not commercially gathered in the Quirimbas but they are elsewhere and may be a potential target species in the future.
- *Synapta* spp	Snake-like seacumbers found mainly within seagrass beds. Not a commercial target group but a conspicuous and important detritivore in many sheltered areas.
Sea Cucumbers - Others	Those species of seacucumbers currently exploited within the Quirimbas, together with some non-target species. Difficulties in identifiing the different species have required that all species are grouped as one.
Shellfish	
- *Murex* spp	Commonly collected as a food item and for their operculi, which are exported to Tanzania.
- Tulip shells (*Fasciolaria trapezium*)	Commonly collected food item.
- Clams (*Tridacna* spp)	Occasionally collected food item.
Urchins (*Diadema* spp)	Important grazers on algae and coral recruits. May also damage the coral with their spines. Can have a significant effect on the reef if occurring in sufficient densities.

Human Impacts:

The second category of the survey contains data elements describing the impacts of human activity, particularly those relating to the damage caused by fishing activity (Table 7). The data elements are relatively straightforward although, as non-experienced observers often find it difficult to determine the exact cause of damage, "anchor-type" damage is used to cover all recently damaged hard coral. However, where the cause of the damage is easily recognisable (e.g. dynamite blast) then this is also noted.

Table 7. Human impact data elements

Data Element	Description and Justification
"Anchor-type" damage	Any recently damaged hard coral. Typical signs include broken off branches and upturned tabular corals. Unless the cause is clear all damage such as caused by dragging anchors, dragging nets, boat grounding, trap placement and storms is grouped together under this heading.
Fishing traps-in use	The use of fishing traps (Kimwani: 'Maremas') is widespread within the seagrass beds and sheltered reef areas of the Quirimbas. A count of all the traps seen that are evidently current (lost or abandoned traps are very quickly overgrown and are found singly, rather than in loose groups, as are traps in use), is made to help assess fishing pressure.
Fishing traps-old	Lost or abandoned traps.The numbers are recorded as traps will often continue to trap and kill fish for sometime after being lost. Although the degradation time of traps of natural materials is relatively short this "ghost fishing" may become significant with the introduction of traps constructed of longer lasting synthetic materials.
Lost Spears	Spear fishing is common throughout the Quirimbas and from a count of the numbers of lost spears it may be possible to estimate relative levels of fishing activity using this method.
Old Fishing Line	Discarded or snagged fishing line. Indication of fishing activity and a potential hazard to marine animals.

Natural Impacts (coral predators and disease):

The third category of data elements in the survey (Table 8) includes some of the more common and recognisable coral predators and diseases and their resultant damage. Data elements are counted in the same manner as the other data elements of this survey with the exception of the C-O-T scar groups. C-O-T scars are recorded as groups of scars rather than as individual scars as the aim is to indirectly assess the number of C-O-T, one individual being responsible for each group of scars. White band disease is also included in the data elements as it is one of the more clearly distinguished coral diseases and is currently the subject of a number of studies (Ormond, pers. com.).

Table 8. Natural coral predators and damage data elements

Data Element	Description and Justification
C-O-T's	Crown of Thorn starfish (*Acanthagaster plancii*). A much publicised predator of corals, especially juvenile colonies, that can have a devastating effect on the reef if present in high densities.
C-O-T scar groups	The feeding scars left behind on the corals. As the C-O-T's can be hard to locate, it is often easier to assess their abundance by counting their feeding scars. Fresh scars are normally found in groups spread over a relatively small area, indicating the activity of a single starfish. C-O-T scars are readily distinguishable from other damage and disease as there is no graduation in the age of the damage within the scar, as with diseased coral.
White Band disease	A relatively common disease of corals which is becoming more widespread throughout the Tropics. It is thought that this increase in recorded incidences of the disease could be linked to human impacts on the marine ecosystem. Easily recognised by a thin white band of 'bleached' coral along the edge of the infected area and graduated colonisation of the dead coral.
Sedimented Massives	In certain areas of the reefs where high turbidity occurs, massive corals can be subjected to a high degree of sediment loading. In cases where the rate of sediment deposition exceeds the rate of sediment clearance by the coral portions of the colony may die. This is commonly manifest by the death of the top portion of the colony.

2.1.2.5 Survey 3: Reef Fish Census

The technique used to census reef fish is a modification of the ReefWatch survey technique originally developed by the Tropical Marine Research Unit (TMRU) at York University, UK. and resulted from discussions between the Programme's science staff and the TMRU. The aim of the survey is to assess the abundance and diversity of a few key fish families which were selected for census on the following bases:

- Fish species are conspicuous and easily identified by non-specialist observers. It was felt important that in order to gain a relatively complete picture of the levels of reef fish biodiversity the surveys should aim to census every species encountered from the selected families. However, due to the high diversity of fish species experienced during the survey work and the similarity between some species within families this was not possible and only the most common species were covered in the standard survey.

- Representatives were included from the full range of trophic levels seen on the reefs.

- Where possible families were selected whose species have relatively small home ranges and/or are found in close association with the reef habitat.

A total of 73 reef associated species were chosen from six families (see Appendix II for the complete list of species names.). As the research assistants are not always biologists, usually common names were used being easier to learn than species names. The common names assigned were either made up by the Programme's staff to describe obvious features of the fish or, where possible, the common names referred to by the FAO were adopted. In addition to these species, recorders are encouraged to note down any fish from the six families that they were unable to recognise for identification post-dive. Identification guides are carried on-board the dive vessels to facilitate this.

Table 9. Selected reef fish families

Data Element	Description and Justification
Acanthurids	Surgeonfishes. An important component of the reef fish catches. Many of the species are algal grazers and are therefore direct competitors of urchins. They help control overgrowth of algae on coral.
Balistids	Triggerfishes. Well documented predators of echinoderms, particularly urchins and C-O-Ts. Targeted by spear-fishermen and often form part of a net catch.
Chaetodontids	Butterflyfishes.Conspicuous and easily identifiable fish, closely associated with the reef. Some are obligate coral feeders. Subject to considerable study world-wide.
Mullids	Goatfishes. Prey on benthic invertebrates within the sand patches on the reef.
Pomocanthids	Angelfishes. Conspicuous and easily identifiable fish, closely associated with the reef.
Tetraodontids	Pufferfishes. Feed on large invertebrates and may also be corallivorous. The potential to consume a considerable number of coral polyps which can have an obvious effect on the reef.
Labrids	Wrasses. Only *Cheilinus undulatus* (Napoleon wrasse) was included due to its massive size and ease of recognition. This is a popular fish with divers at a number of resorts in the tropics.

2.1.2.6 Survey 4: Commercial Fish Census

The aim of the commercial fish census was to gain information on the biodiversity and status of the fish populations to provide an estimate of fishing pressure, to assess the potential for a possible expansion in fishing activity and to provide a baseline for future monitoring. The six families of fish chosen for census as commercially targetted species are presented and described in Table 9. It should be noted that although this survey is termed the 'Commercial fish' survey the fishing activities on the Quirimbas were observed to also target many of the small reef fish not normally classified as commercially important. Only those species known to be poisonous (e.g. pufferfish) or inedible (e.g.

pipefish) were discarded. Consequently, most species recorded within the reef fish census should also be considered commercially important to these particular fisheries.

In the case of the Quirimba islands' fisheries the term 'commercial' refers to fish caught by any of a variety of methods used by the artisanal fishermen for consumption, sale or barter. There is no industrial scale commercial fishing within the archipelago at the time of this Programme.

For each of the six families censuses the number of individuals and their estimated lengths are recorded. As most of the species of these families can occur in large shoals the same abundance categories used for the survey of Invertebrate and Impacts are adopted to speed the recording of abundant species. For shoals of fish, only the estimated average size of fish is recorded. The above protocol enables a recorder to record the abundant species and still be in a position to search for the less numerous species. Where a fish cannot be identified to species, it is recorded under 'Others' within the appropriate fish family. The 'Commercial Fish' survey was carried out on "Horizontal" transects only.

Table 10. Commercial fish families

Data Element	Description and Justification
Carangids	Jacks.Relatively large pelagic fish, loosely associated with the reef systems. There is potential for expansion of the fishery which is underdeveloped in the region.
Haemulids	Grunts and Sweetlips. Large solitary individuals or shoaling smaller individuals. Sought after fish taken by a variety of methods.
Lethrinids	Emperors.Large solitary individuals or small groups although smaller species can form very large shoals. Found commonly over seagrass beds as well as over the reefs. Sought after fish taken by a variety of methods.
Lutjanids	Snappers. Large individuals normally solitary or in small groups, smaller ones can form large shoals. Sought after fish taken by a variety of methods.
Scarids	Parrotfish. Important grazers and larger individuals can be corallivorous and quite destructive. One of the most difficult families to identify to species.
Serranids	Groupers. A target fish for the handline and spear fishermen. Top predators on the reef. Highly susceptable to capture by net, spear and bait fisheries. Territorial and slow growing so vulnerable to overfishing. A good indicator of fishing pressure. Large specimens are popular with divers as they are easily approached..
Siganids	Rabbitfish. Important food fish and grazer of algae both on the reefs and in the seagrass beds

The commercial fish survey, although a standard survey carried out at the majority of the study sites, was not undertaken by all the Programme's research assistants. It was felt that quantity of learning required to identify the reef fish species and the data elements of the

other surveys was sufficient for the majority of the people participating in the survey work. Therefore only the Programme's science staff and a few research assistants who expressed an interest and displayed a good knowledge of fish identification were able to undertake this type of survey.

2.1.3 Turtle Survey

All incidental sightings of turtles are recorded in order to estimate the size of the turtle population in the study area. The following information is recorded, where appropriate, for all underwater sightings, surface sightings from boats, and for dead turtles or turtle remains :

i) Position of sighting: normally recorded with reference to the island adjacent to the sightings. For turtles seen underwater a depth estimate was included.
ii) Number of turtles seen.
iii) Species of turtle: research assistants are given a brief introduction in the identification of the turtle species commonly seen and the relevant features to note if identification is to be made at a later time.
iv) Estimated size: taken as carapace length.

Additional information is collected on the location of nesting beaches and rates of capture in the fisheries, either as a by-catch or as a targeted item, during other surveys on resource use involving the interviewing of the islands' inhabitants.

2.1.4 Marine Mammal Survey

A similar protocol is followed for the Marine Mammal (to include: dolphins, whales and dugongs) Survey as for the Turtle Survey. Size estimations are not normally made but the presence of obviously juvenile individuals is noted.

2.1.5 Intertidal Survey

The survey aims to determine the distribution and community structure of plant and animal species and the composition of the underlying substrata.

Intertidal surveys are carried out using a simple transect method. At each survey site a transect is followed at a bearing perpendicular to the shore from a known position on the high water mark (HWM) to the spring low water mark (SLWM). The length of the transect (and each zone) is determined initially through pacing and is subsequently converted into metres.

The transect is then subdivided into zones based primarily on the abundance and composition of algal species. Within each zone a series of ten 50 cm x 50 cm random quadrats are sampled. The quadrats are distributed so that samples are taken throughout the full length of a zone. In each quadrat the species compositions and abundances of flora and fauna are recorded on standardised recording forms (Appendix IIIe). The abundances of flora are recorded as percentage cover and the associated fauna are recorded as numerical counts. Within the faunal survey emphasis is placed on the census of Mollusca, Echinodermata and Crustacea although members of other taxa are recorded if positively

identified. Specimens not identified in the field are collected for later identification in the laboratory (see Appendix II for reference material used).

2.1.6 Mangrove Survey

The species composition and structure of mangrove stands is assessed within quadrats laid along a line transect. As most stands in the study area run parallel to the shore transects are placed at right angles to the High Water Mark. to give a representative cross section through the stand. Some of the larger stands covered extensive intertidal areas and could not be surveyed using a single transect. In these cases a number of transects were completed that aimed to include the full range of mangrove community compositions within the stand.

The starting point for each transect is recorded using compass bearings. A measuring line is then paid out along the chosen bearing through the mangrove stand. The stand is then described in terms of 'zones' which are classified on the species composition or structure of trees. The lengths of each of the 'zones' are combined to obtain the total stand width. Within each 'zone' a number of 5 m x 5 m quadrats are temporarily marked out for more detailed survey of the flora.

Flora:

Within each quadrat the following information is recorded on floral composition and structure:

i) The number of each species of tree and sapling (see Appendix II for reference material used). A sapling is regarded as any tree less than 1.5 m tall and exhibiting no major branching.

ii) The height of each tree. For trees of height less than 2.5 m the height of the tree is normally measured against a recorder of known height or using a hand-held tape measure. For trees greater than 2.5 m an optical reading clinometer (e.g. Suunto, PM-5 model) is employed. Measurements are taken to the nearest 0.5 m for trees measured with the clinometer.

iii) The diameter at breast height (dbh) for each tree. This dimension is measured as the circumference of the trunk at a standardised height of 1.3 m above the ground. Due to the often irregular branching structure at the base of mangroves, the following procedure is adopted for measuring dbh:

- When the trunk forks below 1.3 m, or originates from a single base close to or above the substrate, the dbh ofeach branch is measured separately.
- When the trunk forks at 1.3 m or slightly above, the diameter is measured directly below any swelling of the trunk caused by the fork.
- When the trunk has prop roots or a buttressed lower portion the diameter is measured just above them/it.
- When the trunk has swellings, branches or abnormalities at the point of measurement the diameter is measured slightly above or below the irregularity.

iv) The number and species of "stumps" remaining from mangrove cutting activities. A "stump" is taken as the remains of a tree left when the major trunk has been cut. All evidence of cutting of branches is noted.

Fauna:

Faunal composition is assessed within a series of smaller 50 cm x 50 cm quadrats (normally 10 taken alongside the larger flora quadrats).The following data are collected within each quadrat:
i) The number of "active" crab burrows. A burrow is considered active if there is waste material present from burrowing activity since the last high tide. The number of active burrows is recorded to indirectly estimate the number of crabs in the quadrat. Due to the behaviour of the animals estimates of their abundance based solely on direct counts would most likely underestimate their numbers.
ii) The number and species of Crustacea (see Appendix II for reference material used). These are direct counts of live animals seen within the quadrats.
iii) The number and species of Mollusca (see Appendix II for reference material used). These are direct counts of live animals seen within the quadrats.

In some areas of mangrove, epiphytic animals are found on the lower portion of the trees. Due to the sometimes complex structure of the root systems, this area may be difficult to assess using a quadrat method. For this reason records, in these areas, visual counts are made of epiphytic animals seen on the lower portions of the trees within an estimated 'quadrat-sized' area.

2.2 Part II: Resource Use Surveys

2.2.1 Introduction

The aims of these surveys are to collect the information required to formulate a management plan for the resources in question and to identify any problems associated with the current level and methods of exploitation.

2.2.2 Finfish Fishery Surveys

Prior to the collection of fisheries data the research assistants are given an introduction to the commonly caught fish species, including notes on their identification, the protocol for the sampling of the catches and the reasoning behind the protocol. Identification skills are developed using a combination of slides, reference books and visits to fish landing sites (see Appendix II for reference material used).

The data are collected though a combination of direct recording of catches on board the fishing boats, analysis of fish brought to the landing sites and through interviews with local fishermen. Most of this information is collected by accompanying the fishermen on their daily fishing trips and filling out standard recording sheets (Appendix IIIf). Information recorded includes the species, numbers, size and weight of fish caught and details of fishing effort. This provides the basic information required to meaningfully describe the fishery in scientific terms.

Similar information is obtained for the small-scale collection of shellfish and octopus on the intertidal areas of the islands.

2.2.2.1 Island Surveys

The island surveys are normally completed during relatively short periods (5-10 days) and aim to make a primary assessment of the types of fishing techniques employed in the area and the extent to which each fishery resource is utilised. The impacts of these fisheries on the marine environment is also considered. The following data is collected:

- Number and type of fishing vessels.
- Number of fishermen regularly using these vessels.
- Number of fishermen using other fishing methods.
- Catch weight and composition by species of samples of each type of catch.
- Fishing sites.
- Local names of species.
- Price per kilo of the fish; fresh and dried.
- Market for fish.

A large proportion of this information is obtained through informal interviews with the fishermen and other local people. Although the islands are very small, there were often a number of discrete fishing communities and it was necessary to talk to representatives of each group.

Fleet surveys are conducted by repeated counts of vessels moored close to or pulled up on the beach at different states of tide (usually all the fishing boats are back at high tide and this is usually a reliable time to make the count). It is also necessary to ask local people how each boat is employed as some are used solely for transportation and not directly involved with fishing activities.

Fishermen using boats usually return between two and three hours after low tide so the observer can often wait at the island's landing site and count the number of boats returning that day and take a sample of the boats to look at catch composition and fish sizes. Efforts were made to sample in detail approximately one third of the vessels returning any one landing site.

On their return to the landing site the fishermen are interviewed. Below is an example selection of questions that are asked:

- *Where did you catch these fish?*

On the smaller islands it is often possible to point to the fishing site. On larger islands local names of sites can be recorded on a map.

- *How did you catch these fish?*

This is often self-evident in the fishing gear visible in the boat, but some fishermen may use a combination of techniques on one trip so it is necessary to ask.

- *Is this amount of fish more, less or roughly the same as your usual catch?*

The relative size of catch usually depends on tides or weather conditions so if the catch is more or less than usual it is worth asking why.

- *What are you going to do with this fish? Is it all for your own consumption, for local sale fresh, for sale elsewhere dried etc?*

Prices asked and destination markets should also be determined.

In the case of small canoe catches the whole catch can usually be identified, measured and weighed fairly rapidly. For larger catches, a random sample of the catch is processed, the size of which is determined by the time available.

The species composition of the catch is determined where possible using the relevant identification keys (Appendix II). Fisherman are also asked the local name for the individual species (usually in Kimwani or Macua for the Quirimba Archipelago) which may assist in later identification.

The fork lengths of fishes are measured to the nearest 0.5 cm using a 55 cm measuring board. The weight of individual fish is measured: for fish less than 200 g, to the nearest gramme, and for fish above 200 g to the nearest 10 g.

2.2.2.2 Case Study : The Quirimba Seagrass Bed Seine Net Fishery

Background:

It was evident from the Programme's studies that the majority of fishing activities around the Quirimba Islands were of a fairly low intensity. The one major exception to this was the exploitation of an area of approximately 25 km^2 in the northern portion of Montepuez Bay, between Quirimba and the mainland (see Fig 5). The bay was intensively fished by net fishing from sailing boats and trap fishing from dugout canoes based at Quirimba Island and at Quissanga on the mainland.

On Quirimba Island, most of the net-fishing sailing dhows and a large proportion of the canoes operated from a single landing site, Quiwandala, which made study of this fishing activity comparatively easy. Only net fishing data was collected for this fishery.

Sampling Protocol:

Pairs of recorders normally aim to arrive at the boat mooring site approximately two hours before low tide when the fishermen are preparing to leave. The recorders then ask to join a fishing trip or are invited by one of the boat captains to join their respective boat. The Programme aimed to survey the activities of as many boats in the fleet as possible during the study and chose at random the boats accompanied on a particular day.

Once on the fishing vessel, the recorders note the following details on a standard form (Appendix IIIf):

- Time of departure
- Time of return

- Boat type and estimated length
- An estimate of net length, cod-end length, a measurement of mesh size (taken as a stretched diagonal length) of the net and the cod-end.
- Name of boat Captain
- Number of crew members
- Time the net goes in and comes out for each haul
- An estimate of total catch of fish either in kilogrammes or buckets (sampling units)*.
- The location and /or the local name for the site at which each haul was taken.

* In this study, a household bucket (volume approximately 9 litres) was found to produce a conveniently sized samples of the catch.

After the first one or two hauls (in this particular fishery there were usually a total of 4 to 5 hauls made per day) a sample is taken from the catch. The relatively small size range of the fish normally caught and the sampling of unsorted catch minimise bias in the samples. A mean sample weight (in this case 15 kg) is established from repeated measuring of sample weights from a variety of catches. The fish in each sample are identified to species level if possible. Any fish not identified is sketched, described (fin ray and spine counts are made) and the local name noted. If possible a specimen is taken for identification at a later date. The fork length of each fish in the sample is measured to the nearest 5 mm.

On a number of selected fishing trips the weight of each fish is also measured (see section 2.2.2.1 for protocol). The data gathered from these trips is used to construct length-weight relationships for each of the species and therefore allow the weights to be estimated for the majority of length only data collected.

2.2.3 Non-Finfish Resource Use Surveys

These surveys aim to combine biological and socio-economic data in order to assess the full impacts of each resource use activity observed. Non finfish surveys concentrate on the intertidal and subtidal gathering of Molluscs and Holothuria (seacucumbers) for both human consumption and the curio trade. Preliminary interviews are undertaken to obtain the local names (in Kimwani and Macua) for the resources, the local names for specific locations along the intertidal and shallow subtidal zones and the cost and use, locally and regionally, for these resources. Knowledge of local resource names is useful when new unidentified resources are being studied and when a resource is processed in some way making it unrecognisable. Local area names are useful when interviews are necessary to determine the areas of daily and longer-term exploitation if it is not possible to accompany the person/s whilst collecting. Knowledge on the cost and use of resources is useful to determine whether a resource is used as a subsistence or a trade good, and if the latter to determine the economics behind its collection.

Descriptions of the major physical and biological characteristics are made of the intertidal and subtidal areas and the different geomorphological/habitat zones within these areas. Each area is then mapped with super-imposed patterns of exploitation.

Direct observations and questions are made, whilst accompanying collectors on surveys of the intertidal and shallow subtidal areas. The following socio-economic and biological data are collected:

- *Area of collection*

The area of collection is categorised in the following terms: firstly, by its geographical area (including the name of the islands and at which particular areas of these islands the activity occurred); secondly, in terms of situation, i.e. intertidal or shallow subtidal; and thirdly by geomorphology and habitat (including: seagrass beds, nearshore bare rock and sand zones, reef lagoon, reef crest and reef subtidal zones).

- *Total numbers and density of collectors*

Collectors are counted over all intertidal and geomorphological zones and geographical areas, as described above.

- *Gender of the collectors*

Two basic divisions are made, first by gender and second by age, so that four groups of collectors are studied: adult females and adult males (above the age of 15 years) and young females and young males (below the age of 15).

- *Group activity*

The numbers of collectors in any group with two or more people are recorded. A group is determined via interviews and observations and is characterised by more than one person who collected for the entire period in the same local area.

- *Origin of the collectors*

This is determined by interviews to determine the place of origin and current residence.

- *Method of collection*

Collection methods are recorded through direct observation at collection sites. The techniques employed include:

- Hand: collection by hand, without the use of any other implements, except occasionally a small knife.
- Iron rods: the use of one or more iron rods, normally 1 m in length and having a curved and sharpened end. Even if collection by hand and small knife complemented this technique, the possession of iron rods is recorded.
- Wooden poles: the use of 1 m wooden poles, curved at either end, complementing collection by hand.
- Snorkel/Hand: the use of mask and snorkel and collection by hand.
- Snorkel/Speargun: the use of mask and snorkel with a speargun.
- Seine: the use of beach seine nets, typically 20 m by 1 m.
- 'Casquinha': the use of 1-2 man dugout canoes, typically 3 m in length, and either being rowed, punted or sailed.
- 'Lancha'(Dhow): the use of 8-12 man, wooden sailing boats, typically 8 m in length.

- *Resource Catch*

The catch is divided into the following categories based on their biological groupings and intended use:

- Bivalves
- 'FO' gastropods: used primarily as a source of food and for sale of the operculi.
- 'CT' gastropods: sold to the curio trade.
- Octopii
- Holothuria (seacucumbers)
- Fish
- Crustaceans
- Urchins
- Chitons

The catch is identified (to species level where possible), quantified (taken as a total weight or total number of individuals) and where applicable, the individuals measured.

2.2.4 Mangrove Resource Use Surveys

The level and nature of exploitation of the mangrove is assessed in conjunction with the standard mangrove surveys (see Section 2.1.6). Supplementary information is gathered on the scale and nature of use of managroves through interviews with the local people.

2.3 Part III:Training Programme for Research Assistants to Conduct of Biological and Resource Use Surveys

A training programme was developed for the research assistants to enable them to learn the necessary skills to perform the biological and resource use surveys described below. The training period varies depending on the ability of the research assistants and the logistics of carrying out the training programme, however, the entire training course can normally be completed within a 15-20 day period.

2.3.1 Theoretical Training

A series of introductory lectures (illustrated with slides) provides a background to the work carried out by the Programme (see Darwall *et al.*, 1995, for details of the lectures). The following lectures are included:

- *Introduction to the Coastal Region of East Africa*

A general introduction to the biogeography and resource use activities of the region, with particular attention to Mozambique. Current and future threats to the marine habitats are discussed.

- *A Brief History of Mozambique*

An overview of the history of Mozambique with particular emphasis on the factors structuring the current political and demographic situation in the country. The development of activities within the coastal zone is discussed.

- *Coral and Coral Reefs*

A basic introduction to coral biology, coral reef formation and geographic distribution. The ecological requirements for coral growth and the importance of reefs in terms of the associated fisheries and coastal protection are discussed.

- *The Mangrove Ecosystem*

A basic introduction to the biology of mangroves, their ecological requirements, their importance to the associated plants and animals as feeding grounds and nurseries, and to coastal stability. This lecture is normally given in the mangroves.

- *Habitat Linkage*

Discussion of the ecological interactions between mangroves, seagrass beds and coral reefs. Examples are given of factors that may occur in one ecosystem but also strongly influence the ecological processes within the other two systems. The importance of developing a resource management plan that includes all of the three ecosystems is addressed.

- *Use of Marine Resources*

The variety of uses of marine resources and the methods of their extraction are discussed in the context of Mozambique and other countries in East Africa. The potential problems for management and sustainable utilisation of these resources are described. Topics included are: finfish capture; mangrove cutting; coral mining; dynamite and poison fishing, and shell collection.

- *Fisheries Management*

An introduction to the collection of fisheries data and their use in resource management. Interpretation of a selection of fisheries statistics is discussed at a basic level.

Additional shorter lectures or discussions are arranged when required and all trainees are encouraged to exchange ideas on relevant issues connected with the work of the programme. To help with the work that involves communication with the local population, lessons in basic Portuguese are undertaken for non-native speakers.

2.3.2 Practical Training

2.3.2.1 Biological Surveys

The lectures are followed up by training in the identification and recognition of the fauna and flora groups and data elements that are included in the biological surveys. Training is assisted through the use of slides, keys and "on-site" identifications. A series of tests are encorporated into the training to assure that all trainees are attaining a sufficiently high level of identification skills. The survey methods used are then explained in detail, after which the research assistants practise the techniques in the appropriate habitat under the supervision of a member of the science staff. The performance of the volunteers is constantly monitored so that errors in the survey techniques and incorrect identifications can be corrected quickly. The subtidal survey training is conducted at a sheltered site which is familiar to the training staff. This minimises the logistical problems associated

with diving more exposed sites and allows the teaching staff to recognise errors in the trainees data relatively easily.

2.3.2.2 Resource Use Surveys

Research Assistants are trained in fish identification through group visits to a nearby landing site followed by fishing trips accompanied by a staff member to reinforce the identification of the common species (where possible, all fish are identified to species level, but some hard to identify fish are identified to the genus level only). On return from these trips time is devoted to looking at the catch species in the identification books. Time is also spent discussing the identification of species not yet encountered but likely to appear in the catches and in the identifying features of difficult to distinguish species. Training is given in the effective use the identification guides. Although Research Assistants are introduced to the scientific names for species on the initial training fishing trip they also have a list of the common names on the waterproof form that they take out on their survey trips. In addition, after each trip made the results collected are briefly discussed and any problems or uncertain identifications resolved while the information is still fresh in their minds.

3.0 Bibliography

C.N.A. 1994. *National Environmental Management Programme.* Draft Government Report. Maputo (Mozambique). May 1994.

Danida. 1995. *Strategy for Danish-Mozambican development co-operation.* Information document produced by the Royal Norwegian Embassy. 36 pp.

Darwall, W., Guard, M., Dulvy, N., Choiseul, V. and Whittington, M. 1995. *Manual of biological and resource use survey methods for tropical marine ecosystems.* Developed by the Frontier-Tanzania Marine Research Programme: 1989-1995. Society for Environmental Exploration. Draft Report. 91 pp.

English, S., Wilkinson, C., and Baker, V. 1994. *Survey manual for tropical marine resources.* Australian Institute of Marine Sciences. ISBN 0 642 20256 7.

Fernandes, A. 1996. *Poluição costeira: factos e figuras.* In Dias, D., Scarlett, P., Hatton, J. and Macia, A. (Eds.). 1996. Proceedings do Workshop O Papel da Investigação na Gestão da Zona Costeira. Maputo, 24-25 April 1996.

Hatton, J. 1995. *A status quo assessment of the coastal zone Mozambique. Phase 1: Ponta do Ouro - Xai-Xai.* Report by the Ministry for Co-ordination of Environmental Affairs and the Eduardo Mondlane University, Maputo. 58pp.

Hatton, J.; Voabil, C. and Manjate, A. 1996. *Tourism, Land Use and Conflicts, Bilene - Xai-Xai - Chongoene.* Paper prepared for the ICZM Workshop, Ilha da Inhaca. 5-10 May, 1996. 11 pp.

Horrill, J.C. and Ngoile, M.A.K. 1991. *Mafia Island project report no. 2; Volume I: Results of the physical, biological and resource use surveys: rationale for the development of a management strategy.* Society for Environmental Exploration. 46pp.

Institute de Desenvolvimento da Pesca de Pequena Escala. 1996. *Relatório de Actividades 1995.* Internal Report. 18pp.

Lopes, L. 1996. *Pressão populacional na zona costeira - mito ou facto.* In Dias, D., Scarlett, P., Hatton, J. and Macia, A. (Eds.), 1996. Proceedings do Workshop O Papel da Investigação na Gestão da Zona Costeira. Maputo, 24-25 April 1996.

Mabjaia, F. 1996. *Está em curso a elaboração do perfil costeiro do distrito de Xai-Xai.* Moçambiente, **3,** 1996, pp 3-5.

Magane, S., 1996. *Strategies for the protection of coastal and marine protected areas.* Paper prepared for the Integrated Coastal Zone Management Workshop, Ilha da Inhaca, 5-10 May 1996.

Magane, S. undated. *Perfil Ambiental do Arquipélago do Bazaruto.* Direcção Nacional de Florestas e Fauna Bravia, internal report. 10pp.

Massinga, A.V.R.. 1996. *Mecufi coastal zone management.* Paper prepared for the Integrated Coastal Zone Management Workshop, Ilha da Inhaca, 5-10 May 1996. 11pp.

Massinga, A. and Hatton, J. 1996. *Country Paper on the Status of the Coastal Zone, Mozambique.* Paper prepared for the ICZM Workshop. Ilha da Inhaca, 5-10 May 1996. 28 pp.

MICOA, 1996. *Programa Nacional de Gestão Ambiental.* Technical Report. 99 pp.

Ngoile, M.A.K. and Horrill, J.C. 1993. *Coastal Ecosystems, Productivity and Ecosystems Protection: Coastal Ecosystem Management.* Ambio, **22**, No.7.

Serra King, H.A. 1995. *Estudo da dinâmica da matéria organica do solo após corte e queimada, Ilha da Inhaca.* B.Sc. Degree thesis, Universidade Eduardo Mondlane, Mozambique.

S.S.F. 1994. State Secretariat of Fisheries. *Master Plan.* August 1994. Government Report, Maputo, Mozambique.

Tinley, K.L. 1970. *Proposed maritime national parks and a dugong and marine turtle sanctuary in the Paradise Island region of the Mozambique coast.* Internal report, Mozambique Veterinary Department.

World Bank, undated. *Africa: A framework for integrated coastal management.* Technical Report. 139 pp.

Appendix I

List of reference material used in the habitat mapping of the study site and the planning of the Programme's survey strategy:

a) Nautical Charts

- Direcção Nacional de Geografia e Cadastro, 1987. Mocímboa da Praia, SC- 37/X. Folha No.-9. 1:250 000.

- Direcção Nacional de Geografia e Cadastro, 1987. Palma, SC-37/Q. Folha No.-2. 1:250 000.

- Direcção Principal de Navegação e Oceanografia do Ministério da Defesa de U.R.S.S. Republica Popular de Moçambique Ministério da Defesa Nacional. 1a Edição 11-X-1986. 1:50 000:
  - No. 46603-M. Canal de Moçambique: Cabo Pequeve ao Cabo Mepandagi.
  - No. 46604-M. Canal de Moçambique: Ilha do Ibo à Ilha Macaloé.
  - No. 46605-M. Canal de Moçambique: Ponta do Diabo à Ilha do Ibo.

- Direcção Principal de Navegação e Oceanografia do Ministério da Defesa de U.R.S.S. Republica Popular de Moçambique Ministério da Defesa Nacional. 1a Edição 11-X-1986. 1:200 000:
  - No. 42621-M. Canal de Moçambique: Baía do Lurio à Ilha Medjumbe

- Portuguese Governement Charts to 1957. Africa East Coast: Ponta Uifundo to Cabo Delgado. No. 2938. 1:300 000.

b) Remote Sensing Images

- LANDSAT 5 TM. Ilha Matemo-Ilha do Ibo, Cabo Delgado. Extrato TM 164-69 de 31/05/91. Canais 2,3,4. Processado por Cenacarta - 1996, Maputo, Moçambique.

- LANDSAT 5 TM. Arimba, Cabo Delgado. Extrato TM 164-69 de 31/05/91. Canais 2,3,4. Processado por Cenacarta - 1996, Maputo, Moçambique.

Appendix II: Identification reference material

Branch, G.M.; Griffiths, C.L.; Branch, M.L. and Beckley, L.E. 1995. *Two Oceans. A Guide to the Marine Life of Southern Africa.* David Philip, Cape Town and Johannesburg. 360pp.

Crosnier, A. 1965. *Crustacés Décapodes: Grapsidae et Ocypodidae.* Volume XVIII. In: Faune de Madagascar.Government of the Republic of Malagasy. 140 pp.

Fischer, W. *et al.* 1990. *Fichas FAO de identificação de espécies para actividades de pesca. Guia de campo das espécies comercais marinhas e de àguas salobras de Moçambique.* Publicação preperada em collaboração com o Instituto de Investigação Pesqueira de Moçambique, com financiamento do Projecto PNUD/FAO MOZ/86/030 e de NORAD. Roma, FAO.1990. 424 pp.

Lieske, E. and Myers, R. 1994. *Coral Reef Fishes. Indo-pacific and Caribbean.* Collins Pocket Guide. HarperCollins Publishers. 400 pp.

Mondadori, A. 1979. *The Macdonald Encyclopedia of Shells.* Macdonald and Co. (Publishers) Ltd., London. 512 pp.

Moorjani, S. and Simpson, B. 1988. *Seaweeds of the Kenya Coast.* Oxford University Press.

Phillips, R.C. and Meñez, E.G. 1988. *Seagrasses.* Smithsonian Contributions to the Marine Sciences. Number 34. Smithsonian Institution Press, Washington DC. 104 pp.

Smith, M.M. and Heemstra, P.C. Eds. 1991. *Smith's Sea Fishes.* Ist Edition. Southern Book Publishers, Johannesburg. 1048 pp, 144 pls.

Van der Elst, R. 1981. *A Guide to the Common Sea Fishes of Southern Africa.* Struik Publishers, Cape Town. 398 pp.

Veron, J.E.N. 1986. *Corals of Australia and the Indo-Pacific.* University of Hawaii Press, Honolulu. 644pp.

Appendix IIIa: Habitat survey data sheet

DATE: OBSERVER: SITE:

TIME IN: TIME OUT: G.P.S./BEARINGS IN:

VISIBILITY: DISTANCE COVERED: DEPTH:

CURRENT:- STRENGTH: DIRECTION:

TIME OR DEPTH

SUBSTRATE OR COVER (%)						
REEF SLOPE						
ROCK						
RUBBLE						
SAND/SHELL						
MUD						
HARD CORAL						
SOFT CORAL						
SEAGRASS						
ALGAE - MACRO.						
ALGAE - *HALIMEDA*						
HETEROGENEITY						
RUGOSITY						

HARD CORAL FORMS - VERTICAL SURVEYS **(FOR HORIZONTAL SURVEYS TICK DOMINANT CORAL FORM)**

Depth	Mush-room	Branch-ing	Stag-horn	Table	Massive Small	Massive Big	Foliose	Plate	Encrusting	Fire

COMMENTS:

Appendix IIIb: Invertebrates and impacts data sheet

DATE: OBSERVER: SITE:

TIME IN: TIME OUT: G.P.S./BEARINGS IN:

VISIBILITY: DISTANCE COVERED: DEPTH:

CURRENT:- STRENGTH: DIRECTION:

TIME OR DEPTH

INVERTEBRATE OR IMPACT							
MACRO SPONGES							
SEA WHIPS							
SEA FANS							
CLAMS							
TRITONS							
MUREX SHELLS							
TULIP SHELLS							
LOBSTER							
SEA CUCUMBER:	*****	*****	*****	*****	*****	*****	*****
- HOLOTHURIA							
- SYNAPTA							
- OTHERS							
SEA URCHINS - DIADEMIDS							
C-O-T INDIVIDUALS							
C-O-T SCAR GROUPS							
WHITE BAND DISEASE							
FRESH DEAD CORAL							
SEDIMENTED MASSIVE CORALS							
ANCHOR "TYPE" DAMAGE							
DYNAMITE BLASTS							
FISH TRAPS - IN USE							
FISH TRAPS - OLD							
FISHING LINE							
FISHING SPEARS							

COMMENTS:

Appendix IIIc: Reef fish census data sheet

DATE: OBSERVER: SITE:

TIME IN: TIME OUT: G.P.S./BEARINGS IN:

VISIBILITY: DISTANCE COVERED: DEPTH:

CURRENT:- STRENGTH: DIRECTION:

	TIME OR DEPTH						TIME OR DEPTH					
SPECIES						**SPECIES**						
BUT'RFLYFISH						**GOATFISH**						
Dot-Dash						Dash-Dot						
Spotted						Long Barbel						
Threadfin						Double Barred						
Blackbacked						Yellow Saddle						
Double Saddle						Yellow Stripe						
Racoon						Brown Stripe						
Meyer's												
Chevron												
Madagascan												
Black Pyramid						**SURGEONFISH**						
Pennant						Dusky						
Masked bannerf'h						Thompson's						
Big Long Nose						Convict						
Vagabond						Powderblue						
Teardrop						Eyestripe						
Zanzibar						Striped						
Lined						Palette						
Fried Egg						Tennent's						
Somali						Goldring Br'tooth						
Blackburn's						Brown tang						
						Sailfin tang						
						Orangespine Uni.						
ANGELFISH						Spotted Uni.						
Royal												
Emperor												
Semicircle						Moorish Idol						
Earspot												
Yellow												
Multispined						**TRIGGERFISH**						
African Pygmy						Redtooth						
White-tailed						Halfmoon						
Yellow Bar						Clown						
Old woman						Picasso						
						Wedge Picasso						
						Titan						
						Orangestripe						
PUFFERFISH												
White Spotted												
Brown Spotted						**OTHERS**						
Guineafowl						Humphead Wr'se						

Appendix IIId: Commercial fish census data sheet

DATE: OBSERVER: SITE:

TIME IN: TIME OUT: G.P.S./BEARINGS IN:

VISIBILITY: DISTANCE COVERED: DEPTH:

CURRENT:- STRENGTH: DIRECTION:

TIME (Mins.)	0-5		5-10		10-15		10-15		15-20*	
SPECIES	**No**	**Size**	**No**	**Size**	**No**	**Size**	**No**	**Size**	**No**	**Size**
LETHRINIDAE										
LUTJANIDAE										
SCARIDAE										
SERRANIDAE										
CARANGIDAE										
SIGANIDAE										

* Table continued as required

COMMENTS:

Appendix IIIe: Intertidal survey recording form

DATE: OBSERVERS: SITE:

LOW WATER: ACTUAL: OBSERVED:

BEARINGS:

ZONE LENGTHS:

ZONE NUMBER	1										2									
QUADRAT NUMBER	1	2	3	4	5	6	7				1	2	3	4	5	6				
SUBSTRATE (% COVER)																				
: ROCK																				
: SAND																				
: MUD																				
: BROKEN SHELL																				
FLORA (% COVER)																				
SEAGRASS:																				
ALGAE:																				
FAUNA (COUNTS/SPECIES)																				

* Table continued for as many zones as required

Appendix IIIf: Seagrass fishery recording form

DATE: OBSERVERS: FISHERY CLASSIFICATION:

LANDING SITE: SITE FISHED:

GEAR TYPE: No. FISHERMEN: BOAT TYPE: CAPTAIN'S NAME:

WEIGHT OF SAMPLE: NO. FISH IN SAMPLE: SAMPLE SIZE: SAMPLE AS A % OF CATCH:

TIME DEPART: TIME RETURN: FISHING START: FISHING FINISH: TOTAL HRS FISHED:

NO. OF OTHER BOATS SEEN FISHING IN THE AREA: DHOWS: CANOES:

HANDLINES: NO. OF LINES: NO. OF HOOKS PER LINE: HOOK SIZE: BAIT:

NETS: NO. OF PIECES: AVERAGE LENGTH PER PIECE: TOTAL LENGTH: MESH SIZE: NO. OF HAULS:

SPECIES COMPOSITION OF SAMPLE NO. OF SPECIES:

LIST SPECIES IN SAMPLE:

OTHER SPECIES PRESENT:

LENGTH AND WEIGHT OF FISH IN SAMPLE (* TABLE CONTINUED AS NECESSARY)

LENGTH	WEIGHT	LENGTH	WEIGHT	LENGTH	WEIGHT	LENGTH	WEIGHT

OTHER OBSERVATIONS:

Appendix IV: Reef Fish Census Species List

List of fish species learnt by the research assistants and included in the Reef Fish survey:

Scientific Name	Common Name
Acanthuridae	**Surgeonfish and Unicornfish**
Acanthurus auranticavus	Orange-socket surgeonfish
Acanthurus dussumieri	Eye-stripe surgeonfish
Acanthurus leucosternon	Powder Blue surgeonfish
Acanthurus lineatus	Striped surgeonfish
Acanthurus nigricauda	Blackstreak surgeonfish
Acanthurus nigofuscus	Dusky surgeonfish
Acanthurus tennenti	Tennent's surgeonfish
Acanthurus thompsoni	Thompson's surgeonfish
Acanthurus triostegus	Convict surgeonfish
Ctenochaetus strigosus	Goldring bristletooth
Naso brevirostris	Spotted unicornfish
Naso hexacanthus	Sleek unicornfish
Naso lituratus	Orangespine unicornfish
Zebrasoma desjardinii	Desjardin's sailfin tang
Zebrasoma scopas	Brown tang
Balistidae	**Triggerfish**
Balistapus undulatus	Orangestriped triggerfish
Balistoides conspicillum	Clown triggerfish
Balistoides viridescens	Titan triggerfish
Melichthys niger	Black triggerfish
Odonus niger	Red-tooth triggerfish
Pseudobalistes fuscus	Blue and Gold triggerfish
Rhinecanthus aculeatus	Picasso triggerfish
Rhinecanthus rectangulus	Wedge picasso triggerfish
Sufflamen bursa	Scythe triggerfish
Sufflamen chrysopterus	Halfmoon triggerfish
Chaetodontidae	**Butterflyfish**
Chaetodon auriga	Threadfin butterflyfish
Chaetodon blackburni	Blackburn's butterflyfish
Chaetodon bennetti	Bennett's butterflyfish
Chaetodon dolosus	African butterflyfish
Chaetodon falcula	Double-Saddled butterflyfish
Chaetodon guttatissimus	Spotted butterflyfish
Chaetodon kleinii	Dot-Dash butterflyfish
Chaetodon leucopleura	Somali butterflyfish
Chaetodon lineatus	Lined butterflyfish
Chaetodon lunula	Racoon butterflyfish
Chaetodon madagascarensis	Madagascan butterflyfish

Chaetodontidae	**Butterflyfish**
Chaetodon melannotus	Black-backed butterflyfish
Chaetodon meyeri	Meyer's butterflyfish
Chaetodon trifascialis	Chevron butterflyfish
Chaetodon trifasciatus	Redfin butterflyfish
Chaetodon unimaculatus	Teardrop butterflyfish
Chaetodon vagabundus	Vagabond butterflyfish
Chaetodon xanthocephalus	Fried Egg butterflyfish
Chaetodon zanzibariensis	Zanzibar butterflyfish
Forcipiger flavissimus	Long-nose butterflyfish
Hemitaurichthys zoster	Black Pyramid butterflyfish
Heniochus acuminatus	Pennant butterflyfish
Heniochus monoceros	Masked bannerfish
Labridae	**Wrasse**
Cheilinus undulatus	Napoleon wrasse
Mullidae	**Goatfish**
Mulloides flavolineatus	Yellowstripe goatfish
Parupeneus barberinus	Dash-Dot goatfish
Parupeneus bifasciatus	Doublebar goatfish
Parupeneus cyclostomus	Yellow-saddle goatfish
Parupeneus macronema	Long barbel goatfish
Parupeneus pleurostigma	Sidespot goatfish
Upeneus tragula	Blackstripe goatfish
Pomacanthidae	**Angelfish**
Apolemichthys trimaculatus	Yellow angelfish
Centropyge acanthops	African pygmy angelfish
Centropyge bispinosus	Two-spined angelfish
Centropyge flavicauda	White-tailed angelfish
Centropyge multispinis	Multi-spined angelfish
Pomocanthus chrysurus	Earspot angelfish
Pomocanthus imperator	Emperor angelfish
Pomocanthus maculosus	Yellow-bar angelfish
Pomocanthus rhomboides	Old Woman angelfish
Pomocanthus semicirculatus	Semicircle angelfish
Pygoplites diacanthus	Royal angelfish
Tetraodontidae	**Pufferfish**
Arothron hispidus	White spotted pufferfish
Arothron immaculatus	Immaculate pufferfish
Arothron meleagris	Guineafowl pufferfish
Arothron nigropunctatus	Black spotted pufferfish
Arothron stellatus	Star pufferfish
Zanclidae	**Moorish Idol**
Zanclus cornutus	Moorish Idol