FISH AND FISHERIES IN THE SEAGRASS BEDS OF THE QUIRIMBA ARCHIPELAGO, NORTHERN MOZAMBIQUE

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O Pescador Velho

Pescador vindo do largo
com o teu calçado de algas
diz-me o que trazes no barco
donde levantas a face

a tua face marcada
pelo sal de horas choradas
dá-me o teu peixe pescado
bem lá no fundo do mar

-nesta água não tem peixe-

pescador dá-me um só peixe
nem garoupa nem xaréu
só um peixinho de prata

-nesta água não tem peixe
foi tudo procurar deus
pró lado do Zanzibar.

Gloria de Sant'anna, Mozambique

ABSTRACT

Despite being an important and widespread use of marine resources, tropical seagrass fisheries have been the subject of very few biological studies. The fish communities of tropical seagrass beds have also been little studied in comparison to the fish communities of coral reefs, which have been the subject of extensive research. Seagrass fisheries are of importance to coastal communities in developing countries because they are usually shallow and close to shore, and in many cases are more accessible than coral reefs, especially to the poorest fishers on foot or in small canoes. The importance of seagrass beds as a component of the interacting tropical coastal ecosystem (with coral communities and mangroves) is more widely recognised. Seagrass beds are often acknowledged as important nursery areas for fisheries or for their role in nutrient cycling and this is often incorporated to some extent in their management. However, the direct use value of seagrass beds as habitats for economically important species is largely ignored. The faunal diversity of seagrass systems is also something that has been studied to a limited extent. Whereas coral reefs are described as the "rainforests of the sea", seagrasses are often thought of as monospecific marine grasslands, productive but not particularly diverse. In this thesis a fishery based almost exclusively on seagrass beds is described, the seagrass beds are characterised in terms of plant species diversity, biomass and cover, and the seagrass fish communities which the fishery exploits is described. Experiments to determine the relative fish productivity and diversity in three of the main seagrass species are described, and experiments determine the efficiency of the trap fishing methods used by local fishers in the seagrass beds. Five of the most abundant species in the fishery, *Siganus sutor, Leptoscarus vaigiensis, Lethrinus variegatus, Lethrinus lentjan* and *Gerres oyena* are studied in more detail, aspects of their biology and life histories are described and are related to possible management strategies for the seagrass fishery. The seagrass fishery was found to be highly productive, to have a remarkably high species diversity and was the major single source of income to local people. The main species of fish in the fishery were found to have very different life histories and ecology, and this coupled with the high overall species diversity presents the prospective manager with the challenge of sustaining an important fishery whilst conserving habitat

integrity and species diversity in what is evidently an ecologically important area. Carefully selected long-term no-take zones, established in close collaboration with fishers and other members of the community, are proposed as the ideal form of management of this multi-species, multi-gear fishery.

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This thesis is the result of two eventful and often disastrous periods of fieldwork based on Quirimba Island, Mozambique. On my first journey from Tanzania to the Quirimba Archipelago the boat sank and I lost virtually all my DPhil equipment, notes and books and all my personal belongings and the project's boat, radios and some diving gear were also lost. After swimming to shore on Mafia Island I had 2 days in Dar es Salaam to buy some clothes and send some faxes then I set off again to the Quirimbas. Five weeks after leaving the UK I arrived at the project "base camp" on Quirimba to find that the camp consisted of two bamboo walls surrounded by dense bush so the first task was to build a camp for 20 people from scratch. All the other camp equipment including diving gear and the second project boat were held in customs until three months later. For those months we lived under a tarpaulin (this was still the rainy season), built the camp and huddled round one lamp and a small camp fire every evening while we waited for a the radio, generator, diving equipment and everything else to arrive. On my second fieldtrip I again arrived on Quirimba 5 weeks after having left the UK, this time spending three weeks stranded on the project's new boat in a small southern Tanzanian port waiting for a vital engine part to arrive and then a week's stormy journey down to the Quirimbas.

I must thank my supervisor Dr Rupert Ormond for giving me the opportunity to risk life and limb in remote parts of East Africa through his collaboration with the Darwin/Frontier-Moçambique Quirimba Archipelago Marine Research Programme. Without working with a large concern like the Frontier-Moçambique project I would never have been able to work in such an interesting and remote place and I thank the Society for Environmental Exploration for taking me on board. They have helped in innumerable ways. I'd like to thank the field staff I worked with in Mozambique, particularly project Research Co-ordinator Dr Mark Whittington who acted as my field supervisor and provided valuable advice, logistical support and the time of the project participants to assist in aspects of my work, Counterpart Research Co-ordinator Mário Carvalho (also of MICOA, the Ministry for the Co-ordination of Environmental Affairs, Mozambique) who introduced me to the wonders of seagrass biology and helped greatly with

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DECLARATION

I was greatly assisted in the collection of fisheries data (fish lengths from the net fishery and catch per unit effort information used in Chapters 2 and 3) by Frontier volunteers and staff, and Mozambican participants in the project. I made approximately half the total fishing trips myself and the other half were made by trained participants under my supervision. I adapted the methods used from the fisheries data collection methods previously used by Frontier, trained the volunteers and co-ordinated the data collection. Mark Whittington and Alex Corrie assisted in the adaptation of the methods and initially helped to set up the data collection with the fishermen. In May and June 1997 when I was not in Mozambique during the project work phase, Mark Whittington co-ordinated and supervised the fisheries data collection.

The seagrass biomass determination in Chapter 1 was done with the assistance of Mário Carvalho. He assisted in the seagrass underwater surveys, seagrass harvesting and did much of the sorting of seagrass into above- and below-ground biomass.

The trap fishing experiments were done with the assistance of Anibal Amade, who fished the traps under my supervision, whilst I recorded the contents of the traps. He advised me on trap fishing methods and the practicalities of the methods. He also collected some fish catch composition data from his own normal trap fishing activities that I used in trap composition studies in Chapter 3.

I collected all other data and interpreted it, and the writing of this thesis is solely my own work. I have had editorial comments on chapters from Dr Callum Roberts, Dr Rupert Ormond and Dr Mark Whittington.

INTRODUCTION

This research was conducted within the Darwin/Frontier-Moçambique Quirimba Archipelago Marine Research Programme, a 2 year collaborative project between the Mozambican Ministry for the Co-ordination of Environmental Affairs and the Society for Environmental Exploration, a UK based scientific expedition company which sends paying volunteers to do research projects in Africa. Other government departments in Mozambique participated including the Ministry of Agriculture and Fisheries (DNFFB), the Institute for Fisheries Research (IIP), the Institute for the Development of Small-Scale Fisheries (IDPPE) and the University of Eduardo Mondlane in Maputo.

The aim of the project was to collect scientific information to be used in the future coastal zone management of the islands in the Archipelago and their associated resources. Two main categories of information were collected, firstly on the location and species composition of marine habitats to identify areas of high biodiversity, and secondly, information on current resource use patterns and levels. The project also had a training element, with participants from the Mozambican counterpart institutes being trained in SCUBA diving and underwater survey techniques. There was no formal social-science or community-participation component to the project as this work was scheduled to be undertaken by researchers from Maputo at a later stage. There were no direct benefits to the local community such as training or capacity building, but hopefully indirect benefits to the community, such as improved management strategies for resource use and some representation of resource-use conflicts at a national level, will eventually reach local people.

The Quirimba Archipelago was chosen as the location for the project because it was a site that had in the past been recognised for its potential high biodiversity and was one of a number of coastal areas in Mozambique that had been suggested as a good site for a marine park. Virtually no marine research had been conducted in the area before the project. J.L.B. and M. Smith collected some fish there in the sixties and a French bioprospecting company took some samples in 1995 and an undergraduate thesis was completed on coral

communities at Ibo Island (Rodrigues 1996) but other than that very little was known of the biology of the area or the distribution of habitats.

The project came to a successful conclusion in March 1998 with a final workshop with the collaborating institutes in Maputo. The results can be found in project technical reports (Heasman *et al.* 1998, Stanwell-Smith *et al.* 1998, Whittington *et al.* 1997, Whittington *et al.* 1998). The Quirimba Archipelago was found to be a highly diverse area in terms of habitats and species. Large areas of mangroves, seagrass beds and coral communities were found, in excellent condition. Resource use was found to be moderate, but intensifying rapidly and moving from local subsistence use to commercial use by people from outside the area. At the time of writing there were no plans to establish a marine protected area in the Archipelago but a large GEF loan has been secured for the region and there are plans for a marine station affiliated with the University of Eduardo Mondlane at either Pemba, to the south of the Archipelago, or Moçimboa da Praia, to the north close to the Tanzanian border (Salomao Bandeira, pers. comm.).

Tropical Seagrass Fisheries

In anticipation of potential confusion, I will define what I mean by a "seagrass fishery" throughout this thesis. I am using "seagrass fishery" in the same way as the term "reef fishery" is often used – meaning the capture of fish from seagrass habitats and not the collection of seagrass plants for human use. Seagrasses are harvested in some areas of the world (Fortes 1990) but this is not usually referred to as a "seagrass fishery". In many areas seagrass fisheries have a fish and an invertebrate component. In terms of fish alone seagrasses are at least as productive as coral areas producing more than 10 tonnes km^{-2} yr^{-1} (del Norte *et al.* 1989) and it is estimated that the total productivity of seagrass areas including invertebrates could be more than 20 tonnes km^{-2} yr^{-1} (McManus 1993).

Seagrasses are common in lagoons, on reef flats and in shallow coastal waters. They are found throughout the tropics with the exception of around steep atolls and other areas with limited shallow waters. Seagrass lagoon and reef flat

areas are available for use by the very poorest fishermen who can't afford boats or engines (McManus 1993), and are therefore often the focus for fisheries in undeveloped areas where fishers have limited resources, e.g. in South East Asia (McManus 1993, Dayaratne *et al.* 1995). The apparent lack of interest in seagrass fisheries may be connected with this economic factor. Some of the poorest people in coastal areas depend on seagrass resources, mainly small fish and shellfish consumed locally, and their monetary value is negligible compared to that of many commercially exploited coastal resources although their value to local people is incalculable.

The aims of the research presented in this thesis were:

1. To describe the fisheries of the seagrass beds of Quirimba Island in term of methods used, fish caught and economics.
2. To investigate the seagrass fish communities.
3. To relate fisheries catches to the habitat fished.
4. To look at the sustainability of the fishing methods used and the threats to the fishery.

In Chapter 1 the seagrass beds of the fishing grounds of Quirimba are described in terms of plant species composition and biomass, and the mean biomass of the seagrass in the fishing sites is related to the fisheries catches obtained from these sites.

In Chapter 2 the fishing methods used on Quirimba are described and a more detailed study of the 2 major fishing gears, seine net and fish traps, in the seagrass beds of the Montepuez Bay is presented. Catch per unit effort for each fishing methods and estimated values for total annual catch and catch per unit area are given. Fish catch per boat and catch per unit effort is related to tidal cycle and to human factors such as number of crew. Seasonal catch data over the 2 year study period is also presented.

In Chapter 3 the fish species and size composition of the catches from seine netting and trapping are presented, with seasonal catches and catches from different fishing sites described. A complete fish species list is given with fish names in the local language, Kimwani. Aspects of the ecology of the exploited

fish species are discussed, such as life histories and ontogenetic migrations, trophic groups and habitat associations.

In Chapter 4 the five most important species in the seagrass fishery are studied in more detail in terms of the life stages at which they are vulnerable to the fishery and the potential for a sustainable fishery based on these main species.

In Chapter 5 a series of trap fishing experiments are presented. In one set the fish faunas of 3 different seagrass communities and bare sand are compared. The spacing of traps is also examined, using a variety of trap spacings including the standard spacing used by trap fishermen on Quirimba.

In Chapter 6 the socio-economic status of the seagrass fisheries are considered in the context of the economic situation on the island and alternative sources of income. Results of interviews and workshops conducted in the community are presented. Socio-economic implications of possible management considerations are considered.

Each of these chapters is intended to stand alone in the format of a scientific paper.

In the final Discussion these 6 related chapters are briefly brought together and the future of the Quirimba seagrass fishery is discussed. Wider implications of the importance of seagrass fish communities as productive and economically important and also biologically diverse and of high conservation value are considered.

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CHAPTER 1

CHARACTERISATION OF THE FISHING SITES OF THE MONTEPUEZ BAY

ABSTRACT

The fishing sites of the northern Montepuez Bay were studied to determine seagrass percentage cover, biomass and species composition. Seagrass assemblages and densities were found to vary considerably between sites. Ten species of seagrass were found in the Bay, the most common being *Enhalus acoroides.* Monospecific stands of *Enhalus acoroides* were common but mixed species stands, often incorporating an "understorey" of small seagrass species were also common. Fishing sites with high seagrass cover were found to also have a high catch per unit effort in the artisanal seine net fishery. Above ground biomass values for the seagrass beds were found to equal or exceed those found elsewhere in the Indo-Pacific region. The high fisheries productivity of the Montepuez Bay could be attributed to the unusual extent of monospecific *Enhalus acoroides.*

INTRODUCTION

Tropical Seagrasses

Seagrasses are angiosperms that can grow completely submerged in shallow seas but are also tolerant of varying degrees of desiccation at low tides, depending on species. They are widely distributed throughout temperate and tropical seas and estuaries, but are not found in freshwater. In the Western Indian Ocean region 12 species of seagrass have been identified in two families, the Cymodoceaceae and the Hydrocharitaceae. These species are *Thalassia hemprichii, Zostera capensis, Enhalus acoroides, Halophila ovalis, Halophila stipulacea, Halophila minor, Cymodocea rotundata, Cymodocea serrulata, Thalassodendron ciliatum, Halodule uninervis, Halodule wrightii* and *Syringodium isoetifolium* (Bandeira 1997). There is variation in the zonation of

these species across the tidal range and with depth (Bandeira 1997), but this zonation is not particularly distinct or universal and has been found to vary considerably between studies (Ruwa 1996). These seagrasses occur with characteristic macroalgae, both substrate-attached such as *Turbinaria* and drift algae such as *Hydrocalthrus*, and are also host to a wide variety of epiphytes which form an important part of the seagrass system (Borowitz & Lethbridge 1989).

Seagrasses are an important component of the suite of interacting habitats that compose the typical tropical coastal system, along with mangroves and coral reefs (Ogden and Gladfelter 1983, Parrish 1989, Ogden 1997). Although seagrasses are a key element in the "tropical coastal seascape" (Ogden 1997) they are generally less conspicuous than mangroves or coral reefs. Consequently, the importance of seagrasses has often been underestimated in comparison to their more attractive or obvious neighbouring ecosystems (Fortes 1990). Until the 1970s, the majority of seagrass research focussed on the ecology of single species or on the ecophysiology of species, and community ecology was virtually unstudied. The turning point in seagrass ecology came in 1973 with the first International Seagrass Workshop where a major recommendation was to view seagrasses in their ecosystem context (Philipps and Meñez 1988, McRoy *et al.* 1973).

Since then, seagrasses have been increasingly recognised for their ecological importance. According to Heck and Orth (1980) the three main ecological roles of seagrass meadows are as:

1. Nursery areas for large numbers and a wide diversity of fishes and other animals
2. Feeding grounds for fishes, invertebrates, turtles, dugongs and waterfowl
3. Sediment stabilisers improving water clarity

They provide shelter for a large variety of fish and invertebrates and a substrate for a diverse community of sessile invertebrates and epiphytes (Randall 1965, Ruwa 1996, Ogden 1997).

Seagrass beds are areas of high primary productivity in the form of algae, epiphytes and of course the seagrasses. They have been identified as one of the most productive marine ecosystems in terms of primary productivity with typical values of 500-1000 grams of carbon per metre squared per year (Klumpp *et al.* 1989, Hillman *et al.* 1989, Wood *et al.* 1969 in Zieman and Wetzel 1980). Numerous studies have indicated that very little of this primary productivity is available directly as food for herbivorous fish and invertebrates because the leaves are either very low in nutrients (Bjorndal 1980, Duarte 1990) or the animals are unable to digest the cellulose (Lawrence 1975). The contribution of seagrasses to the ecosystem through direct herbivory was therefore thought to be fairly small and of greatest importance in tropical seagrasses, and particularly in the Caribbean (Randall 1965, Ogden 1976, 1980, Weinstein and Heck 1979). However, there is increasing evidence of a significant role for seagrass as a component in the diets of seagrass fauna in the Indo-Pacific, reviewed in Valentine and Heck's recent paper (1999).

Economic importance of seagrass beds

The economic importance of seagrass beds can be considered in two ways. Firstly, there is the direct economic value of seagrass beds to the coastal communities who directly harvest resources such as fish, invertebrates and other seagrass products. In terms of cash, the value of these resources may often not be high. However, the nature of tropical seagrass beds – habitats which are highly productive and usually easily accessible to some of the poorest people on the coast - means that their value in terms of the survival and the basic livelihoods of millions of people is high (McManus 1993). Seagrass beds and their associated resources can be used in a wide variety of different ways by people, from using seagrass plant roots to make flour for bread, which is reported in Kenya, to collecting sea cucumbers from seagrass beds (Fortes 1990).

The second way in which the ecosystem can be valued is to look at the direct and indirect values or "services" provided by seagrass habitats on a large ecosystem scale. Researchers have estimate the value of extensive seagrass beds to local economies in terms of such functions as the ability of large areas of seagrass to reduce coastal erosion, to deal with certain types of organic

pollution and as a nursery area for commercial fisheries. The total value of the coastal protection that would be necessary if the seagrass beds were not there and the economic cost of losing the fisheries with the nursery area, together put a high value on the continued existence of the seagrass beds. In Cairns, Australia, seagrass beds supported fisheries estimated to be worth US$540,000 per year in the 1980s (Coles 1986, in Fortes 1990). In Puget Sound, USA the value of a 0.4ha area of eelgrass was estimated at US$412,000 in the 1970s in terms of energy provision, nutrient cycling, fisheries, aquaculture and birds (Helfferich and McCoy 1978, in Fortes 1990).

Costanza *et al.* (1997) attempted valuation on a global scale using estimates of the areas of seagrasses worldwide and their value in terms of large scale ecosystem effects. The total value of seagrasses worldwide was estimated at US$3,801 billion ($10^9$) per year. Nutrient cycling was given as the main economically important role of seagrasses globally. The majority of the economic value of coral reefs was accounted for in this study by fisheries but no value was given to the fisheries value of seagrasses. Even so, the value per hectare of seagrass beds (US$19,004 per hectare annually) is the third highest value of all the major ecosystems studied, exceeded only by tropical forest and the swamp floodplain habitat. The total value of seagrass beds exceeds that of coral reefs by ten times and is more than twice that of mangroves (although it must be remembered that this includes the extensive areas of temperate seagrass beds, whereas coral reefs and mangroves are restricted to the tropics).

The role of seagrass beds in nutrient cycling has been studied extensively, their role being most important in "nutrient stripping" which is important in the maintenance of coastal water quality (Patriquin 1972, Harlin 1980, den Hartog 1967, Dawes 1981 in Coppejans 1992).

Conservation status of seagrass beds and global threats to seagrasses

Seagrasses are vulnerable to a number of human impacts. They are particularly vulnerable to high levels of siltation from rivers and from coastal development, and their tolerance to this is species-dependent (Duarte *et al.* 1997).

Seagrasses have suffered from widespread die-offs in Florida, where over 40,000 hectares of seagrass have been lost through as yet unknown causes (Robblee *et al.* 1987). Recently a restricted range seagrass species *Halophila johnstonii* found in Florida was listed as endangered (Sea Wind, November 1998), becoming the first marine plant to be considered at risk of extinction.

In tropical areas around the world seagrass beds are at threat from a range of sources. Coastal development and inland deforestation have led to increased sediment entering seagrass beds and in some areas this has destroyed them, or selectively removed the most vulnerable species (Fortes 1990). Pollution has affected many areas of seagrass near large towns and cities. In a Mexican study comparing a polluted seagrass system with an unpolluted one over a period of nine years, the polluted estuary suffered a loss of seagrass and algae cover, changes in fish communities such as the loss of seagrass-associated species and an increase in planktivores (Livingston 1984). The dumping of spoil from mining is a major threat to seagrass beds in many places in South East Asia, and blast fishing has caused destruction over large areas of seagrass in Malaysia, Thailand, Indonesia and the Philippines (Fortes 1990).

Direct removal of seagrasses by dredging has been a big problem in ports and for major developments, for example in Boca Ciega Bay in Florida (Taylor & Salomon 1968). In-filling of seagrass beds for land reclamation schemes is also a threat, for example in Tarut Bay in the Arabian Gulf (MEPA 1989, 1992).

Seagrasses in the Quirimba Archipelago

Seagrass meadows are a major component of the nearshore coastal zone of the Quirimba Archipelago. There are large areas of sheltered sand, mainly in the shallow waters between the islands of the archipelago and the mainland, which provide the ideal situation for the growth of seagrasses. In the Archipelago large areas of subtidal seagrass are found between Matemo and Ibo and the mainland, between Quirimba Island and Quissanga on the mainland, and between Quisiva and the mainland (Fig. 1). Seagrasses are also a very important component of the extensive intertidal flats found around most of the islands (pers. obs, Whittington *et al.* 1997).

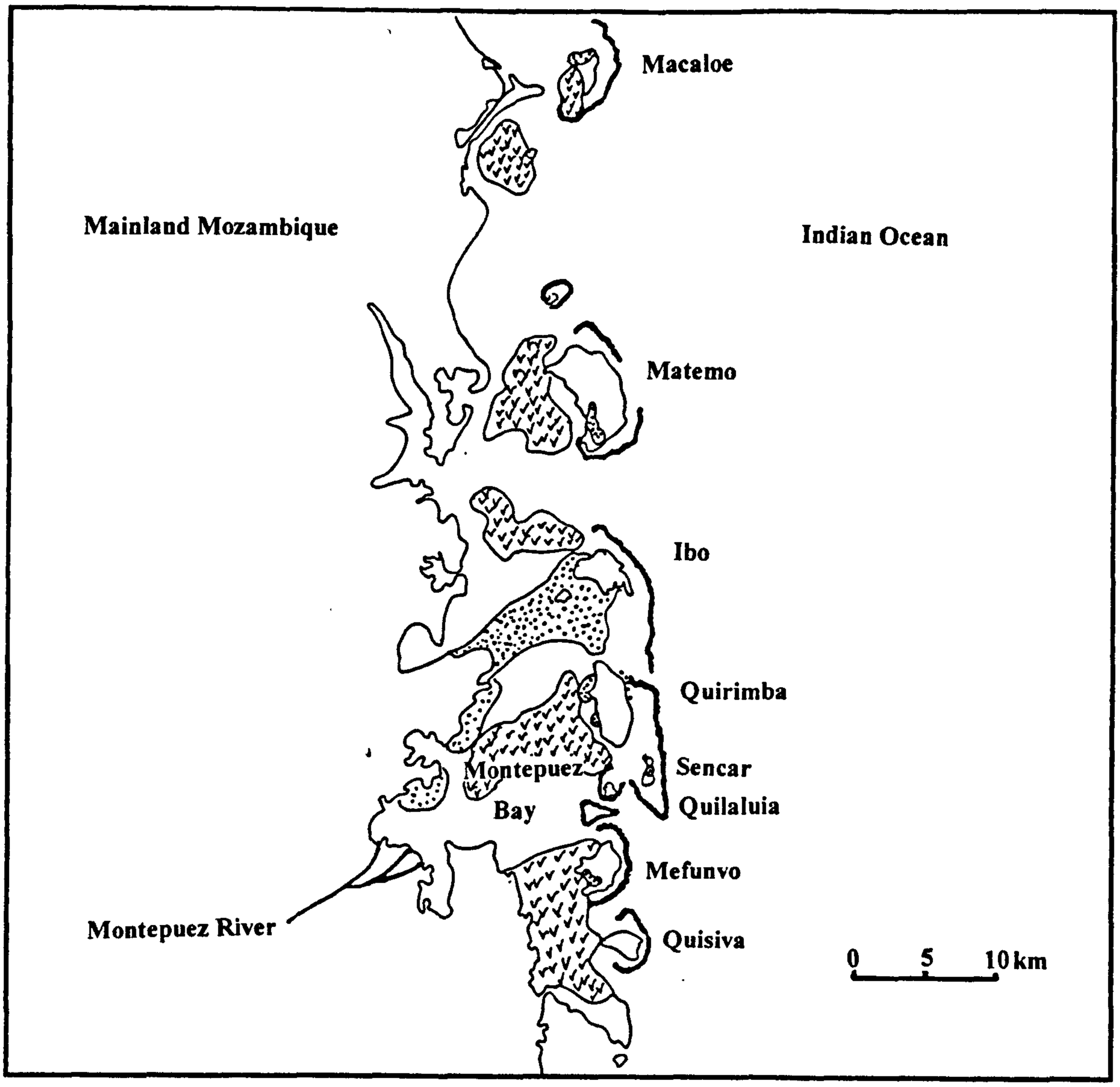

Fig. 1. The southern islands of the Quirimba Archipelago showing the location of the major seagrass beds, mangroves and coral reefs (adapted from maps in Whittington *et al.* 1998).

= seagrass = mangrove = coral reefs

As the seagrass beds of the Montepuez Bay are such an important habitat for the marine species on which the Quirimban people depend, particularly for the seagrass fishery, it was important to describe the seagrass habitat and characterise it in terms of seagrass species and their abundance.

STUDY SITE

The study site was the northern end of the Montepuez Bay between the mainland coast of Cabo Delgado in northern Mozambique and Quirimba Island (Fig. 2). The northern end of the bay is shallow with a maximum depth of 10m. It has a total area of approximately 50km^2. The Montepuez River enters the bay to the south. To the north, around Ibo Island there are extensive areas of mangrove and small stands fringe most of the north and west shores of the bay. To the south east there are extensive shallow coral communities and reefs. The bay has a tidal range of over 4m. At low spring tides more than half of the study area is exposed. Strong tidal currents run into and out of the Bay via two inlets, one to the south between the southern tip of Quirimba and the island of Sencar, and the other to the north between the northern tip of Quirimba and the mangrove forests of Ibo Island. The intertidal fringes of the bay are composed either of mangrove forest or fossil coral flats with varying thicknesses of sediment and a variety of seagrass and algal vegetation. Subtidally the bay is composed of bare sand and patchy seagrass beds, some of them large. Large raised sandbanks are also a feature of the bay. A number of small shallow coral communities can be found in the middle of bay, often in the form of clumps of massive corals in sand and seagrass areas. In other areas small branched corals (less than 15cm tall) grow amongst sparse seagrasses.

METHODS

Preliminary data on the distribution of major marine habitats in the area were collected as part of the Frontier-Moçambique Quirimba Archipelago Marine Research Programme (Whittington *et al.* 1997, 1998). This entailed the basic identification of the distribution of major habitat types such as reefs, mangroves and seagrass beds at a number of sites around the coast of Quirimba. The distribution of major habitat types in the Montepuez Bay was also determined by

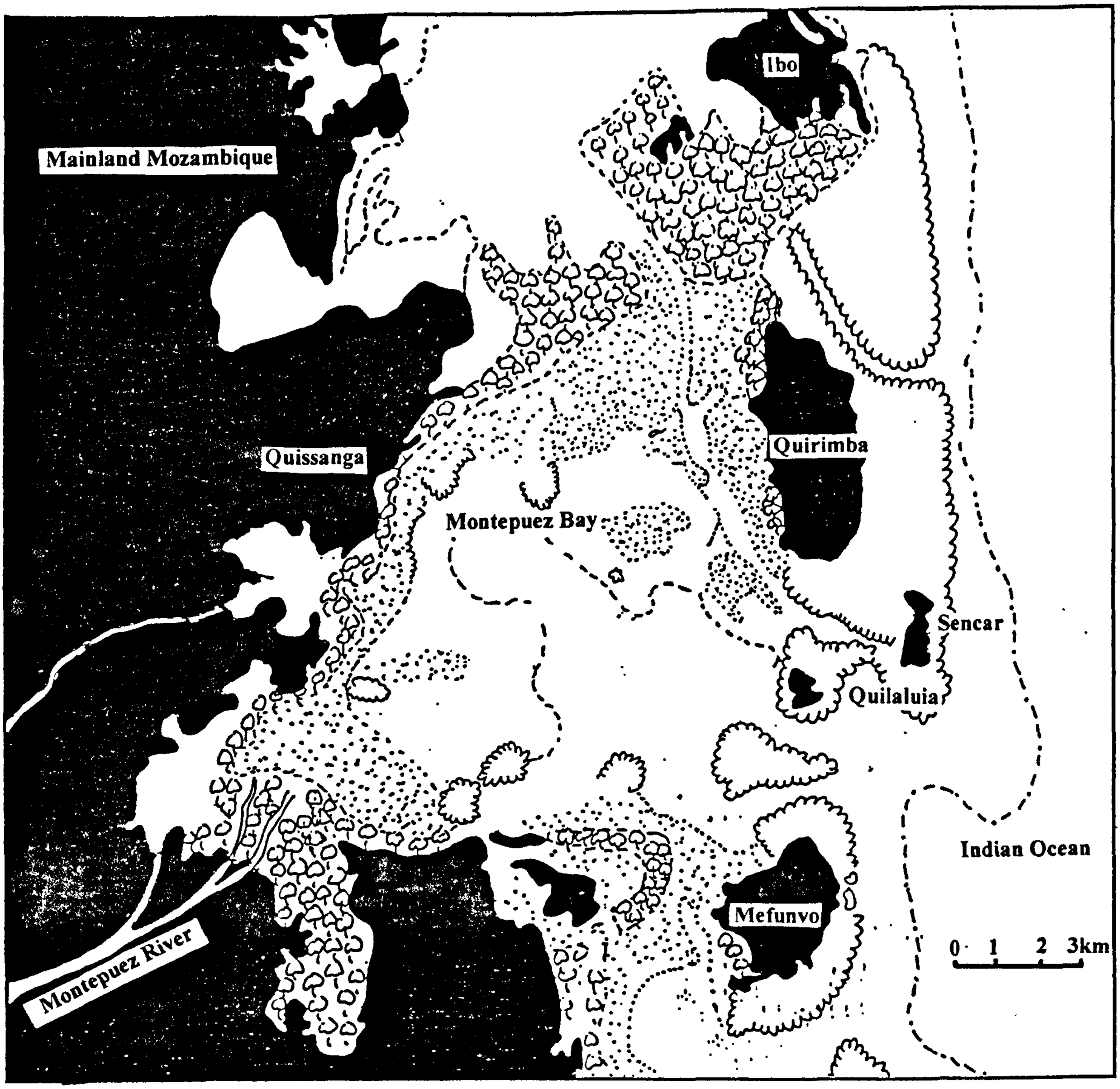

Fig. 2. The study area – the Montepuez Bay and Quirimba Island showing the major physical features of the Bay and some key depth contours (adapted from British Admiralty and Portuguese charts).

= intertidal = mangrove = rock and reef

= land ----- = 10m contour -·-·- = 200m contour

accompanying fishermen on fishing trips. As the water is very shallow and fishing trips took place around low tide it was possible to see the main composition of the fishing sites identified by the fishermen, aided with a very basic Perspex underwater viewer and by snorkelling. GPS readings were taken for the main fishing sites as identified by fishermen, and the main seagrass species present and estimates of the level of cover were recorded.

To obtain a more accurate assessment of the distribution, abundance and species composition of seagrass I employed a calibrated visual assessment technique (Mumby *et al.* 1997). The sites identified during fishing trips were surveyed using quadrats in a random stratified sampling method. The quadrats were $1m^2$ in area and were studied in groups of three randomly selected quadrats with at least 10m between each group. Within each quadrat the seagrass biomass category was estimated on a scale of 0 to 6. These biomass categories were calibrated before the surveys began. This was done by repeatedly estimating the cover category of sample quadrats until myself and a second researcher consistently agreed on the category we gave each quadrat. I aimed to harvest five $0.25m^2$ samples of each of the six categories and separated the harvested material into above and below ground biomass. The material was dried in the field using a home-made drying oven, and weighed on a top pan balance to 0.1 gram accuracy. I calculated a mean figure for the above- and below-ground biomass per metre squared of each of the 6 categories. Having obtained estimates for the biomass of each category, and consistency in the allocation of the categories to quadrats, it was possible to rapidly estimate biomass of the seagrass in the survey quadrats visually. The biomass categories used throughout the study were checked at the end of the study by repeating the harvesting calibration to ensure that our biomass estimates had remained constant.

In addition to biomass category, the percentage cover by each species of seagrass was estimated to the nearest 10% and depth, substrate type, the presence of coral, sponges and other habitat features were recorded. When the seagrass was harvested a number of other characteristics of the seagrass in the harvested quadrats were recorded to quantify composition. The numbers of shoots and leaves of each species were counted, the numbers of flowers and

fruits (where present), the number of fish bites taken from the leaves, the number of whole undamaged leaves and the number of broken leaves and leaves without apices or growth tips.

Large, obvious macro-invertebrates, fish or evidence of fish or invertebrates such as burrows and mounds within the quadrats were recorded. A minimum of 12 quadrats were studied per site but for larger sites as many as 56 quadrats were studied. Maritime Charts (British and Portuguese) were used to establish the major topographical features of the area and aerial photographs of the Montepuez Bay area were also used to assess the large scale distribution of seagrass, sand, reef and other major habitat types. Catch per unit effort values and fisheries catch composition data for each of the study sites were taken from Chapters 2 and 3 (see Methods in these chapters for details).

RESULTS

The 18 main fishing sites identified by the Quiwandala fishermen were mapped as shown in Fig. 3. The 13 sites most commonly fished by boats from Quirimba were chosen for detailed study. These sites were: Banco, Balanzi, Kasuco, Lusino, Makome, Mecute, Momade Assane, Pakilima, Pantopi, Quiutu, Quiwandala, Quiwandala Julu and Santa Maria. The majority of the fishing sites commonly used by the fleet from Quirimba were close to Quirimba and to some extent the "borders" of the common fishing grounds of Quirimba, Quilaluia and Quissanga were identified. Some of the fishing sites were demarcated by some natural or manmade feature, for example Makome (named after the murex shell *Chicoreus ramosus* which was abundant in the area) was identified by the presence of an area of rocks and coral that were exposed at low tide. Momade Assane was near a sand bank on which someone called Momade Assane traditionally maintained a fish trap. Most of the fishing sites were used regularly by fishermen from Quirimba. The areas designated as belonging to the fishermen of other islands were the area called Quirimba Jambandi, said to traditionally belong to the fishermen of Quilaluia; and Mfaranca, Abujati and Panteramouco to the west of the Montepuez Bay which were regarded as the fishing grounds for fishermen from Quissanga.

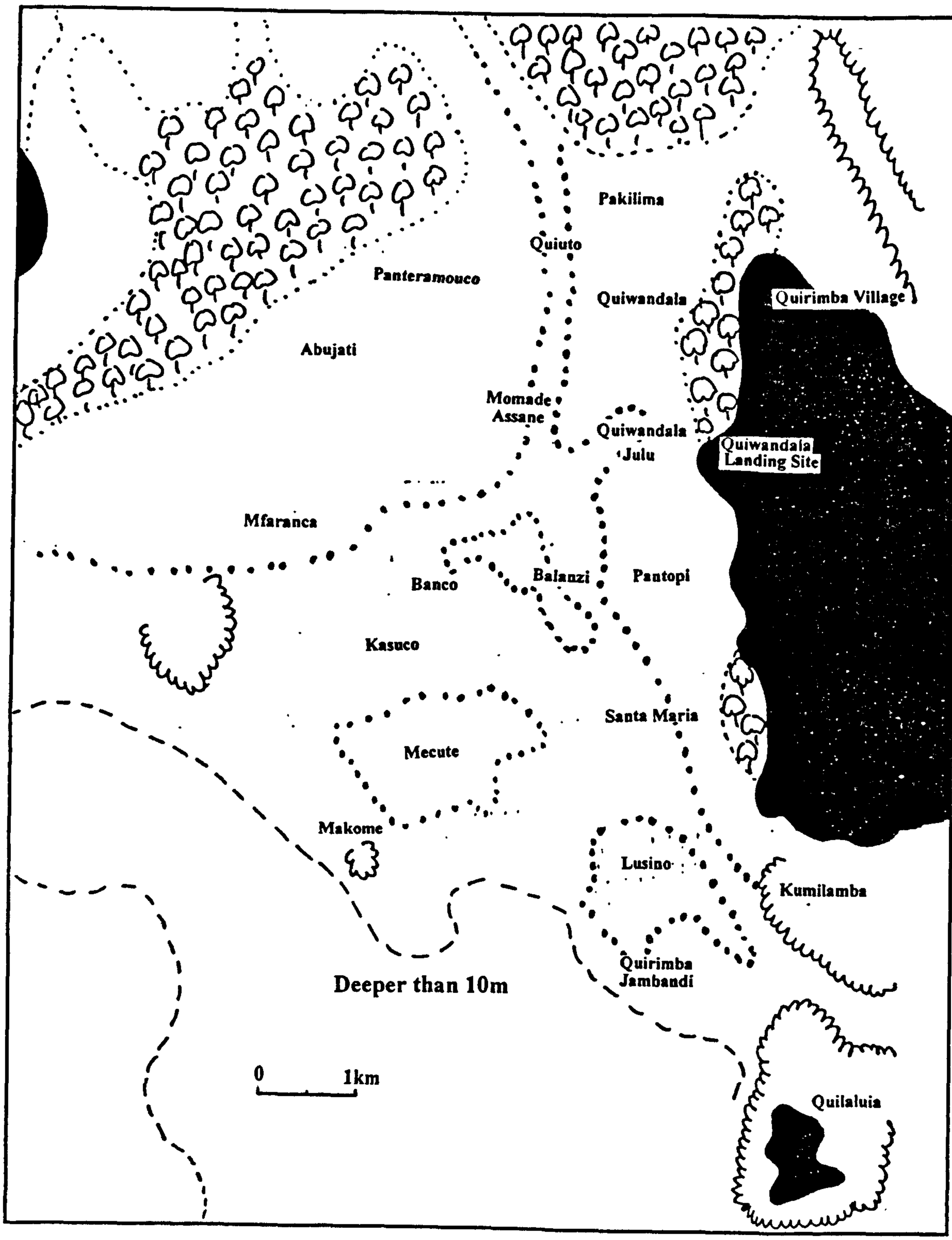

Fig. 3. The northern Montepuez Bay showing the major fishing sites. All sites north of the dashed line are less than 10m deep, and those within the dotted lines are less than 2m deep.

= mangrove = rock and reef = land

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Biomass categories

Table 1 shows the value of the six biomass categories in terms of dry weight of above-ground material in grams per metre squared. Biomass categories ranged from biomass category 1 with a mean value of 12.8 gm^{-2} to biomass category 6 with a mean value of 576.6 gm^{-2}. The full range of categories encompassed all possible densities of seagrass from a few shoots of the smallest seagrasses, *Halophila ovalis* or *Halodule wrightii,* to 100% cover of *Enhalus acoroides*. For example, Category 1 could be one long leaf of *Enhalus acoroides* or a high percentage cover of *Halophila ovalis*. A Category 4 quadrat could contain 80% cover of *Cymodocea rotundata* or alternatively 40% of *Enhalus acoroides*. Category 6 quadrats had over 90% cover of a large species such as *Enhalus acoroides* or *Thalassodendron ciliatum*. The ratio of above to below ground biomass for *Enhalus acoroides* was found to be 1:13.

Seagrass species and abundance

The most common seagrasses were the larger leaf species *Enhalus acoroides, Thalassodendron ciliatum, Cymodocea rotundata* and *Cymodocea serrulata*. Less abundant were *Syringodium isoetifolium, Halophila ovalis, Halophila stipulacea, Halodule uninervis and Halodule wrightii.* Although *Thalassia hemprichii* was not present in the fishing sites it was very abundant in the intertidal zone of the west coast of Quirimba and was also found covering extensive areas in the lagoon on the east coast of Quirimba. Of the 12 East African species only *Zostera capensis* and *Halophila minor* were not present in the northern Montepuez Bay.

Out of 265 quadrats studied in the Montepuez Bay area, 108 were dominated by *Enhalus acoroides* (41%), 44 were dominated by *Cymodocea serrulata* (16.6%), 40 by *Thalassodendron ciliatum* (15.1%) and 29 by *Cymodocea rotundata* (10.9%). In total over 80% of quadrats were dominated by these "large-leaf" species. The most common biomass categories were 3 and 4 (between 100 and 330 gm^{-2}), each accounting for 26% of all quadrats. Seagrass cover within quadrats varied from 0% to 95% with the most common values falling in the 61-70% cover category. Seagrass cover values were fairly evenly distributed between 11 and 90% and only the 0-10% and 91-100% categories were uncommon.

Table 1: Biomass categories from seagrass samples harvested in the Montepuez Bay and their mean dry weight biomass of seagrass, the range of biomass values for each category, one standard error and standard deviation.

Biomass category	Mean biomass gm-2	SE	SD	Min	Max	Range	N
Category 1	12.8	2.8	5.6	6.4	20	13.6	4
Category 2	45.7	9.1	18.1	24.4	67.6	43.2	4
Category 3	113.8	20.5	50.2	70.4	201.6	131.2	6
Category 4	317.7	15.6	38.1	246	349	102	6
Category 5	416.4	20.28	35.1	383	453	70	3
Category 6	576.6	73	127	502	723	222	3

Table 2 shows the presence of seagrass species at each site. A maximum of six species of seagrass were found within a single $1m^2$ quadrat, the most common number being two in one quadrat (in 28.4% of quadrats). Over 20% of quadrats surveyed had four or more species of seagrass. The maximum number of species of seagrass to be found at one site was eight, at Lusino. Six of the thirteen sites had seven species of seagrass. One fishing site, Quiutu, had just one species in all quadrats, *Enhalus acoroides*. Table 2 shows the presence and absence of seagrass species at each site. *Halophila ovalis* appeared in the highest number of sites: 12 of a possible 13. *Halodule wrightii* was only present in one site.

Seagrass assemblages

Monospecific stands of seagrass were most common in the larger species *Enhalus acoroides, Thalassodendron ciliatum* and *Cymodocea serrulata*. Stands containing only *Enhalus acoroides* were numerically the most common type of monospecies stand, accounting for over a quarter of all quadrats. Twenty percent of quadrats containing *Thalassodendron ciliatum* were monospecific. Nearly a quarter of quadrats containing *Cymodocea serrulata* were single species but less than seven percent of quadrats containing *Cymodocea rotundata* were monospecific. *Halodule uninervis* and *Halophila stipulacea* were never found as the only seagrass species in a quadrat, but 11 percent of quadrats containing *Halophila ovalis* contained only *H. ovalis*.

The most common combination of seagrass species was *Enhalus acoroides* with *Halophila ovalis*, followed by *Enhalus acoroides* with *Cymodocea rotundata*. These three species were also common in combination. *Halophila ovalis* frequently occurred with *Thalassodendron ciliatum*. Another common combination was *Cymodocea serrulata* and *Syringodium isoetifolium*. *Syringodium* was found very rarely indeed with the largest seagrass species *Enhalus acoroides* and *Thalassodendron ciliatum*, and *C. serrulata* was also found rarely with these two species.

Table 2: Presence and absence of seagrass species in the sites studied in the northern Montepuez Bay. + denotes the presence of the species, no symbol denotes absence. Total numbers of species at each site, and total number of sites at which each seagrass species was observed, are also shown.

Site Seagrass family and species	Balanzi	Banco	Kasuco	Lusino	Makome	Mecute	Momade Assane	Pakiilma	Pantopi	Quiutu	Quiwand-ala	Quiwand-ala Julu	Santa Maria	Total
Hydrocharitaceae														
Enhalus acoroides	+	+	+	+					+	+	+		+	8
Halophila ovalis	+	+	+	+	+	+	+	+	+		+	+	+	12
Halophila stipulacea	+	+		+		+	+	+	+		+	+	+	10
Cymodoceaceae														
Cymodocea rotundata	+	+	+	+	+	+		+	+		+	+	+	11
Cymodocea serrulata		+	+	+			+	+	+		+	+	+	9
Halodule uninervis	+		+	+	+		+		+		+	+	+	9
Halodule wrightii			+											1
Syringodium isoetifolium		+	+	+		+	+	+	+		+	+	+	10
Thalassodendron cililatum	+	+		+	+	+	+	+				+		8
Total	6	7	7	8	4	5	6	6	7	1	7	7	7	

Seagrass profiles of sites

Mean biomass categories of sites varied between 2.4 and 4.3, a mean biomass of 94 gm^{-2} to 304 gm^{-2} and approximately 100 to 600 leaves per metre squared. A summary of the seagrass cover, biomass and species composition is shown in Table 3. Makome, the site around the rock and coral outcrop had the lowest mean biomass category of 2.4. Makome was dominated by *Thalassodendron ciliatum* and *Cymodocea rotundata* and had a mean percentage cover of 25%. This was the only the site to have abundant free-growing branching coral. The site with the highest mean biomass category (4.3) was Balanzi. Balanzi was dominated by *Enhalus acoroides*, with an average of 37% cover of *Enhalus acoroides*, and low cover of *Cymodocea rotundata, Halophila ovalis* and *Halophila stipulacea*. Mean total cover was also high at nearly 60%. Kasuco had a mean biomass value of 4.2 and a mean seagrass cover of 63.4%. Kasuco was also dominated by *Enhalus acoroides* with nearly 50% mean cover of this species. The most unusual sites were Quiutu with mean cover of 25% and only *Enhalus acoroides* present and Pantopi, which was dominated by the otherwise locally uncommon *Syringodium isoetifolium*.

Correlations between site characterisations and seagrass fish

Fig. 4 shows the relationship between mean percentage seagrass cover at a site and the total percentage of the eleven most common species of fish in the seagrass fishery (see Chapter 3). These species were: *Siganus sutor* (Siganidae), *Lethrinus lentjan* (Lethrinidae), *Lethrinus variegatus* (Lethrinidae, *Leptoscarus vaigiensis* (Scaridae), *Amblygobius albimaculatus* (Gobiidae), *Stethojulis strigiventer* (Labridae), *Gerres oyena* (Gerreidae), *Calotomus spinidens* (Scaridae), *Sphyraena flavicauda* (Sphyraenidae), *Cheilio inermis* (Labridae) and *Scolopsis ghanam* (Nemipteridae). Sites such as Momade Assane, Santa Maria and Quiutu which all had very low seagrass percentage covers, of between 20 and 30 percent, also had a low proportion of these species of fish in the catches obtained from these areas. Catches taken from sites with high mean seagrass cover, for example Pakilima, Mecute, Pantopi and Lusino all of which had mean seagrass cover of 40 percent and above had over 75 percent of the "typical" seagrass fish in their catches. Table 4 shows a summary of the fish species composition of sites.

Table 3: Profiles of the sites studied in the northern Montepuez Bay. The mean biomass category, dominant seagrass species, total cover of seagrass and seagrass species composition are given for each site.

The seagrass species names are abbreviated as follows:
Ea = *Enhalus acoroides*, Tc = *Thalassodendron ciliatum*, Si = *Syringodium isoetifolium*, Cr = *Cymodocea rotundata*, Cs = *Cymodocea serrulata*, Hs = *Halophila stipulacea*, Ho = *Halophila ovalis*, Hu = *Halodule uninervis* and Hw = *Halodule wrightii*.

Site	Biomass category	Dominant seagrass	Mean % Cover	% Ea	%Tc	%Si	%Cr	%Cs	%Hs	%Ho	%Hu	%Hw
Balanzi	4.3	Ea	59.9	36.9	8.9	0	7.8	0	3.2	4	1.1	0
Banco	3.3	Tc	46.7	3	25.3	5.7	8.5	5.3	0.2	0.3	0	0
Kasuco	4.2	Ea	63.4	49.6	0	1.5	6.5	0.03	0	3.3	1.3	1.6
Lusino	3.8	Ea	51.4	36.8	0.2	1.7	6.8	2.2	3.4	0.5	0	0
Makome	2.4	Tc/Cr	25.1	0	14.2	0	4.8	0	0	6.6	0	0
Mecute	3.3	Tc	46.3	0	21.2	9.3	4	0	3.6	9.1	0	0
Momade Assane	2.5	Cs	20.8	0	1.5	4.7	0	14.8	0.2	0.3	0.2	0
Pakilima	2.9	Tc	45	0	37.4	0.4	0.4	4.1	0.6	3.2	0	0
Pantopi	3	Si/Ea	47.6	7.7	0	20.8	9.3	1.1	1.6	7.5	0.05	0
Quiutu	3.8	Ea	25	25	0	0	0	0	0	0	0	0
Quiwandala	3.5	Cs	51.3	8.4	0	6	2.5	34.2	1.3	0.9	0.8	0
Quiwandala Julu	3.7	Si/Cs/Tc	66.1	0	20.5	18.9	3.4	20.7	2.9	1.2	0.2	0
Santa Maria	2.8	Cs	29	8.7	0	3.1	3.1	10.2	2.5	0.7	0.6	0

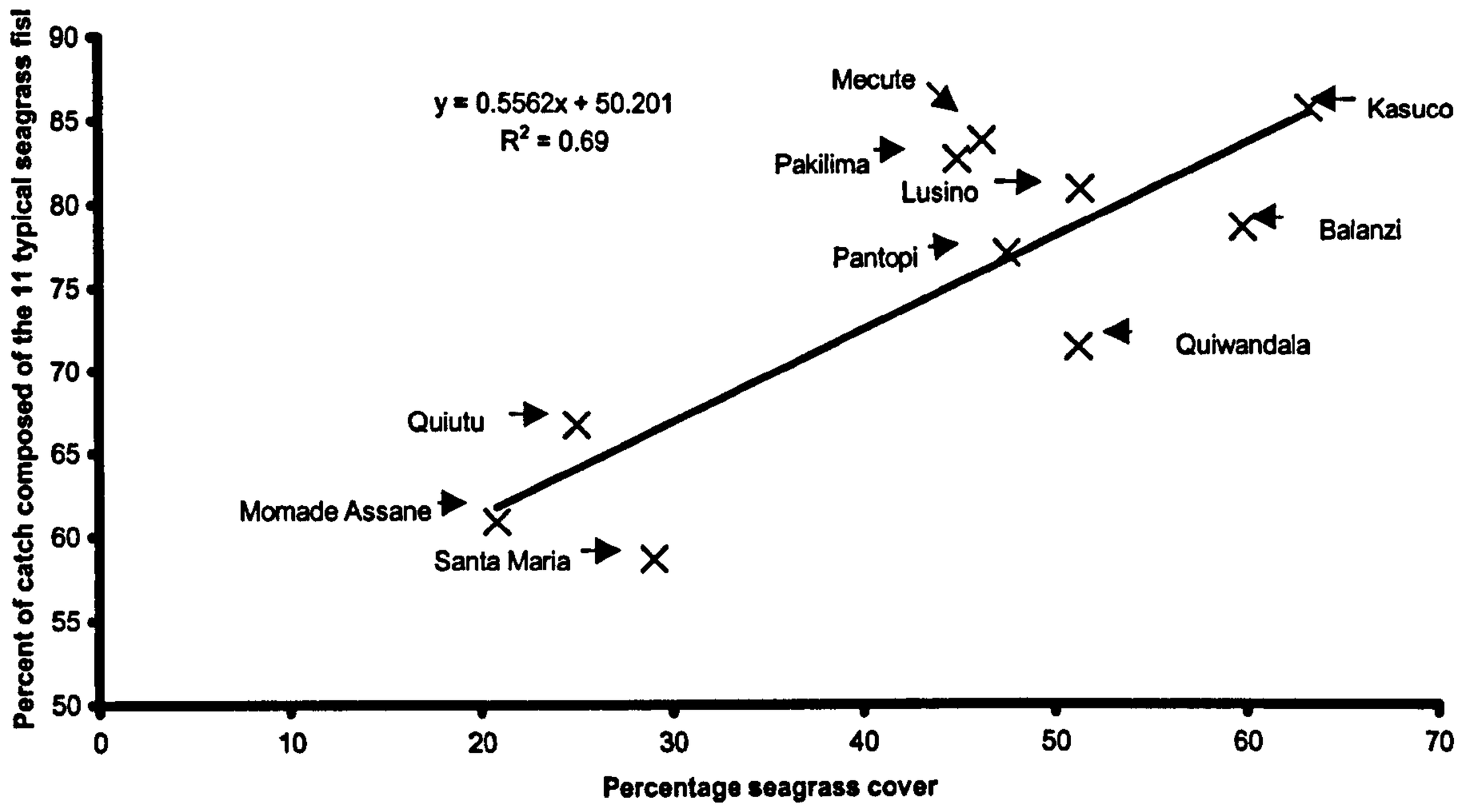

Fig. 4: Relationship between the mean percentage seagrass cover of fishing sites and the total percentage of the 11 most common seagrass fish species.

Site characterisation and catch per unit effort

There was a general positive relationship between mean seagrass biomass category and mean catch per unit effort (CPUE) (see Fig. 5). Conversely the low seagrass biomass categories at the two coral rich sites Quiutu and Santa Maria corresponded with low values of CPUE. There was also a positive relationship between mean seagrass percentage cover and mean CPUE for the fishing sites (Fig. 6).

Fish present in seagrass surveys

Table 4 shows the most commonly seen fish during the subtidal seagrass surveys. The most common was *Siganus sutor*, accounting for over 18% of fish seen, followed by *Lethrinus variegatus* (13.4%), *Leptoscarus vaigiensis* (10.5%), *Pteragogus flagellifera* (Labridae 7.3%) and *Amblygobius albimaculatus* (6.1%). A total of 36 species were observed with 7 species accounting for more than 50% of the total number (the five species mentioned above and *Corythoichthys sp.* (Syngnathidae) and *Dascyllus aruanus* (Pomacentridae).

Fish bites on seagrass leaves

From a total of 1201 leaves of *Enhalus acoroides* examined, I counted 120 bites, a mean of nearly 0.1 bites per leaf, or a bite in one in every ten leaves. I found a similar incidence of fish bites in *Cymodocea rotundata* in which from 911 leaves examined 90 bites were found, a rate of nearly 0.1 bites per leaf. *Cymodocea serrulata* had a rate of 0.05 bites per leaf examined or one in every 20 leaves with bites. A mean value of 0.16 bites per leaf was found for *Halodule uninervis*. The other species of seagrass were either too small to see identifiable bites or had leaves which could be taken whole, e.g. *Halophila ovalis*. The loss of whole ends of leaves could not be definitely attributed to fish so only obvious bite-shaped scars were counted.

Invertebrates present in seagrass characterisation surveys

In the seagrass characterisation quadrats we identified 182 large conspicuous invertebrates, in 34 different taxa. The most common were the sea urchin *Diadema setosum*, the pen shell *Atrina vexillum*, the *Enhalus acoroides*-associated oyster *Pinctada nigra*, the urchin *Tripneustes gratilla*, the pinna shell

Species	Number	% of total
Siganus sutor	46	18.62
Lethrinus variegatus	33	13.36
Leptoscarus vaigiensis	26	10.53
Pteragogus flagellifera	18	7.29
Amblygobius albimaculatus	15	6.07
Coryoichthys sp.	14	5.67
Dascyllus aruanus	8	3.24
Stethojulis strigiventer	7	2.83
Goby sp.(pinkspotted)	7	2.83
Chrysiptera annulata	7	2.83
Goby sp.(brownspotted)	6	2.43
Synodus sp.	6	2.43
Labroides dimidiata	5	2.02
Parupeneus barberinus	4	1.62
Cheilio inermis	4	1.62
Hipposcarus harid	4	1.62
Lethrinus mahsenoides	3	1.21
Lutjanus fulviflamma	3	1.21
Lethrinus mahsena	2	0.81
Pterois sp.	2	0.81
Canthigaster bennetti	2	0.81
Upeneus tragula	2	0.81
Parupeneus heptacanthus	2	0.81
Cheilodipterus quinquelineatus	2	0.81
Scarus ghobban	2	0.81
Scolopsis ghanam	2	0.81
Goby sp. (brownstriped)	2	0.81
Platax orbicularis	2	0.81
Arothron stellatus	2	0.81
Canthigaster sp.	2	0.81
Fowleria variegata	1	0.40
Goby sp. (pinkstriped)	1	0.40
Goby sp. (pale green)	1	0.40
Apogon aureus	1	0.40
Pomacentrus trilineatus	1	0.40
Neopomacentrus fulginosus	1	0.40
Dascyllus trimaculatus	1	0.40
Total	247	100.00

Table 4: The species of fish observed on seagrass survey dives for all sites studied, number of fish observed and percentage of total fish observed.

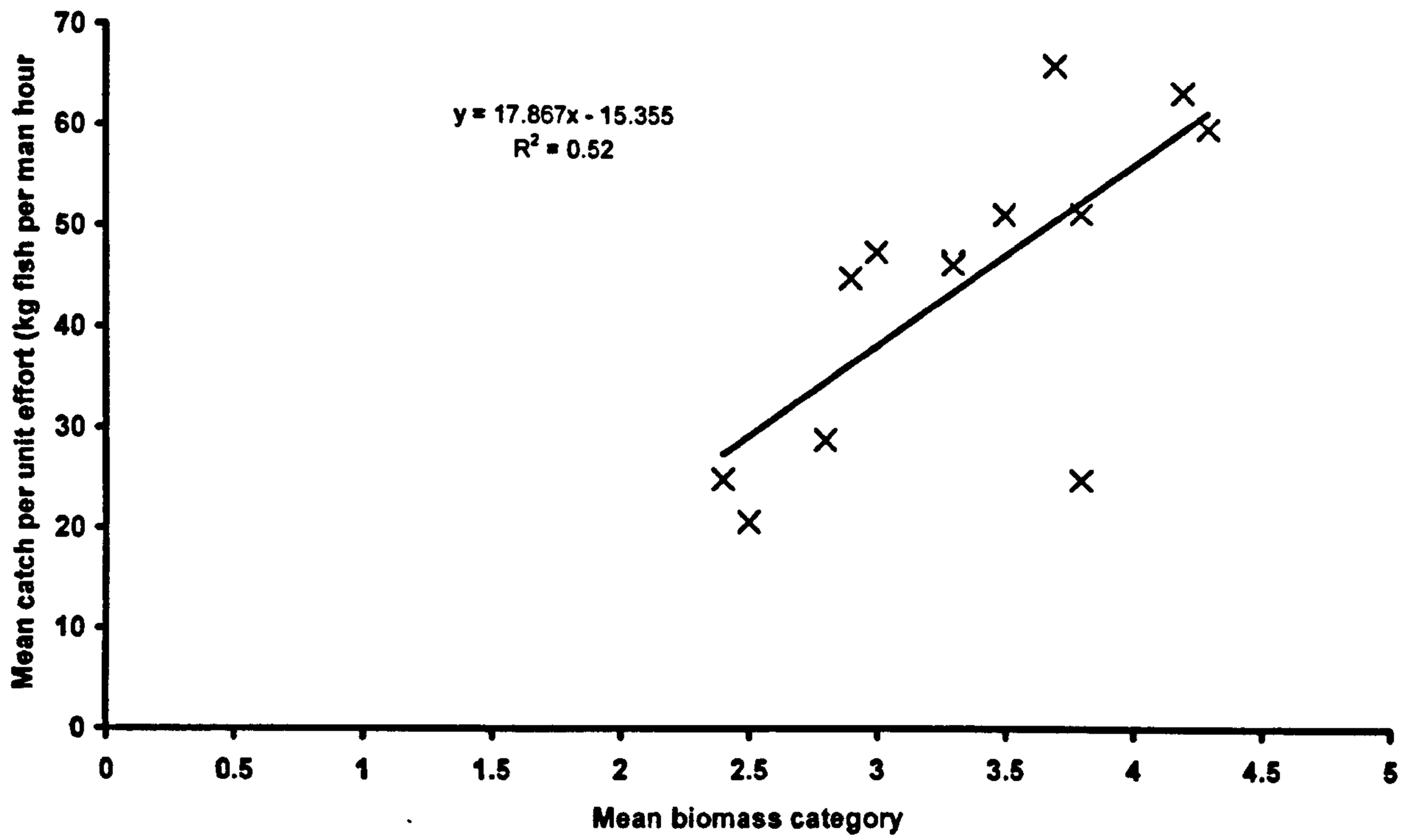

Fig. 5: Mean biomass category versus mean catch per unit effort for the fishing sites. Each point represents the mean values for an individual site, as labelled.

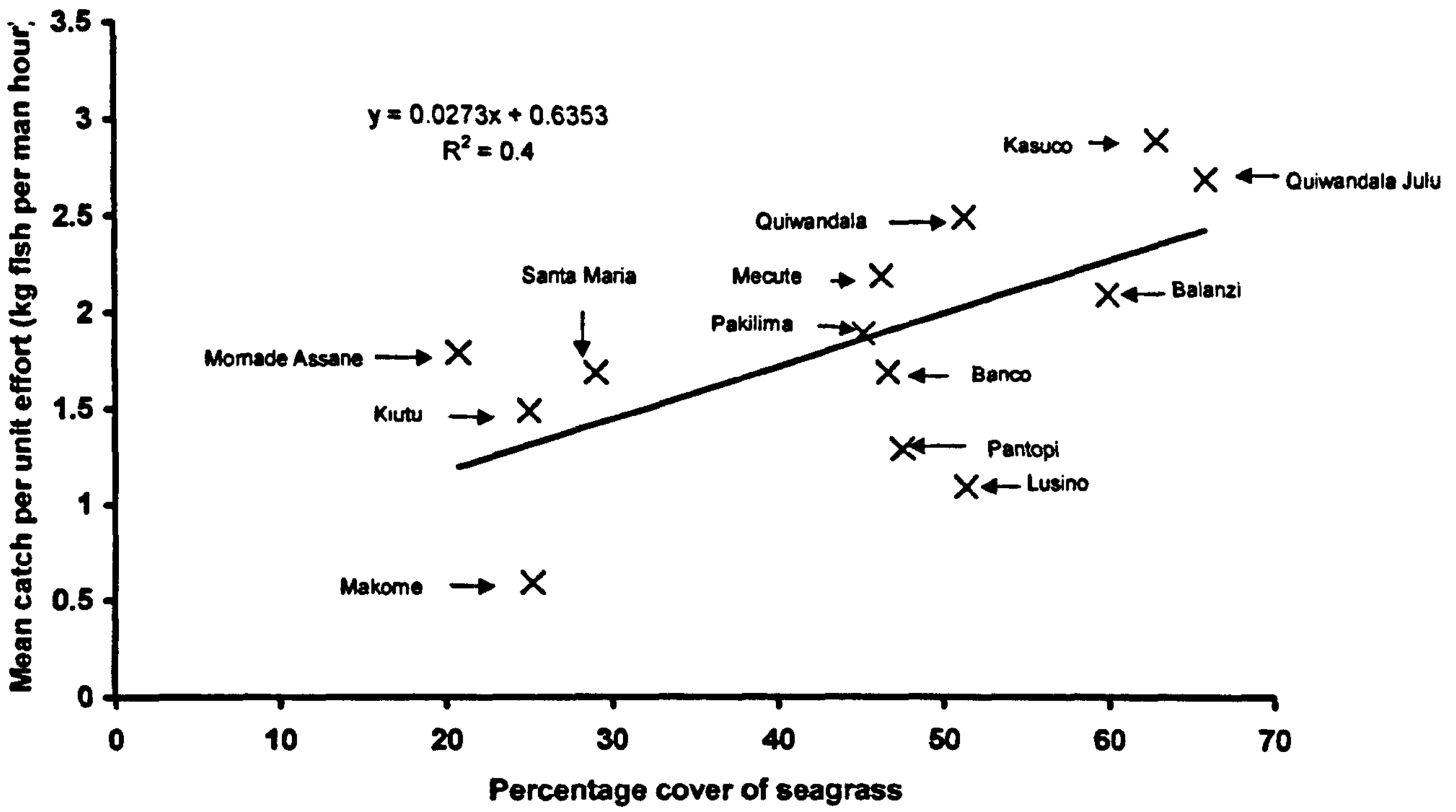

Fig. 6: Mean percentage cover of seagrass versus mean catch per unit effort for the fishing sites. Each point represents the mean value for an individual site, as labelled.

Pinna muricata and the sea cucumber *Synapta maculata*. Other conspicuous seagrass residents included the brightly coloured starfishes *Pentaceraster tuberculatus* and *Protoreaster lincki*.

Invertebrate or fish burrows were very common, as were mounds of sand that seemed to have been formed by invertebrates, probably large burrowing *Holothuria*. These mounds were very large, up to 0.5 metre high and sometimes wider in diameter, and often did not have seagrass growing on them. In their study of seagrass beds in Kenya, Coppejans *et al.* (1992) also found many of these "cone-like bumps" extruding sediments from a central crater and they too were uncertain as to what was producing them.

Algae and epiphytes

The seagrass beds had a wide variety of algae, both free-growing and epiphytes. Epiphytes were particularly common on *Enhalus acoroides* and at some sites almost completely covered the fronds. M.C. António identified over 30 species of algae living with or on the seagrass and this work will be presented elsewhere (Whittington *et al.* 1997, 1998).

DISCUSSION

The species composition of seagrass beds

There have been various broad descriptions of the zones within a tropical Indo-Pacific seagrass bed. Ruwa (1996) gives the following pattern for the East Africa region: Intertidally, there is pattern of succession of species, starting with small seagrasses like *Syringodium* and *Halophila*, and progressing to larger, taller species. *Syringodium* and *Halophila* are found very rarely in subtidal beds. Subtidally, either *Thalassodendron ciliatum* or *Thalassia hemprichii* are dominant and *Enhalus acoroides* is common in muddy areas and is also found in deep sandy pools but rarely in extensive beds. In Bandeira (1996) the pattern of zonation of Eastern African seagrasses is slightly different, and more similar to the distributions I found in Quirimba. In this scheme *Syringodium* and *Halophila* are found throughout the tidal range, including true subtidal areas, *Thalassodendron ciliatum* is found subtidally and in intertidal pools and *Enhalus acoroides* is found predominantly subtidally. The only species described as not

common subtidally were *Thalassia hemprichii, Zostera capensis, Halodule sp.* and *Cymodocea sp.* In Quirimba *Cymodocea sp.* was found subtidally but *Thalassia hemprichii* was not. The only site where *Syringodium isoetifolium* was dominant was also the most intertidal fishing site in the bay, corresponding to Ruwa's (1996) scheme of zonation. It seems that the concept of zonation and succession in Western Indian Ocean seagrass beds can only be a rough guide to what is seen in reality.

In southern Mozambique the common combinations of seagrass were *Thalassodendron ciliatum* with *Cymodocea serrulata*, *Thalassia hemprichii* with *Halodule wrightii* and *Zostera capensis* with *Halodule wrightii*, with *Syringodium isoetifolium* most commonly found at the subtidal fringe (S. Bandeira pers. com.). In the Montepuez Bay it was common to find a large seagrass species dominating with a patchy "understorey" of a small species such as *Halophila ovalis*, but mixed beds of larger species were also fairly common. The most striking point in terms of seagrass distribution or zonation was the absence of *Thalassia hemprichii* from the subtidal seagrass beds. Ruwa (1996) suggested that *Thalassia hemprichii* may be limited subtidally because it is the preferred species for parrotfish grazing. The seagrass-grazing parrotfishes *Leptoscarus vaigiensis* and *Calotomus spinidens* were extremely common in the Montepuez Bay (see Chapter 3) with the trap fishery being based almost entirely on these species, so this may well be a contributory factor.

A survey of intertidal and subtidal seagrasses at Gazi Bay, Kenya (Coppejans *et al.* 1992) found distinct zonation with *Enhalus acoroides* from low water at neap tide, mixed meadows of *Thalassia hemprichii, Cymodocea serrulata, Cymodocea rotundata* and *Halodule uninervis* with patches of *Syringodium* to one metre. Below one metre they found monospecific beds of *Thalassodendron ciliatum*, with patches of *Enhalus acoroides*. The distribution is broadly similar to that which I found, but again *Enhalus acoroides* was much more abundant in the Montepuez Bay.

In a description of the seagrass and macroalgal communities of Sungai Pulai Estuary in Peninsular Malaysia a similar seagrass community is described to that in Montepuez Bay, but at a generally lower level of biomass (Bujang *et al.*

1996). There, *Enhalus acoroides* and *Halophila ovalis* were found with the intertidal species of seagrass *Thalassia hemprichii* in a "middle zone" of seagrass that is exposed at low tide. In the Montepuez Bay, large areas of *Enhalus acoroides* were indeed exposed at low tides, especially low spring tides, particularly in the Pantopi area, and areas surrounding the sand banks in the bay (Kasuco, Banco and Lusino). *Enhalus acoroides* and *Halophila ovalis* are reportedly able to withstand temporary desiccation (Marmelstein *et al.* 1968 in Bujang *et al.* 1996) which may explain their common co-existence in the Montepuez Bay and their tolerance to exposure at low spring tides. In the unexposed zone in Sungai *Cymodocea serrulata* and *Syringodium isoetifolium* and *Halodule uninervis* formed a permanently subtidal zone (Bujang 1996). In Quirimba *Cymodocea serrulata* and *Syringodium isoetifolium* also formed a distinct community.

In the Puttalam Lagoon in Sri Lanka the predominant seagrass species are also *Cymodocea rotundata* and *Enhalus acoroides* (Johnson and Johnstone 1995). These two species are most commonly found together in the lagoon, but are also found with *Thalassia hemprichii, Halodule uninervis, Syringodium isoetifolium, Cymodocea serrulata, Halophila ovalis* and *Halophila decipens.* The Puttalam lagoon also supports a locally important fishery (Johnson and Johnstone 1995).

In their paper on the response of seagrass beds to burial in sediment, Duarte *et al.* (1997) describe the seagrass bed they used for their experiments in the Philippines as typical of the seagrass beds of the South East Asia region. Their bed was composed of seven species of seagrass – dominated by *Thalassia hemprichii*, with *Enhalus acoroides*, *Cymodocea rotundata, C. serrulata, Halodule uninervis, Syringodium isoetifolium,* and *Halophila ovalis*. With the exception of the dominance of *Thalassia hemprichii* subtidally, this composition is similar to Quirimba. However, they stated that all the species could be found within a 0.25 metre squared plot which was not true for the Quirimba seagrass beds. One out of 13 sites at Quirimba contained all 8 species and the maximum number of species in a one metre squared quadrat was 6 and this was found on just one occasion. Although the same species are present Quirimba they were not so mixed or consistently multi-species as in the study in the Philippines.

The significance of *Enhalus acoroides* as the dominant species

The seagrass beds of the Montepuez Bay area formed the largest continuous areas of seagrass in the Archipelago but there were also extensive areas between Quisiva and Mefunvo and the mainland, between Matemo and the mainland and northwest of Ibo. From the surveys described in this chapter and observation from boats it was evident that beds of *Enhalus acoroides* in the Montepuez Bay extended over areas of the order of hundreds of metres squared. In all other sites in the Archipelago *Thalassia hemprichii* dominated the intertidal seagrass beds, and *Thalassodendron ciliatum* was the most dominant subtidal species (pers. obs., Whittington *et al.* 1998). Quirimba was the only area within the Archipelago where *Enhalus acoroides* was present in extensive monospecific stands. From observations throughout the East African region, marine botanist Salomao Bandeira of Universidade Eduardo Mondlane in Maputo also believes that extensive beds of *Enhalus acoroides* are not common (S. Bandeira, pers. comm.). In the only other study of seagrass distribution in the north of Mozambique (Bandeira & António 1996) in Mecúfi Bay, just south of Pemba *Enhalus acoroides* was not found at all, although it is found further south in Mozambique (Bandeira 1995). At Mecúfi the mainly subtidal species *Zostera capensis* is present, which was absent just a few hundred kilometres north in the Montepuez Bay. Ruwa (1996) states that in the East African region *Enhalus acoroides* rarely forms the kind of extensive beds formed by *Thalassodendron ciliatum* and *Thalassia hemprichii*. In Papua New Guinea (Brouns & Heils 1985) large monospecific stands of *Enhalus acoroides* were only found in the sheltered side of the island studied and were only 7m or so across.

The reason for the unusual extent of *Enhalus acoroides* may be due to the geography of the Montepuez Bay area. It is a large sheltered area with a high turnover of water through tides, but a relatively stable substrate that may have allowed large beds of *Enhalus acoroides* to have formed and be maintained in the area. The main physical pressure in the Montepuez Bay is the strong current caused by rising and falling tides entering and exiting the Bay from the open sea, and the high level of exposure to the air and sun at low spring tides.

Extensive areas of the bay were exposed to the sun at low tides and this may also explain the dominance of desiccation-resistant species such as *Enhalus acoroides*. *Enhalus acoroides* may actually need to be exposed to the air at low spring tides to allow the plant to flower (Phillips and Menez 1987).

The unusual extent of *Enhalus acoroides* bedsmay explain why the Montepuez Bay supports such a productive and diverse fishery (Chapters 2 and 3). With its larger longer leaves providing shelter, heavy epiphyte load providing extra food, high growth rates and resilience to desiccation, and high above to below ground biomass ratio, *Enhalus acoroides* may provide a better habitat for fish than other smaller, more sparsely growing species. The large areas of *Enhalus acoroides* in the Montepuez Bay would therefore be expected to sustain a high fisheries productivity.

Seagrass biomass values

The dry weight biomass values found in the Montepuez bay were slightly higher than those in the Sungai Pulai Estuary in Malaysia (Bujang 1996). The highest mean total biomass of Sungai seagrasses was 176-276 gm^{-2}, whereas the mean biomass of the middle and most common biomass categories (3 and 4) on Quirimba were 113.8 and 317.7 gm^{-2}. Maximum above ground biomasses in Quirimba exceeded 500gm^{-2}. However Bujang *et al.* (1996) do say that their values are lower than those found in similar studies. The mean total biomass for *Enhalus acoroides* in Quirimba was found to be 414 gm^{-2} which is very close to the value found in the Flores Sea, Indonesia of 416 gm^{-2} (Nienhuis *et al.* 1989), and slightly lower than the values estimated for Sabah, Malaysia of 468.5 gm^{-2} (Norhadi 1993) or West Java, Indonesia 467.6-500.4 gm^{-2} (Kiswara 1992) (all referred to in Bujang 1996).

The above to below ground biomass ratio of 1:13 that we found for *Enhalus acoroides* was closest to that found for the species by Norhadi (1993) in Malaysia. A low below ground biomass may be indicative of low pressures from being swept away, i.e. low currents (Phang and Sasekumu 1996). If large dense stands of *Enhalus acoroides* are rare elsewhere, this strategy of forming dense stands may be adaptive in Quirimba because of the persistently strong currents in the Montepuez Bay. *Enhalus acoroides* forms dense stands with strong roots

and must be very difficult to dislodge compared with open stands of smaller species such as *Cymodocea*.

Fish composition

The fish assemblages of different areas were broadly different depending on seagrass composition and general habitat character. In some cases the relationship between the catch composition and the biomass category of seagrass may have had more to do with what was present in the areas apart from seagrass, than on the low biomass of seagrass. This may be particularly true in areas with high coral cover in close proximity. In the case of Santa Maria and Quiutu one of the reasons for low seagrass cover was the presence of small coral communities, often centred around large massive corals, and small patches of free-standing branching corals. The presence of coral in the area may account for the lower proportion of "typical seagrass fish", as coral areas are likely to have more species of fish typically associated with coral reefs than non-coral areas and so less of the total fish biomass would be accounted for by seagrass species. These mixed coral and seagrass communities may also have their own distinct fish faunas. In other studies (Weinstein & Heck 1979, Baelde 1990) seagrass beds in close proximity to reef areas had a greater variety of species and a higher abundance of herbivores and piscivores. In seagrass beds in close proximity to mangroves the fish assemblages have been found to be highly changeable, perhaps as a result of pulses of recruitment of juveniles as have been observed in mangroves and seagrass beds by others (Carr and Adam 1973, Kikuchi 1974, Weinstein and Heck 1979, Ogden 1980, Bell *et al.* 1984).

Site characterisation and CPUE

There are a number of possible reasons why CPUE would be higher in areas of high seagrass cover. Areas of high seagrass cover are easy to fish with nets – they are usually flat shallow areas with a sandy substrate and do not cause problems for fishermen and their nets, so they can be fished quickly and efficiently. Rocky places or areas with large corals cause problems for fishermen snagging their nets and making it difficult to navigate. More time is needed to haul the net and there is a higher potential for net damage. Nets

hauled slowly and subject to tangling are less likely to bring a large catch because fish have more opportunity to escape. Areas of high seagrass cover and high biomass may have higher numbers of fish. High biomass and high percentage cover of seagrass were associated with areas of *Enhalus acoroides*. Quirimban fishermen say that *Enhalus acoroides* is the best place to catch fish. Trap experiments confirm this, traps placed in areas of *Enhalus acoroides* catching a higher biomass of fish then those placed in beds of smaller species such as *Cymodocea spp.* (Chapter 5).

It seems likely that large leaf species, such as *Enhalus acoroides* and *Thalassia hemprichii,* would support a higher biomass of fishes because they provide a more structurally complex habitat, especially when they also have an understorey of a smaller species. They can therefore provide improved shelter and a higher surface area as substrate for epiphytes and prey fauna (Heck & Orth 1980, Raz-Guzman & Sanchez 1996).

In studies comparing fish biomass in vegetated versus unvegetated areas, an extreme version of the varying degrees of seagrass biomass in our fishing sites, some studies have found increased biomass in seagrass areas (Jenkins and Wheatley 1998 – a temperate example from southern Australia). In other studies this has been inconclusive and has depended on the depth and location of seagrass beds (Jenkins *et al.* 1997). In a study of seagrass fish species composition and biomass in tropical seagrass beds in Northern Australia, in water of more than 2m most species of fish were more abundant in tall seagrass (*Cymodocea* and *Enhalus*) than in small seagrass or bare areas (Blaber *et al.* 1992).

The influence of seagrass type on biomass and species composition of fish fauna was studied in Puerto Rico where Martin and Cooper (1981) found that mean fish biomass in stands of *Thalassia* was nearly three times that in stands of the very small, fine species *Syringodium*. They also found significant differences in the species and families of fish present.

Threats and management

Fortes (1990) put seagrass beds in South East Asia into three categories: pristine, disturbed and heavily impacted or altered. Pristine seagrass beds were described as remote from human settlements, typically with dense stands of *Enhalus acoroides*, *Thalassia hemprichii* and *Cymodocea rotundata*. Disturbed seagrass beds were described as near human habitation and constantly disturbed by human activity, but still potentially yielding high biomass and productivity. Seagrass beds in these first two categories could have high or low species diversity but those in the third category, altered or heavily impacted, could only have low diversity as a result of having been permanently changed by human activities such as the construction of ponds for aquaculture. The seagrass beds of Quirimba were mechanically and ecologically disturbed by the fishery, but still had the seagrass species assemblages that Fortes (1990, 1992) describes for climax assemblages in a pristine seagrass meadow. According to Fortes (1992), disturbed seagrass ecosystems can still have high species diversity and yield high biomass but are used intensively by people, and should be managed accordingly. The seagrass beds of Quirimba fall into the category of disturbed seagrass ecosystems that continue to be highly diverse and productive in terms of plants and animals.

How tolerant are the seagrass beds of Quirimba to the present level of human use? *Enhalus acoroides*, the most abundant species in the area was the seagrass most tolerant of burial by sediment in Duarte *et al.*'s study (1997), so this species may be able to tolerate increasing levels of sedimentation and disturbance. Large seagrass species like *Enhalus acoroides* and *Thalassodendron ciliatum* also seemed to be more tolerant of the dragging of nets in fishing as they are very rarely uprooted unlike small fragile species such as *Halophila spp.* (pers. obs. from underwater observation of hauls). One of the potential threats to the Montepuez Bay is the risk of an increased sediment load from upriver deforestation on the mainland. Presently, although the bay is near the mouth of a large river the sediment input is seasonal (rain is almost exclusively experienced during the few months of the full rainy season) and relatively low. However, if this were to become a problem in the future, *Enhalus acoroides* may be able to continue to grow well, but the more vulnerable species, *Thalassia hemprichii* followed by *Cymodocea rotundata, Syringodium*

isoetifolium and *Halodule uninervis* may be lost (Duarte 1997). The present lack of *Thalassia hemprichii* subtidally may be attributed to present high levels of sediment deposition or heavy sedimentation events in the recent past such as a huge influx of river-borne silt in the rainy season, as in Duarte *et al.* (1997). *Thalassia hemprichii* was found to be vulnerable to even moderate burial treatments and did not recover after burial events. It is possible that some catastrophic burial event in the past, maybe associated with high levels of erosion caused by widespread slash and burn and commercial logging inland, may have caused selective die-off of *Thalassia hemprichii.* In the 1960s after extremely heavy rains the Montepuez River swelled to the extent that the whole of the Montepuez Bay was inundated with freshwater and there was a catastrophic loss of fish, plants and corals in the bay (J. Gessner pers. com.). This event or a similar one more recently could well have caused a long-term change in the species composition of the seagrass communities of the bay, and might explain two key factors about the Montepuez Bay seagrass beds. Firstly the lack of *Thalassia hemprichii* subtidally and secondly the unusual extent of *Enhalus acoroides*, which could have become more common because it was tolerant to very levels of burial in sediment and had a competitive advantage over the other species.

Alternatively, the repeated trawling of the bay by fishers could possibly produce levels of disturbance and sedimentation on a continuous basis that are sufficient to prevent *Thalassia hemprichii* re-establishing itself subtidally. If disturbance by fishers is preventing the growth of *Thalassia hemprichii* in the fishing sites and giving *Enhalus acoroides*, the seagrass that apparently provides the most productive habitat for fish, a competitive advantage, the fishermen are altering the habitat in a way that may ultimately be increasing their fisheries potential and the chance of the fishery remaining sustainable.

The large fish and invertebrate burrows and mounds may have an influence on the extent of seagrass beds and the distribution of species. Burrowing shrimps can build mounds that bury seagrass in up to 30cm of sediment (C.M. Duarte, J. Terrados & M.D. Fortes, unpublished data in Duarte *et al.* 1997). These mounds are colonised by *Halophila spp.*, followed by *Halodule, Cymodocea and Syringodium*. The patterns of recolonisation and recovery are very similar in

large and small-scale burial events. On a small scale, patches of seagrass may be continually being destroyed by burrowers and recolonised naturally (Duarte *et al.* 1997).

In northern Mozambique where coastal development has been minimal the conventional threats to seagrasses also appear to be minimal; there are very few motor boats in the area, no industrial development and very little tourist development. Commercial logging and subsistence slash and burn agriculture are intensive on the mainland and on some of the larger islands in the north of Mozambique and at the time of this study were largely unregulated. In the rainy seasons increased soil erosion and river-borne sediment may yet develop into the most serious threat to the seagrasses.

In Quirimba over half of the population derive a large proportion of their food and income from seagrass resources. Any threat to the integrity of the seagrass ecosystem of the Montepuez Bay must therefore be taken very seriously. The loss or degradation of the seagrass beds would have a serious impact on the local community both economically and socially. Situations similar to that in the Montepuez Bay can be found throughout the tropics, where communities depend to a large extent on seagrass related resources and where accelerating development and land-use changes are serious threats to the seagrass beds (Fortes 1990, MEPA 1992). It is important that the productivity and fisheries importance of tropical seagrass beds are recognised on a global scale and that they are managed sustainably.

In future conservation measures for the seagrass beds of Quirimba Island, it will be important not only to maintain the cover and high total biomass of seagrass, but also their diversity of seagrass species. High cover and biomass by large species such as *Enhalus acoroides* are obviously important in maintaining the seagrass fishery, but in the long term, the variety of seagrass species is likely to be important in maintaining the productivity of the habitat and sustainable fish catches. The wide diversity of growth forms and level of adaptation to desiccation, strong currents, various light levels and different substrate type represented by the ten species of seagrass present in the Montepuez Bay, is vital within the seagrass ecosystem. The diversity allows the seagrass meadow

as a whole to adapt to changes in the environment, and to maintain a high level of productivity. Possible short term environmental changes include increased siltation resulting from erosion caused by land-use changes upriver inland and in the coast and an increase in nutrient-loading from human waste. Possible long term changes in the environment include the results of global warming or the large scale industrial development of the area.

There is no strong evidence from this study that higher diversity of seagrass species in the scale of the small seagrass beds is related to high productivity of fish, as has been found elsewhere. However, on the scale of the whole bay the high diversity of seagrass species utilising the broad range of zones or niches may well contribute to the fisheries productivity. More fish were caught in areas of high percentage cover of large species, and these were nearly always accompanied by understoreys of small species.

Conclusion

The seagrass beds of the Montepuez Bay were found to be a highly diverse and productive assemblage of seagrasses and algae providing a structurally diverse habitat for seagrass fish and invertebrates. The beds were patchy in distribution and in terms of species of seagrass present. The total standing crop of the Montepuez Bay was similar to or higher than that found in other areas of the Indo-Pacific. The most unusual feature was the extent of seagrass beds dominated mainly by the species *Enhalus acoroides*. The fishing sites with the highest percentage cover and total biomass of *Enhalus acoroides* and the other large species of seagrass were also the most productive in terms of fish caught per unit effort and attracted the highest intensity of fishing. Thus, the species composition, cover and biomass of seagrasses may have had a strong influence on fish communities and thus on the local economy. The health and maintenance of seagrass beds in their productive and diverse state is therefore of great importance in any future management of the area from both an ecological and an economic point of view. Coastal areas of rural Mozambique may be on the verge of a period of social and industrial development that could rapidly change the way resources are used and greatly increase the pressures on the seagrass habitat. A number of studies have shown the connection between rapid growth of human population and large-scale changes in the

distribution and abundance of seagrass communities (Cambridge and McComb, Cambridge *et al.* 1986, Pulich and White 1991, in Fong *et al.* 1997). The majority of studies of large-scale loss or change of seagrass systems through anthropogenic impacts have been undertaken in Australia and the USA. Although the ecological and economic consequences in these places have undoubtedly been serious, they are unlikely to have had such a direct impact on human well-being as a serious loss of seagrass habitat would have in a poor tropical coastal area where many local people depend directly on seagrass-based resources to survive. The value of the seagrass beds of the Montepuez Bay in terms of ecological system functioning and their economic contribution to local people can not be overestimated.

Remote sensing techniques for seagrasses and other tropical marine habitats are improving and satellite imagery is becoming much more available and interpretable to ever-increasing levels of accuracy (Mumby *et al.* 1997 a, b), and is thus becoming an important tool in the rapid assessment, monitoring and broadscale management of nearshore coastal habitats. For future monitoring and management it is important that the seagrass resources of Northern Mozambique are studied on a much larger scale than that of the study presented here.

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CHAPTER 2

FISHING METHODS, EFFORT AND YIELDS OF AN ARTISANAL SEAGRASS FISHERY AT QUIRIMBA ISLAND, NORTHERN MOZAMBIQUE

ABSTRACT

A wide variety of fishing methods were used on Quirimba Island, but the most important of these in terms of catch sizes and people employed were the seagrass seine net and trap fishery. Nearly 400 people were employed in these fisheries on the island. They fished during daylight hours around low tide at all stages of the tidal cycle, with the exception of 2-5 days every fortnight when low tide fell outside daylight hours. Seine netting was done from sail-powered boats and the average catch per boat per trip was 75kg and CPUE was 3.6kg fish per man hour fished. Trap fishing was done from outrigger canoes, the mean catch per boat per trip was 6.7kg and the CPUE was 2.2kg fish per man hour spent fishing. CPUE for the net fishery was found to be higher around spring tides and lower around neap tides. Fishing effort in Quirimba was on the increase. Trap fishing gear was becoming increasingly available and net fishing effort was increasing with the numbers of itinerant fishers in the area. Over the 2 year study period CPUE appeared to have decreased slightly. The total annual catch for the Quirimban trap and net fishing fleet in the seagrass beds was estimated at 500 tonnes.

INTRODUCTION

Tropical Coastal Fisheries

Small scale nearshore fisheries using traditional methods are important throughout Africa and the rest of the tropics. These fisheries typically involve a range of fishing methods and target a large number of species of fish and invertebrates from a wide variety of families (Munro 1996). Coastal communities in the tropics are often heavily reliant on fish resources for income and food, with marine fish and invertebrates often forming the main source of protein (Ruddle 1996). Throughout the Indian Ocean region fishing effort has increased in recent times as coastal populations have grown and people have found that fishing is their only opportunity to feed their family and possibly earn a small wage.

Common fishing methods in the Western Indian Ocean

Throughout the East African coast, from Kenya to the south of Mozambique, and in the Comores and Madagascar, there are some striking similarities in artisanal fishing methods used. Woven hexagonal or "arrowhead" basket traps, known variously as *madema, malema* or *marema* down the East African coast, are a common fishing gear. Similar traps are also used in some freshwater systems in East Africa (A. Amade pers. comm.) and the design is used as far afield as the Caribbean (C. Roberts pers comm). Nets of various sorts have also been used in the region for a long time. Originally made from natural materials (for example elders in southern Kenya remember nets being made from the bark of a coastal tree, McClanahan *et al.* 1997), most nets are now made from monofilament and are usually produced commercially.

In many East African coastal communities there is clear division of labour between male and female fishers. Men predominantly fish from boats with nets, traps or lines, and women dominate fishing activities carried out on foot from shore: invertebrate collection and fishing in the shallows with fine nets and even sheets or sarongs (Mozambique and Tanzania: pers. obs, Comores: Dahalani 1997). The majority of nearshore fishing for finfish throughout the region is artisanal, with commercial effort concentrated on prawns and large pelagics (Ardill 1983, Richmond 1997).

Many nearshore fisheries are reef–associated and selected reef fisheries of the region have been the subject of intensive study, for example the reefs of Kenya (Nzioka 1990, Watson & Ormond 1994, Watson *et al.* 1997), Tulear in Madagascar (Harmelin-Vivien 1977, 1981), Seychelles (Jennings *et al.* 1995, 1996), Mafia Island and the Songo Songo Archipelago in Tanzania (Darwall 1996a, b). However, many isolated reef fisheries remain unstudied. In general, the reef fisheries studied have been shown to yield diverse and productive catches (reviewed in Dalzell 1996). There have been few studies of fisheries dependent on seagrass beds. There may be a number of reasons for this. In many areas seagrasses are sparse and patchy or are closely associated with reefs and so do not provide a discrete habitat for fishing. Secondly, seagrass-associated fisheries may be important but more often as a component of mixed seagrass and reef fisheries. Thirdly, seagrasses are not considered a glamorous habitat. They often have poor underwater visibility and their inhabitants are less

colourful than their photogenic coral reef counterparts. Seagrasses as an ecosystem have been neglected in the same way.

When the importance of seagrasses for tropical marine fisheries has been recognised, it is usually because of their role as a nursery area for juvenile reef fish. Seagrasses have rarely been acknowledged as an important habitat directly supporting fisheries. The importance of individual seagrass fisheries and their high productivity has been studied to some extent in the Philippines (Fortes 1990) and in Sri Lanka (Dayaratne *et al.* 1995a, b). Many relevant studies by fisheries institutes and universities may also remain inaccessible in the "grey literature" of reports and theses. In an extensive literature search only one paper (McManus 1993) could be found directly considering the management of small-scale seagrass fisheries in the tropics.

It is important that we broaden our base of knowledge on these fisheries so that we can assess how seagrass fish can be exploited at a sustainable level. We also need to be able to evaluate the ecosystem effects of fishing in seagrasses and the larger ecosystem effects of the exploitation of key linked ecosystems – coral reefs, seagrasses and mangroves. Attempts have been made to study these interlinkages (Ogden 1987, Parrish 1989), but this has to be done alongside more detailed studies of the ecology of each system within the whole large ecosystem. The value of seagrasses and the fisheries they support also needs to be acknowledged in the context of coastal development and pollution issues. Ignorance may lead decision makers to undervalue seagrasses leading to their loss and potentially far-reaching consequences. At the Second International Seagrass Workshop held in Australia in 1996 a Statement of Concern was adopted, expressing the anxieties of the seagrass research community about global seagrass habitat destruction and its consequences (Kuo *et al.* 1996). This statement acknowledged the importance of seagrass habitats for fisheries:

"The steady global loss [of seagrass habitats] results in the loss of important ecological functions and their value to human populations, including reduction in fisheries productivity, water quality, sediment stability, and coastal ecosystem biodiversity."

However, not one of the papers presented at this symposium addressed any aspect of seagrass fisheries or other seagrass resource use and just one paper was presented on seagrass fish ecology (Kuo *et al.* 1996).

In this study I will describe the main fishing methods used in the Quirimba Archipelago and examine levels of effort and catch for these main gears. I also estimate the yield of fish from the seagrass beds of the northern Montepuez Bay.

STUDY SITE

The study site was Quirimba Island and its surrounding waters. Quirimba Island is situated a few kilometres from mainland Mozambique, in the southern island group of the Quirimba Archipelago (see Fig. 1 in Chapter 1). On the east coast there are well-developed coral reefs extending to over 20 metres deep. The continental shelf drops off rapidly to over 200 metres within a few kilometres of the islands. The island has large areas of intertidal fossil coral flats, at some points extending to over 1km between high and low tide marks. The main distribution of marine habitats in the vicinity of Quirimba Island is shown in Fig. 2 in Chapter 1. The seagrass fishery focussed on the northern end of the Montepuez Bay, between Quirimba Island and the mainland coast of northern Mozambique, described in Chapter 1.

METHODS

General fishing survey

The majority of Quirimba Island's population of approximately 3000 live in Quirimba village on the north east coast of the island. However, there are small communities elsewhere, particularly in the Kumilamba area at the south of the island. In the initial general survey of fishing methods I made observations of all fishing activity going on around the island and sought evidence of fishing activity carried out at other times. Fishers were interviewed about the fishing methods they or their colleagues used and fishers were accompanied to obtain first hand experience of the methods used, the fish caught and the sites fished. I recorded the gear type, time spent fishing, habitat type fished and target species for these fishing methods, and used interviews, gear and boats counts and direct observation, to estimate the importance and intensity of each method. Some reference to invertebrate fisheries will be made in the results section but for more detailed biological aspects of the invertebrate fisheries of Quirimba Island see Barnes *et al.* 1998.

Detailed studies of the net and trap fisheries

The two main fisheries, the seagrass basket trap and seine net fisheries, were studied in more detail to quantify effort and catch. The landing site for the seagrass fishery in the Montepuez Bay was Quiwandala, a small mangrove area in the north west of the island. The majority of seine net fishing boats and a small proportion of trap fishers operated from this point.

Fleet size

The number of boats (canoes and sail boats) fishing each day and the time spent at sea were observed from a good vantage point at Santa Maria beach from which the main fishing sites could be seen. Days when there was no fishing, because of the tidal cycle or because of weather conditions, were also recorded. Boats were also counted on a regular basis as they left the landing sites and from other boats whilst on fishing trips.

Seine net fishery

I collected a large proportion of catch and effort information for the seine net fishery by accompanying fishermen on fishing trips. This method was chosen because of the difficulty of obtaining accurate information from the fishermen by interview or from shore-based observation. My initial interview approach proved unsuitable for the situation. Much of the information I wanted: time spent fishing, weight of catch and so on was quantitative and in many cases I was asking for values that the fishermen were not able to quantify. It quickly became apparent that the only way to collect accurate catch per unit effort (CPUE) data for this fishery would be by direct observation. It was possible to do this on a large scale because of the number of project participants available to assist with data collection. With the agreement and full co-operation of the fishermen I accompanied a random sample of boats on daily fishing trips for one week every month for seven months a year for two years. I aimed to complete 20 fishing observation trips per month.

I met the fishermen at the main landing beach, Quiwandala, two hours before the time given for low tide in Pemba in local tide tables. The information collected was filled in on forms which were printed on waterproof paper and taped to writing slates with pencils attached. The following information was recorded:

1. Time boat left fishing beach.
2. Time fishing commenced.
3. Times that nets went in and came out for each haul.
4. Time fishing ended.
5. Time boat returned to fishing beach.
6. Number of fishermen.
7. Length of net (usually an estimate).
8. Name of Captain.
9. Boat type.
10. Fishing site (local name and GPS if possible).
11. Estimate of total catch weight and catch weight per haul.
12. Number and type of boats in immediate vicinity and number of boats visible altogether.

Information on habitat type and catch composition were also collected and these methods and findings are outlined in Chapters 1 and 3 respectively.

Trap fishery

It was difficult to collect accurate quantitative information on the trap fisheries because it was not possible to accompany trap fishers in their small one-person canoes. I also encountered the same problems interviewing trap fishers as I had with net fishers. The method eventually used was a combination of direct observation and a very basic interview. Time spent fishing was estimated by observing when canoes left the shore and when they returned. Catches were weighed on return to shore. Effort in terms of number of traps set could be easily determined through brief interview, and once the details of a particular trap fisherman were known they could be used reliably on future occasions.

Later in the research programme I was able to accompany a trap fishermen with a larger boat on fishing trips on a regular basis. This provided a valuable insight into the methods and routines of trap fishing that would otherwise not have been possible by interview alone. Quantitative data on trap catches, effort and other information were collected from over twenty of these trips.

RESULTS

Fishing methods used in Quirimba

The fishing methods used in the Quirimba Archipelago were very similar to those found throughout the East African coast, and similar also to the relatively nearby islands of the Comores and the west coast of Madagascar (Dahalani pers. comm. and 1997, Vasseur 1995). The main difference between the artisanal fishing fleets of the Quirimbas and others in the region was that none of the Quirimban fishing boats had engines. Elsewhere, such as in the Comores (Stobbs & Bruton 1991) or in Tanzania, outboard engines on traditional fishing vessels are becoming ubiquitous. The lack of engines in the north of Mozambique was a consequence of the economic situation in the area and its isolation. To buy a new outboard engine in Pemba it had to be ordered from South Africa and shipped over 3000km which was extremely expensive. This lack of engine power had a strong influence on the fishing methods used in the Quirimbas and on the areas open to fishers.

The main fishing methods were as follows:

1. Seine net fishing from small sailed powered *mashuas*

This was practised by over 300 people on Quirimba with a fleet of approximately 30 boats. Nets were generally about 100m long with 4cm stretch mesh and a 5m cod-end of 2cm to less than 1mm mesh. They were deployed by fishermen in water of 1-8m, and commonly in water of less than 2m which the fishermen entered on foot to position and haul the net. The net was secured at one end on the boat and at the other end in the water and the boat was then moved around in a circle by poling to close the net. The net was hauled by hand into the boat. This method did not have specific target species but over 250 species of fish were caught (see Chapter 3). The nets were deployed preferentially in areas of the large strap-like seagrass *Enhalus acoroides*. Areas of large hard corals were not fished to avoid the risk of damage to the nets. Areas of seagrass in the vicinity of these coral areas were not popular fishing sites despite giving catches of much larger fish (Chapter 3). Fishing activity took place around low tide when the seagrass areas were shallowest and when the currents were weakest.

Seine net fishing was always undertaken during the day and followed a rigid tidal cycle that avoided fishing outside daylight hours. Fishing boats left the landing site two hours before low tide and returned two to three hours after low tide. The two week fishing cycle started when two hours before low tide was just after sun rise and ceased when the sun sets within two or three hours of low tide. In this cycle 9 or 10 days could be fished per fortnight and commonly boats fished 8 days per 14 day tidal cycle.

2. Trap (*marema*) fishing from outrigger canoes

Trap fishing involved between 50 and 70 people with a fleet of more than 40 boats, consisting of two to three metre long canoes with two outriggers. The traps used were made from woven bamboo strips forming a mesh size of approximately 4cm. The entrance hole was 7cm in diameter. Traps were set in areas of *Enhalus acoroides* at low tide on one day and were emptied the following day: a soak time of 24 hours. Some fishermen baited their traps with crushed *Terebralia* snails collected around the mangrove areas, or with pieces of squid, but many fishermen did not use bait. Trap fishermen set and hauled an average of 40 traps, for approximately two hours either side of low tide. Although they followed a similar fishing pattern to the net fishermen they fished more days, usually missing just 2 days per 14 day tidal cycle.

Traps were placed in lines of ten with a marker such as a tree branch at one end of the line so that once the first trap was found the rest could be easily located. There was approximately 5m between traps. The traps were weighted with rocks to keep them from moving. Part of the importance of placing traps in the long, dense *E. acoroides* was that the seagrass prevented the traps from moving with the strong tidal currents. In experiments, traps placed in sandy areas or areas of short seagrasses such as *Cymodocea* spp. or *Syringodium* sp. were often difficult to find because, even when well weighted, they moved with tidal currents and were sometimes lost completely (Chapter 5).

3. Gill netting on the exposed reef flat

This was a minor fishing method used by only two groups of fishermen on Quirimba. Short nylon monofilament gill nets with 6cm stretch mesh were deployed by groups of three fishermen: two to hold the net and a third to encourage the fish to enter by beating the water. The nets were approximately 20m in length. This fishing method targeted

large adults of schooling reef flat and lagoon species such as the gerrids, *Gerres oyena* and *G. acinaces*, the snapper *Lutjanus gibbus* and the rabbitfish *Siganus sutor*, though small numbers of other reef or sand-associated fish were occasionally captured. This method was carried out intermittently at low tide on the exposed reef flat on the east coast of Quirimba and between Quirimba and Sencar.

4. Fence traps

A small number (no more than four at any one time) of traditional *luwando* fence traps or fish corrals were maintained around the coast of Quirimba. These were funnel-shaped arrangements of fencing that catch fish as the tide falls and leaves fish stranded. Long rolls of fence were constructed in the village by lashing slender tree saplings together. This roll of fence was then carried to the shore and secured in place. *Luwandos* were very labour intensive to build, and were usually built by old men who had the time for such a project. Once the traps were up and running the effort involved was minimal – one member of the family who owned the trap would go twice a day and collect any fish that had been trapped as the tide falls. The main effort involved with fence traps was their maintenance. Catches were highly variable. Night time catches were usually higher, but catches varied from a couple of squid and a pufferfish, to large schools of snapper (Lutjanidae) or jacks (Carangidae). Fence trapping was one of the few fishing methods on the island to be subject to traditional management. There were a limited number of sites where *luwandos* were traditionally set and each of these sites belonged to a particular family. The family with rights to fish a *luwando* site paid for the materials and construction of the trap. By tradition, the people who built the trap were entitled to the first catch taken.

5. *Suri* trapping

Suri traps look very similar to maremas and were made to the same design and from the same material but are smaller. Despite these similarities they were deployed in a very different way. *Suris* were always baited, usually with squid or octopus. They were secured at the end of a piece of rope, weighted and lowered into water a few metres deep. The end of the rope was marked with a buoy of some sort and a few of these traps would be deployed at one time. They were left for half an hour to an hour and caught almost exclusively juvenile *Lethrinus variegatus* (Lethrinidae). The entrance hole was 6cm in diameter and the mesh 4cm. The same method is used in the Caribbean

and is called "tombée et levée" (drop and lift) (C Roberts pers. comm.). *Suri* trapping was probably the most time consuming fishery.

6. Big *marema*

Large versions of *marema*, approximately twice as big (up to 1.5m wide), were set in sand in areas of strong current or in the vicinity of reefs and targeted large reef fish such as snappers (Lutjanidae), adult emperors (Lethrinidae) and groupers (Serranidae). The same sort of trap was also used by fishermen without boats who set them in pools at low tide and collected them the next day or, with baited ones, sometimes the same day.

Results of Detailed Studies

Table 1 shows the key findings in terms of fishing patterns, catch, effort and CPUE.

Net fishing

In total 187 fishing trips were completed with net fishermen over the two year study period, with a mean of 16 trips per month. There were approximately 30 sail powered fishing boats in regular operation from Quirimba. On an ordinary fishing day with favourable tides at least 15 boats operated from Quiwandala. The same fishing area was also used to some extent by another 15 boats from Quissanga which used identical methods and gears. Although Quissanga boats fished primarily in the western sector of the Montepuez Bay there was always some overlap in fishing grounds, with boats from Quirimba sometimes fishing as far west as the Quissanga-Ibo mangroves and boats from Quissanga fishing in the main Quirimban fishing grounds such as Balanzi. The main fishing grounds for Quirimba Island, Quissanga village and Quilaluia Island are shown in Fig. 3 in Chapter 1. Certain sites were used very intensively by large numbers of boats in close proximity, and many areas, particularly Balanzi and Lusino, were used intensively by trap fishermen too. During fishing, 57% of boats were observed to have a trap fisherman fishing within a radius of approximately 50m and 46% had another net fishing boat within 50m. 18% of all boats had 3 or more other boats or canoes fishing within 50m.

Mesh sizes were generally very small and some fishers used flour sacks sewn together as cod-ends, so in some cases even larvae were vulnerable to capture. All boats used cod-ends with a mesh of 2cm stretch or less which captured fish from 5cm upwards. The majority of fish were less than 15cm in length and mainly juveniles (see Chapter 3).

Fishing aspect	Trap fishery	Net fishery
Days fished per tidal cycle	11-12	8-10
Number of fishermen	1	8
Boat type	Outrigger canoe	Sailing dhow
Gear type	40 woven bamboo traps	Nylon seine net – 100m
Mesh size	4cm diameter holes	4cm stretch main net 2cm to < 1mm cod-end
Time spent at sea	4 hours and 11 minutes	4 hours and 48 minutes
Time spent fishing	3 hours	2 hours and 42 minutes
Catch per trip	6.7kg	75kg
Catch per man hour at sea	1.7 kg	2kg
Catch per man hour fishing	2.2 kg	3.6 kg
Number of boats in fleet	40	30
Number of fishermen	50	>300
Estimate of catch per year	60 tonnes	438 tonnes

Table 1: A summary of the key effort and catch details for the trap and net fisheries. Note that the figures shown are averages.

Fishing boats and nets were generally owned by a businessman in the village who either paid a wage to a captain and crew to fish their gear or paid the crew a reduced price for the catch. Their crew also had various entitlements to a small share of the catch. The fishermen were generally very young, many were teenagers or in their early twenties. Very few fishermen had a background of fishing and many were refugees from inland areas. Very few of the ordinary fishermen had been involved in fishing for longer than five years. The boat captains were generally older, often in their thirties or forties and were more likely to have been involved in the fishery for more than five years (see Chapter 6).

Fishing effort was concentrated almost exclusively in heavily vegetated seagrass areas. (the habitat composition of the main fishing sites are outlined in Chapter 1). Sites containing *Enhalus acoroides* were preferred to those containing smaller seagrass species, or hard corals that might snag the nets. Areas of seagrass close to the mangrove areas in the north were fished but the mangroves themselves were not.

About five boats operated from Kumilamba at the southern tip of the island. These were owned and crewed by residents of the houses in the *machambas* (agricultural land or allotments) of the Kumilamba area. On a seasonal basis there were also three or four boats that operated from South Santa Maria. These boats were owned and crewed by people from the village of Mahate on the nearby mainland. Again, the gears and methods used were identical to those used by Quirimba fishermen, although the Mahate fishermen often used two boats working together with two nets tied together, a method used occasionally by Quiwandala fishermen.

One additional source of fishing pressure in the seagrass beds which was difficult to quantify was boats from outside the Archipelago. During the first study year small camps were set up on Quirimba by itinerant fishermen. These fishermen were usually from Nampula, the next province south, but there was at least one small group from Tanzania fishing mainly for sea cucumbers. During the second year of the study a large camp of about 50 fishermen from Nampula was established in front of Quirimba village. They operated a number of boats concentrating on gill-netting on the reef flat. However, they did fish in the seagrass beds, particularly those in the vicinity of the village, and increasingly from Quiwandala.

Effort, catch and yield

The mean catch per unit effort of the net fishery was 2kg man hr^{-1} (±0.08 SE) when effort was calculated as man hours at sea (time from boat leaving the shore until its return), or 3.6 kg man hr^{-1} (±0.1 SE) when effort was calculated in man hours actually fishing (from when net first goes in until final haul is brought in). The mean total catch per fishing trip was 75kg (±2.7 SE) and catches ranged from 15 kg to 188kg per trip. The mean time spent fishing was 2 hours and 40 minutes (±0.04 hours SE), and the mean time spent at sea was 4hrs and 47 minutes (±0.05 hours SE). The mean number of fishermen per boat was 8 (±0.2 SE), but ranged from 4 to 20.

Mean catches per trip remained around 75 kg throughout the study period, although in the last four months of study, August to November 1997, there was an apparent decrease in both fishing effort and catch per unit effort, the mean catch for November 1997 being just 53kg per trip (see Fig. 1). A summary of monthly catch and effort data is shown in Table 2. There were no obvious monthly or other seasonal patterns in the net fishing catch, effort or CPUE, although we do not have data for the majority of the wet season which is when one would expect the dramatic change in weather conditions and other environmental variables to influence fishery effort and catch.

There was a definite correlation between tidal height and catch (in terms of total catch and CPUE). Fig. 2 shows the tidal amplitude over a 14 day lunar cycle and the corresponding mean CPUE for these tidal amplitudes. There was a very clear relationship between the size of the low tide and the CPUE. For 8 days around the lowest tides the CPUE were relatively high at around 4 kg per man hour fished. Towards the higher low tides CPUE were lower, around 2 kg per man hour fished. This tendency for lower catches and CPUE around neap tides was reflected in the fishing pattern of the net fishing fleet. On the two days either side of the rest days when it would be possible to leave and return from a fishing trip within the hours of daylight, approximately half of the net fishing boats did not go out. These were the days in the tidal cycle with some of the highest low tides and the lowest CPUE.

Values for CPUE varied considerably between fishing sites (see Fig. 3 and data summarised in Table 3). Makome, Pantopi, Lusino, Quiutu and Momade Assane all had a mean CPUE per trip of less than 3 kg man $hour^{-1}$. Quiwandala, Kasuco and Mecute all

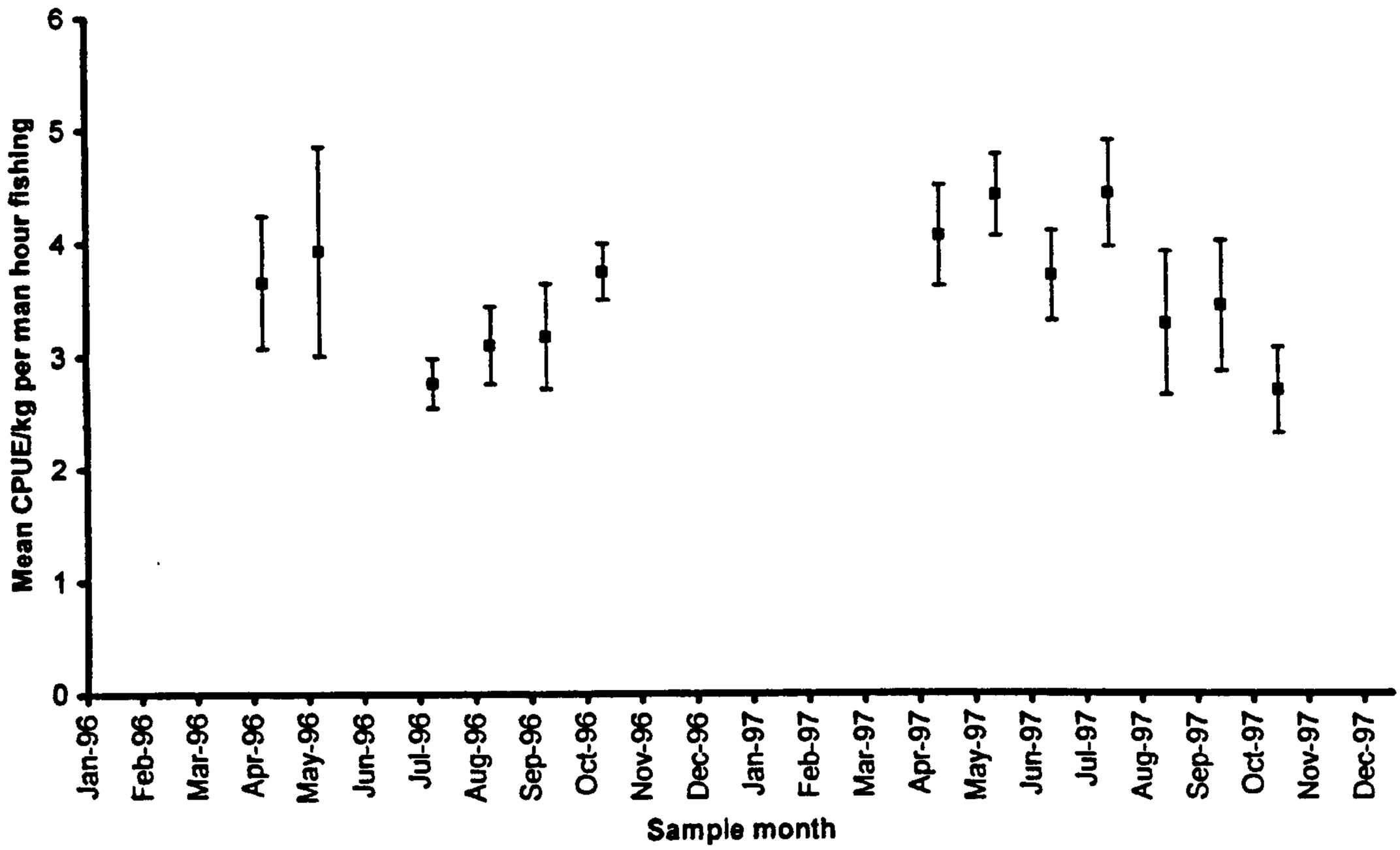

Figure 1: Mean values for catch per unit effort in kg of fish per man hour spent fishing for each of the thirteen study months. Error bars show ±1 SE.

Table 2: A summary of the catch and effort data for net fishing trips for the 13 study months, showing the sample size for each month (N) and ± SE.

Month	N	CPUE kg/ man hr fished	SE	CPUE/kg man hr at sea	SE	Effort/ man hrs	SE	Catch/trip kg	SE	No. hauls /trip	SE	No. fishers	SE
May-96	6	3.7	0.6	2.3	0.4	38.3	2.9	86.7	12.9	4.7	0.3	8.4	0.4
Jun-96	7	3.9	0.9	2.3	0.4	37.9	2.1	79.1	12.4	4	0.3	8.4	0.5
Aug-96	15	2.8	0.2	1.4	0.1	47.9	3.5	67.6	4.7	3.1	0.2	9.6	0.6
Sep-96	10	3.1	0.3	1.9	0.3	45.3	4.7	82.1	10.1	3.5	0.5	10.9	1.2
Oct-96	10	3.2	0.5	1.7	0.3	38.4	2.1	68.3	11.7	2.9	0.3	8.3	0.3
Nov-96	21	3.8	0.2	2.1	0.2	37.3	1.9	78.3	7.6	3.6	0.2	7.6	0.3
96 Mean	69	3.4	0.2	2	0.1	40.6	1.2	76.2	3.8	3.5	0.1	8.7	0.2
May-97	21	4.1	0.4	2.3	0.2	40.6	2.8	86.6	7.2	4.1	0.4	8.3	0.5
Jun-97	9	4.4	0.4	2.6	0.3	41.7	3.9	103.8	9.8	4.2	0.4	8.2	0.6
Jul-97	18	3.7	0.4	2.1	0.2	37.5	2.7	76.8	8.2	3.9	0.3	7.8	0.4
Aug-97	26	4.4	0.5	2.4	0.3	34.8	2.6	78.5	8.5	4	0.2	7.2	0.5
Sep-97	18	3.3	0.6	1.5	0.3	53.1	7.9	73.8	14.2	3	0.4	11	1.7
Oct-97	12	3.5	0.6	2	0.5	34.9	3.2	60.1	9.9	4.4	0.3	6.8	0.5
Nov-97	24	2.7	0.4	1.4	0.2	36.7	2.5	53.5	8.5	3.6	0.2	7.8	0.4
97 Mean	116	3.7	0.2	2.1	0.2	38.2	1.2	74.3	3.7	3.9	0.1	7.9	0.2
96/97 Mean	185	3.6	0.1	2	0.1	39.2	0.9	75.2	2.6	3.8	0.1	8.2	0.2

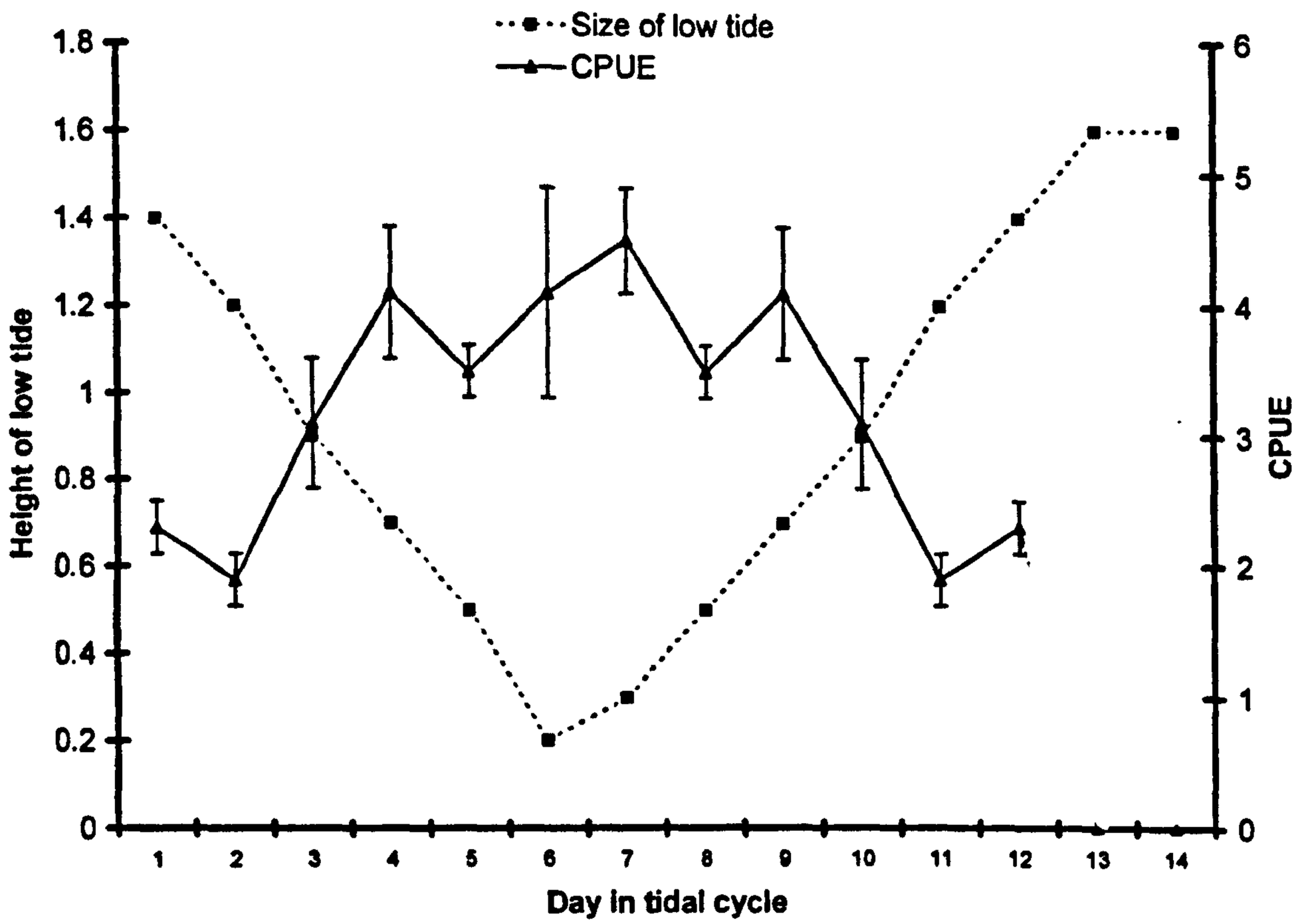

Fig. 2: Height of low tides and mean CPUE for net fishing trips. Error bars show ±1 SE for mean values of CPUE.

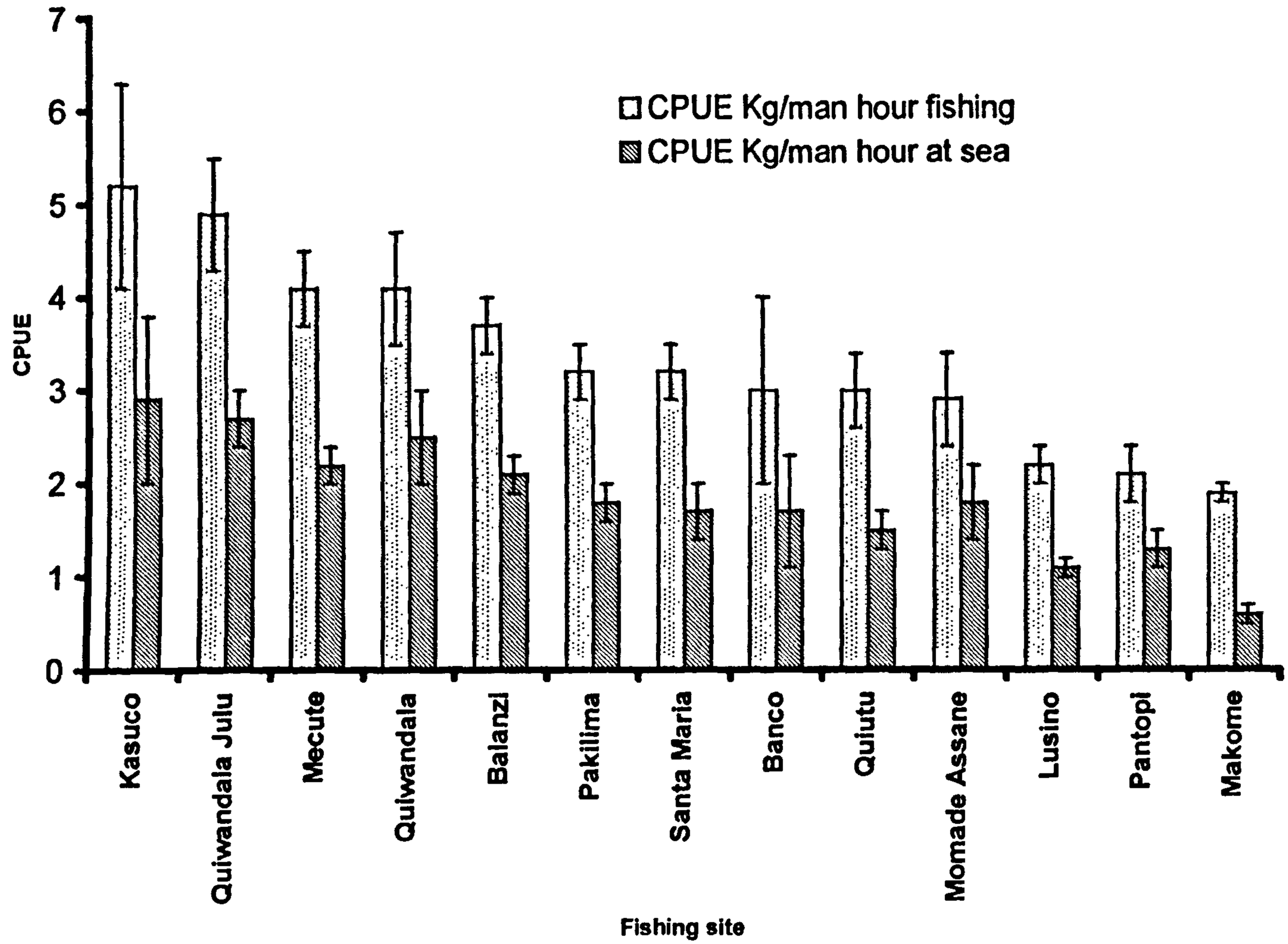

Fig. 3: Histogram of the means of the two types of catch per unit effort for each main net fishing site. Error bars show ±1 SE.

Table 3: Summary of the mean net catches per trip and two types of catch per unit effort (catch per man hour at sea and catch per man hour spent fishing) for the main fishing sites.

Site	Mean catch kg	SE	Mean CPUE kg/man hr at sea	SE	Mean CPUE kg/man hr fishing	SE	N
Kumilamba	65	13	1.1	0.1	2.1	0.2	3
Pantopi	38	2	1.3	0.2	2.1	0.3	4
Lusino	35	5	1.1	0.1	2.2	0.2	10
Kiutu	68	9	1.5	0.2	2.9	0.4	5
Momade Assane	64	9	1.8	0.4	2.9	0.5	5
Banco	55	13	1.7	0.6	3	1	2
Pakilima	89	11	1.8	0.2	3.3	0.3	13
Santa Maria	72	8	1.7	0.3	3.3	0.4	12
Balanzi	83	6	2.1	0.2	3.7	0.3	34
Quiwandala	70	9	2.5	0.5	4.1	0.6	11
Mecute	90	9	2.2	0.2	4.2	0.4	25
Quiwandala Julu	101	20	2.7	0.3	4.9	0.6	4
Kasuco	74	14	2.9	0.9	5.2	1.1	8

had significantly higher CPUEs, all over 4 kg man hour^{-1}. (see Chapter 1). The mean number of net hauls per trip was 4 and as the number of the haul increased, the duration of the haul (i.e. the soak time of the net) and the mean catch per haul decreased (Fig. 4).

It was observed qualitatively that fishing boats with large crews seemed to be less efficient than those with a smaller crew. This was confirmed quantitatively by CPUE data showing that when an optimum number of fishermen, ten, was exceeded, the CPUE declined (Fig. 5). The most efficient number of crew in terms of high CPUE and consequently higher economic gain would be 4. All crew numbers from 5 to ten have a similar CPUE, then with eleven crew or more the mean CPUE becomes consistently lower. Similarly, total catch per trip increased with increasing crew size up to ten fishermen and a mean catch of 100kg, after which the total catch actually began to decline (Fig. 6). As hauling the large net repeatedly would be exhausting for 4 people, the benefit of fishing with this number may not be worth the relatively small economic gain. For the crews of 5 to 10 fishermen, if the catch per unit effort is going to be similar whether they have 5 or 10 crew its obviously better to have ten crew as fishing would be easier. The most common number of fishermen is eight which probably allows efficient hauling of nets with minimal crowding.

Nets and boats were poorly maintained. Large holes in the net allowed a large proportion of the potential catch to escape (observed by snorkelling around the nets during hauls), and large amounts of fishing time were invested in temporary repairs of nets and ropes, and bailing leaking boats.

Trap fishing

Trap fishing from Quirimba did not take place from a few major landing sites but from many individual sites all the way round the coast from the Quiwandala mangroves to Kumilamba. About 40 canoes were in regular use around the coast, almost all of them owner-operated. There did not seem to be any non-Quirimban canoes fishing the Montepuez bay from Quirimba; visiting fishermen did not use canoes for fishing.

I was only able to assess directly a relatively small number of trap fishing trips the majority of observations were qualitative. It is not possible to make any observations on the CPUE of the trap fishery over time as sufficient data are not available. One change

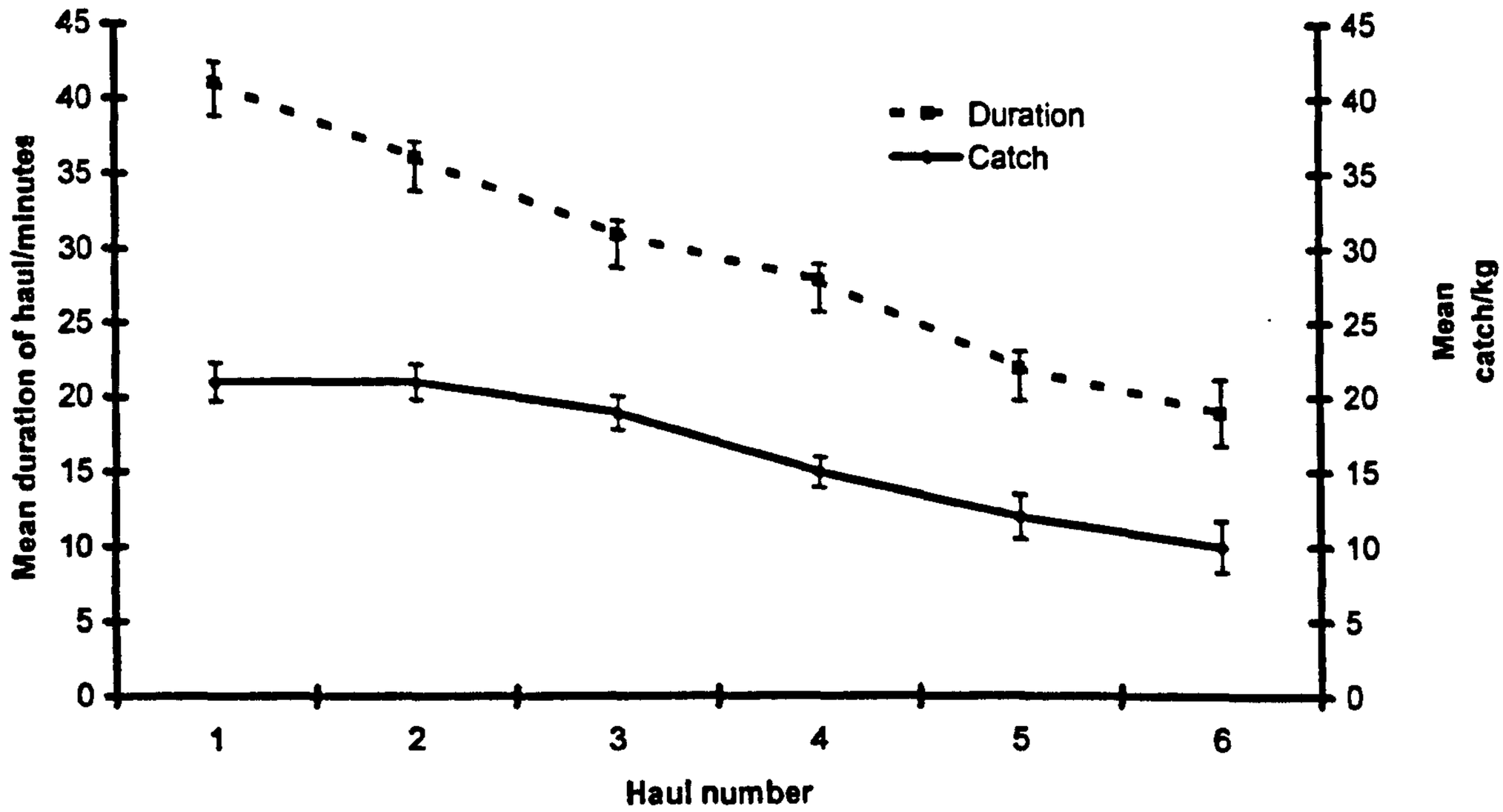

Fig. 4: The mean duration and mean catch of the first to sixth hauls on net fishing trips, with error bars showing ± 1 SE.

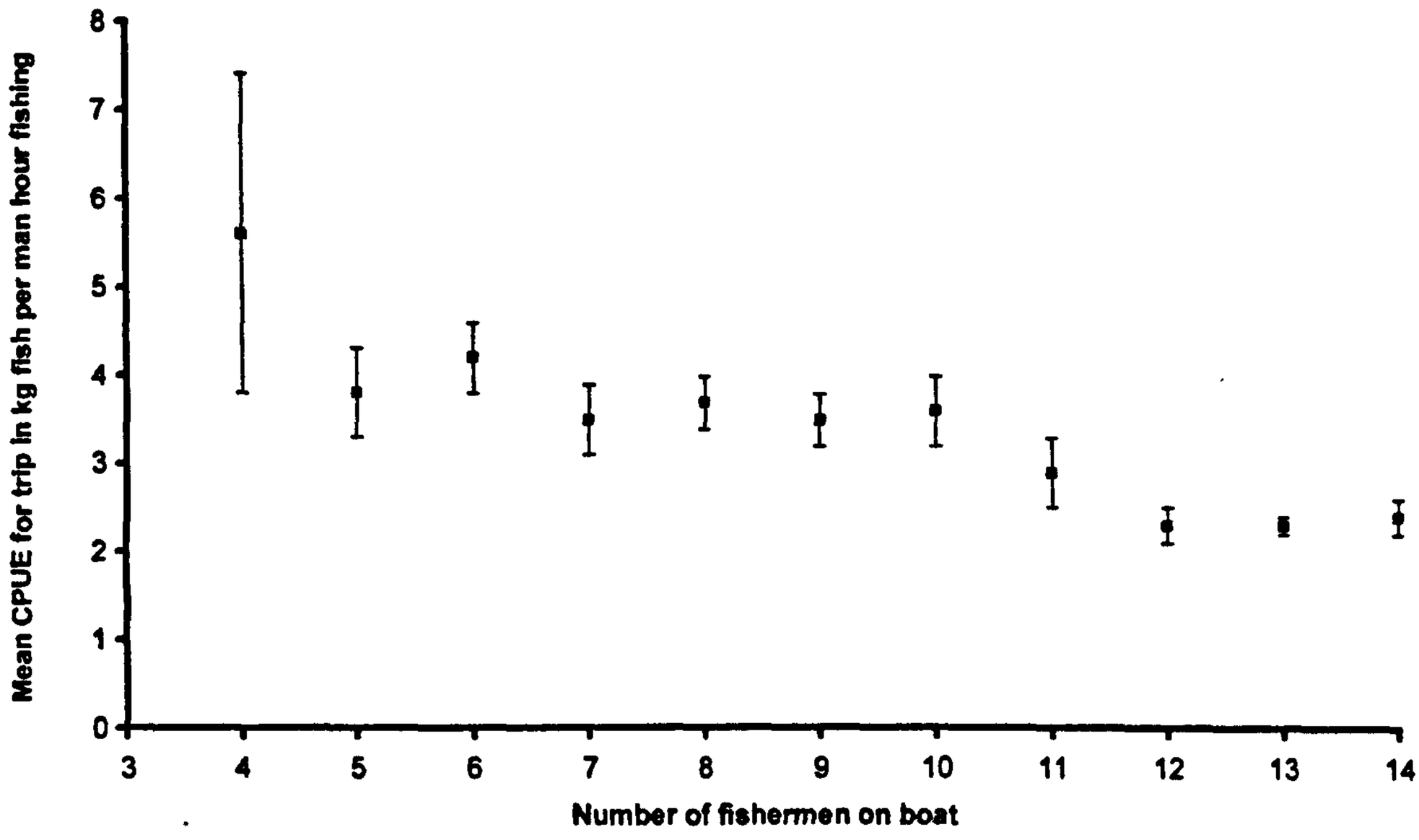

Fig. 5: Mean catch per unit effort in kg per man hour fishing for the range of numbers of fishermen per boat. Error bars show ± 1 SE.

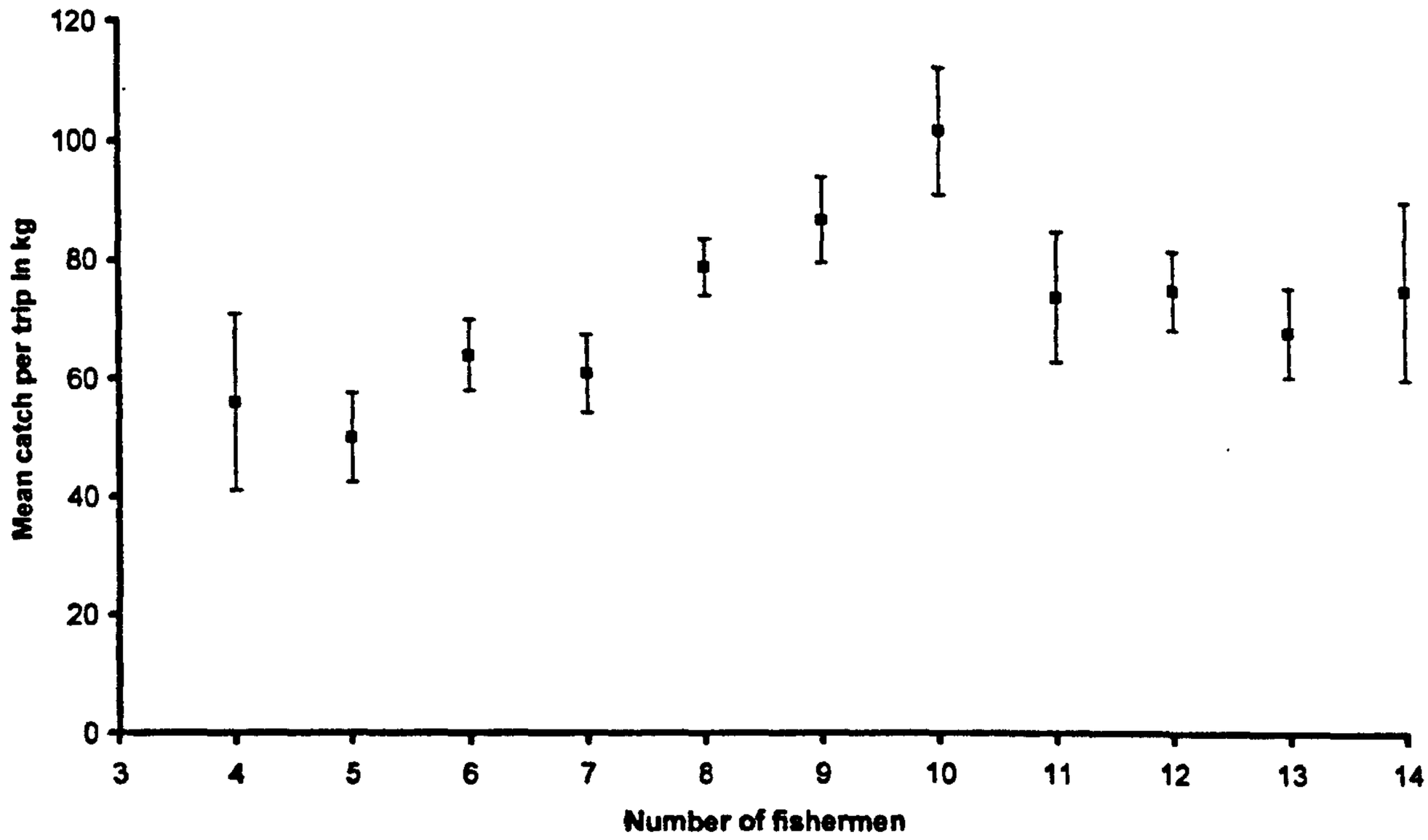

Fig 6: Mean catch per trip in kg for the range of numbers of fishermen per boat. Error bars show ±1 SE.

in the fishery that I was able to identify over the two year study period was an increase in trap fishing effort by local fishers. When the study first began, traps were bought in inland villages and from Pemba, which was a time-consuming and expensive journey only made occasionally. Towards the end of the study period it became possible to buy the traps (they are sold in "flat-pack form" for home assembly) in Quissanga, the mainland village directly opposite Quirimba Island, and more recently in Quirimba village market.

Trap fishing was almost invariably carried out by solitary fishermen. Trap catches were very variable, from just 1kg of fish per trip to more than 17 kg. Most trap fishermen fished around 40 traps which allowed efficient emptying and setting of traps in the time allowed by the tidal cycle. The mean catch per trip for forty traps was 6.7kg. The mesh size of the traps was a uniform 4cm. The entrance hole to the trap was approximately 8cm in diameter. Mean duration of fishing trip was 4 hours and 11 minutes. Catch per man hour spent at sea was 1.7kg and per man hour spent actively fishing was 2.2 kg. Mean catch per trap haul was 195g (ranging from 0g to 2286g in one trap). Over 30% of the 761 traps hauled in trap fishing observations were empty, 24% of traps contained between 1 and 100g of fish and only 3% of traps had more than 500g of fish. The mean number of fish per trap was three. 17% of traps contained one fish and twenty percent of traps had more than five fish (see Fig. 7). The highest number of fish found in one trap was 23.

Yield for seagrass fisheries (trap and net)

On the basis of the mean catches and effort for the two main fishing methods, the total annual yield of fish for the whole of the Montepuez Bay seagrass area was estimated as approximately 500 tonnes of fish per year, or 14.3 tonnes $km^{-2}year^{-1}$. This was based on an estimated regular fleet size of 40 net fishing boats catching an average of 75kg per day for between five and ten days per cycle. This gives a total annual net fishing catch of 438 750kg. If an average of thirty canoes go out for 11 days per cycle and catch an average of 7kg the mean annual trap fishing catch can be estimated as 60 270kg. The area of the Montepuez Bay seagrass meadow was estimated at $35km^2$. It is estimated that every square kilometre of seagrass in the northern Montepuez Bay is trawled 73 times per year.

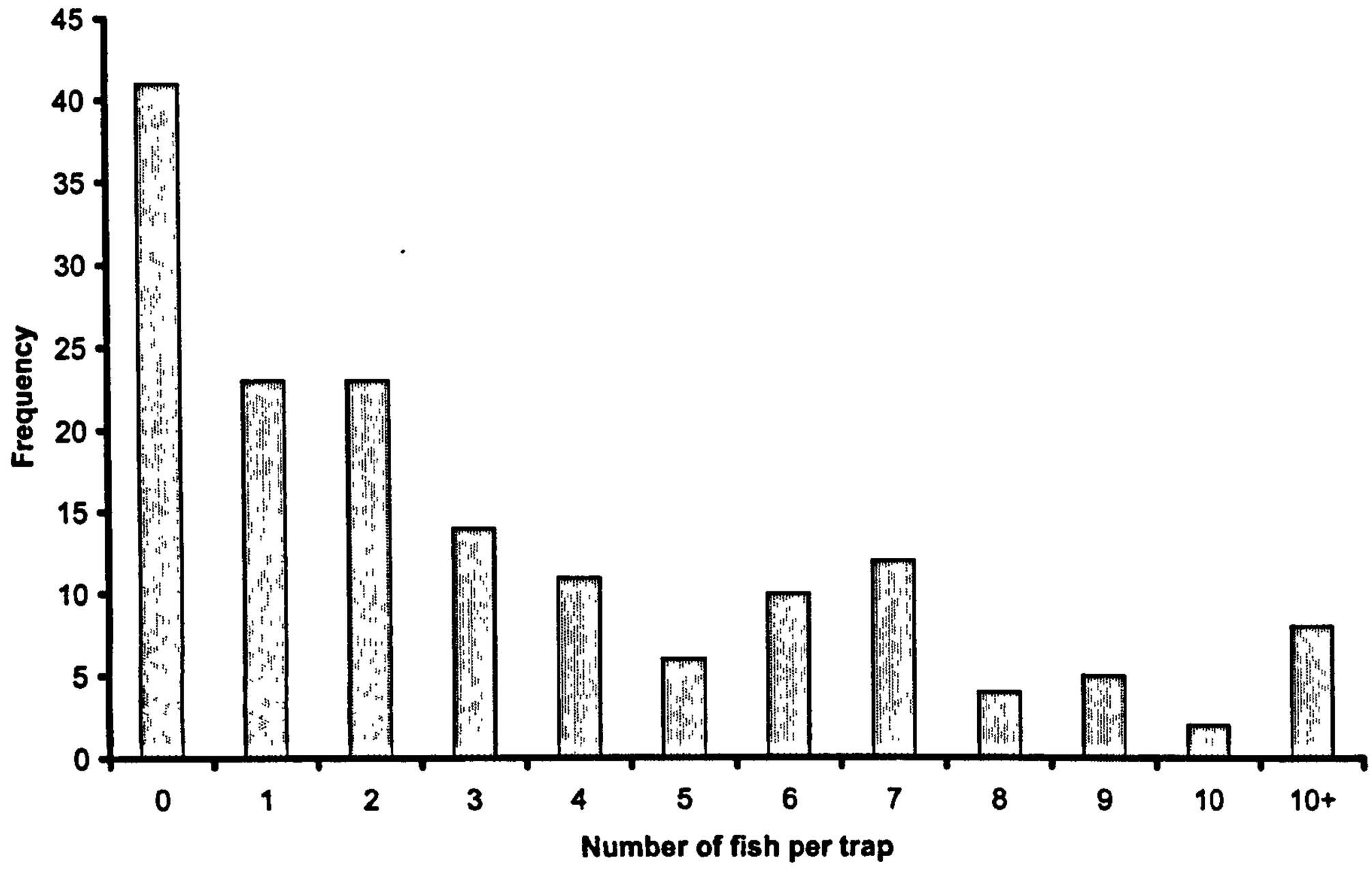

Fig 7: The frequency of traps containing numbers of fish between 1 and 10.

DISCUSSION

The method used for CPUE data collection is very important in the assessment of the status of fisheries. In this study I was fortunate to have sufficient observers to carry out a programme of direct observation on boats. This is rarely possible when fisheries researchers have limited financial resources and personnel. Regular fishing trips allow researchers to see for themselves the fishing methods in action, the problems encountered by fishers, the habitat types targeted and the intensity of fishing methods. Bycatch and habitat damage can be directly observed. Many questions which people find difficult to answer are answered much more easily by direct observation. It is also much easier to design research programmes, interviews and questionnaires when you have been out fishing and identified the key points to investigate. In addition to accompanying fishers on trips as an observer, it was an invaluable learning experience to actually participate in fishing, gaining first hand experience of the process.

A boat-based observation technique, from which the methods in this study were adapted, has been used for a number of years by Frontier-Tanzania, on reef fisheries on Mafia Island and the Songo Songo Archipelago in Tanzania (Darwall 1996 a, b) and is suited to rural areas where fisheries officers have not been very active and where fishermen are not wary of government regulation or interference in the fishery. Fishermen in Maputo (the Mozambican capital) were reported to refuse entry of fisheries researchers onto their vessels (R. Abdulla, pers. comm.).

Fishing methods in Quirimba

The fishing methods of Quirimba were fairly typical of the region. The main difference between the fisheries of Quirimba and others in the region was the lack of reef-based fishing effort, in a large part because of the lack of outboard engines on boats. Line fishing was also used a lot less than was common in other areas (Loureiro 1998, Darwall 1996 a, b). The main fishing methods seemed to be divided between the traditional, mainly trap fishing done by older men and the more modern methods such as seine netting carried out by the younger men (see Chapter 6).

Formal fisheries management is currently virtually non-existent on Quirimba. Fisheries Officers worked on Ibo, the next island north but very little regulation or enforcement of

regulations seemed to take place throughout the rest of the Archipelago during the study period. Before independence the Portuguese administration were very active in the area enforcing mesh size regulations with radical measures such as burning nets found not to comply with legal requirements. Despite this lack of formal control, the fisheries of Quirimba seemed to operate within reasonable limits and with some self-management. Although the fishery is intensive, destructive practices such as dynamite fishing, which was until recently such a serious problem just over the border in Tanzania, are not used. In other areas, such as the Philippines blast fishing has been found to be a major threat to seagrass beds (Fortes 1990).

Catches and yields

Compared to other tropical coastal fisheries studies the CPUE for the Quirimba seagrass fisheries is relatively high (Dalzell 1996). Tables 4 and 5 show some CPUE statistics for tropical net and trap coastal fisheries around the world. The mean catch per trap of 195g of fish was much higher than the value given for traps placed in mixed seagrass and reef sites at Cape Bolinao in the Philippines (Acosta and Recksiek 1989). They found the mean catch per trap to be 129 g trap haul^{-1}. Their mean number of fish per trap varied from 2.7 to 5.2, generally higher than the mean number of three fish in this fishery, indicating smaller fishes. However the majority of other trap fisheries studied had much longer soak times, and consequently a higher catch weight per trap. If catch per day of soak time is calculated the Quirimbas' values appear quite high.

The mean CPUE values of 2kg of fish per man hour at sea or 3.6 kg of fish per man hour fishing were relatively high for a seine net fishery. In a review of CPUE for various fishing methods Dalzell (1996) gave values ranging from 0.25 kg man hr^{-1} for a reef and lagoon fishery in Guam (Katnik 1982, Amesbury *et al.* 1986) to a high of 4.95 kg man hr^{-1} in Port Moresby, Papua New Guinea (Lock 1986) (see Table 4). It is very difficult to compare values of CPUE for different fisheries because of the different variables and methods of measurement. One of the problems with measuring CPUE in Quirimba in terms of kilos of fish caught in man hours was that the level of intensity of fishing within those "man hours" was very variable. One of the striking things when one accompanied Quirimban net fishermen on a fishing trip was the low level of fishing intensity and the relaxed attitude to the size of the catch.

Country	Location	Net type	Net length	Mesh/cm	Target stock	Catch per trip/kg	No. fishers	CPUE	Yield kg/km2/yr	Source
Tanzania	Mafia Island	Seine net	100-1000	3 to 6	Reef fish	99	10	3.3	5.2	Darwall 1996
	Songo Songo Archipelago	Seine net			Reef fish				3	Darwall 1996(2)
Papua New Guinea	Port Moresby	Seine net		5-12.7	Reef and lagoon			2.5		Lock 1986
	Tigak Island	Seine net	100	6.3-7.5	Reef and lagoon			3.9		Wright & Richards 1985
Guam		Seine net	140-280		Reef and lagoon			0.25		Katnik 1982, Amesbury 1986
Madagascar		Seine net				17				
Seychelles		Seine net				89				
Mauritius		Seine net				15				
Kenya		Seine net				33				
South Africa	West Coast	Beach seine				294				Lamberth et al 1997
	Southern Cape coast	Beach seine				393				
	Eastern Cape coast	Beach seine				199				
	Kwazulu Natal Coast	Beach seine								
Madagascar	Tulear	Seine net				31.9				Laroche & Ramanarivo
Seychelles		Seine net				205				Sanders et al 1988
Mauritius		Seine net				33				Sanders et al 1988
Kenya		Seine net				108				Sanders et al 1988

Table 4: A summary of seine net catches and CPUE for a variety of coastal fisheries from the literature.

Country	Location	Trap design	Depth/m	Target stock	Mean catch per trap /kg	Mean soak time/days	Source
Papua New Guinea	Tigak Island	Arrowhead	5 to 20	Shallow reef	2.3	5	Dalzell & Alni 1992
Maldives		Arrowhead	1 to 60	Shallow reef	1.9	5	Van de Knaap et al 1991
Philippines	Bolinao	Rectangular	1 to 5	Shallow reef	0.13	1	Acosta & Recksiek 1989
Philippines	Bolinao			Reef flat/seagrass	0.14	1	Campos et al 1994
Seychelles		Arrowhead	10 to 40	Shallow reef	4.6	2	de Moussac 1987
Kenya/Tanzania		Arrowhead	<30	Shallow reef	33.3	2	de Moussac 1987
Jamaica	Offshore	Dollar & hexagonal	15 to 30	Shallow reef	21	2	Munro 1983
Jamaica				Reef flat/seagrass	1.1		Koslow et al 1994
Tanzania	Songo Songo	Arrowhead	2 to 8	Shallow reef	0.85	1	Darwall 1997

Table 5: A summary of catches from tropical trap fisheries from the literature.

From April 1997 to November 1997 mean CPUE fell by nearly a third and mean catch per trip by nearly 25% (see Fig 1). This decrease could be an indication of a decline in fish stocks but it could also be a seasonal pattern or may be associated with weather patterns. The decline could also be a consequence of fluctuations in the recruitment of key fish species. It is impossible to say which of these possibilities is the most likely without year round data for more than two years. Also, when the decline in 1997 is looked at in the context of the fluctuations in CPUE over 1996-1997, the lowest point (November 1997) is not much lower than other low monthly levels in 1996. In interviews we attempted to obtain more information about what happened to effort and catch during the rainy season but the accounts given by different fishermen were so conflicting that it was impossible to determine what had actually happened. The status of the fisheries of Quirimba Island during the wet season is something that needs to be studied in more detail.

Catches were generally very variable, as might be expected of any fishery that depends on the chance capture of highly mobile schooling fish (see Chapter 3). The collection of CPUE and catch composition data was designed to collect data for the whole fishery on a monthly basis and there were not enough samples representing each of the many combinations of tide, season, weather, fishing site or fishing boat to attempt to show correlations with all of these variables. The biggest fluctuations in CPUE were observed to correspond with tidal amplitude. Small, neap tides were associated with low CPUE and large spring tides were associated with high CPUE. At lower low tides much of the bay became exposed and the area of water left for fish was greatly reduced so the fish may have become more densely distributed in the remaining area and therefore more catchable.

The yield for the whole area was high compared to yields from many artisanal, low technology fisheries in tropical coastal areas elsewhere, including coral reef and estuarine fisheries but very few seagrass fisheries for comparison, summarised in Table 6. It has been suggested that a fishery with a high proportion of juveniles might have the potential for a high yield because of juveniles being harvested at a stage when natural mortality is high anyway (Campos 1994, Chapter 3 and 4).

Country	Location	Fishing methods	Habitat	Yield tonnes/km2/yr	Source
Philippines	Bolinao	Traps, Spears, Fish	Seagrass beds and shallow corals	14.5	Campos et al 1994
		Corrals, Gillnets			
India	Hooghly-Matlah		Open estuary	11.4	Jhingran 1991
	Vellor-Coloroon		Open estuary	11.1	Venkatesan 1969
South Africa	Kosi system	Fence and barrier fish traps	Coastal lakes, open estuary	1	Kyle 1988
USA	Texas Bays		Estuarine coastal waters	12.1	Jones et al 1963
El Salvador (USA)	Jiauilisco		Estuarine coastal waters	1.7	Hernandez & Calderon 1974, Phillips 1981
Tanzania	Songo Songo Archipelago	Traps	Reef	31 t/year	Darwall 1996
		Nets	Reef	300 t/year	Darwall 1996
		Handlines	Reef	200 t/year	Darwall 1996
Fiji	Caku Levu	Spear and line	Lagoon and patch reef	0.9-10.2	Jennings and Polunin 1995
South East Asian Region		All gears	Seagrass beds	20	McManus 1993
South East Asian Region		All gears	Seagrass beds	>10	del Morte et al 1989
Papua New Guinea	Tigak Island	Spear, net and handline		1.72kg/ha	Dalzell & Wright 1990
Papua New Guinea	Port Moresby			80kg/ha	Lock 1986
Kenya	Kilifi Reef	Handlines, traps, gillnets and shark nets	Coral reefs	8.8	Nzioka 1990
Jamaica		All gears	Reef and seagrass	0.55	Koslow et al 1994
Belize		All gears	Reef and seagrass	0.34	Koslow et al 1994
Madagascar	Tulear	Line, gillnet and seine	Reef and surrounding shallows	12	Laroche & Ramananarivo 1995
Mauritius		Seines, traps, handlines	Reef and surrounding shallows	4.5	Wheeler & Ommanney 1953, in Marshall 1985

Table 6: A summary of yields from various tropical fisheries from the literature.

Habitat damage and sustainability

There is the potential for habitat damage by seine nets. When nets were hauled along the seafloor the seagrasses themselves remained largely undamaged (although there was some loss of leaves), but other less robust elements of the seagrass bed habitat are destroyed. Large sponges were dislodged, small coral colonies become caught in the nets and turbidity was greatly increased. Net fishing also involved trampling of the seagrass beds and associated habitats such as coral communities.

The main concern about the seine net fishery was the small mesh size and small fish captured. In some cases larvae were caught in cod-ends and a large proportion of the catch was composed of juveniles. Although the small fish were usually used dried for consumption and not wasted, a major management recommendation would be to increase the size of the cod-end mesh, maybe to 3cm stretch or even to 4cm stretch in line with the rest of the net. The use of flour sacks and other such material should be strongly discouraged through education programmes and discussion with the fishers. It may be that sacks are used because of lack of resources to buy normal net cod-ends, which is an issue that could be addressed. An increase of cod-end mesh from 2cm to 3cm would increase the minimum size at capture from around 5 to 6cm depending on species to around 7 to 8cm. This would lead to the loss of perhaps 10% of the previous useful catch but could in the long term improve, or at least guard against the decline of catches. The impact of gear changes on the 5 key species will be discussed in more detail in Chapter 5.

From a habitat protection point of view trap fishing is the preferable method. Traps appear to have very little impact on the seagrass. They do not move extensively and are usually located easily. As the traps are made of a natural material they break down almost completely within a few months if lost and do not lead to long term problems of ghost fishing. Without regular cleaning and maintenance a lost trap may stop catching fish within a few weeks. Traps also allow the fishermen to return unwanted species of fish and invertebrates directly to the sea, thus reducing wasteful bycatch.

A self-regulation mechanism?

There were a number of points about the seagrass seine net fishery that initially seem very surprising. Considering the very low level of income of the fishermen (net fishermen working for a boat owner earn as little as 10,000Mts, less thanUS$1 per day,

see Chapter 6), their attitude to one of few possible sources of income was very relaxed. The fishing nets were poorly maintained and on numerous occasions when the process of fishing was observed (by actually going into the water with the fishermen and snorkelling around the net during the fishing process) large quantities of fish initially seen inside the net, were lost through large holes. The fishermen wore masks when they were in the water during the hauling of the net and were also able to see the extent to which fish escape through holes in the net, yet nets were rarely repaired. This could not be through lack of opportunity in terms of non-fishing days, as every fortnight the fishermen had five or six days with the net out of the water. Lack of materials may have been a more important factor.

The same enigma can be found in the number of days an average boat goes out fishing. Some boats fish ten days per fortnight, indicating that it is possible to fish at these times but some boats take six days or more off around the less favourable tides. On 14% of trips fishermen did two or less hauls before returning to shore. Occasionally there was an obvious reason for not continuing fishing; bad weather or a problem with the net or the boat, but often there was no reason for ending the fishing trip. Often during the fishing trip the fishermen would just decide to finish for the day and sail back. This decision rarely seemed to reflect the quantity of fish already caught. The fishing boats that fished regularly from Quiwandala became well known to the observers and even during suitable tides it was not uncommon for fishing trips to be cancelled for no apparent reason.

It has been suggested by other researchers (P. Medley pers. comm.) in similar fisheries that this apparently "inefficient" behaviour of fishermen who do not seem to be maximising their efforts and who barely seem to gain the calorific value of fish that they are expending to catch it, may in fact be a implementing a form of self-regulation. This could be a complete misreading of the situation in Quirimba and the benefits of inefficiency may be purely incidental. Whatever the motivations or social reasons behind the behaviour of the fishermen, it currently may contribute to the sustainability of the fishery.

The relationship between numbers of fishermen and catch and CPUE also indicated inefficiencies on the boats with large crews. After a crew size of ten men was exceeded, the catch began to decrease, apparently because the chaos that ensued on the boat

and in the water outweighed the advantages of the increased man power. There were obviously social reasons why boat owners and captains had larger crews and if a large crew allowed the job to be done with less effort expended by each individual it may have been preferable to catching slightly more fish per person.

The possible downward trend in CPUE, although it can not be confirmed as a real, year-round trend, is nonetheless worrying, along with the simultaneous increase in fishing effort, both from fishers from the islands and from outside. The population of Quirimba Island has increased by 50% in the past ten years (J. Gessner pers. comm.), and this growth has inevitably been reflected in the growth of the seagrass fishery as the main source of employment. The increase in the numbers of itinerant fishermen is the most worrying trend as even with appropriate local management regimes a problem on the scale of the hundreds of Nampula fishermen in the Quirimbas will be difficult to tackle and would involve complex political and economic issues of resource ownership, and rights to reside. There is also a potential source of conflict between resident fishermen and itinerants.

Implications for future management

The biggest immediate threat to the Quirimba seagrass fishery is probably the increasing fishing effort and the potential for a sudden dramatic improvement in fishing efficiency. Rapid increase in efficiency could come in the form of a development project to improve fishing technology, improve the repair of nets, to encourage more intensive fishing and to offer refrigeration for catches and improved marketing opportunities, without first assessing how these changes might affect the future of the fishery. The seagrass beds are productive, the harvesting of juveniles with high natural mortality may be a good strategy for high yields (see Chapter 3) and the seagrass beds may be replenished by juveniles from spawning adults on coral reefs and fish from unexploited areas of seagrass and mangrove. However, a much higher number of fishermen per unit area of seagrass bed and an increased fishing efficiency is not likely to be sustainable. The impact on the area could be disastrous, with indirect impacts on the populations and communities in associated marine ecosystems, particularly coral reefs (large numbers of reef fish juveniles appear in the seagrass fishery – see Chapter 3).

Fishing effort is likely to continue to increase in the form of a larger fishing fleet on the island and an increase in the number of visiting fishing boats. The fishing intensity in the

Montepuez Bay may not be particularly high in comparison to intensively fished areas elsewhere such as in the Philippines where destructive methods such as blast fishing are used, but it is still at a high level. From estimations of the area of seagrass trawled on each fishing trip it is estimated that each km^2 of shallow seagrass in the Montepuez Bay is trawled more than 70 times per year, which is a fairly high intensity of fishing.

One management solution may be to encourage the diversification of the fishing methods (for example onto the reef flats and reefs) and other sources of employment so that no one population or habitat is exploited to unsustainable levels. However, complete lack of exploitation of adult reef fish may contribute to the sustainability of the largely juvenile seagrass fishery. The main outer reefs of the islands were not accessible because they were exposed to heavy seas and strong winds, and areas of patch reef were not favoured by fishers as they made fishing in the very shallow water difficult and there was a risk to gear and boats. Reef areas may therefore have provided a form of natural refugia to fishes along with other unfished areas such as deeper waters within the bay and mangroves.

The seagrass-based fishery at Quirimba involved a variety of gears and was highly productive. The fish caught were a vital component of the local diet and economy. Although ideally more fisheries assessment is needed to complete the picture in terms of the fishing patterns and catches for the wet season, the possibility of a falling CPUE perhaps demands more immediate action. The catches and CPUE for this fishery should be monitored on a regular basis, in particular the situation with the itinerant fishermen. The careful and sensitive implementation of existing fisheries legislation such as mesh sizes might be helpful. The increasing numbers of resident and visiting fishermen is a serious problem that will need addressing throughout the Archipelago and maybe even throughout the province and beyond to tackle the sources of these problems.

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CHAPTER 3

THE CATCH COMPOSITION OF THE NET AND TRAP FISHERIES OF THE QUIRIMBA SEAGRASS BEDS

ABSTRACT

The seagrass fishery at Quirimba was a multi-gear, multi-species fishery in which over 250 species of fish were captured. Five species accounted for more than 60% of total fish biomass: *Siganus sutor, Leptoscarus vaigiensis. Lethrinus variegatus, Lethrinus lentjan* and *Gerres oyena*. The African white-spotted rabbitfish, *Siganus sutor,* was the dominant species caught by seine net, whereas the seagrass parrotfish, *Leptoscarus vaigiensis,* was the dominant species caught by trap. Catch species could be put into three main categories based on the role of the seagrass habitat in their life history: seagrass residents, juveniles only in the seagrass habitat and adults only in the seagrass habitat. When the fishing sites were defined in terms of the proximity of other habitats: i.e. – reef-associated seagrass sites, mangrove associated seagrass sites and ordinary seagrass sites, differences were found in the fish faunas of these sites. Seagrass and mangrove associated sites were dominated by rabbitfishes (Siganidae), whereas coral-associated sites were dominated by emperors (Lethrinidae). The species present in the Quirimba seagrass fishery represented a broad range families with very different life histories. This high diversity of species is a challenge to fisheries managers who aim to maintain a sustainable fishery and conserve species.

INTRODUCTION

Seagrasses and their fish communities

Seagrasses are an important tropical marine habitat that covers large areas of the nearshore coast throughout the Indo-Pacific. They are found on intertidal flats, in coastal lagoons, within estuaries, in shallow (usually less than 10m) sandy areas, and in association with coral communities (Richmond 1997). Along with coral reefs and mangroves, seagrasses provide an important habitat for a wide diversity of fish, invertebrates and other animals, and thus a source of food and income for coastal populations.

Coral reef fisheries have recently become the subject of much discussion and research, and their importance to coastal people in all tropical areas where they occur is widely appreciated (Polunin & Roberts 1996). However, other coastal tropical fisheries, such as estuarine and seagrass fisheries have received less attention. In some coral rich areas reef fisheries have been the main source of fish and it is only as reefs have been destroyed by dynamite fishing, coral mining or even bleaching events that fishermen have turned to the seagrass beds for fish (Fortes 1990). This is a common occurrence in the Philippines, but it is also happening elsewhere.

In the context of fisheries, seagrasses have most often been recognised as ecologically and economically important habitats for juvenile fish and prawns, supplying large commercial fisheries, for example the King George whiting fishery in Victoria, Australia and the prawn fishery of northern Australia (Bell & Pollard 1989). In many cases, fishing does not actually occur in the seagrass but depends on seagrass as a habitat for juveniles that will later recruit to a fishery elsewhere. Threats to these fisheries may come from pollution, dredging or other human damage to the seagrass environment unrelated to the fishery (Fortes 1990). In developed tropical areas such as Florida, pollution is a major threat to seagrass health and serious die-off events have taken place (Robblee *et al.* 1987).

In tropical developing countries people are much more directly dependent on seagrass. In many Indo-Pacific areas the fauna associated with seagrass beds is a valuable component of fisheries that provide an income and a source of protein in the diet of local people. In Sri Lanka the seagrass lagoon area of Puttalam (Dayaratne *et al.* 1997) supports an artisanal fishery that is a vital part of the local economy. In the Philippines, a wide variety of organisms are collected from seagrass habitats, from the seagrass itself, parts of which are eaten, to the animals that live in it (Fortes 1990).

Most work on seagrass fisheries prior to 1984 was done in the USA and Japan (Burchmore *et al.* 1984) but in the later 1980s and 1990s seagrass research also became important in Australia for commercial reasons, particularly for the prawn fisheries. There have been a number of general studies of the

importance of the seagrass habitat for resource use in the Philippines (Fortes 1990, McManus 1993). However, it is only rarely that seagrass fisheries are considered separately from the reef fisheries that often occur in close proximity. This is the case for a variety of reasons. Seagrass fish may be caught as part of a catch that is apparently dominated by species also caught on reefs. When catches from predominantly seagrass areas are landed, if those who are monitoring the fishery from the landing site do not know the area well, it is easy to assume that the fish are from reef areas, reefs often being the most conspicuous habitat.

The seagrass fishery of Quirimba Island is the single most important provider of food and income on the island. It is also a diverse fishery based on an interesting and little studied ecosystem. The two main gear types, seine nets and basket traps, captured fish of a wide variety of sizes and were a convenient way to sample the fish communities of the seagrass habitat. Relatively few studies of tropical seagrass fish communities have been carried out in the Western Indian Ocean and little is known of the seagrass fish communities of the East African region. In this study I describe the catch composition of an important artisanal fishery and the seagrass fish communities of the Montepuez Bay on which it depends.

METHODS

Study site

The Montepuez Bay is a large bay between Quirimba Island and mainland Mozambique. It is shallow with large sand banks and deeper channels, and is dominated by mixed seagrass meadows covering an area of approximately 35km^2. The meadows were dominated by the seagrass species *Enhalus acoroides, Thalassodendron ciliatum* and *Cymodocea serrulata*. Also present are *Syringodium isoetifolium, Cymodoea rotundata, Halophila ovalis, H. stipulacea, Halodule uninervis, Halodule wrightii* and *Thalassia hemprichii* (an intertidal species) (see Chapter 1 for a more detailed description of the site).

The majority of the island's 3000 people live in Quirimba village on the north-east coast. Some boats operate directly from the village on the east coast of

Quirimba, fishing the reef flat or the outer reef when weather conditions allow, but the main local fishery is based on the seagrass bay. The landing site for this fishery is in a small mangrove area in the north west of the island, called Quiwandala. The majority of net fishing boats operate from this point and some of the trap fishing canoes (see Chapter 2).

From the start of the survey it was evident that to study the catch composition using landed fish would be difficult and misleading. Much of the catch was bartered for, sold or taken by fishermen before the boat even reached the shore and what remained had to be processed immediately on landing. Therefore, wherever possible I studied the catch on the fishing boats immediately after capture. This gave me the opportunity to sample the whole catch as it was brought onto the boat, including bycatch species that were later discarded.

Observers (myself or trained project participants) accompanied fishermen on the fishing trip recording effort and catch data on a set of forms printed on underwater paper. To study catch composition the catch was sampled using a standard household bucket. The volume of fish sampled varied between half and a whole bucketful of fish (7 to 15 kg) per trip, depending on time available, and the sample size was recorded. The sample was collected randomly from the fish landed in the boat, usually after the first haul of the trip.

I measured the fork length (or total length for fish with unforked tails) of the fish in the sample to the nearest 0.5cm using a 30cm measuring board. For about one third of the samples I weighed the fish to the nearest gram (0-200g) or 5g (> 200g) using spring balances. Fish were identified on the boat with the help of laminated cards showing colour illustrations of the common species, and by using identification books (Lieske & Myers 1996 and Fischer *et al.* 1990). Any fish not identified were brought back to base camp for further study and for preservation for later identification where possible.

Other items of interest were also noted including any invertebrates captured during the fishing trip, fish thrown back and turtles or other unusual species captured. Any interesting fish not previously seen were kept and identified even if they did not appear in the sample. This information was recorded separately.

I carried out sampling for a period of a week each month for a total of 13 full months over a two year study period. During this time there were two five month periods during the wet season in which no sampling was undertaken because the project was suspended for these periods. I calculated length weight relationships for 44 species commonly occurring in the catch (see Chapter 5 for the common species). I used these to convert lengths collected in length-only samples into weights so total biomass of component fish species could be calculated for each sample and for each month. For less common species, length-weight relationships were taken from the literature (many found using references in Fishbase 1996).

I obtained the majority of trap fishery samples at landings along the west coast of Quirimba from Quiwandala to Santa Maria. I also collected catch composition data from approximately 20 fishing trips with a canoe fisherman fishing in the fishing sites of Lusino and Kumilamba in the south of the island.

Statistical analysis

To look at broad correlations between site characteristics and species abundances, Spearman's rank order correlation was used. This is a non-parametric test suitable for the non-normal data used. The diversity and species structure of the samples were studied using the following indices using PRIMER (Warwick and Clarke 1996): Margalef's index of species richness (numbers of species taking into account sample size), Shannon diversity index (incorporating species richness and equitability), Pielou's evenness index (expressing equitability) and Simpson's dominance index.

RESULTS

Net fishery

Species composition

The majority of the catches in the fishery were taken in seagrass beds. Sites containing a large proportion of *Enhalus acoroides* and other large species of seagrass were preferred as fishing sites. Most sites were less than two metres deep and were fished around low tide (see Chapter 2 for details of fishing

patterns). Some hauls encompassed areas of sand and shallow coral and the fringes of mangrove forests.

A total of 46,629 fish were sampled from 207 fishing trips in the Montepuez Bay over the two year study period. An average of 16 trips were sampled every month for 13 months: May to November 1996 (excluding July) and May to November 1997. I identified 225 species of fish from 56 families in these samples. A further 27 species and 2 families not in the samples were identified making a total of 252 species from 58 families from catches made in the seagrass beds. A full species list with families, common names and local Kimwani names is shown in Table 1.

The catch composition details for the 25 most common species in the net and trap fishery are shown in Table 2. Also shown is biological and ecological information about the species from this study and from the literature. The species composition of the net catches in terms of weight and numbers are shown in Fig. 1(a). The most abundant species in terms of biomass and number was the African whitespotted rabbitfish, *Siganus sutor*. This fish accounted for 24.4% of total weight of fish sampled and for 15.6% of fish by number. The mean length of individuals over the two year study period was 13.9cm and the modal length was 12cm. Individuals of over 30cm were very rarely encountered in the fishery. *Siganus sutor* and five other species accounted for over 60% of sampled biomass. These species were: *Lethrinus lentjan* (pink ear emperor), *Leptoscarus vaigiensis* (seagrass parrotfish), *Lethrinus variegatus* (variegated emperor), *Gerres oyena* (blacktip mojarra) and *Calotomus spinidens* (spiny tooth parrotfish) (see Table 2).

A further 12 species of fish each accounted for more than 1% of the total weight of catch sampled. These included a wide range of fish from typical fisheries species such as the blackspot snapper *Lutjanus fulviflamma* (2% by weight, 0.9% by number) and the snubnose emperor *Lethrinus mahsenoides* (1.3% by weight and 1.5% by number) to the small wrasse *Stethojulis strigiventer* (2.4% of weight, 5.9% by number) and the goby *Amblygobius albimaculata* (2.2% by weight, 3.3% by number) (Table 2).

Table 1: Species caught in the Quirimba seagrass fishery and their scientific, common and local names. Where Kimwani names are omitted they were either not known by the fishermen as the species appeared rarely in the catch or in a few cases the specific local name was not determined. In a number of cases the same name was used for all members of a family. (English and Portuguese names from FAO 1990, Lieske and Myers 1996 and Smith and Heemstra 1995).

Scientific	English	Portuguese	Kimwani
Acanthuridae	**Surgeonfishes**	**Cirurgiões**	**Ngadga**
Acanthurus auranticavus	Orange socket surgeon		Ngadga
Acanthurus dussmieri	Eye stripe	Cirurgião coroada	Ngadga
Acanthurus mata	Elongate	Cirurgião comprido	
Acanthurus nigricauda	Black streak	Cirurgião graduado	Ngadga
Acanthurus nigrofuscus	Dusky surgeon	Cirurgião castanho	Ngadga
Acanthurus nigroris	Blue-lined surgeon		Ngadga
Acanthurus thompsoni	Thompsons	Cirurgião chocolate	Ngadga
Ctenochaetus striatus	Striped bristletooth	Barbeiro estriado	Ngadga
Ctenochaetus strigosus	Goldring bristletooth	Barbeiro manchado	
Naso brevirostris	Spotted unicornfish	Rufia manchada	Muju (juvenile)
Naso unicornis	Blue-spine unicorn	Rufia espigão azul	Ngadga
Zebrasoma desjardini	Desjardin's sailfin tang	Canivete	Ngadga
Antennariidae	**Frogfishes**	**Peixes-sapo**	
Antennarius commersonii	Giant frogfish		Kindwani
Antennarius indicus	Indian frogfish		
Apogonidae	**Cardinalfishes**		**Senda**
Apogon aureus	Ringtail cardinal		
Apogon cyanosoma	Yellowstriped cardinal		
Apogon lateralis	Inshore cardinal		
Apogon leptocanthus	Bluestreak cardinal		
Apogon nigripinnis	Bullseye cardinal		
Apogon nigrofasciatus	Blackstripe cardinal		
Cheilodipterus quinquelineatus	Fiveline cardinal		
Foa brachygramma	Bay cardinal		
Fowleria variegata	Variegated cardinal		
Siphamia mossambica			
Atherinidae	**Silversides**	**Peixes-Rei**	
Atherinomorus duodecimalis	Tropical silverside	Rei tropical	
Atherinomorus lacunosus	Hardyhead silverside	Rei cabeçudo	
Hypoatherina temmincki	Whitebait silverside	Rei samoano	
Spratelloides gracilis			
Aulostomidae	**Trumpetfishes**	**Peixes-trombeta**	
Aulostomus chinensis	Trumpetfish	Trombeta	Uvuve
Balistidae	**Triggerfishes**	**Peixes-porco**	**Kokomwe**
Balistapus undulatus	Orange-striped triggerfish	Porco ondulado	
Balistoides viridescens	Titan triggerfish	Porco ponteado	
Melichthys niger	Black triggerfish	Porco preto	
Rhineacanthus aculeatus	Picassofish	Porco estriado	
Sufflamen chrysopterus	Half-moon triggerfish	Porco meia-lua	
Sufflamen fraenatus	Bridled triggerfish		
Belonidae	**Needlefishes**	**Agulhas**	**Nzera**
Tylosurus crocodilus	Hound needlefish	Agulha crocodilo	Nzera
Blenniidae	**Blennies**	**Marachombas**	
Meiacanthus mossambicus	Mozambique fangblenny		
Petroscirtes mitratus	Marbled fangblenny		
Petroscirtes variablis	Variable fangblenny		
Bothidae	**Left-eye flounders**	**Areeiros**	**Kipama**
Bothus mancus	Tropical flounder	Areeiro tropical	Kipama
Bothus pantherinus	Leopard flounder	Areeiro leopardo	Kipama
Caesionidae	**Fusiliers**	**Fuzileiros**	**Neeto**
Caesio caerulaurea	Blue and gold fusilier	Fuzileiro azul	
Caesio lunaris	Blue fusilier	Fuzileiro lua	
Caesio teres	Yellowback fusilier	Fuzileiro bonito	
Caesio xanthonota	Yellowfin fusilier	Fuzileiro barbatana amarela	
Pterocaesio chrysozona	Goldband fusilier	Fuzileiro banda dourada	
Pterocaesio marri	Twinstripe fusilier	Fuzileiro de Marr	
Pterocaesio pisang	Ruddy fusilier		

Scientific	English	Portuguese	Kimwani
Callionymidae	**Dragonets**	**Peixes-pau**	**Dunfera**
Synchiropus marmoratus	Marbled dragonet		
Synchiropus stellatus	Starry dragonet		
Carangidae	**Jacks etc**	**Carapaus etc**	
Alectis indicus	Indian threadfish	Xaréu cabecu	Njolwe
Carangoides ferdau	Bar jack	Xaréu azul	Njolwe
Carangoides fulvoguttatus	Yellow spotted trevally	Xaréu cintilante	Njolwe
Carangoides orthogrammus	Yellow spotted trevally		
Scomberoides tol	Needlescale queenfish	Machope comum	Njolwe
Selar crumenopthalmus	Big eye scad	Carapau preto	Kirumbwe
Selaroides leptolepis	Smooth-tailed trevally		Njolwe
Chirocentridae	**Wolf-herrings**	**Machopes**	
Chirocentrus dorab	Dorab wolf-herring	Machope espada	
Chaetodontidae	**Butterflyfishes**	**Peixes-borboleta**	**Sungaramarime**
Chaetodon auriga	Threadfin		
Chaetodon falcula	Double saddle		
Chaetodon kleinii	Dot-dash		
Chaetodon melannotus	Black-backed		
Chaetodon trifasciatus	Red fin		
Chaetodon xanthocephalus	Yellow head		
Hemitauichthys zoster	Black pyramid		
Heniochus acuminatus	Bannerfish		
Clupeidae	**Sardines**	**Sardinhas**	
Herklotsichthys quadrimaculatus	Bluestripe herring	Sardinha banda azul	
Sardinella gibbosa	Goldstripe sardine	Sardinha dourada	
Cynglossidae	**Tongue soles**	**Linguados**	**Kipauma**
Cynnoglossus spp.			
Dactylidae	**Flying gurnards**	**Voadores de fundo**	**Manzi**
Dactyloptena orientalis	Oriental flying gurnard	Voador oriental	
Dasyatidae	**Stingrays**	**Ratão**	
Taeniura lymna	Bluespotted ribbontail ray	Ratão pintalgado	
Echeneidae	**Remoras**	**Pegadores**	
Echeneis naucrates	Sharksucker		
Remora remora	Remora		
Engraulidae	**Anchovies**	**Anchovas etc**	
Stolephorus heterolobus	Shorthead anchovy		
Entriscidae	**Shrimpfishes**		
Aeoliscus punctulatus	Speckled shrimpfish		Kifu
Fistularidae	**Cornetfishes**	**Cornetas**	
Fistularia commersoni	Cornetfish	Corneta pintada	Uvuve
Gerreidae	**Mojarras**	**Melanúrias**	
Gerres acinaces	Longtail silver biddy	Melanúria timoneira	Sala
Gerres oyena	Blacktip mojarra	Melanúria comum	Sala
Gobiidae	**Gobies**	**Cabozes**	**Dunfera**
Amblygobius albimaculatus	Tailspot goby		
Amblygobius semicinctus			
Amblygobius sphynx	Sphinx goby		
Bathygobius cyclopterus	Spotted frill goby		
Cryptocentrus caeruleomaculatus	Blue speckled prawn goby		
Yongeichthys nebulosus	Shadow goby		
Grammistidae	**Soapfishes**	**Sabonetes**	
Grammistes sexlineatus	Sixstripe soapfish	Sabonete fita dourada	
Haemulidae	**Grunts**	**Peixes pedra**	
Diagramma pictum	Painted sweetlips	Pargo mulato	Neke
Plectorhinchus albovittatus	Giant sweetlips		
Plectorhinchus flavomaculatus	Gold-spotted sweetlips	Pargo limão	
Plectorhinchus gaterinus	Blackspotted grunt	Pargo galinha	Nrere
Plectorhinchus orientalis	Oriental grunt	Pargo oriental	Nrere

Scientific	English	Portuguese	Kimwani
Plectorhinchus schotaf	Minstrel sweetlips	Pargo trovador	Sende
Plectorhinchus sordidus	Sordid rubberlips	Pargo sórdido	Sende
Pomadasys furcatum	Grey grunter	Roncador de seis bandas	
Hemiramphidae	**Half-beaks**	**Meias-agulhas**	
Hemiramphus far	Black-barred halfbeak	M-agulha manchada	Ningalare
Hemiramphus lutkei	Lutke's halfbeak	Meia-agulha de Lutke	Ningalare
Hyporhamphus affinis	Insular halfbeak	Meia-agulha affinis	Ningalare
Holocentridae	**Squirrelfishes**	**Esquilos**	
Sargocentrum diadema	Crown squirrel	Esquilo sammara	Dada
Sargocentrum rubrum	Redcoat	Esquilo vermelho	Dada
Neoniphon sammara	Bloodspot squirrel	Esquilo sammara	Dada
Kyphosidae	**Rudderfishes**	**Preguiçosas**	
Kyphosus vaigiensis	Lowfin rudderfish	Preguiçosa bronzeada	
Labridae	**Wrasses**	**Bodiões**	
Anampses caeruleopunctatus	Blue-spotted wrasse	Bodião pintalgado	Nsingombe
Cheilinus bimaculatus	Twospot wrasse		Nsingombe
Cheilinus oxycephalus	Snooty wrasse		Nsingombe
Cheilinus trilobatus	Three-lobed wrasse	Bodião trilobatus	Nsingombe
Cheilinus undulatus	Humphead wrasse	Bodião napoleao	Nsingombe
Cheilio inermis	Cigar wrasse	Madonoli	Kisuare
Coris caudimacula	Spottail coris		Nsingombe
Cymolutes praetextatus	Knife razorfish		Nsingombe
Cymolutes torquatus	Finescale razorfish		Nsingombe
Halichoeres hortulanus	Checkerboard wrasse	Bodião axedrezado	Nsingombe
Halichoeres marginatus	Dusky wrasse		
Halichoeres scapularis	Zigzag wrasse		Nsingombe
Halichoeres zeylonicus	Goldstripe wrasse		
Labroides dimidiatus	Bluestreak cleaner wrasse		Nsingombe
Novaculichthys macrolepidotus	Seagrass wrasse		Nsingombe
Novaculichthys taeniourus	Rockmover wrasse	Donzela alguiera	Nsingombe
Oxycheilinus arenatus	Arenatus wrasse		
Oxycheilinus digrammus	Cheeklined wrasse		Nsingombe
Pteragogus flagellifera	Flagfin wrasse		Nsingombe
Stethojulis albovittata	Blue-lined wrasse		Shingu
Stethojulis interrupta	Cutribbon wrasse		Shingu
Stethojulis strigiventer	Three ribbon wrasse		Shingu
Thalassoma fuscum	Christmas wrasse	Peixe-verde de Natal	Nsingombe
Thalassoma purpureum	Surge wrasse	Peixe-verde turquesa	Nsingombe
Xyrichthys pavo	Peacock wrasse	Bodião pavao	Nsingombe
Xyrichthys pentadactylus	Five finger wrasse	Bodião ocelado	Nsingombe
Lethrinidae	**Emperors**	**Ladroes/Imperadores**	
Gnathodentex aurolineatus	Yellowspot emperor	Ladrão-imperador	
Gymnocranius griseus	Grey barenose	Ladrão cinzento	
Lethrinus harak	Thumbprint emperor	São Pedro	Njana baka
Lethrinus lentjan	Pink ear emperor	Ladrão de lentejoulas	Njana
Lethrinus mahsena	Sky emperor	Ladrão mahsena	Sangu
Lethrinus mahsenoides	Snubnose emperor		Kilundumasa
Lethrinus microdon	Smalltooth emperor	Ladrão de boca doce	Sunguri
Lethrinus nebulosus	Spangled emperor	Ladrão relâmpago	Sangu
Lethrinus obsoletus	Yellow-banded emperor	Ladrão de bandas	
Lethrinus olivaceous	Longface emperor		
Lethrinus rubrioperculatus	Redgill emperor	Ladrão maquilhado	Fimbo
Lethrinus variegatus	Variegated emperor	Ladrão moteado	Sololo
Monotaxis grandoculis	Bigeye emperor		
Lutjanidae	**Snappers**	**Pargos**	
Aphareus furcatus	Smalltooth jobfish	Pargo de boca doce	
Aprion virescens	Green jobfish	Pargo verde	
Lutjanus bohar	Two spot snapper	Pargo de manchas	
Lutjanus ehrenbergi	Ehrenberg's snapper	Pargo carpa	Kerare
Lutjanus fulviflamma	Blackspot snapper	Pargo tinteiro	Kerare
Lutjanus fulvus	Flametail snapper	Pargo rabo negro	
Lutjanus gibbus	Humpback snapper	Pargo curvado	Numba
Lutjanus lemniscatus	Sweetlip snapper	Pargo de raios amarelos	
Lutjanus lutjanus	Yellow snapper	Pargo de Madras	
Pristopomides multidens	Gold-banded jobfish	Pargo de cauda	
Monacanthidae	**Filefishes**	**Peixes-porco-galhudos**	
Aluterus scriptus	Scribbled leatherjacket	Porco rabiscado	Nanamali

Scientific	English	Portuguese	Kimwani
Amanses scopas	Broom filefish		Kokoma
Paluteres prionurus	Blacksaddle mimic		Kipweti
Paramonacanthus barnardi	Wedgetail filefish		Kokomwe
Paramonacanthus frenatus			Kokomwe
Pseudalutarius nasicornis	Rhinocerous filefish		Kokomwe
Thamnoconus sp.			Kokomwe
Monodactylidae	**Monos**	**Lunados**	
Monodactylus argenteus	Mono	Lunado prateado	
Mullidae	**Goatfishes**	**Salmonetes**	
Mulloides flavolineatus	Yellowstripe goatfish	S. de estria amarela	Nkundage
Mulloides vanicolensis	Yellowfin goatfish	S. de vanicola	Nkundage
Parupeneus barberinus	Dash-dot goatfish	Salmonete barberino	Nkundage
Parupeneus cinnabarensis	Cinnabar goatfish	Salmonete cinnabar	Nkundage
Parupeneus cyclostomus	Gold saddle goatfish	Salmonete dourado	Nkundage
Parupeneus heptacanthus	Redspot goatfish		Nkundage
Parupeneus macronema	Long-barbel goatfish	S. barba longa	Nkundage
Parupeneus pleurostigma	Sidespot goatfish	Salmonete pastilha	Nkundage
Parupeneus rubescens	Rosy goatfish	Salmonete rosado	Nkundage
Paruupeneus indicus	Indian goatfish	Salmonete do Indico	Nkundage
Upeneus moluccensis	Goldband goatfish	S. de banda dourada	Nkundage
Upeneus taeniopterus	Fin stripe goatfish	Salmonete estriado	Nfionyo
Upeneus tragula	Freckled goatfish	Salmonete sardento	Nfionyo
Upeneus vittatus	Striped goatfish	Salmonete laranjeiro	Nfionyo
Muraenidae	**Moray eels**	**Moreias**	
Siderea picta	Speckled moray	Moreia sideral	
Nemipteridae	**Threadfin breams**	**Bagas, Sizis**	
Scolopsis bimaculatus	Thumbprint spinecheek	Sizi São Pedro	
Scolopsis ghanam	Arabian spinecheek	Sizi de Arabia	Abudala
Ostracidae	**Trunkfishes**	**Cofres**	
Lactoria cornuta	Longhorn cowfish		Kilamba
Ostracion cubicus	Yellow boxfish		Kilamba
Pegasidae	**Seamoths**		
Eurypegasus sp.			
Platacidae	**Batfishes**	**Morcegos**	
Platax orbicularis	Batfish	Morcego	Kipukupu
Platycephalidae	**Flatheads**	**Sapateiros**	
Papilloculiceps longiceps	Crocodile flathead	Sapateiro crocodilo	Manzi/Atjari
Thysanophrys arenicola	Broadhead flathead		Manzi/Atjari
Thysanophrys chilionae	Longsnout flathead		Manzi/Atjari
Plotosidae	**Catfishes**	**Patunas**	
Plotosus lineatus	Striped eel catfish	Patuna raiada	Ngo
Pomacanthidae	**Angelfishes**	**Libres**	**Kipapais**
Centropyge multispinus	Multispined angelfish		
Pomacanthus chrysurus	Ear-spot angelfish	Lebre cauda dourada	
Pomacentridae	**Damselfishes**	**Castanhetas**	**Gugrue**
Abudefduf sparoides	False eye sergeant		
Abudefduf sexfasciatus	Scissortail sergeant8		
Abudefduf vaigiensis	Indo-Pacific sergeant		
Amphiprion allardi	Allard's anemonefish		
Chromis opercularis	Doublebar chromis		
Chrysiptera annulata	Footballer demoiselle		
Dascyllus aruanus	Humbug dascyllus		
Dascyllus carneus	Indian dascyllus		
Dascyllus trimaculatus	Three spot dascyllus		
Neoglyphidodon melas	Black damsel		
Neopomacentus fulginosus	African demoiselle		
Plectroglyphidodon lacrymatus	Jewel damsel		
Pomacentrus trilineatus	Threeline damsel		
Priacanthidae	**Bigeyes**	**Fura-vasos**	
Priacanthus cruentatus	Glasseye	Fura-vasos de rochas	Dada
Priacanthus hamrur	Moontail bigeye	Fura-vasos espelhudo	Dada

Scientific	English	Portuguese	Kimwani
Rhynchobatidae	**Guitar fishes**	**Peixes cunha**	
Rhynchobatus djeddensis	White spotted guitarfish		Saluware
Scaridae	**Parrotfishes**	**Papagaios**	
Calotomus carolinus	Carolines parrotfish	P. das Carolinas	Bonju
Calotomus spinidens	Spinytooth parrotfish	P. dentuço	Bonju
Hipposcarus harid	Indian Ocean longnose parrot	P. candelamoa	Mono
Leptoscarus vaigiensis	Seagrass parrotfish	Papagaio manchado	Bonju
Scarus ghobban	Blue barred parrotfish	P.de escamas amarelas	Mono
Scarus japanensis	Palecheek parrotfish	P. rosto pálido	Mono
Scarus psitticas	Common parrotfish	Papagaio vulgar	Mono
Scarus sordidus	Daisy parrotfish	Papagaio margarida	Mono
Scarus viridifucatus	Round head parrotfish	P. cabeça redonda	Mono
Scombridae	**Tunas and mackerels**	**Serras, cavalas, atuns**	
Rastrelliger kanagurta	Indian mackerel	Cavala	
Scorpaenidae	**Scorpionfish**	**Galinhas**	
Dendochirus brachypterus	Shortfin lionfish		
Parascorpaena mossambica			Kindwani
Pterois miles	Lionfish	Peixe-fogo diabo	Namatanga
Scorpaenopsis venosa	Raggy scorpionfish	Rascasso esfarrapado	Kindwani
Scorpaenopsis spp.	Scorpiuon fish	Rascasso	Kindwani
Serranidae	**Groupers**	**Garoupas**	**Kushaywa**
Cephalopholis argus	Peacock grouper	Garoupa pavão	Kushaywa
Epinephelus flavocaeruleus	Blue and yellow grouper	Garoupa azul e amarela	Kushaywa
Epinephelus fuscoguttatus	Brown marbled grouper	Garoupa manchada	Kushaywa
Epinephelus longispinus	Longspined grouper	Garoupa espigão	Kushaywa
Plectropomus areolatus	Squaretail coral grouper	Garoupa rabo cortado	Kushaywa
Siganidae	**Rabbitfishes**	**Coelhos**	
Siganus stellatus	Stellate rabbit	Coelho margarida	Safi manga
Siganus sutor	African whitespotted rabbit	Coelho sapateiro	Safi
Soleidae	**Soles**	**Linguas**	
Pardichirus marmoratus	Moses sole	Lingua de leite	Kipauma
Solenostomidae	**Ghost pipefishes**		
Solenostomus cyanopterus	Ghost pipefish		
Sphyraenidae	**Barracudas**	**Barracudas**	
Sphyraena barracuda	Great barracuda	Barracuda bicuda	Luluva
Sphyraena flavicauda	Yellowtail barracuda	B. de rabo amarelo	Luluva
Sphyraena forsteri	Bigeye barracuda	B. de forsteri	Luluva
Sphyraena jello	Pickhandle barracuda	Barracuda serpentina	Luluva
Sphyraena putnamie	Sawtooth barracuda	Barracuda serrote	Luluva
Sphyraena qenie	Blackfin barracuda	Barracuda barbatana negra	Luluva
Syngnathidae	**Pipefishes and Seahorses**		
Corythoichthys flavofasciatus	Network pipefish		
Corythoichthys haemopterus	Sculptured pipefish		
Corythoichthys schultzi	Guilded pipefish		
Hippocampus histrix	Spiky seahorse		
Syngnathoides biaculeatus	Alligator pipefish		
Synodontidae	**Lizardfishes**	**Peixes-banana**	
Saurida gracilis	Gracile lizardfish	Peixe-banana gracioso	
Synodus variegatus	Variegated lizardfish	Peixe-banana matizado	
Teraponidae	**Terapons**	**Peixes zebra**	**Oo-ee**
Pelates quadrilineatus	Four-lined terapon	Peixe-zebra aurora	Ngungungu
Terapon theraps	Straight-lined thornfish	Peixe-zebra tigre	Ngungungu
Tetraodontidae	**Pufferfishes**	**Peixes-bola**	**Kipweti**
Arothron hispidus	Whitespotted puffer		
Arothron immaculatus	Immaculate puffer		
Arothron mappa	Map puffer		
Arothron meleagris	Guineafowl puffer		
Arothron nigropunctatus	Black-spotted puffer		
Arothron stellatus	Star puffer		
Canthigaster bennetti	Bennett's toby		
Canthigaster janthinopera	Honeycomb toby		

Scientific	English	Portuguese	Kimwani
Canthigaster solandri	Spotted toby		
Canthigaster valentini	Black-saddled toby		
Cyclichthys orbicularis	Orbicular burrfish		
Diodon liturosus	Blackblotched porcupine		
Lagocephalus sceleratus	Silverstripe blaasop		
Tetrarogidae	**Waspfishes**		
Ablabys binotatus	Redskinfish		Kindwani
Triglidae	**Gurnards**	**Ruivos**	
Chelidonichthys kumu	Bluefin gurnard	Ruivo barbatana azul	Manzi
Zanclidae			
Zanclus cornutus	Moorish idol		Kipapes

Table 2: The common fish species in the seine net and trap fisheries showing the percentages for which they accounted in the net and trap samples, mean lengths, maximum length, trophic group, main juvenile habitat and main adult habitat (from a combination of observation and from the literature: FishBase 1996, Smith & Heemstra 1995, Lieske & Myers 1994, Carpenter & Allen 1989, Woodland 1990, Bruce and Randall 1985).

	Net fishery		Mean	Max	%	Trap fishery		Mean	%	Dominant	Trophic	Juvenile	Adult
	weight	number	length	length	Max	weight	number	length	Max	life	group	Habitat	Habitat
Fish Species	%	%	cm	cm	Length	%	%	cm	Length	stage			
Siganus sutor	24.4	15.6	13.4	50	26.8	5.0	11.5	11.9	23.8	Juvenile	Herbivore	Seagrass	Reef flat
Lethrinus lentjan	12.2	5.1	14.6	50	29.2	0.1	0.1	19.0	38.0	Juvenile	Invert. feeder	Seagrass	Reef
Leptoscarus vaigiensis	11.0	9.7	13.0	35	37.1	85.9	72.9	17.3	49.4	All	Herbivore	Seagrass	Seagrass
Lethrinus variegatus	7.4	14.7	9.7	20	48.5	0.5	1.0	12.4	62.0	All	Invert. feeder	Seagrass	Seagrass
Gerres oyena	6.3	7.0	11.1	25	44.4	0.0	0.0			Juvenile	Invert. feeder	Seagrass/sand	Reef flat/sand
Calotomus spinidens	3.2	5.5	10.0	19	52.6	5.9	10.0	12.9	67.9	All	Herbivore	Seagrass	Seagrass
Cheilio inermis	3.0	2.4	20.2	50	40.4	1.0	0.7	25.0	50.0	All	Invert. Feeder	Seagrass	Seagrass
Sphyraena flavicauda	2.6	3.8	17.9	37	48.4	0.0	0.0		0.0	All	Piscivore	Seagrass/mangrove	Seagrass/mangrove
Stethojulis strigiventer	2.4	5.9	9.4	14	67.1	0.1	0.2	10.8	77.1	All	Invert. feeder	Seagrass/reef	Seagrass/reef
Amblygobius albimacul.	2.2	3.3	12.2	18	67.8	0.02	0.03			All	Omnivore	Sand/seagrass	Sand/seagrass
Lutjanus fulviflammus	2.0	0.9	14.7	35	42.0	3.4	6.8	12.0	34.3	Juvenile	Fish and invert.	Seagrass/mangrove	Reef
Hemiramphus far	1.5	0.4	28.8	45	64.0	0.0	0.0			All	Seagrass, fish	Seagrass/alagal	Seagrass/alagal
Parupeneus barberinus	1.4	1.6	11.3	50	22.6	3.4	4.4	13.9	27.8	Juvenile	Crustaceans	Seagrass	Reef
Scolopsis ghanam	1.4	1.7	10.9	30	36.3	0.2	0.4	11.6	38.7	All	Invert feeder	Reef/seagrass	Reef/seagrass
Lethrinus mahsenoides	1.3	1.5	10.4	40	26.0	2.2	3.3	12.6	31.5	Juvenile	Invert feeder	Seagrass	Reef
Fistularis commersoni	1.2	0.8	40.6	160	25.4	0.0	0.0			All	Piscivore	Various	Various
Siganus stellatus	1.0	1.1	11.7	40	29.3	0.1	0.2			Juvenile	Herbivore	Seagrass	Reef
Scarus ghobban	0.9	0.8	43.9	74	59.3	1.1	1.8	13.0	17.6	Juvenile	Herbivore	Seagrass	Reef
Carangoides fulvoguttat.	0.9	0.0	33.5	100	33.5	0.0	0.0			Adult	Piscivore		Pelagic
Lactoria cornuta	0.8	0.2	17.3	46	37.6	0.01	0.1	7.0	15.2	All	Invert feeder	Reef	Reef
Upeneus tragula	0.6	1.0	10.3	30	34.3	0.1	0.1	18.5	61.7	Juvenile	Invert feeder	Seagrass	Sand/reef
Pelates quadrilineatus	0.6	1.0	10.6	30	35.3	0.04	0.03			Juvenile	Omnivore	Estuarine/mangrove	Estuarine/mangove
Diagramma pictum	0.6	0.1	28.3	100	28.3	0.5	0.3	19.5	19.5	Juvenile	Inverts and fish	Seagrass	Reef
Cheilodipterus quinquelin.	0.1	1.0	7.6	12	63.3	0.0	0.0			All	Inverts and fish	Seagrass	Seagrass
Plectorhinchus gaterinus	0.5	0.4	12.8	50	25.6	0.4	0.1	13.5	27.0	Juvenile	Inverts	Seagrass	Reef
Pteragogus flagellifera	0.1	0.1	9.4	20	47.0	3.3	10.1	10.9	54.5	Adult		Seagrass	Seagrass
Epinephelus flavocaerul.	0.01	0.01		90		0.6	0.1	25.8	28.7	Adult	Piscivore	Reef	Reef

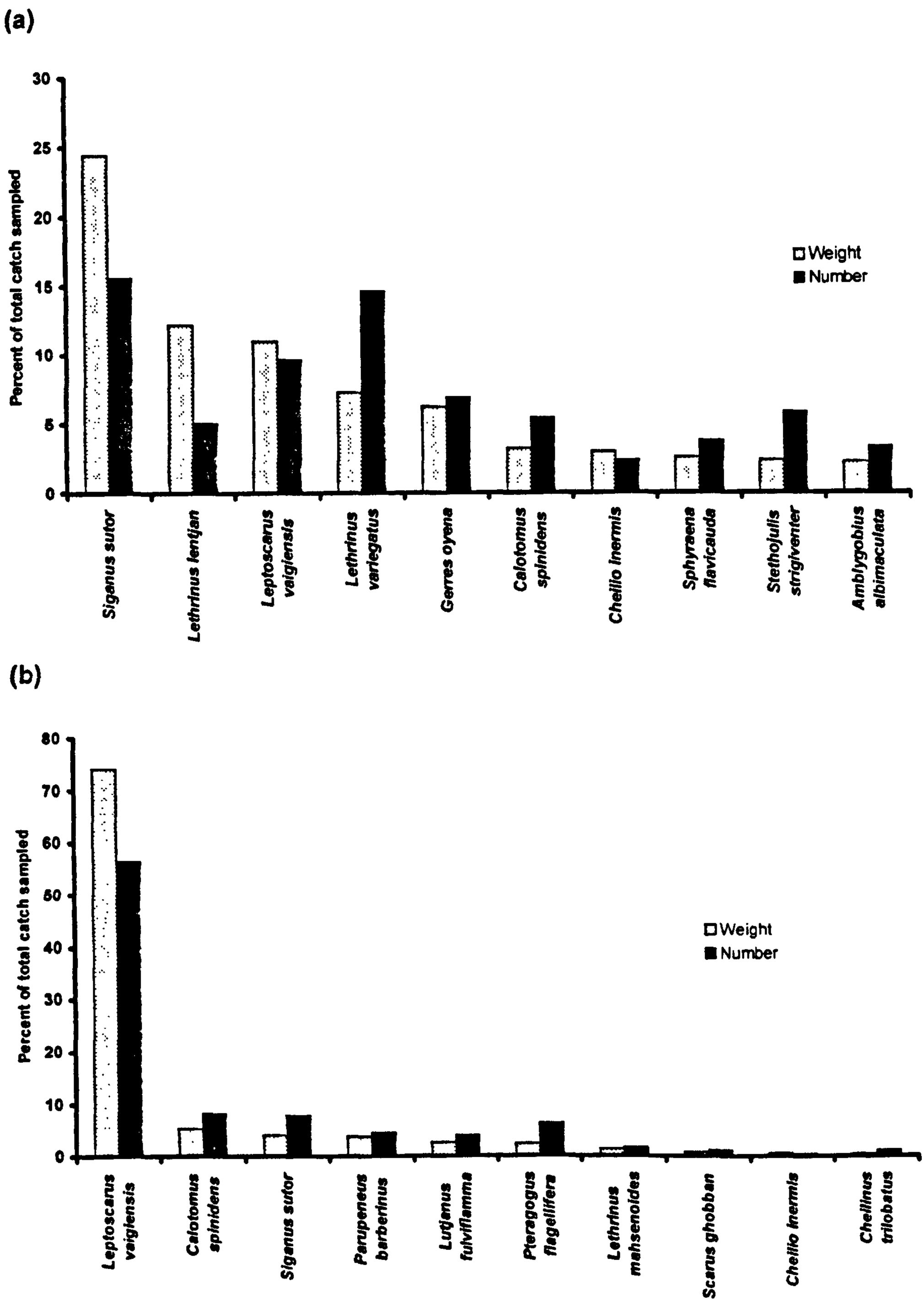


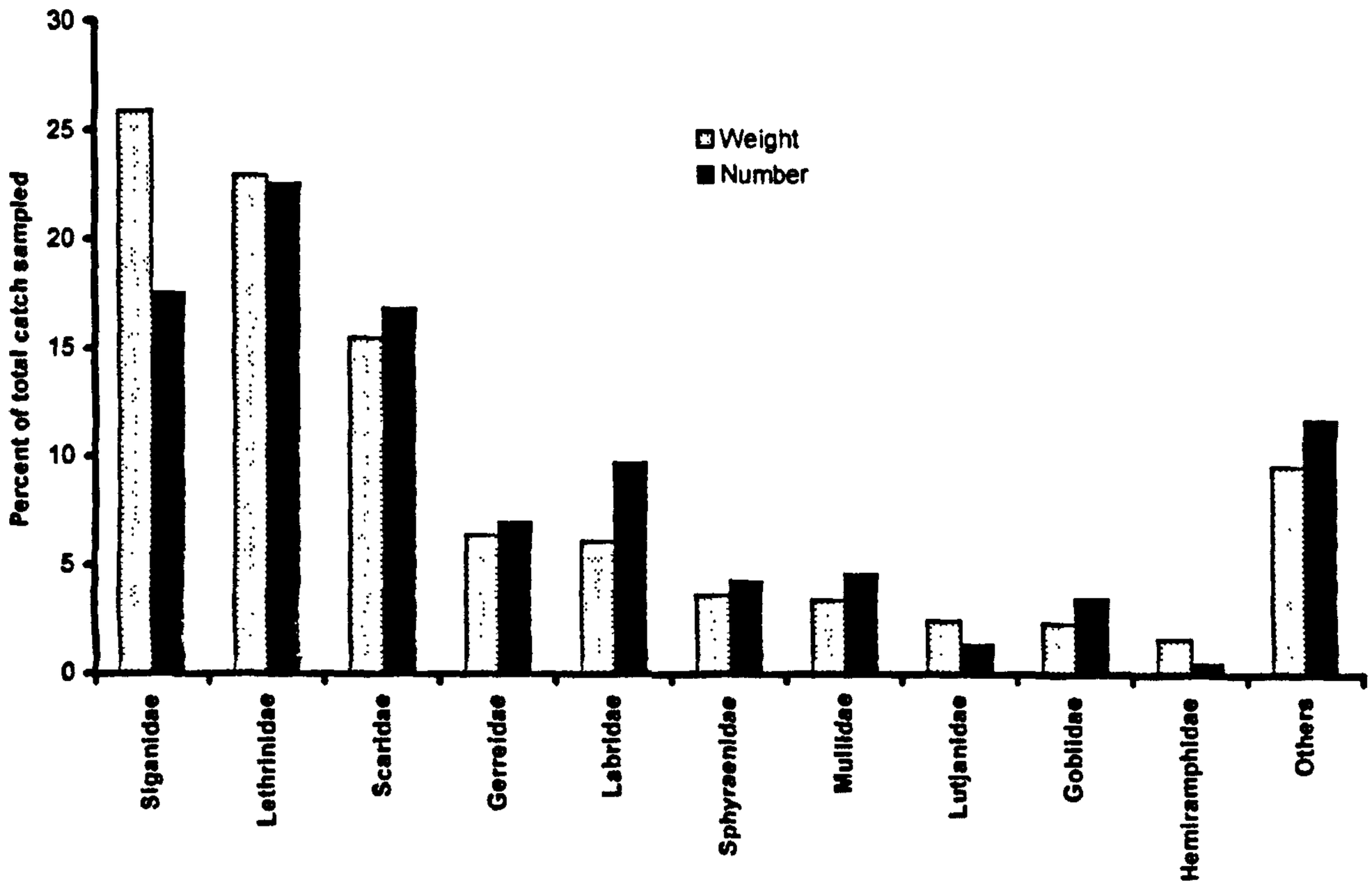
Fig. 1: The ten most abundant species in (a) the seine net fishery and (b) the trap fishery showing percent by weight and by number of total fish sampled.

The percentages of families in the catch are shown in Fig. 2(a), the main families being Siganidae (rabbitfishes) 25.9%, Lethrinidae (emperors) 22.9%, Scaridae (parrotfishes) 15.5%, Gerreidae (mojarras) 6.4% and Labridae (wrasses) 6.2%. The species diversity within these groups varied greatly, for example Siganidae and Gerreidae were dominated by one or two species whilst the Labridae were composed of more than 20 species.

Size of fish

One of the most striking aspects of the net fishery was the small size of the fish caught. The modal length for nine out of the ten most abundant species was 15cm or less whereas the maximum attainable length for seven of these species was more than 35cm. A large proportion of fish in the catches were less than 10cm, a combination of small species such as the wrasse *Stethojulis strigiventer*, and juveniles of larger species such as *Siganus sutor*. These small fish were all eaten locally. Five of the ten most abundant fish in the catch, accounting for nearly 20% of the total catch by weight, were small species of fish, fully grown at 25cm or less: *Gerres oyena, Calotomus spinidens, Stethojulis strigiventer* and *Amblygobius albimaculata*. Other species in the catch could potentially grow to large sizes but were present predominantly as juveniles. For example, the most abundant fish, *Siganus sutor* can potentially grow to over 50cm and was commonly seen in the Quirimba reef flat fisheries catches at 30cm or more. In the seagrass fishery however, the mean length of *Siganus sutor* individuals was just 13cm. *Lethrinus lentjan*, which also reached maximum lengths of over 50cm, had a mean length in the fishery of 14.5cm and a modal length of 10cm. Large adults of *Leptoscarus vaigiensis*, which can reach 35cm, were common. The mean and modal lengths were 13cm for this species but it was present at all life stages from 6cm juveniles upwards.

Length-frequency histograms of some of the commonest species in the net and trap catch are shown in Figs. 3(a)-3(i). It is immediately clear that in the many cases the length distributions for the trap fishery cover a much smaller range of lengths and the lengths are generally greater, for example in *Cheilio inermis* Fig. 3(f), *Calotomus spinidens* Fig. 3(d), *Lethrinus variegatus* Fig. 3(c), *Pteragogus flagellifera* Fig. 3(i). In *Siganus sutor* and *Lutjanus fulviflamma* this trend for longer modal lengths in trap-caught fishes was not followed and each



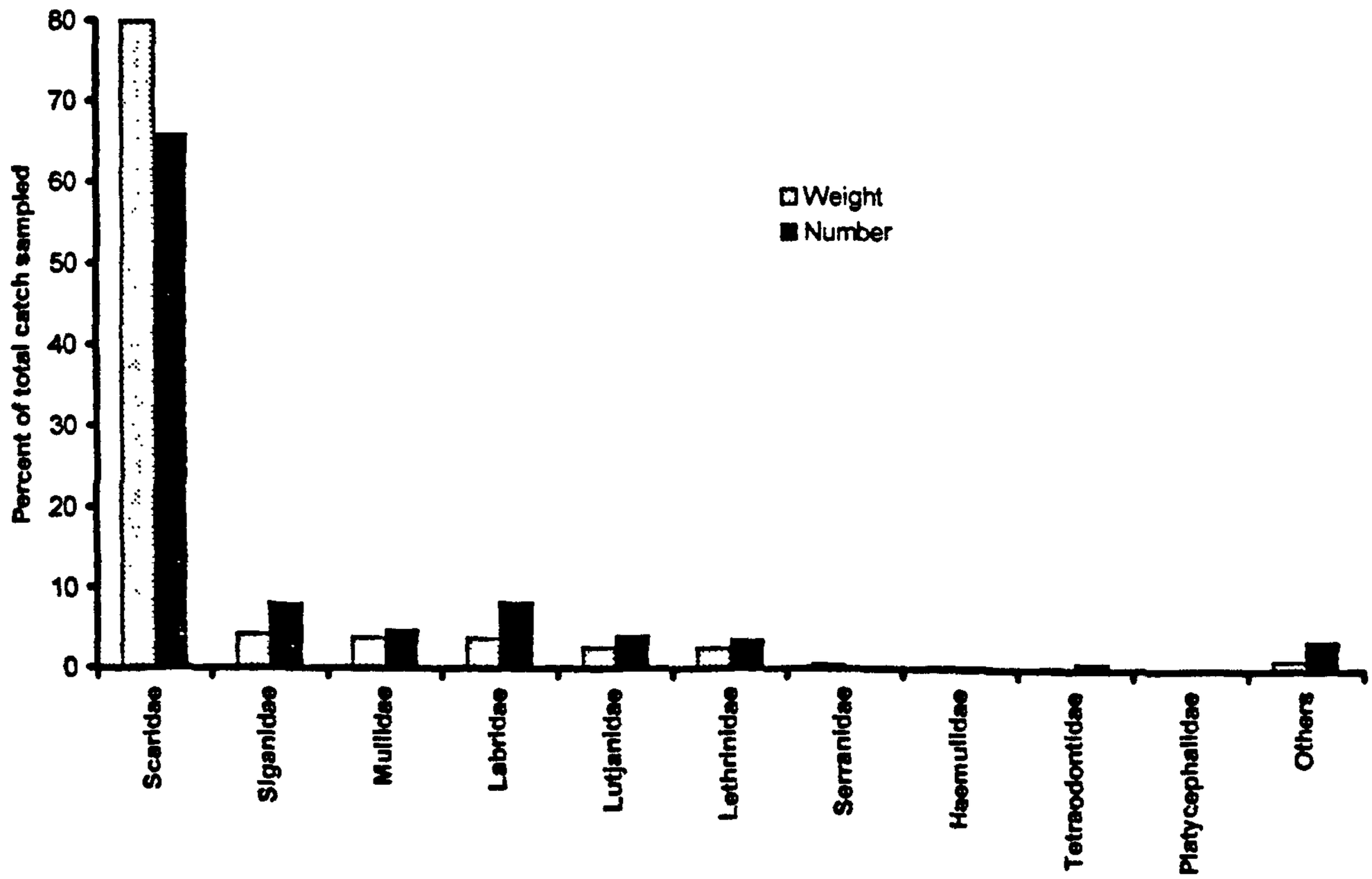
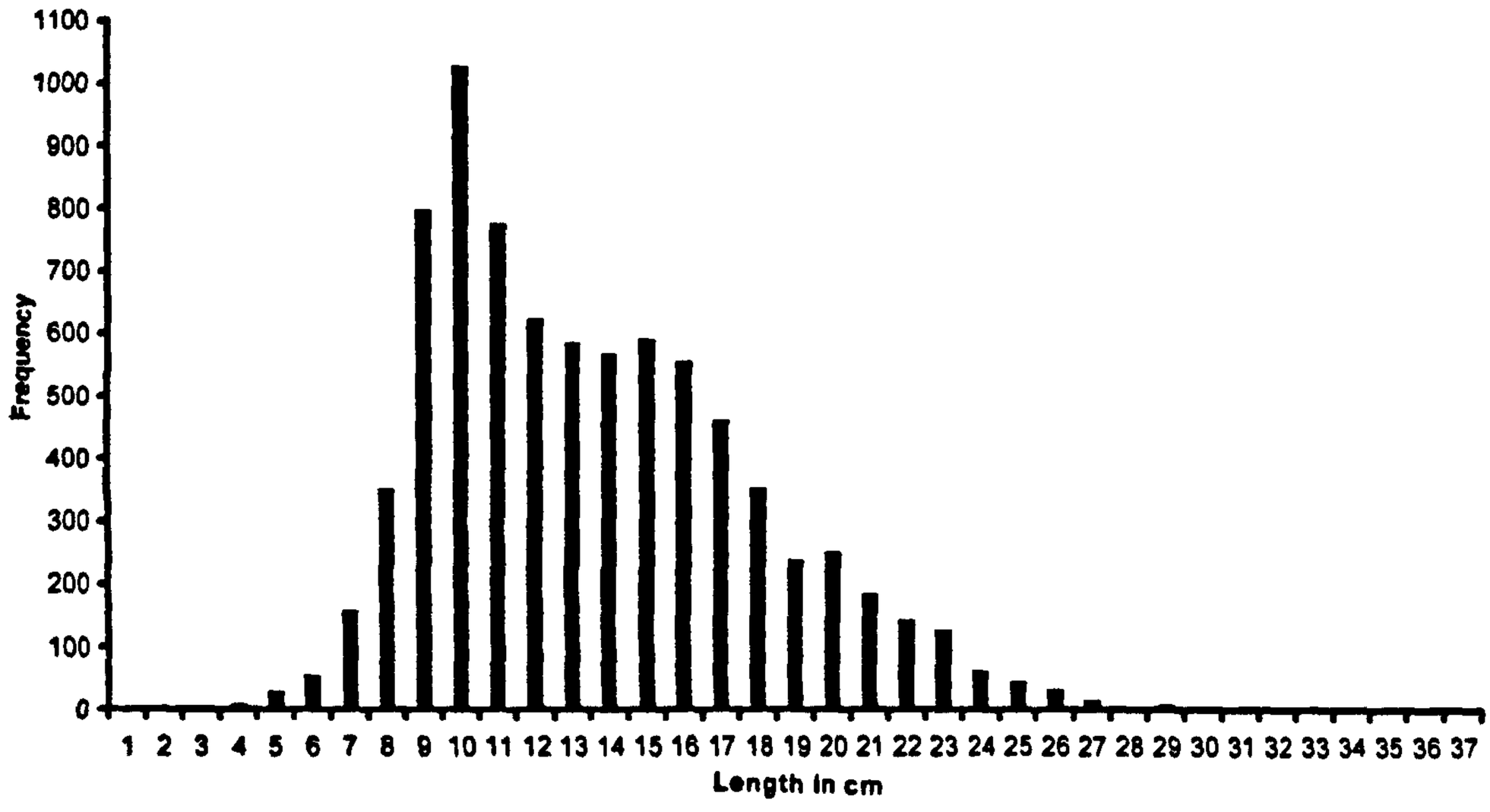


Fig. 2: The ten most abundant families in (a) the seine net fishery and (b) the trap fishery showing the percent by weight and by number of total fish sampled.



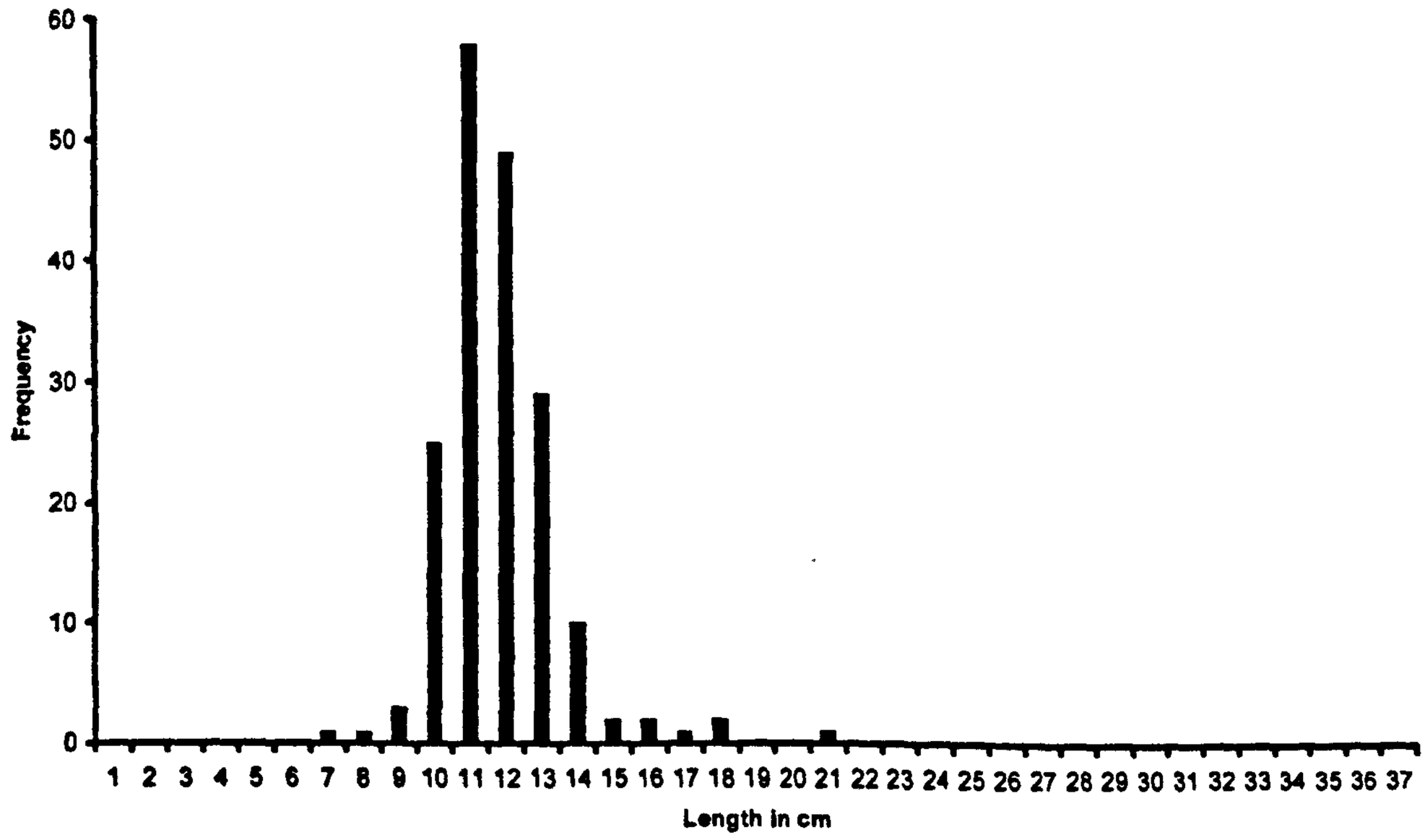


Fig. 3(a) : Length frequency histograms for *Siganus sutor* from the net fishery (top) and the trap fishery (bottom) using all lengths from 1996 and 1997.

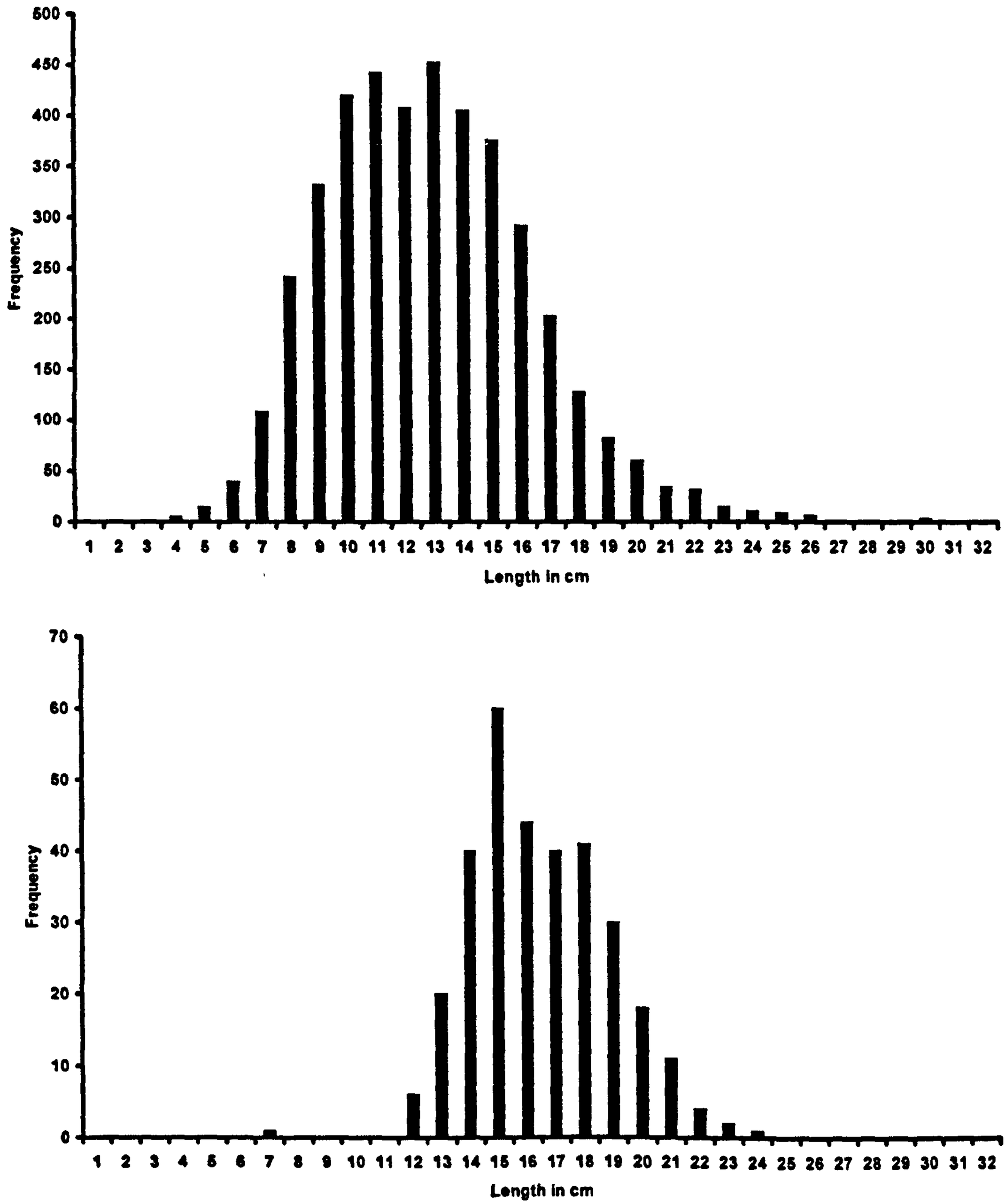


Fig. 3(b): Length frequency histograms for *Leptoscarus vaigiensis* from the net fishery (top) and the trap fishery (bottom) using all lengths from 1996 and 1997.

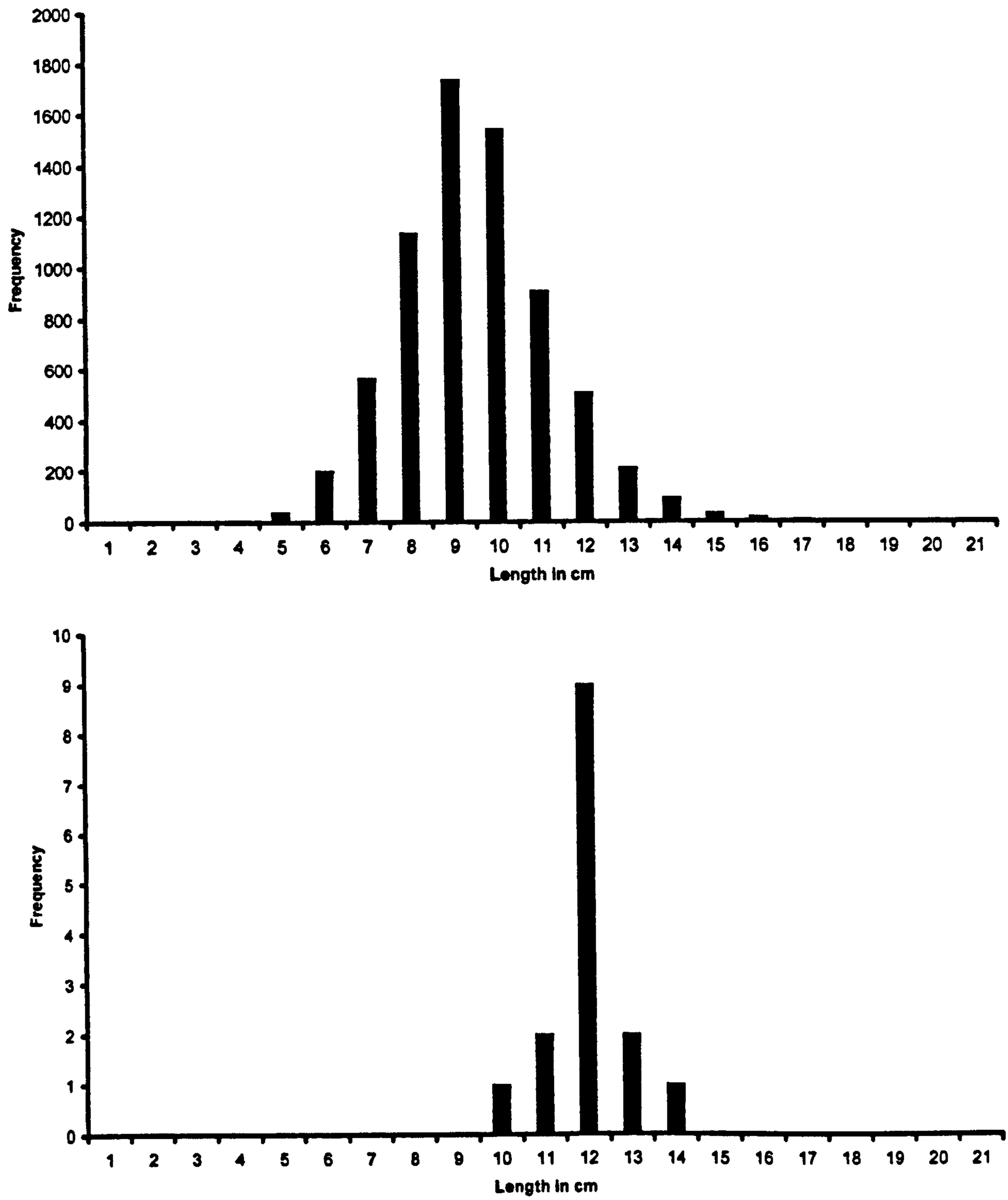


Fig. 3 (c): Length frequency histograms for *Lethrinus variegatus* from the net fishery (top) and the trap fishery (botttom) using all lengths from 1996 and 1997.

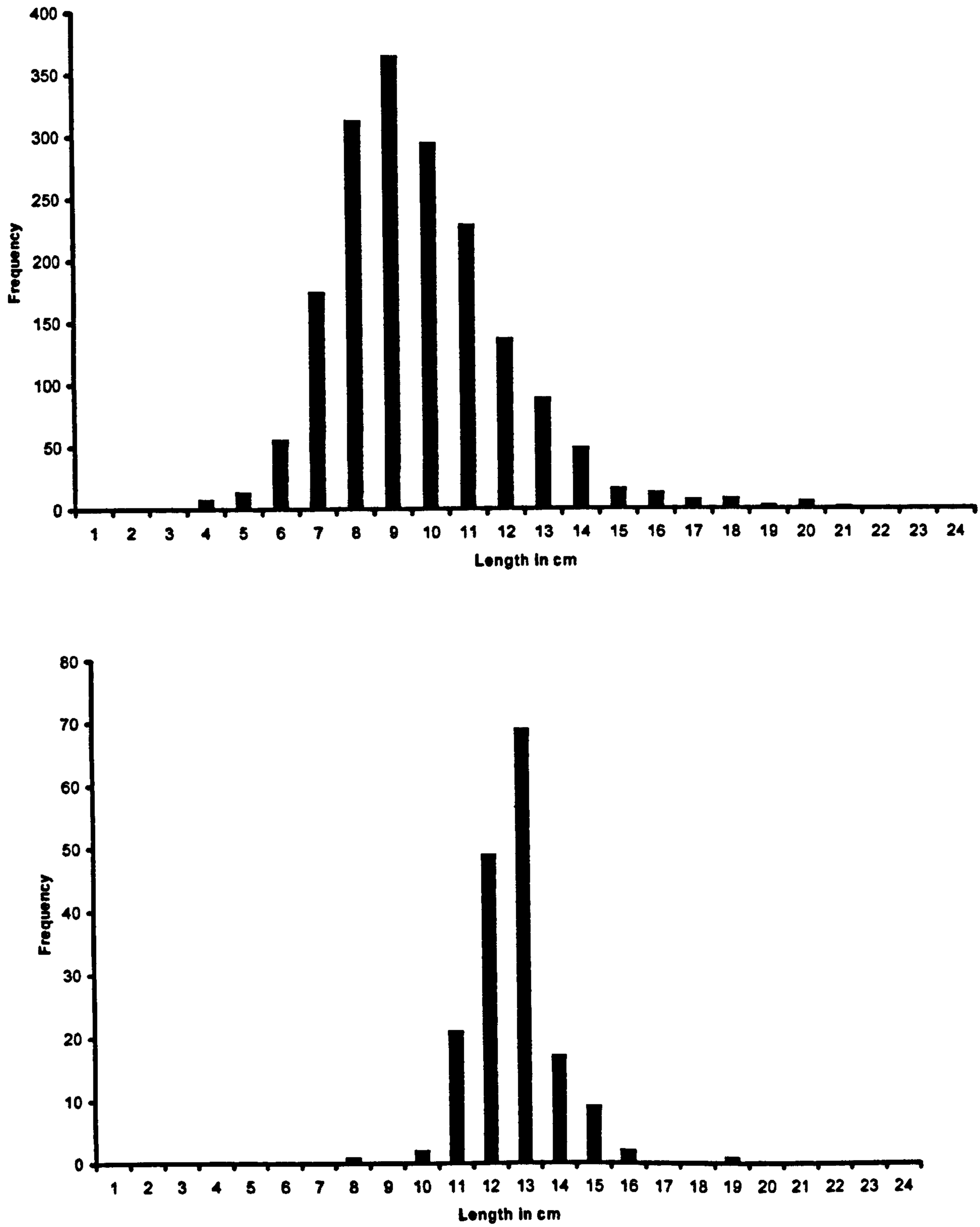


Fig. 3(d): Length frequency histograms for *Calotomus spinidens* from the net fishery (top) and the trap fishery (bottom) using all data from 1996 and 1997.

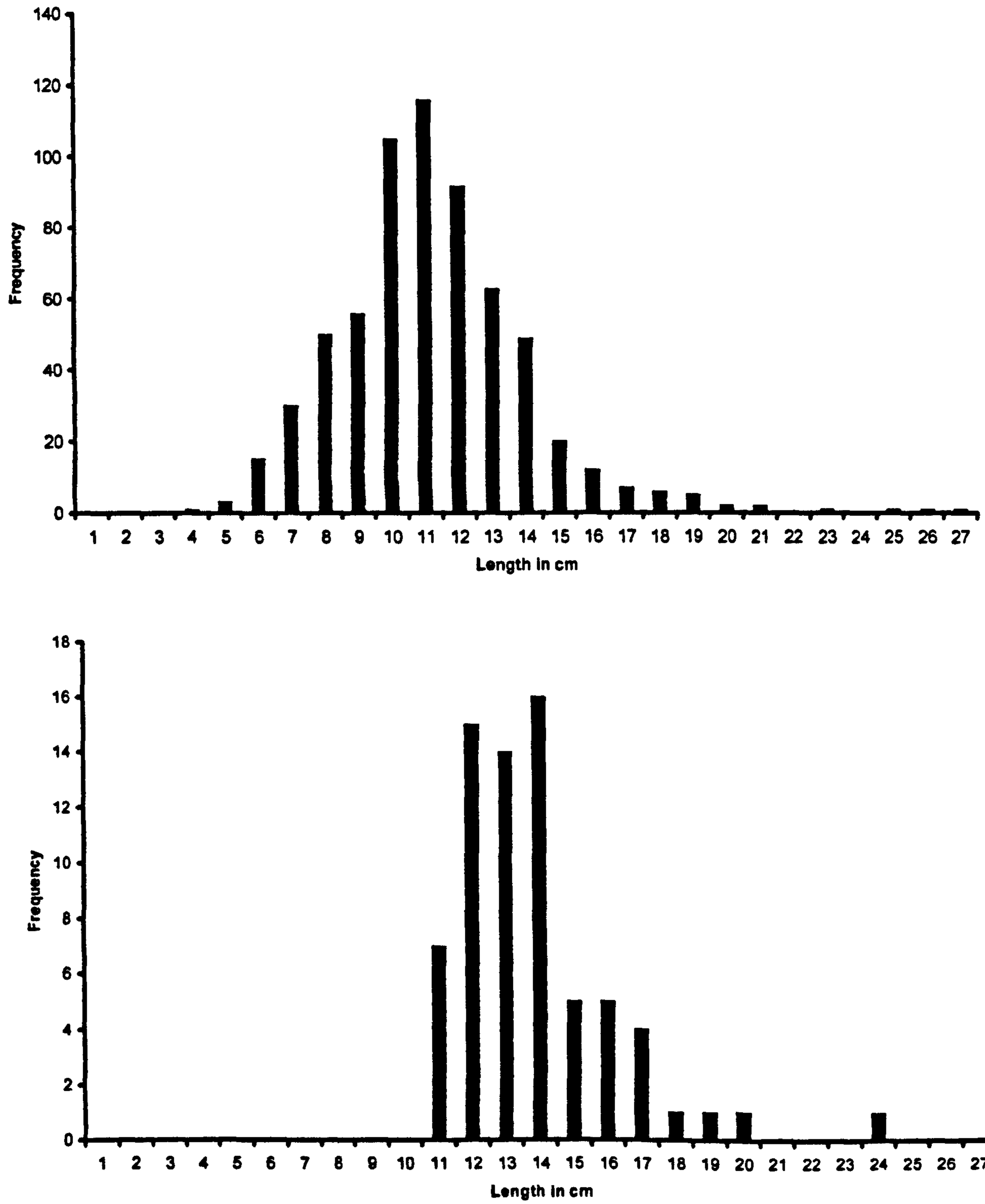


Fig. 3(e): Length frequency histograms for *Parupeneus barberinus* from the net fishery (top) and the trap fishery (bottom) using all lengths from 1996 and 1997.

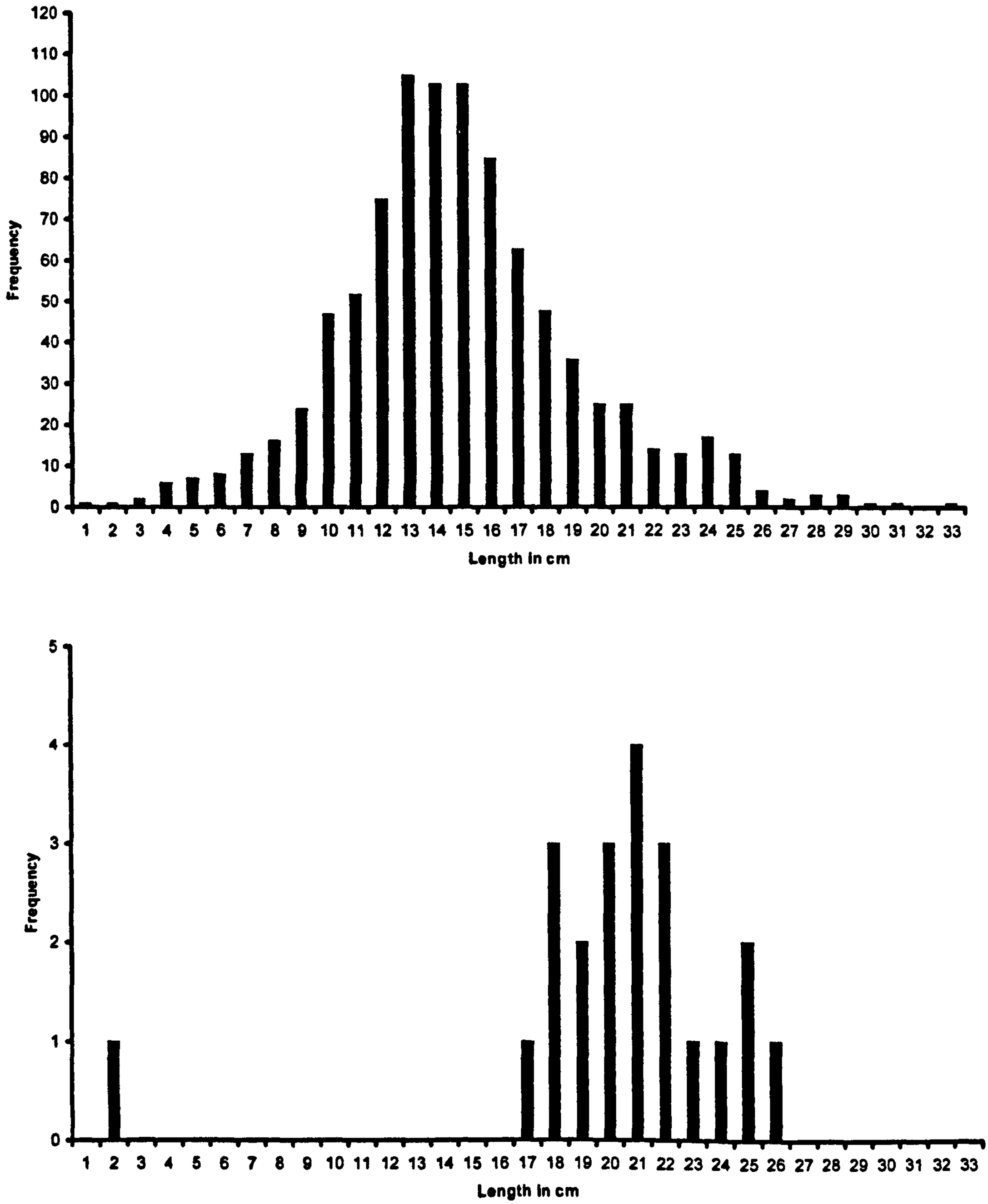


Fig. 3(f): Length frequency histograms for *Cheilio inermis* from the net fishery (top) and the trap fishery (bottom) using all lengths from 1996 to 1997.

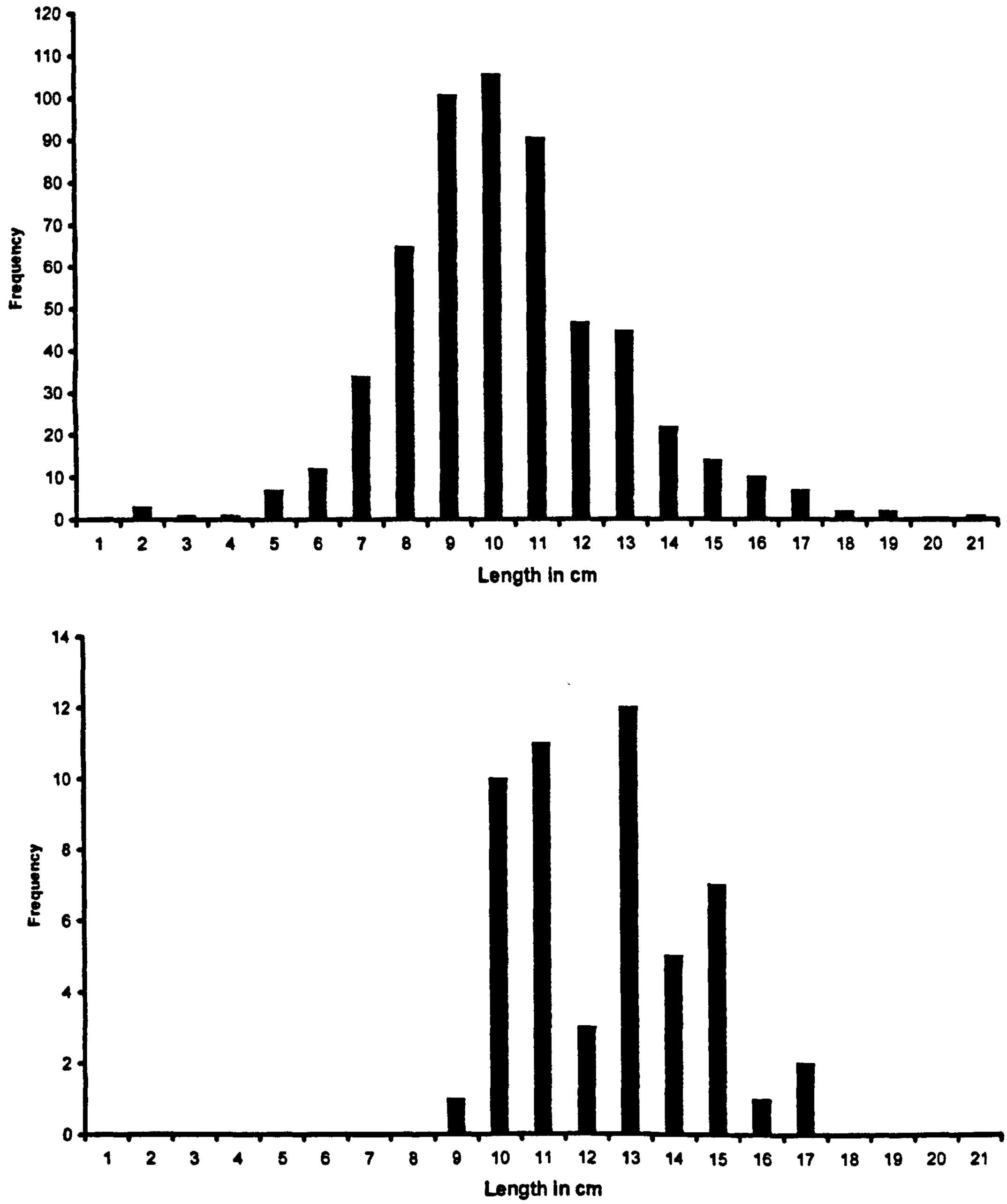


Fig. 3(g): Length frequency histograms for *Lethrinus mahsenoides* from the net fishery (top) and the trap fishery (bottom) using all lengths from 1996 and 1997.

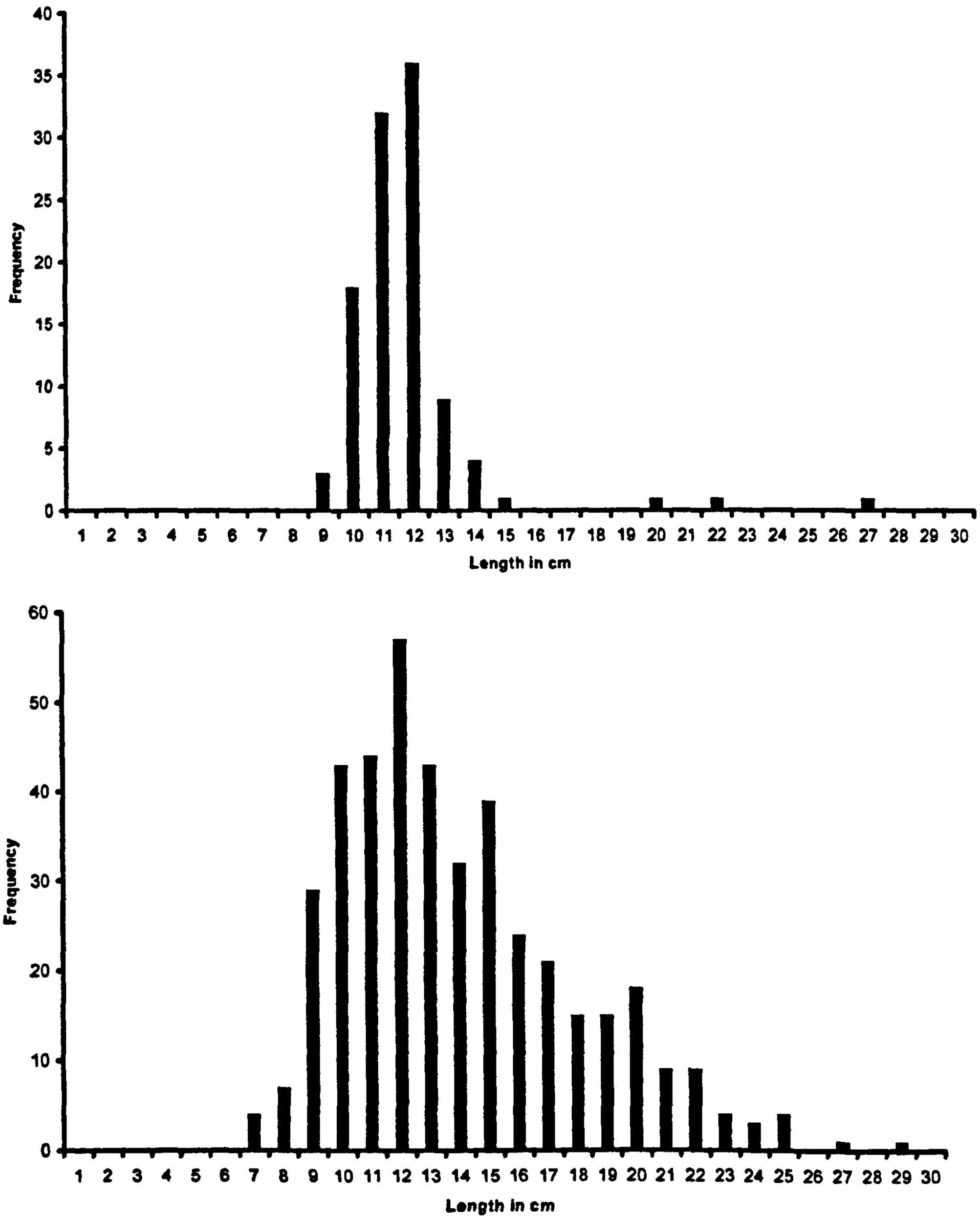
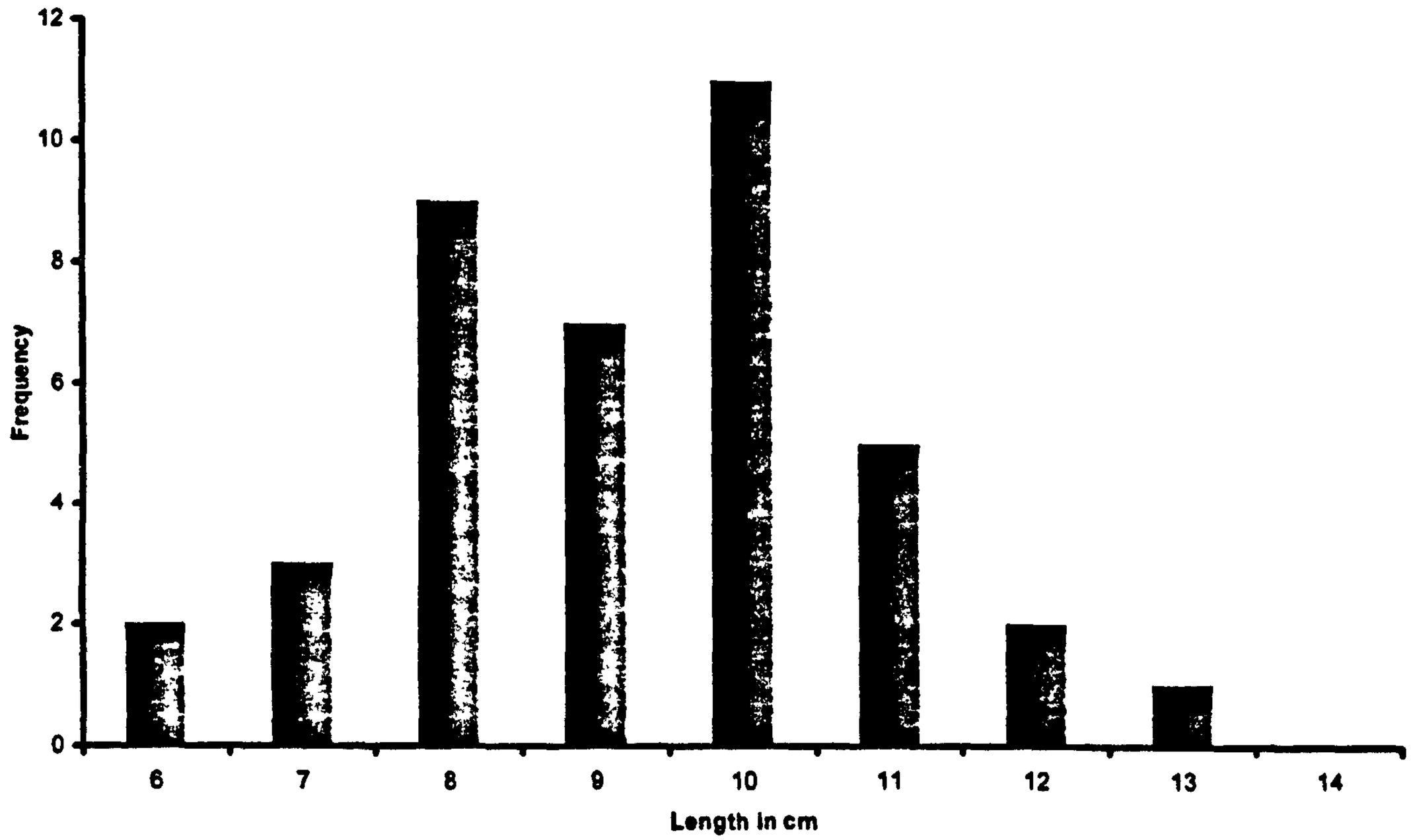


Fig. 3(h): Length frequency histograms for *Lutjanus fulviflamma* from the net fishery (top) and the trap fishery (bottom) using all lengths from 1996 and 1997.



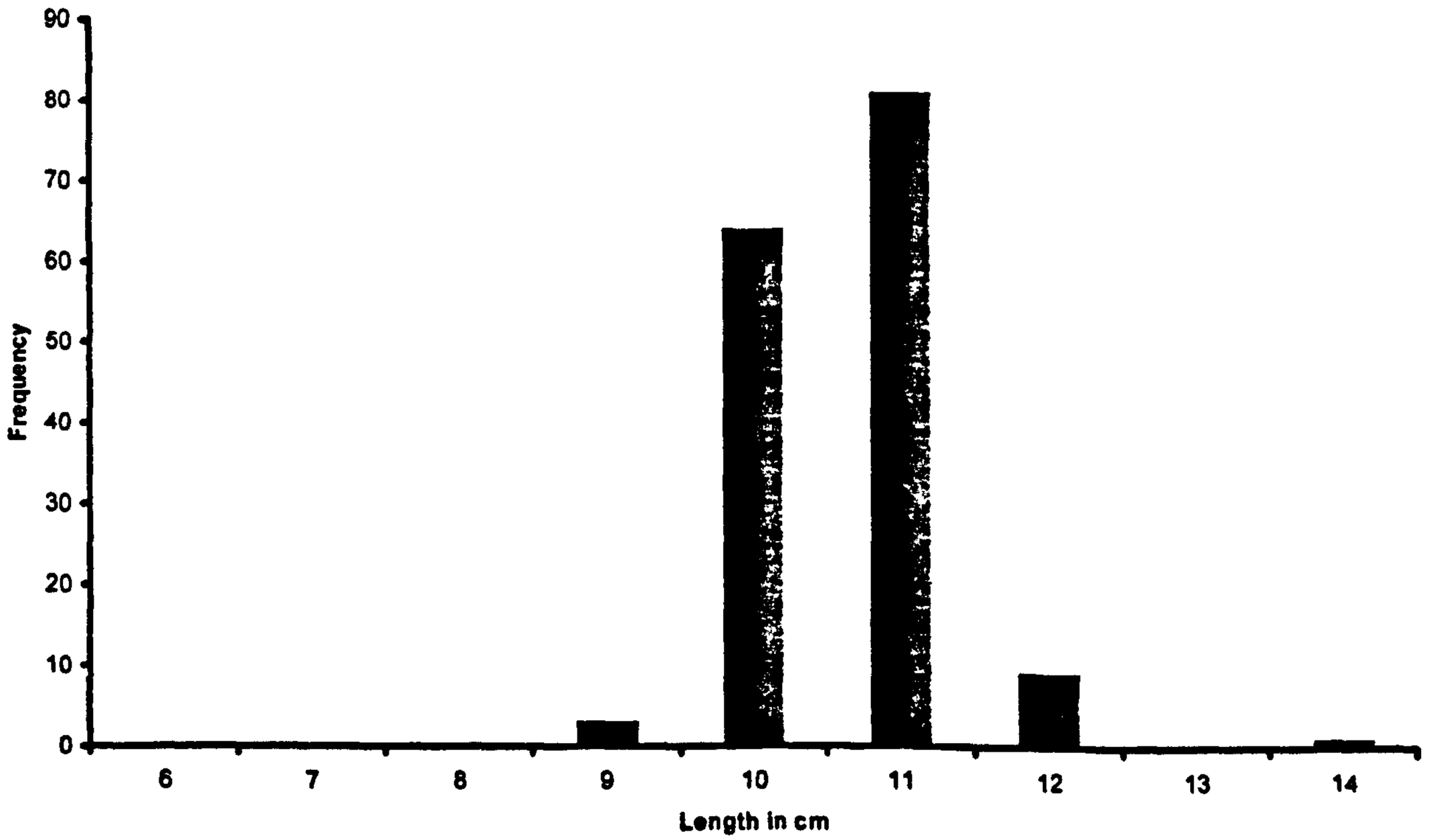


Fig. 3(i): Length frequency histograms for *Pteragogus flagellifera* from the net fishery (top) and the trap fishery (bottom) using all lengths form 1996 and 1997.

of these species have a peak in frequency corresponding with the first of at least three cohorts in the net fishery. More than one cohort or peak in frequency can not really be seen in any trap-caught species. In *Siganus sutor* there were three peaks in length frequency at 10cm and 15cm, 20 cm, whereas in the trap-caught fish there was a single peak at 12cm (Fig. 3(a)). In *Lutjanus fulviflamma* the single peak in frequency in the trap fishery at 12cm corresponded with the first cohort in the net fishery at 12cm where it was followed by peaks at 15 and 20cm.

In *Leptoscarus vaigiensis* (Fig. 3(b)) the range of lengths in the net fishery spans over 25cm, from 4cm to 30cm but there are no obvious cohorts in the pooled data for all samples (the population structure of this species is examined in more detail in Chapter 4). In the trap fishery the main distribution of *Leptoscarus vaigiensis* falls between 12cm and 24, with possible evidence of another cohort peak at 18cm.

Seasonality in net fishing catches

There were no great differences in the catch composition between the two years. A summary of the monthly sample details is shown in Table 3. In the majority of species no obvious seasonal patterns could be discerned for the six months in which data were collected in both years. One would expect the most striking seasonal differences to be found between the dry season and the wet season, but because of logistical constraints data were only collected during the mainly dry months of May to November. The monthly relative abundance and biomass for some key species are described below and illustrated in Figs. 4(a) to 4(l).

Siganus sutor (Fig. 4(a))

The percentage of *Siganus sutor* in the catches remained stable around 25-30% of weight and around 15% of numbers sampled each month. There was a slight decrease in abundance of this species around the months of July and August during both years. Percentages by number were highest around May-June and November.

Table 3: A summary of the monthly samples taken from the seine net fishery during May to November 1996 and 1997. Species richness is Margelef's Index which incorporates the sample size (see Methods).

Year	Month	Number of fish sampled	Weight of fish sampled in kg	Species number	Family number	Species Richness
1996	May	1418	74.5	67	30	9.1
	June	5472	173.9	90	37	10.3
	August	3630	181.1	97	35	11.7
	September	1771	102.3	87	35	11.5
	October	2467	107.6	85	32	10.8
	November	7174	211.9	90	35	10.0
1997	May	3855	132.9	91	38	10.9
	June	1723	71.8	65	32	8.6
	July	3102	127.7	80	34	9.8
	August	5817	177.0	80	34	9.1
	September	1574	72.9	70	30	9.4
	October	3184	91.7	76	29	9.3
	November	5417	218.6	87	32	10.0
	Total	46629	1743.8	225	46	20.8

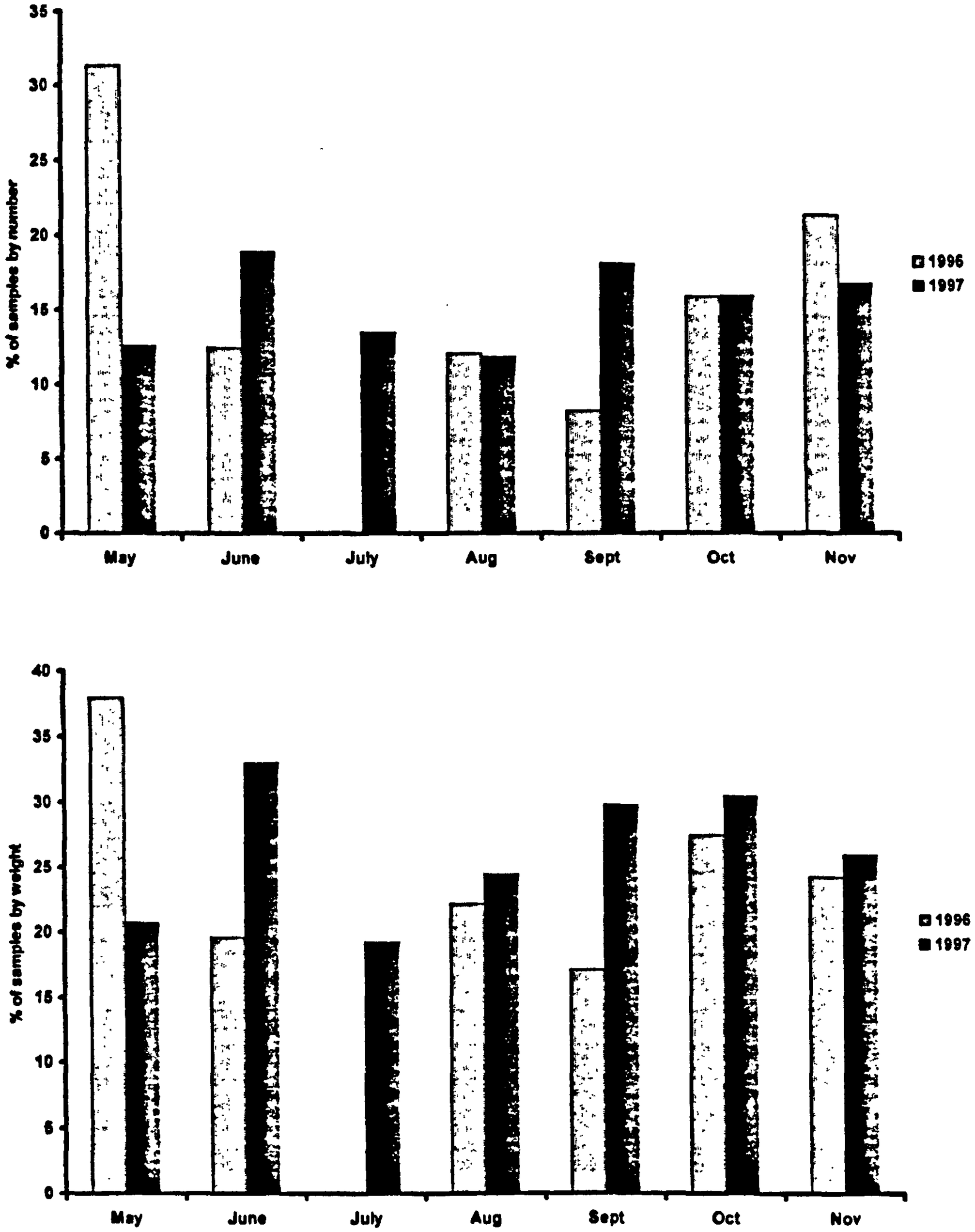


Fig. 4(a): Percentages of *Siganus sutor* in terms of numbers of individuals (top) and catch weight (bottom) in the total monthly samples for 1996 and 1997.

Lethrinus lentjan (Fig. 4(b))

The abundance of *Lethrinus lentjan* was low (around 5% by weight) during the first few study months (May, June, July) during both years, rising towards the latter months of the year, particularly September and November (15 –25% by weight).

Leptoscarus vaigiensis (Fig. 4 (c))

Abundances of *Leptoscarus vaigiensis* were higher around June and November (12%) and lowest in September (5%) in both years.

Lethrinus variegatus (Fig. 4(d))

Lethrinus variegatus peaked in number in September in both years (around 20%) and there was also a peak in numbers in June 1996. Weights varied between 5 and 10% and peaked around July-August.

Gerres oyena (Fig. 4(e))

There seemed to be very little correspondence between monthly samples from each year apart from very low abundance in November with 3% by weight and number, whereas in the other months abundance varied between 5 and 10% weight and number.

Calotomus spinidens (Fig. 4(f))

This species peaked in numbers and weights in June and November, with lows in August and September. High numbers were around 5% and lows less than 2%, whereas weights were high at around 7% and low around 2%.

Sphyraena flavicauda (Fig. 4(g))

There was a noticeable increase in the numbers and biomass of *Sphyraena flavicauda* in August of both years. This would be the coolest time of the year and the middle of the dry season. The majority of these barracuda were small juveniles. In 1997 *Sphyraena barracuda* rose from less then 2% of the catch by number for the other sample months to 16% by number and by weight in both 1996 and 1997 the proportion rose to over 6% of the catch. There was also a smaller peak in November in 1996.

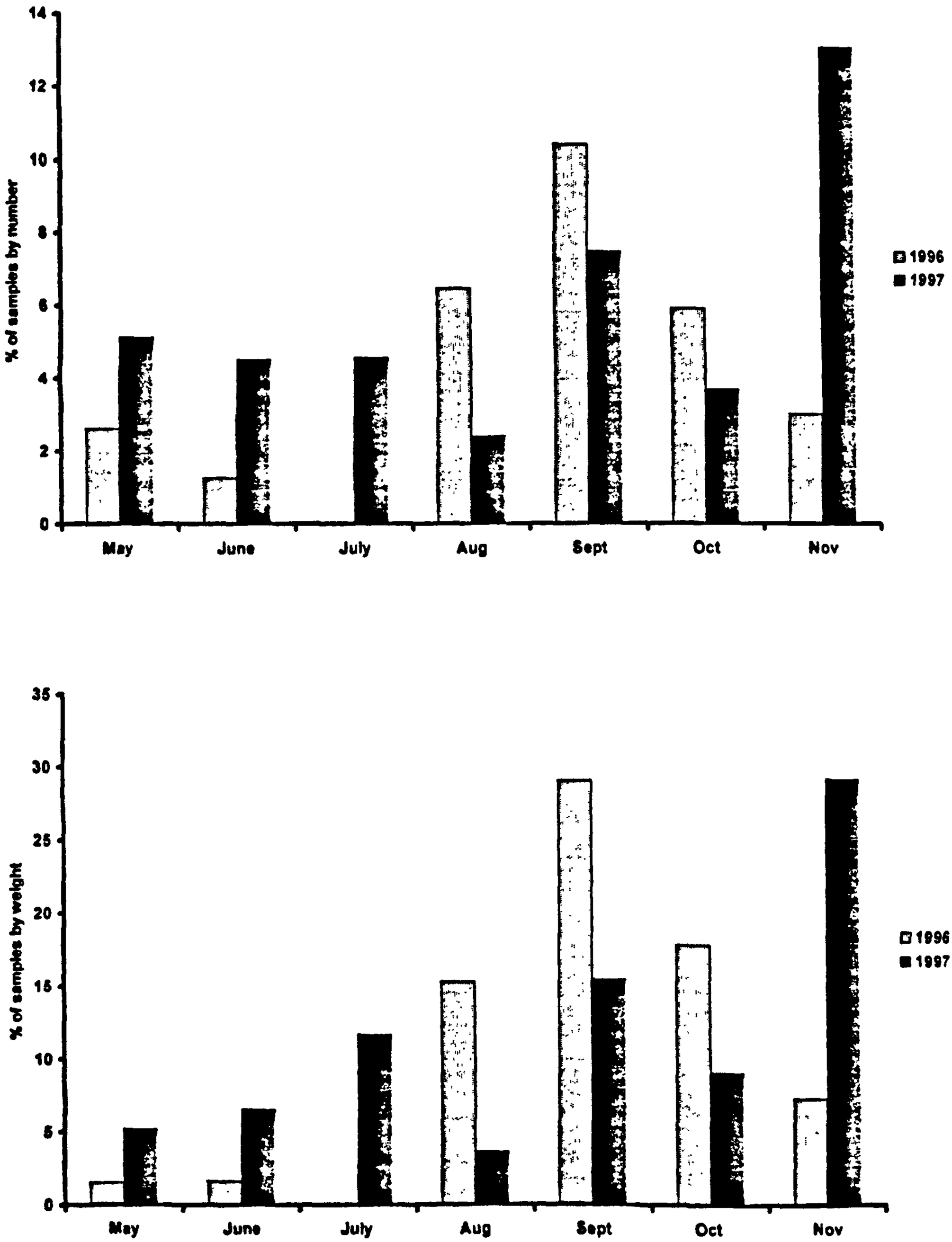
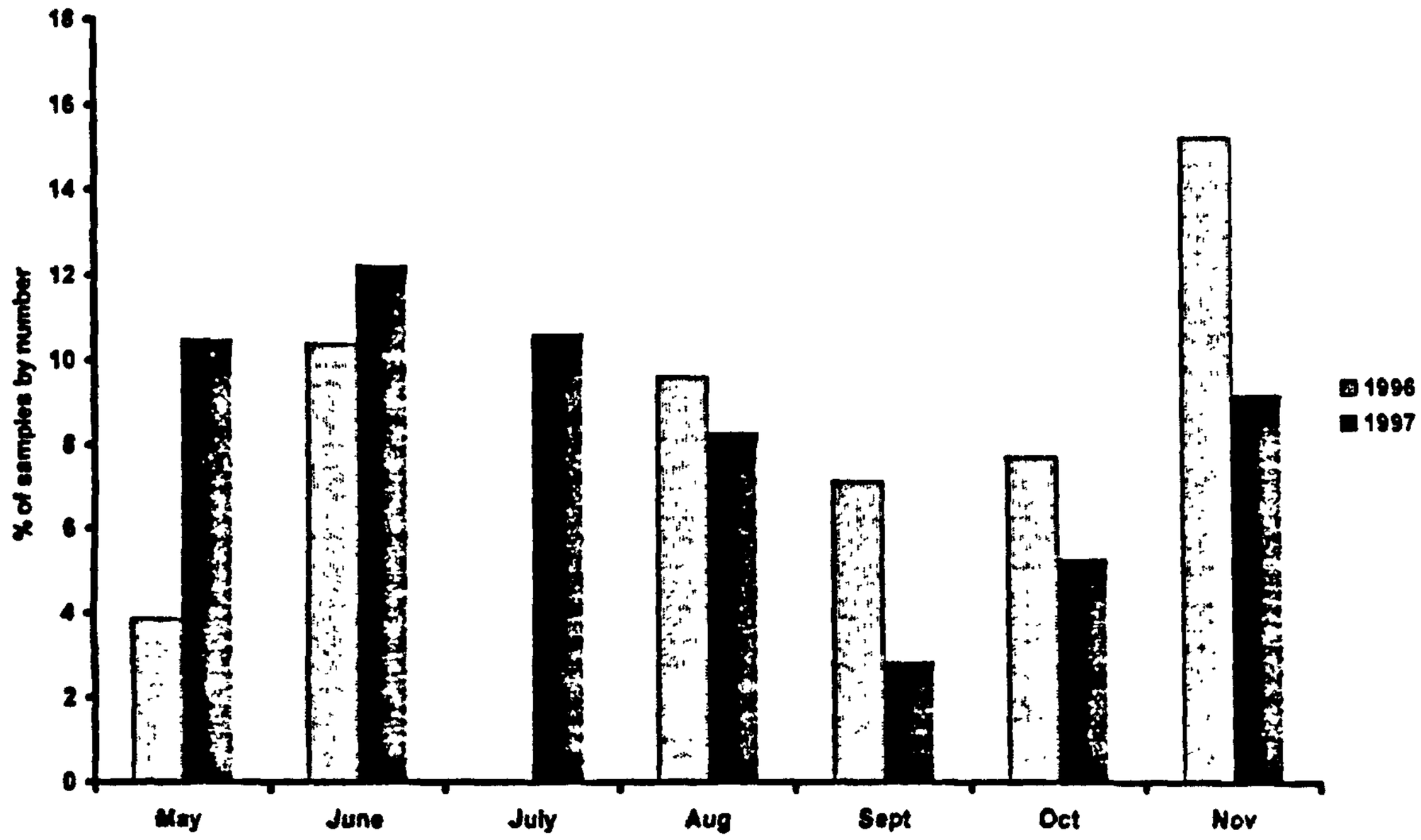


Fig. 4(b): Percentages of *Lethrinus lentjan* in terms of numbers of individuals (top) and catch weight (bottom) in the total monthly samples for 1996 and 1997.



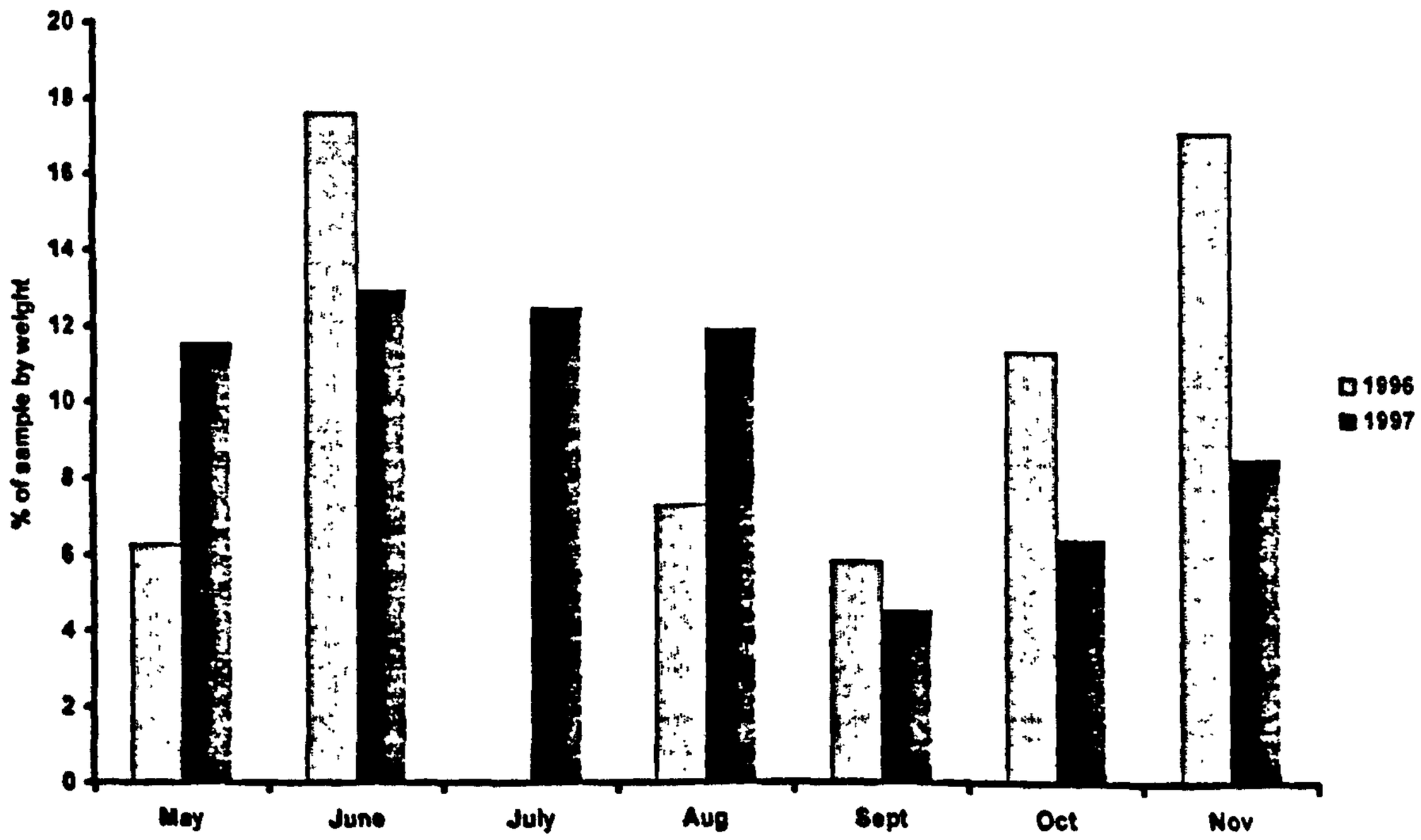


Fig. 4(c): Percentages of *Leptoscarus vaigiensis* in terms of numbers of individuals (top) and catch weight (bottom) in the total monthly samples for 1996 and 1997.

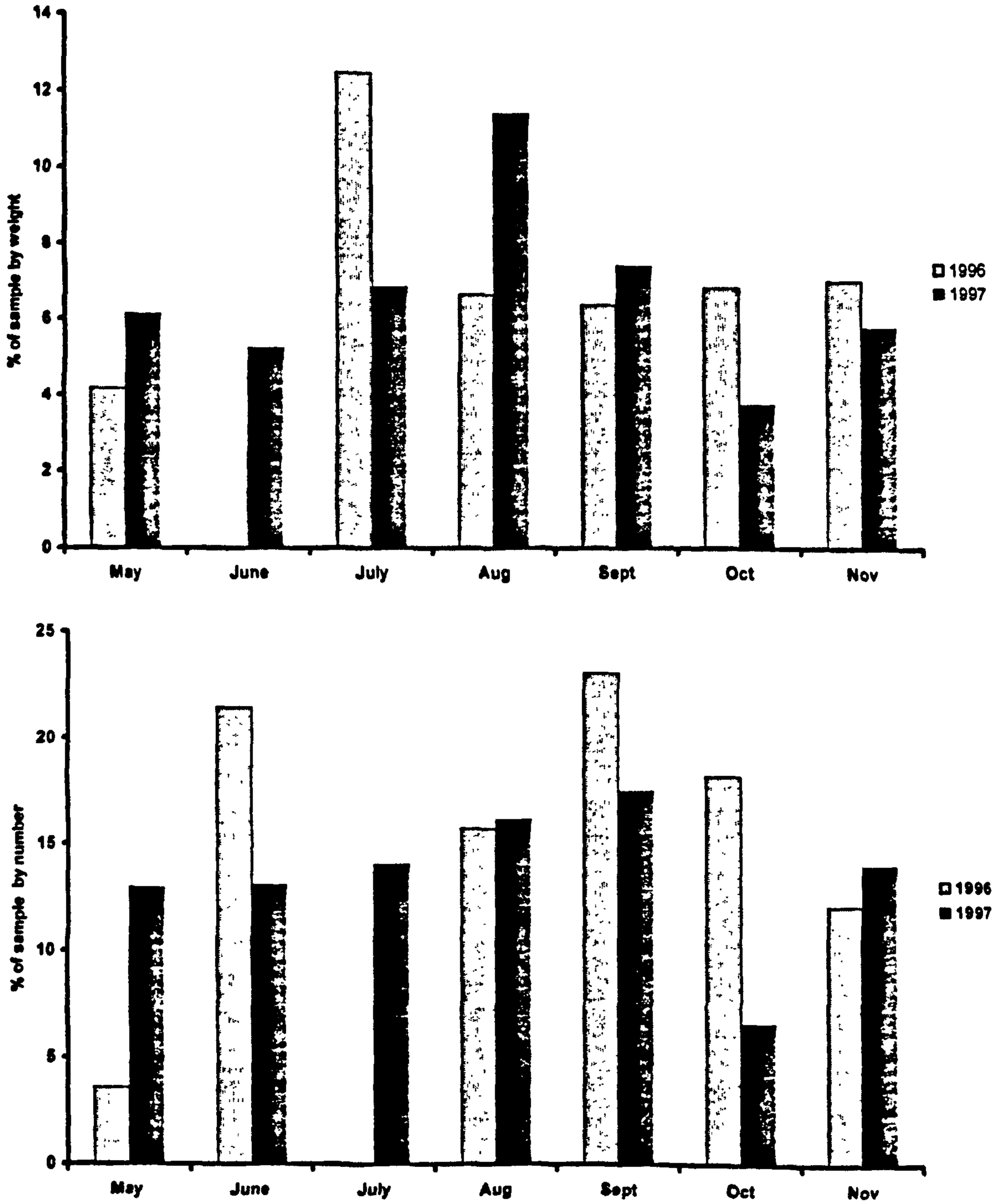


Fig. 4(d): Percentages of *Lethrinus variegatus* in terms of number of individuals (top) and catch weight (bottom) in the total monthly samples for 1996 and 1997.

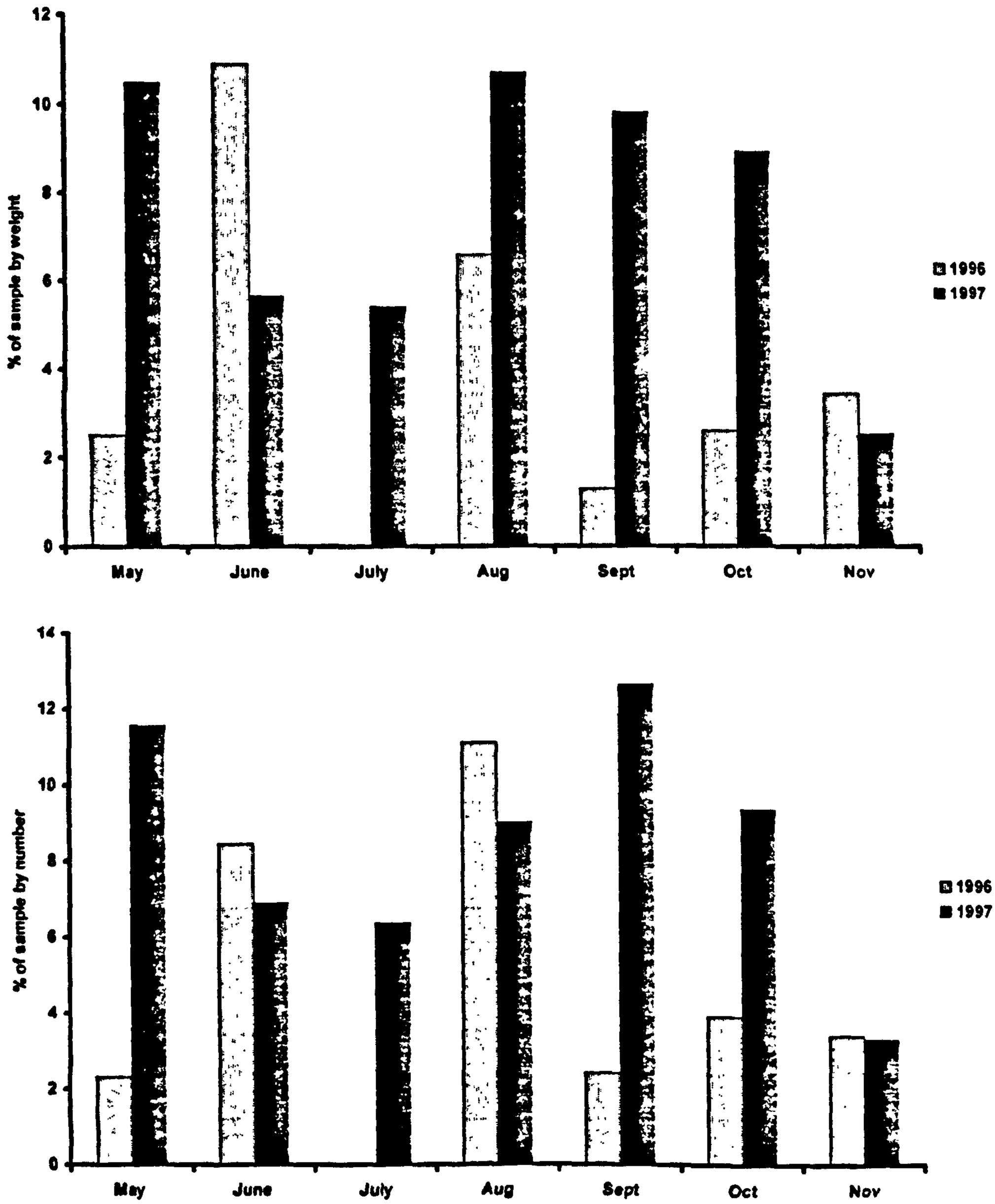


Fig. 4(e): Percentages of *Gerres oyena* in terms of number of individuals (top) and catch weight (bottom) in the total monthly samples for 1996 and 1997.

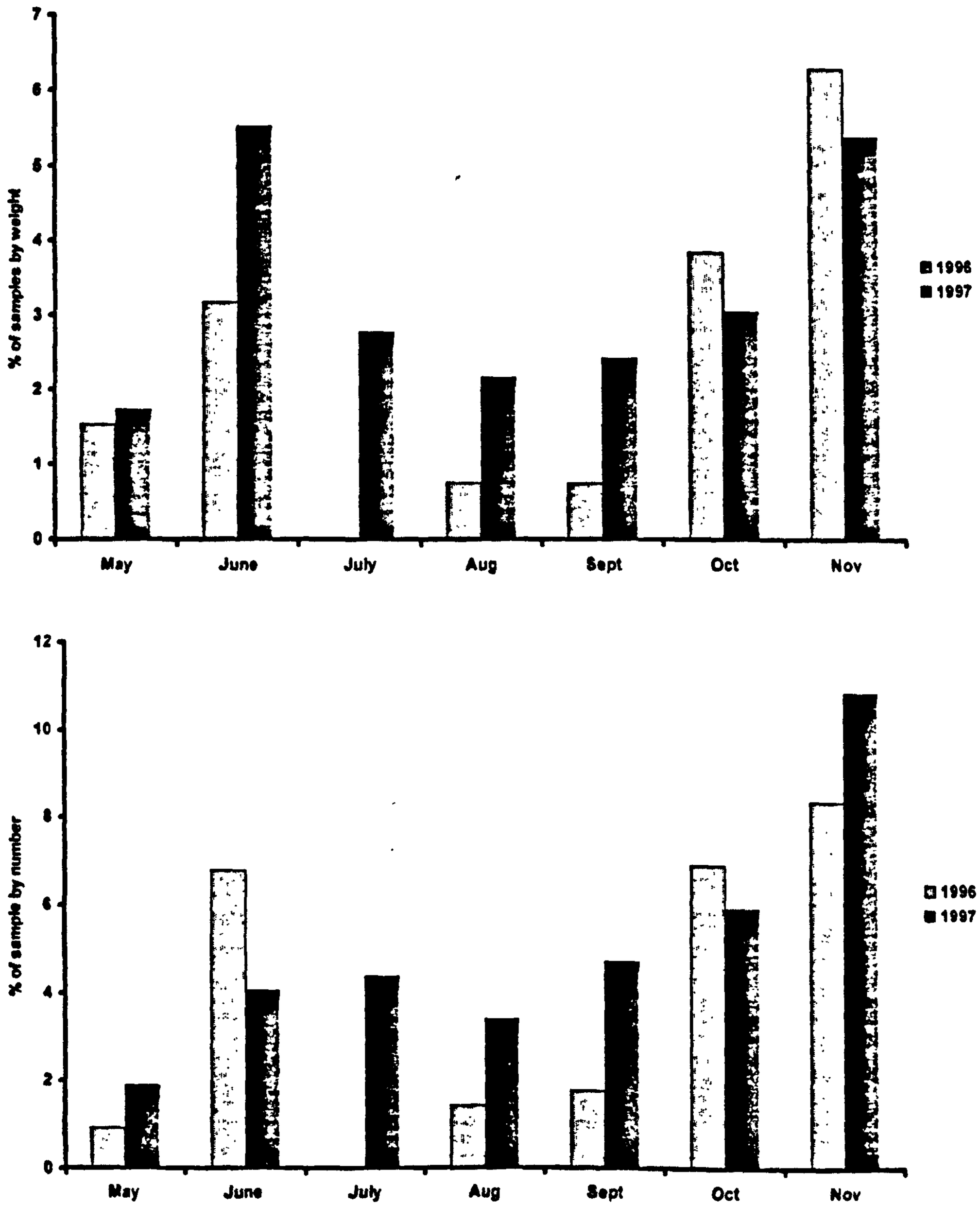


Fig. 4(f): Percentages of *Calotomus spinidens* in terms of number of individuals (top) and catch weight (bottom) in the total monthly samples for 1996 and 1997.

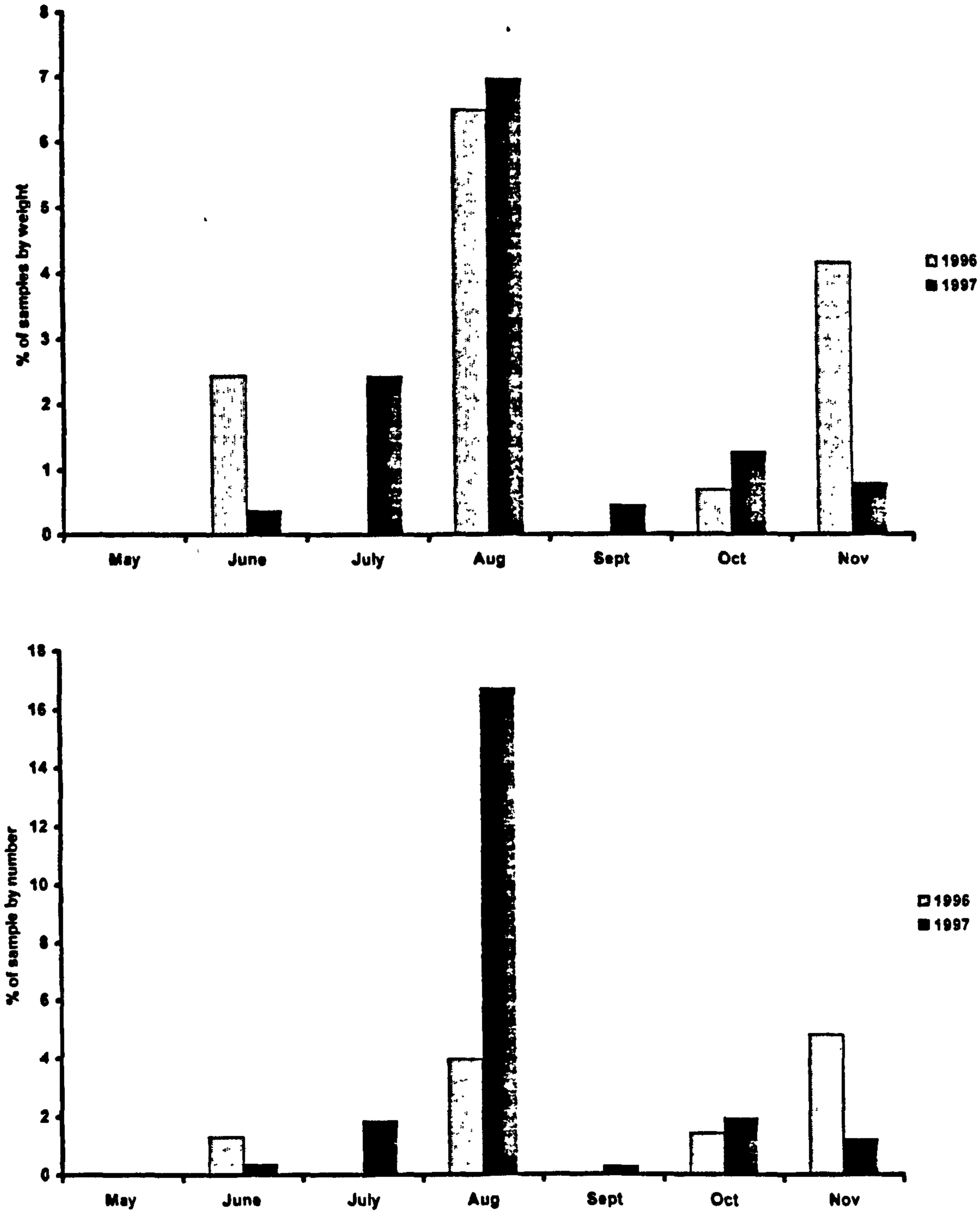


Fig. 4(g): Percentages of *Sphyraena flavicauda* in terms of numbers of individuals (top) and catch weight (bottom) in the total monthly samples for 1996 and 1997.

Stethojulis strigiventer (Fig. 4(h))
No obvious seasonal patterns were evident.

Amblygobius albimaculatus (Fig. 4(i))
No obvious seasonal patterns were evident but there seemed to be a lower abundance in May of both years.

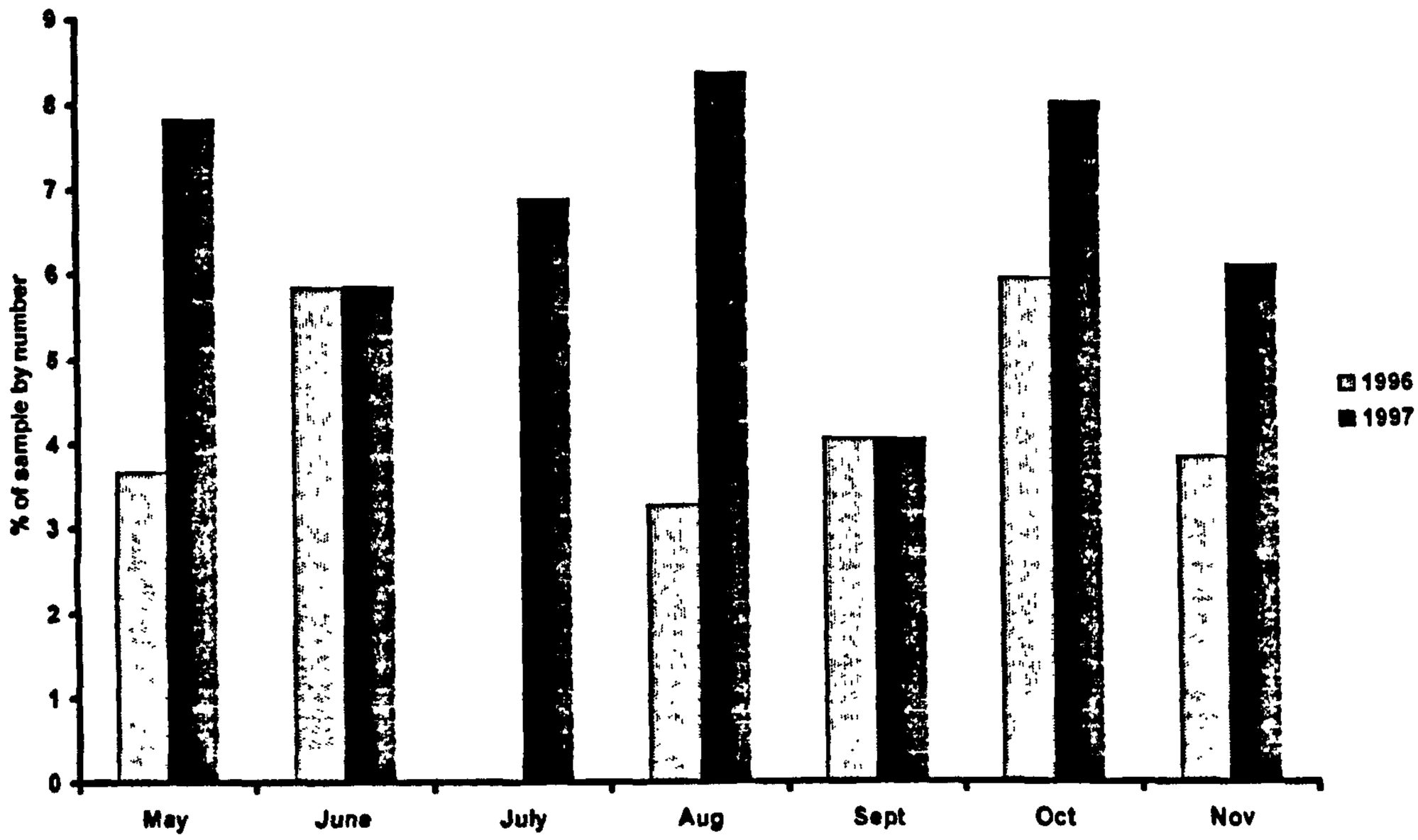
Lutjanus fulviflamma (Fig. 4(j))
In both years the abundance of *Lutjanus fulviflamma* rose in October and November when temperatures were rising at the beginning of the summer rainy season. Abundance doubled from around 1.5% by weight from May to September to 3% in October and November.

Scolopsis ghanam (Fig. 4(k))
The abundance of *Scolopsis ghanam* appeared to decrease from May to November both years, from 4% to 1% by number and 2.5 to 1% by number.

Lethrinus mahsenoides (Fig. 4(l))
There was a peak in number and weight in November of both years.

Trap Catch Composition

The composition of trap catches by species is shown in Fig. 1(b) and by families in Fig. 2(b), and further details about the key species in the trap fishery can be seen in Table 2. From a total of 3544 fish sampled from trap catches 61 species were identified from 24 families. The trap fishery was dominated by the seagrass parrotfish *Leptoscarus vaigiensis* which accounted for over 85% of the total weight of fish sampled. *Siganus sutor* and *Calotomus spinidens* were an important component of the catch in the trap fishery too but *Lethrinus lentjan* was very rarely caught in traps. The wrasse *Pteragogus flagellifera*, the goatfish *Parupeneus barberinus* and the snapper *Lutjanus fulviflamma* all accounted for more than 3% of the total catch sampled. The mean lengths of fish caught in traps were generally higher than those caught in the nets because very small fish (less than 10cm) were not caught in traps as the mesh was larger than that of nets (see Chapter 2). The mean lengths of *Leptoscarus vaigiensis*, *Lethrinus*



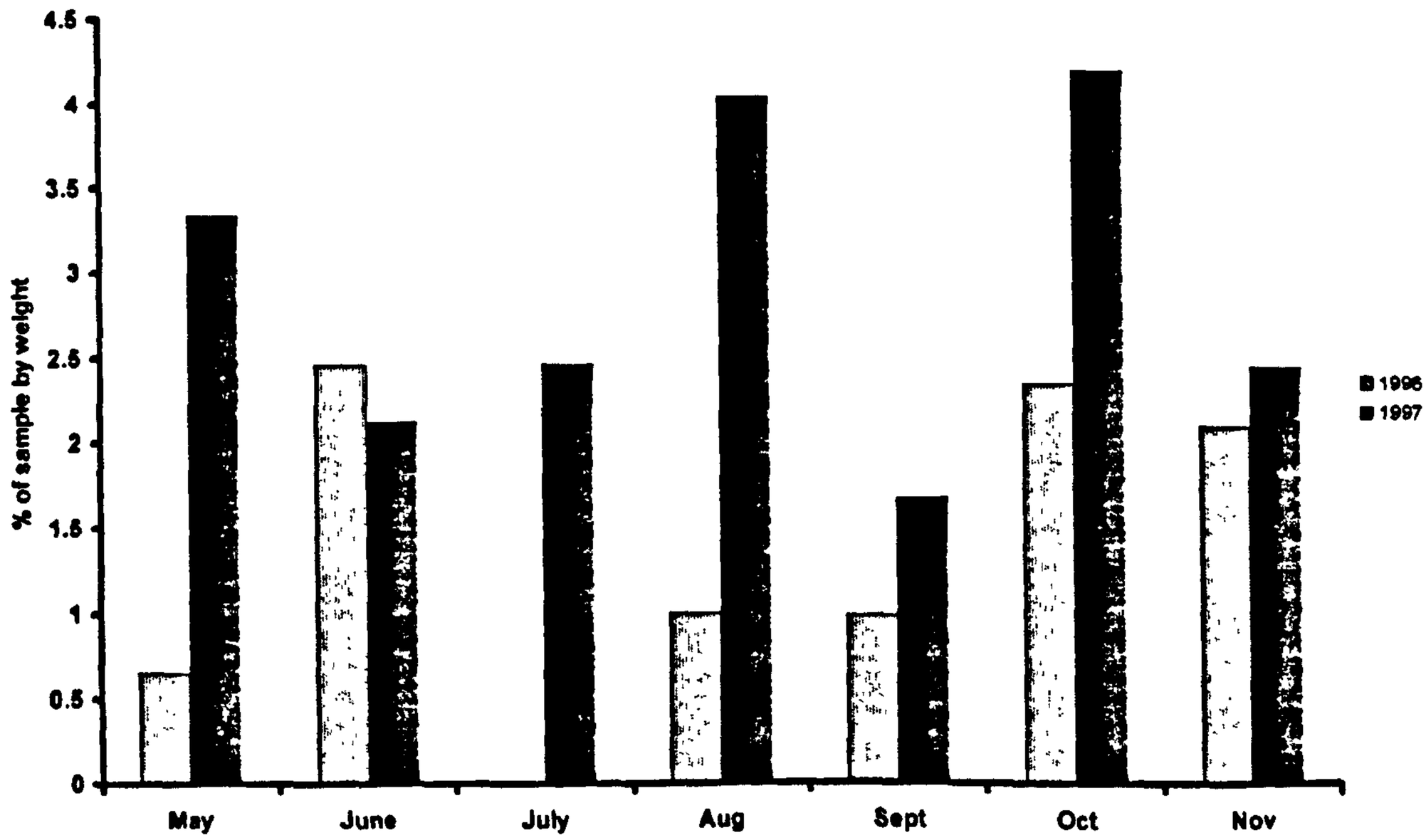


Fig. 4(h): Percentages of *Stethojulis strigiventer* in terms of numbers of individuals (top) and catch weight (bottom) in the total monthly samples for 1996 and 1997.

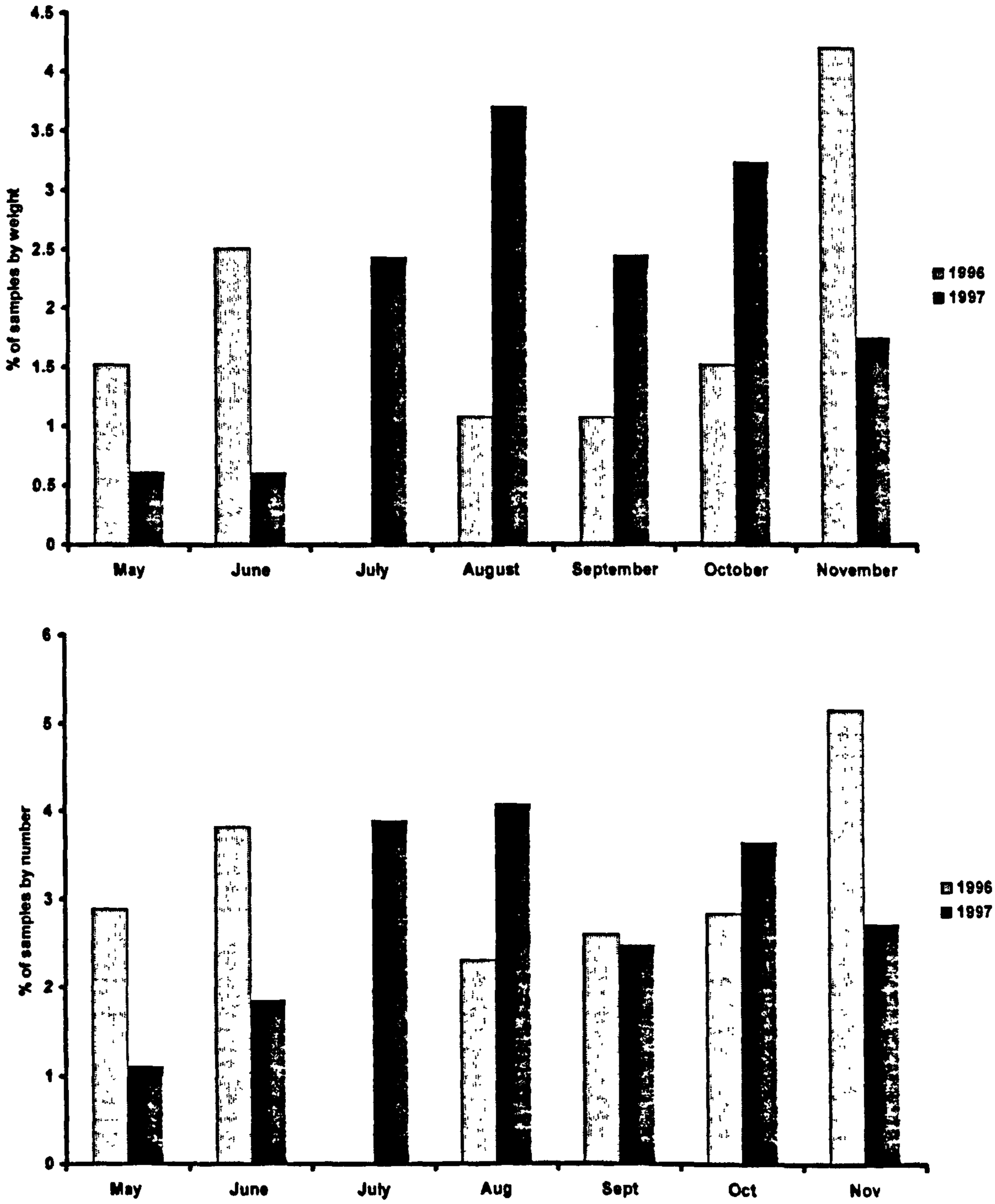
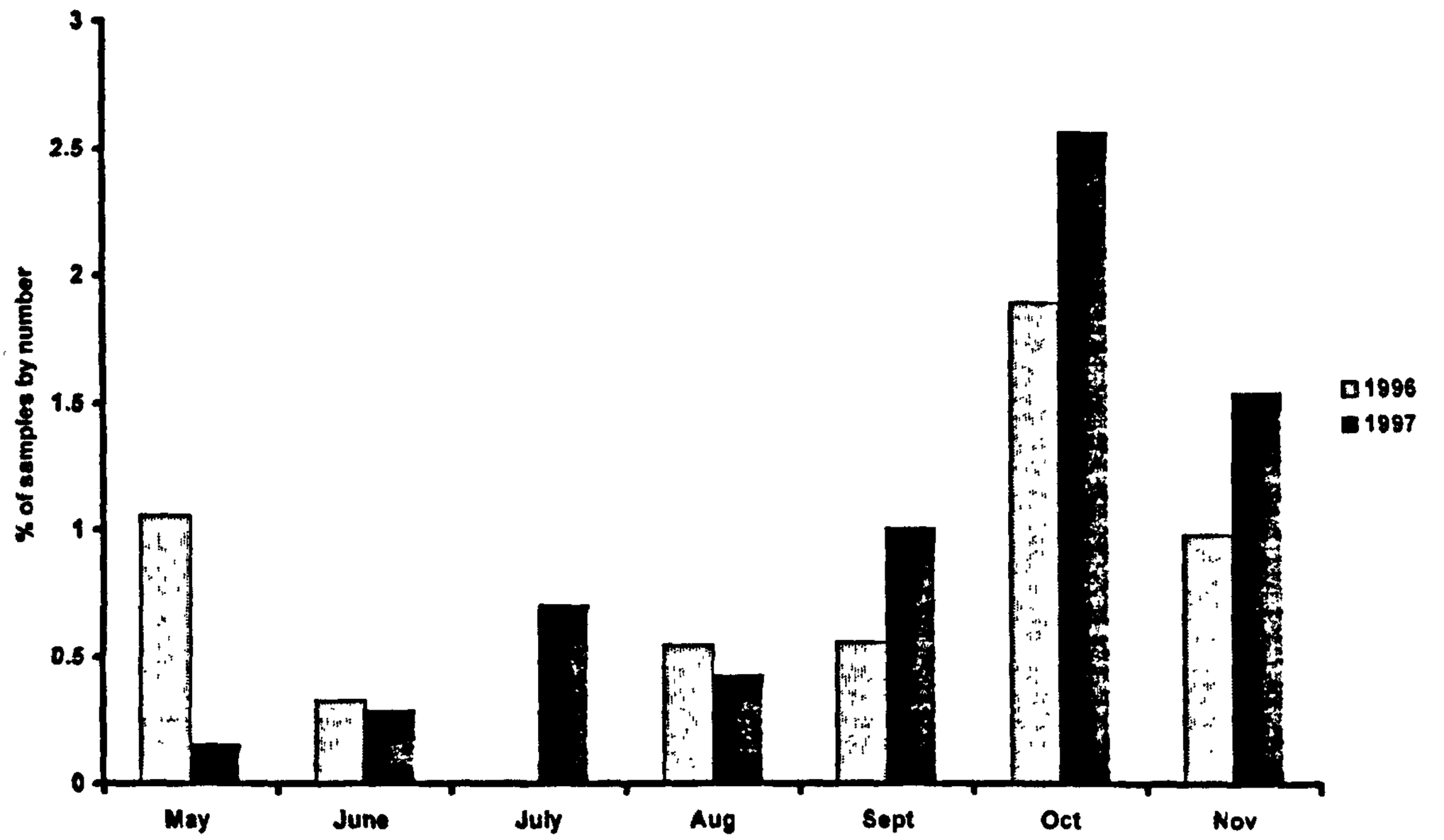


Fig. 4(i): Percentages of *Amblygobius albimaculatus* in terms of number of individuals (top) and catch weight (bottom) in the total monthly samples for 1996 and 1997.



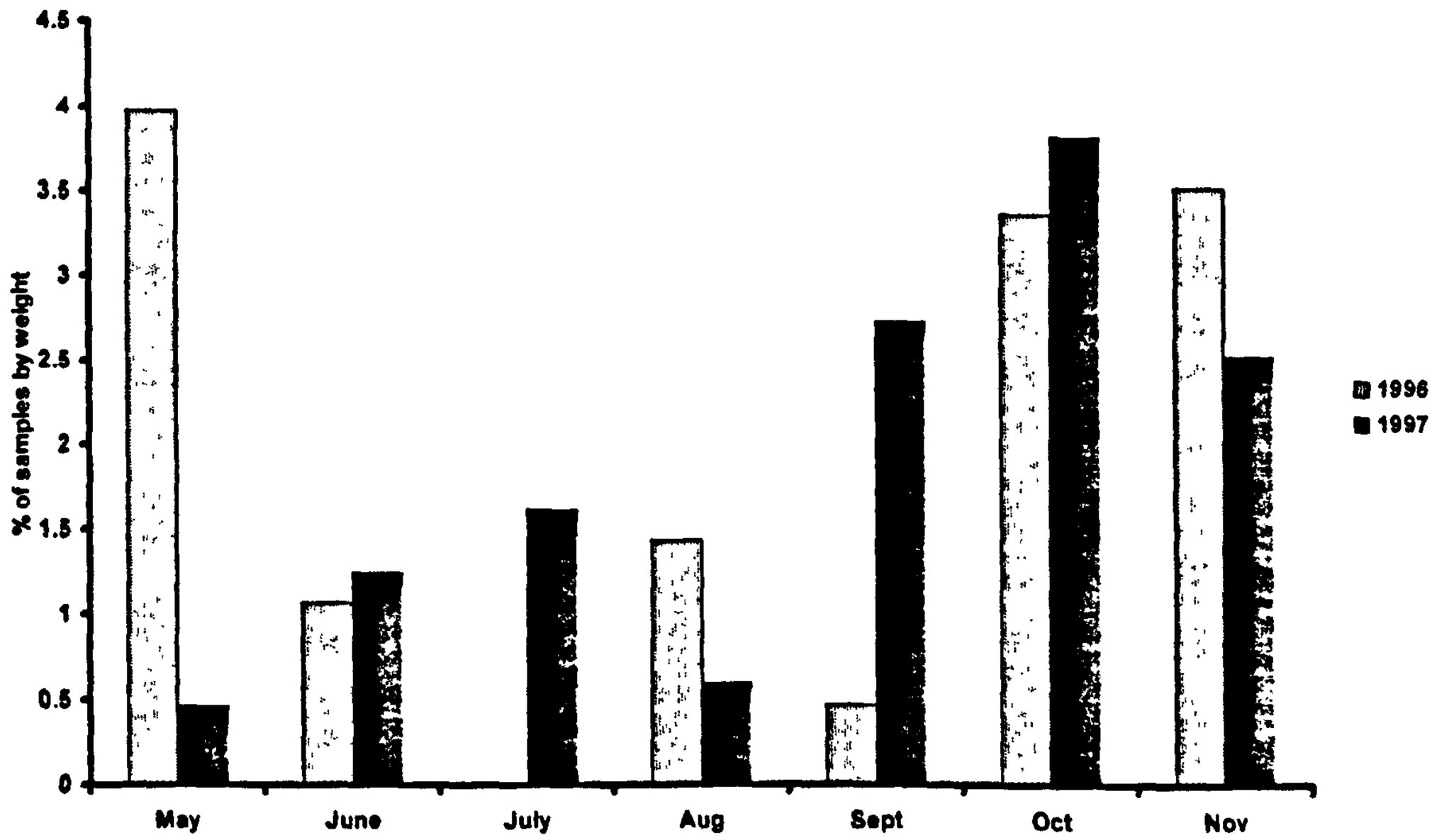
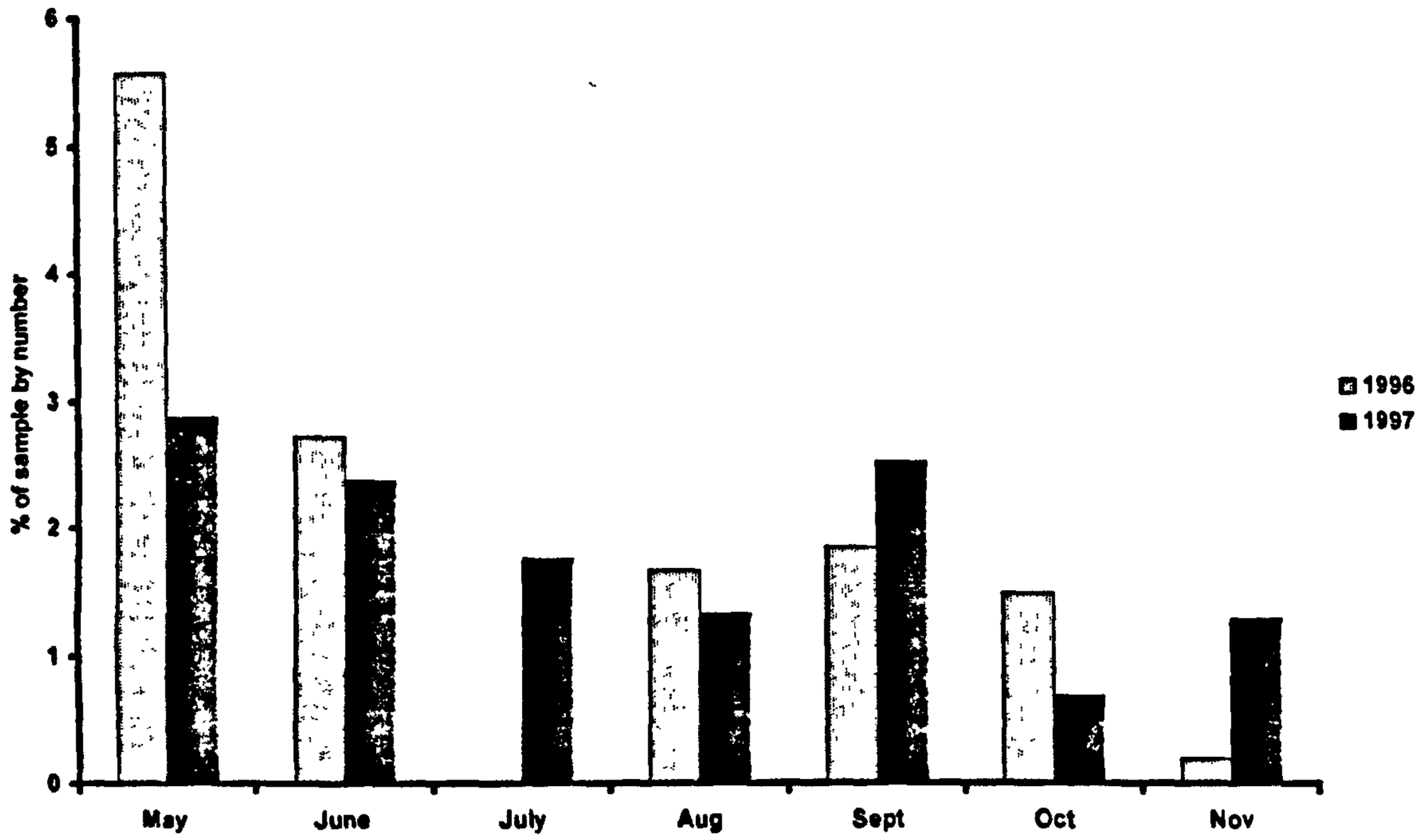


Fig. 4(j): Percentages of *Lutjanus fulviflamma* in terms of number of individuals (top) and catch weight (bottom) in the total monthly samples for 1996 and 1997.



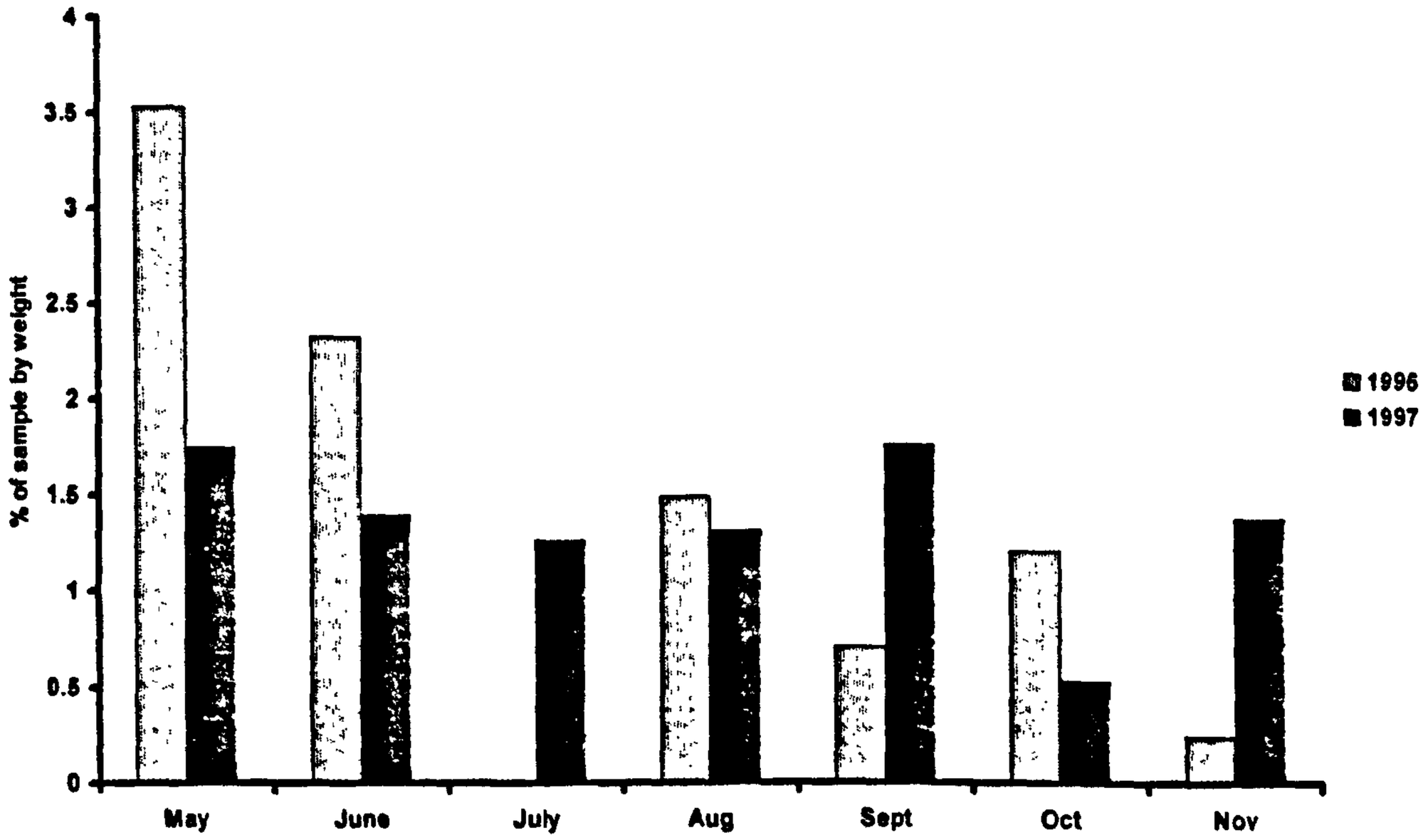
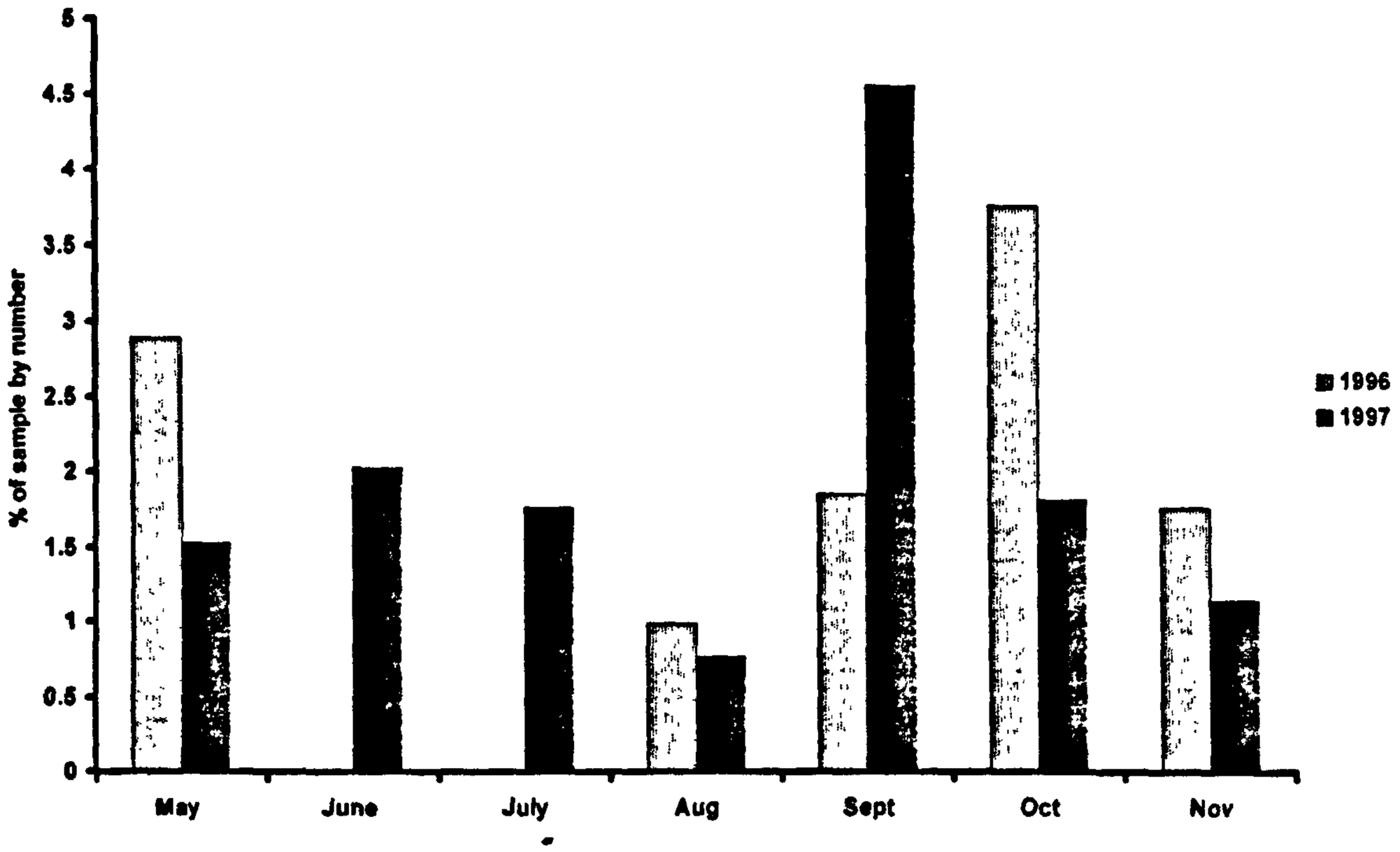


Fig. 4(k): Percentage of *Scolopsis ghanam* in terms of number of individuals (top) and catch weight (bottom) in the total monthly samples from 1996 and 1997.



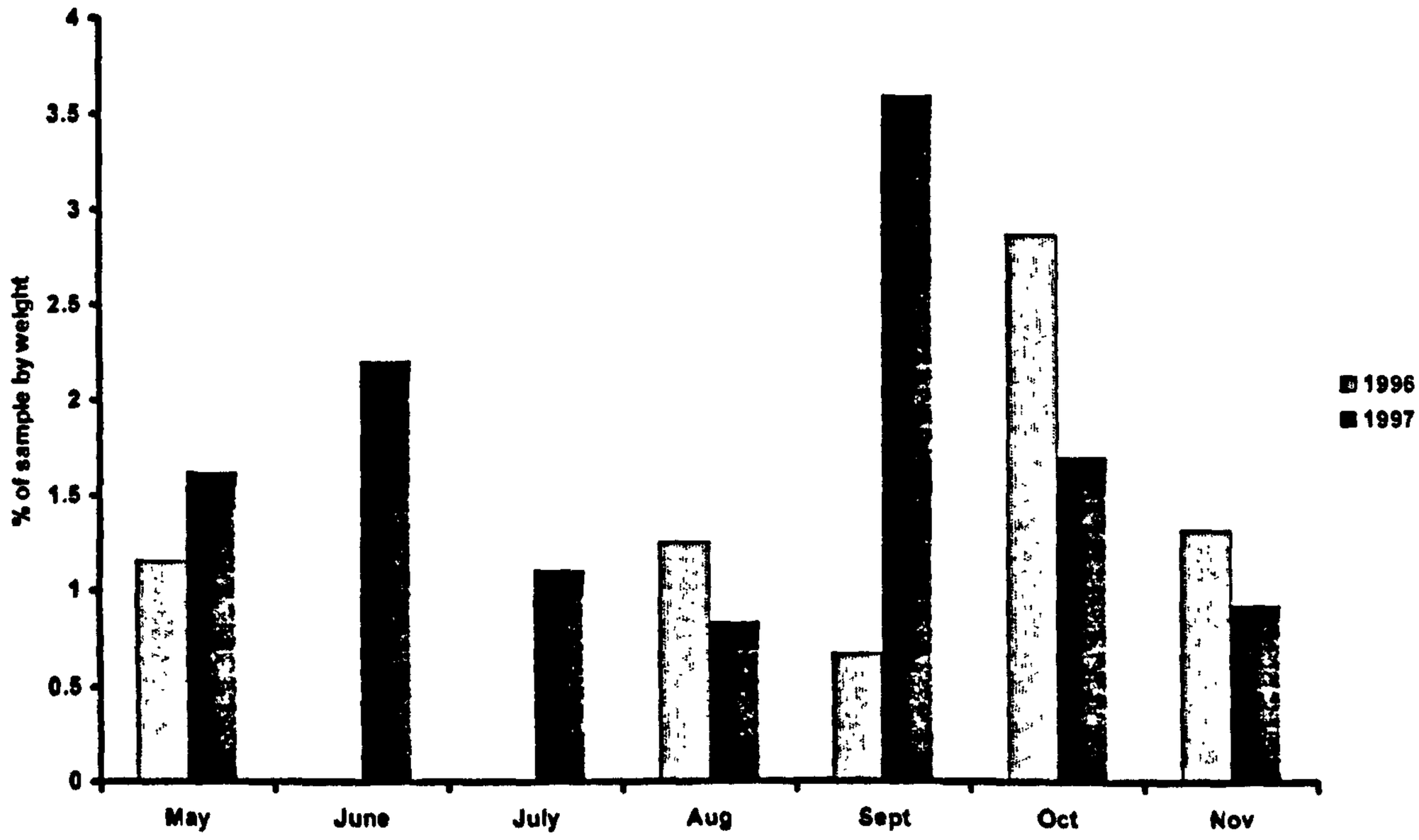


Fig. 4(l): Percentages of *Lethrinus mahsenoides* in terms of number of individuals (top) and catch weight (bottom) in the total monthly samples from 1996 to 1997.

variegatus, *Calotomus spinidens*, *Cheilio inermis*, *Stethojulis strigiventer* and *Parupeneus barberinus* were all higher in the trap fishery than in the net fishery. However, the deep-bodied species *Siganus sutor* and *Lutjanus fulviflamma* had a higher mean length in the net fishery than in the trap fishery.

In terms of families, the trap catch was dominated by Scaridae (more than 80% by weight) with Siganidae, Mullidae, Labridae, Lutjanidae and Lethrinidae all accounting for less than 5% of the catch by weight (see Fig. 2b).

The community structure patterns obtained from the net fishery and trap fishery samples were very different, as illustrated in Fig. 5, a species abundance chart. The sample taken from the trap fishery was much smaller than for the net fishery but it was still evident that the fish vulnerable to the trap fishery were heavily dominated by one species (*Leptoscarus vaigiensis*) whereas the net fishery had a number of important species.

Life stages of main fish species in the seagrass fishery

From field observations (presence of ripe individuals in catches, observations of fish sizes in other fisheries in the area and from underwater visual census and general underwater observation) and from the literature I would put the 25 main catch species into the following categories:

Predominantly juveniles present in the fishery: *Siganus sutor, Lethrinus lentjan, Lethrinus variegatus, Gerres oyena, Lutjanus fulviflamma, Parupeneus barberinus, Lethrinus mahsenoides, Siganus stellatus, Scarus ghobban, Upeneus tragula and Plectorhinchus gaterinus, Naso brevirostris, Lutjanus gibbus, Plotosus lineatus, Parupeneus macronema, Hipposcarus harid, Lethrinus harak*

All life stages present in the fishery (excluding very small fish of less than 6cm not vulnerable to capture): *Leptoscarus vaigiensis, Calotomus spinidens, Cheilio inermis, Sphyraena flavicauda, Hemiramphus far, Scolopsis ghanam, Fistularia commersoni, Lactoria cornuta, Pelates quadrilineatus, Cheilodipterus quinquelineatus, Chrysiptera annulata, Cheilinus trilobatus, Petroscirtes variablis, Novaculichthys macrolepidotus,*

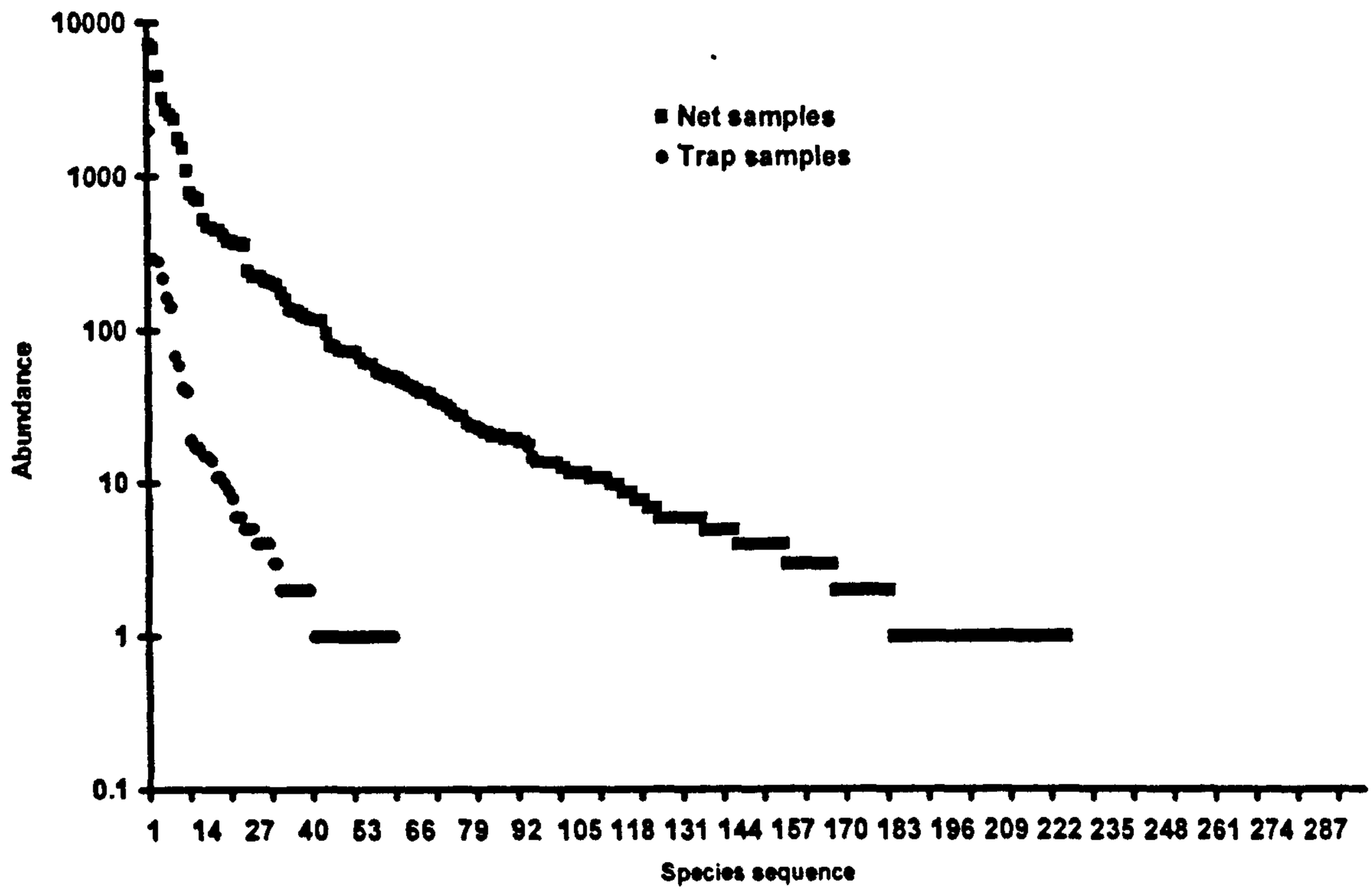


Fig. 5: Species abundance curves for the net and trap fisheries. The abundance axis has a log scale.

Only adults present in fishery: *Stethojulis strigiventer, Amblygobius albimaculata, Pteragogus flagellifera, Carangoides fulvoguttatus, Diagramma pictum, Herklotichthys quadrimaculatus, Tylosurus crocodilus.* It is almost certain that in most cases for the small species, like the first 3 in this list, other life stages are present in the seagrass habitat but are not vulnerable to capture.

Catch composition from different net fishing sites

Samples were analysed on the basis of the locally designated fishing sites in which they were caught and the species totals and diversity, richness, evenness and dominance indices for each site are shown in Table 4. Balanzi, the largest and most heavily fished site, had the highest number of species (108) but also the highest number of fish sampled. Santa Maria had the highest value of Margalef's species richness index and the highest Shannon Diversity Index. Santa Maria had the second highest number of species (97) from a much smaller sample. Abujati and Banco had the lowest numbers of species (33 and 35 respectively) but both also had small samples. Quiutu, the site with the lowest diversity of seagrass species (Chapter 1), had the highest Simpson dominance index. Although the Margalef richness index takes account of sample size, significant positive correlations ($P < 0.01$) were found using Spearman rank correlations between the number of individuals in the sample and the Margalef's richness index. A significant negative correlation ($P < 0.01$) was found between the number of individuals and Pielou's evenness index. There was no significant correlation between number of fish in the samples and Shannon diversity indices or the Simpson dominance indices.

The highest Margelef's species richness indices were from Balanzi and Santa Maria, the lowest from Abujati and Banco. Samples from Quiwandala and Santa Maria had the highest Shannon diversity indices, while the lowest were found at Abujati and Kasuco. The highest Pielou's diversity indices were found at Quiwandala Julu, Banco and Fragani and the lowest at Pakilima and Mecute. Pakilima and Quiutu had the highest Simpson's dominance indices and Quiwandala Julu and Santa Maria had the lowest.

Table 4: The species numbers, sample sizes and indices of species diversity for each fishing site in the Montepuez Bay.

Site	Number of Species	Fish Sampled	Margelef's Richness	Shannon Diversity	Pielou's Evenness
Abujati	33	837	4.75	2.60	0.74
Balanzi	108	6677	12.20	3.04	0.65
Banco	35	413	5.64	2.72	0.77
Fragani	42	746	6.20	2.89	0.77
Kasuco	54	1905	7.02	2.64	0.66
Kumilamba	47	592	7.21	2.79	0.72
Lusino	61	1843	7.98	2.84	0.69
Makome	38	639	5.73	2.67	0.74
Mecute	89	6356	10.00	2.83	0.63
Momade Assane	45	887	6.48	2.92	0.77
Pakilima	70	3066	8.59	2.66	0.63
Panteramouco	51	877	7.38	2.78	0.71
Pantopi	55	921	7.91	2.91	0.73
Quiutu	67	1035	9.51	2.80	0.67
Quiwandala	76	3294	9.26	3.29	0.76
Quiwandala Julu	46	682	6.90	2.99	0.78
Santa Maria	97	2469	12.30	3.34	0.73

Table 6 shows the five most abundant species by weight for each site and the proportion of the catch which they represent.

When catch composition from different sites were compared using Spearman's rank correlations there were significant positive correlations ($P < 0.01$) between *Lutjanus fulviflamma* and *Scarus ghobban*; *Pteragogus flagellifera* and *Sphyraena flavicauda*; *Pteragogus flagellifera* and *Lethrinus lentjan* and *Amblygobius albimaculatus* and *Paramonacanthus barnardi.* Significant negative correlations at the 0.01 level were found between *Lutjanus fulviflamma* and *Upeneus tragula*; *Scarus ghobban* and *Calotomus spinidens*; *Upeneus tragula* and *Scarus ghobban* and *Scarus ghobban* and *Lethrinus variegatus.*

There were also some significant correlations between seagrass characteristics of the sites and the abundance of some species. For example: there was a significant negative correlation ($P < 0.01$) between seagrass percentage cover at a site and the percentage of *Lethrinus mahsenoides* in the catch. The percentage cover of *Halophila ovalis* was significantly ($P < 0.01$) positively correlated with the percentage of *Calotomus spinidens* in the catch. Percentage cover of *Halophila stipulacea* was significantly positively correlated ($P < 0.01$) with percentage of *Lethrinus lentjan*, *Pteragogus flagellifera and Parupeneus macronema* and significantly negatively correlated with *Lethrinus mahsenoides.*

Table 5 shows the significant correlations between fish species percentages from each site and between seagrass site characteristics and fish species. Fig. 6 shows a multi-dimensional scaling plot of the main fishing sites in terms of the relative abundances of 22 of the most common fisheries species. There were no obvious clusters of sites, but the slightly outlying points of Santa Maria, Abujati and Fragani all corresponded with geographically outlying sites (see fishing site map in Chapter 1).

Site categories

The sixteen main sites from which fish catches were sampled were divided into three habitat categories based on habitat type within the site and the proximity to coral communities and mangroves. All were dominated by seagrass but some sites contained areas of coral communities ("coral-associated") whilst

Table 5: A summary of the significant Spearman rank correlation between fish species abundances in fishing sites and between fish species abundances and seagrass species cover. * denotes P < 0.05, ** denotes P < 0.01.

Characteristic 1	Characteristic 2	Spearman's rank correlation	Significance (2 Tailed)	N
Fish Correlations				
Calotomus spinidens	*Amblygobius albimaculata*	0.610	0.027 *	13
Calotomus spinidens	*Paramonacanthus barnardi*	0.582	0.037 *	13
Calotomus spinidens	*Lutjanus fulviflamma*	-0.621	0.024 *	13
Calotomus spinidens	*Scarus ghobban*	-0.729	0.005 **	13
Calotomus spinidens	*Paramonacanthus barnardi*	0.582	0.037 *	13
Lethrinus lentjan	*Pteragogus flagellifera*	0.729	0.005 **	13
Lethrinus variegatus	*Parupeneus barberinus*	-0.588	0.035 *	13
Lethrinus variegatus	*Scarus ghobban*	-0.696	0.008 **	13
Lutjanus fulviflamma	*Upeneus tragula*	-0.841	0.000 **	13
Paramonacanthus barnardi	*Amblygobius albimaculata*	0.687	0.010 **	13
Parupeneus macronema	*Pelates quadrilineatus*	0.617	0.025 *	13
Scarus ghobban	*Amblygobius albimaculata*	-0.613	0.026 *	13
Scarus ghobban	*Lutjanus fulviflamma*	0.796	0.001 **	13
Siganus sutor	*Upeneus tragula*	-0.648	0.017 *	13
Sphyraena flavicauda	*Pelates quadrilineatus*	0.606	0.028 *	13
Sphyraena flavicauda	*Pteragogus flagellifera*	0.712	0.006 **	13
Stethojulis strigiventer	*Lutjanus fulviflamma*	-0.665	0.013 *	13
Stethojulis strigiventer	*Calotomus spinidens*	0.571	0.041 *	13
Upeneus tragula	*Stethojulis strigiventer*	0.560	0.046 *	13
Upeneus tragula	*Scarus ghobban*	-0.580	0.038 *	13
Fish and Seagrass Correlations				
Cymodocea serrulata cover	*Scarus ghobban*	0.699	0.012 *	13
Cymodocea serrulata cover	*Calotomus spinidens*	-0.613	0.026 *	13
Cymodocea serrulata cover	*Lethrinus variegatus*	-0.616	0.025 *	13
Halophila ovalis cover	*Lutjanus fulviflamma*	-0.663	0.014 *	13
Halophila ovalis cover	*Calotomus spinidens*	0.801	0.001 **	13
Halophila ovalis cover	*Scarus ghobban*	-0.613	0.021 *	13
Halophila stipulacea cover	*Lethrinus lentjan*	0.689	0.009 **	13
Halophila stipulacea cover	*Pteragogus flagellifera*	0.746	0.003 **	13
Halophila stipulacea cover	*Lethrinus mahsenoides*	-0.705	0.007 **	13
Halophila uninervis cover	*Lethrinus mahsenoides*	-0.705	0.007 **	13
Halophila uninervis cover	*Parupeneus macronema*	0.704	0.007 **	13
Seagrass cover	*Lethrinus mahsenoides*	-0.698	0.008 **	13

Table 6: The main fishing sites, their category type (M = mangrove-associated seagrass sites, C = coral-associated seagrass sites, S = seagrass sites), and the percent by number and by weight of the 5 most abundant species by weight in the total sample from each sites. The fish species are as follows: *Lethrinus variegatus* – variegated emperor (Lethrinidae), *Siganus sutor* – African white-spotted rabbitfish (Siganidae), *Leptoscarus vaigiensis* – seagrass parrotfish (Scaridae), *Lethrinus lentjan* – pink-eared emperor, *Hemiramphus far* – spotted halfbeak (Hemiramphidae), *Sphyraena flavicauda* – yellow-tailed barracuda (Sphyraenidae), *Gerres oyena* – black-tipped mojarra (Gerreidae), *Lutjanus fulviflamma* – blackspot snapper, *Carangoides fulvoguttatus* – yellow-dotted trevally (Carangidae), *Siganus stellatus* – stellate rabbitfish (Siganidae), *Stethojulis strigiventer* – three-ribbon wrasse, *Scarus ghobban* – blue-barred parrotfish (Scaridae), *Amblygobius albimaculatus* – tail-spot goby (Gobiidae), *Scolopis ghanam* – Arabian spine-cheek (Nemipteridae), *Lethrinus mahsenoides* – snub-nosed emperor (Lethrinidae), *Lethrinus nebulosus* – spangled emperor (Lethrinidae), *Calotomus spinidens* – spiny-tooth parrotfish (Scaridae), *Tylosurus crocodilus* –crocodile needlefish (Belonidae), *Diagramma pictum* – painted sweetlips (Haemulidae).

Site		Species 1	% N	% W	Species 2	% N	% W	Species 3	% N	% W	Species 4	% N	% W	Species 5	% N	% W
Abujati	M	*L. vaigiensis*	8.8	19.1	*L. variegatus*	26.3	13.2	*S. sutor*	14.0	12.8	*S. stellatus*	4.4	9.4	*A. albimaculatus*	8.0	6.2
Balanzi	S	*S. sutor*	22.4	35.1	*L. lentjan*	7.4	10.9	*L. vaigiensis*	7.5	9.1	*G. oyena*	8.6	6.7	*L. variegatus*	13.5	4.5
Banco	S	*S. sutor*	13.2	36.6	*L. vaigiensis*	20.7	24.0	*L. fulviflamma*	2.4	7.6	*L. variegatus*	16.6	4.3	*G. oyena*	3.6	4.1
Fragani	S	*L. vaigiensis*	10.1	17.7	*S. sutor*	11.4	16.8	*G. oyena*	9.7	12.2	*L. variegatus*	12.5	8.9	*S. strigiventer*	15.0	5.3
Kasuco	S	*S. sutor*	14.1	29.4	*L. vaigiensis*	11.5	16.1	*G. oyena*	11.3	10.1	*S. strigiventer*	9.3	4.7	*C. spinidens*	5.0	4.3
Kumilamba	C	*L. lentjan*	10.8	32.0	*S. flavicauda*	20.4	20.4	*S. sutor*	17.6	19.8	*L. nebulosus**	0.3	5.5	*S. ghanam*	5.7	2.8
Lusino	C	*S. sutor*	16.1	24.9	*L. vaigiensis*	21.3	17.6	*L. variegatus*	11.8	8.5	*L. lentjan*	2.9	7.9	*A. albimaculata*	8.0	6.7
Makome	C	*S. sutor*	8.4	23.0	*C. spinidens*	18.0	14.3	*L. variegatus*	20.5	14.3	*L. mahsenoides*	7.5	7.5	*L. vaigiensis*	3.3	6.1
Mecute	C	*L. lentjan*	6.4	23.9	*S. sutor*	12.7	13.3	*L. vaigiensis*	11.1	12.1	*L. variegatus*	16.2	9.5	*C. spinidens*	12.3	8.6
Momade Assane	C	*S. sutor*	15.4	24.2	*L. vaigiensis*	8.9	11.5	*G. oyena*	13.0	11.0	*S. ghobban*	9.4	8.2	*L. variegatus*	13.5	6.2
Pakilima	M	*S. sutor*	27.6	26.9	*L. lentjan*	11.9	17.4	*L. vaigiensis*	12.8	15.1	*S. flavicauda*	3.0	9.4	*L. variegatus*	11.8	5.7
Panteramouco	M	*S. sutor*	20.6	20.7	*L. vaigiensis*	9.1	14.8	*L. lentjan*	7.2	9.1	*L. variegatus*	18.0	7.4	*S. strigiventer*	8.8	4.9
Pantopi	S	*S. sutor*	17.3	36.1	*G. oyena*	13.0	13.0	*L. variegatus*	16.3	8.1	*L. lentjan*	4.0	4.4	*L. fulviflamma*	3.5	4.4
Quiutu	M	*S. sutor*	15.7	31.4	*L. variegatus*	28.2	11.7	*G. oyena*	9.1	8.7	*L. fulviflamma*	2.2	8.2	*L. lentjan*	4.8	6.7
Quiwandala	M	*S. sutor*	11.8	22.9	*L. vaigiensis*	9.6	10.9	*G. oyena*	8.9	8.2	*L. lentjan*	4.2	5.5	*S. strigiventer*	9.9	4.7
Quiwandala Julu	S	*H. far*	5.7	19.8	*S. sutor*	12.3	18.5	*L. vaigiensis*	9.1	8.9	*L. variegatus*	14.2	7.7	*T. crocodilus*	1.8	6.8
Santa Maria	C	*L. lentjan*	7.6	23.9	*S. sutor*	11.6	12.9	*C. fulvoguttatus*	0.5	9.5	*D. pictum*	0.5	6.0	*L. variegatus*	17.4	5.8

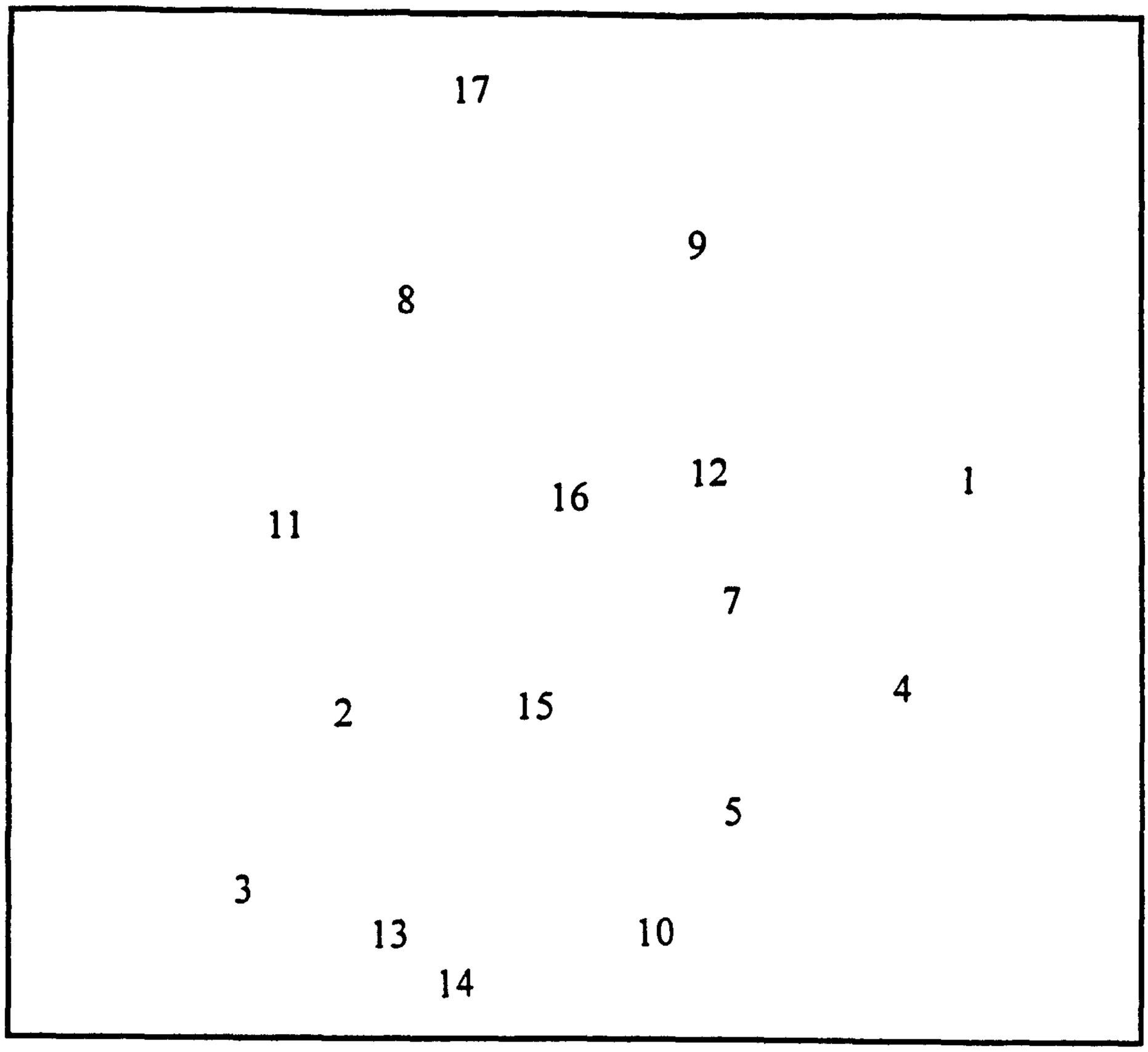


Fig. 6 : Multi-dimensional scaling plot of the 17 main fishing sites in the Montepuez Bay, on the basis of relative abundances in terms of number of 22 of the most common fish species in catches from these sites. The numbers correspond with the following sites:

1 = Abujati
2 = Balanzi
3 = Banco
4 = Fragani
5 = Kasuco
6 = Kumilamba
7 = Lusino
8 = Makome
9 = Mecute
10 = Momade Assane
11 = Pakilima
12 = Panteramouco
13 = Pantopi
14 = Quiutu
15 = Quiwandala
16 = Quiwandala Julu
17 = Santa Maria

others contained or were bordered by mangroves ("mangrove-associated"). Another group of sites contained or were in the vicinity of neither coral nor mangroves and were categorised simply as "seagrass" sites and were situated mainly in the centre of the bay.

1. Seagrass sites: Kasuco, Banco, Balanzi, Pantopi and Quiwandala Julu

The percentages given are for all data from these sites pooled and not mean data per trip. Seagrass sites were dominated by the families Siganidae (35% by weight), Lethrinidae (17%) and Scaridae (14%), and by the species *Siganus sutor* (33%), *Leptoscarus vaigiensis* (10%), *Lethrinus lentjan* (8%) and *Gerres oyena* (8%). In total the seagrass sites had 133 species of fish in 45 families. 27 of these species appeared only once during sampling. The abundances of the 10 most common fish are shown in Fig. 7.

All but one of the individual seagrass sites were dominated by *Siganus sutor.* Quiwandala Julu was dominated by the half-beak *Hemiramphus far* (19.8%), followed closely by *Siganus sutor* (see Table 6).

2. Coral-associated sites: Santa Maria, Makome, Kumilamba, Momade Assane, Mecute and Lusino

Coral associated sites were dominated by the families Lethrinidae (33% by weight), Siganidae (17%) and Scaridae (15%), and by the species *Lethrinus lentjan* (20%), *Siganus sutor* (17%), *Leptoscarus vaigiensis* (9%) and *Lethrinus variegatus* (7.5%). Coral-associated sites had 147 species of fish in 47 families of which 31 species appeared only once. The jack *Carangoides fulvoguttatus* appears in the top ten most important species in terms of weight in these sites but does not feature at all in the samples from the seagrass and mangrove-associated sites. The abundances of the 10 most common fish are shown in Fig. 8. Coral-associated sites with large coral structures such as massive corals amongst the seagrass generally had the largest fish caught in the whole fishery. Adult reef fish such as *Lethrinus lentjan, Lutjanus fulviflamma* and *Diagramma pictum* were often caught from seagrass in the coral-associated areas of Santa

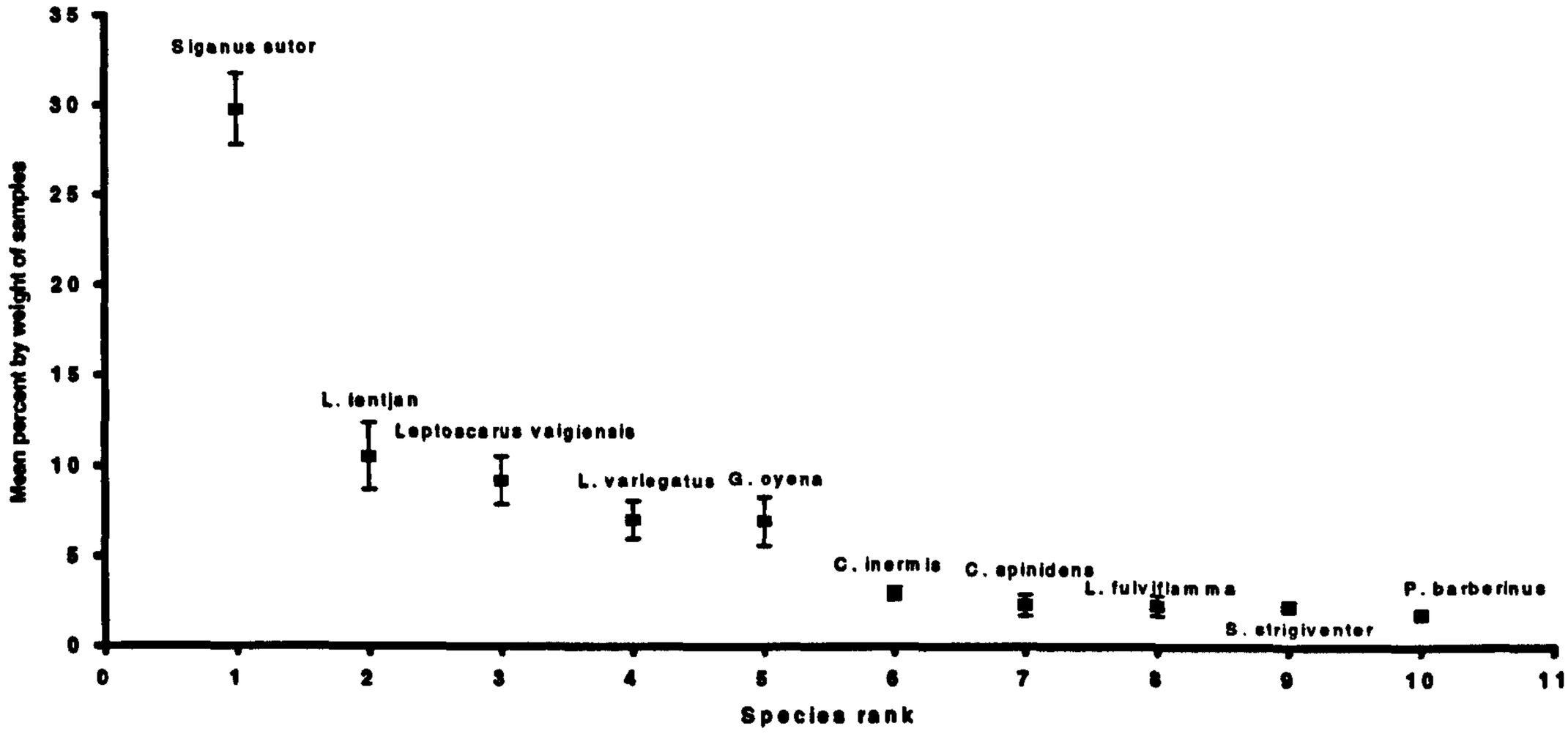


Fig. 7: Species abundance curve for all "seagrass" category sites. Error bars show ±SE.

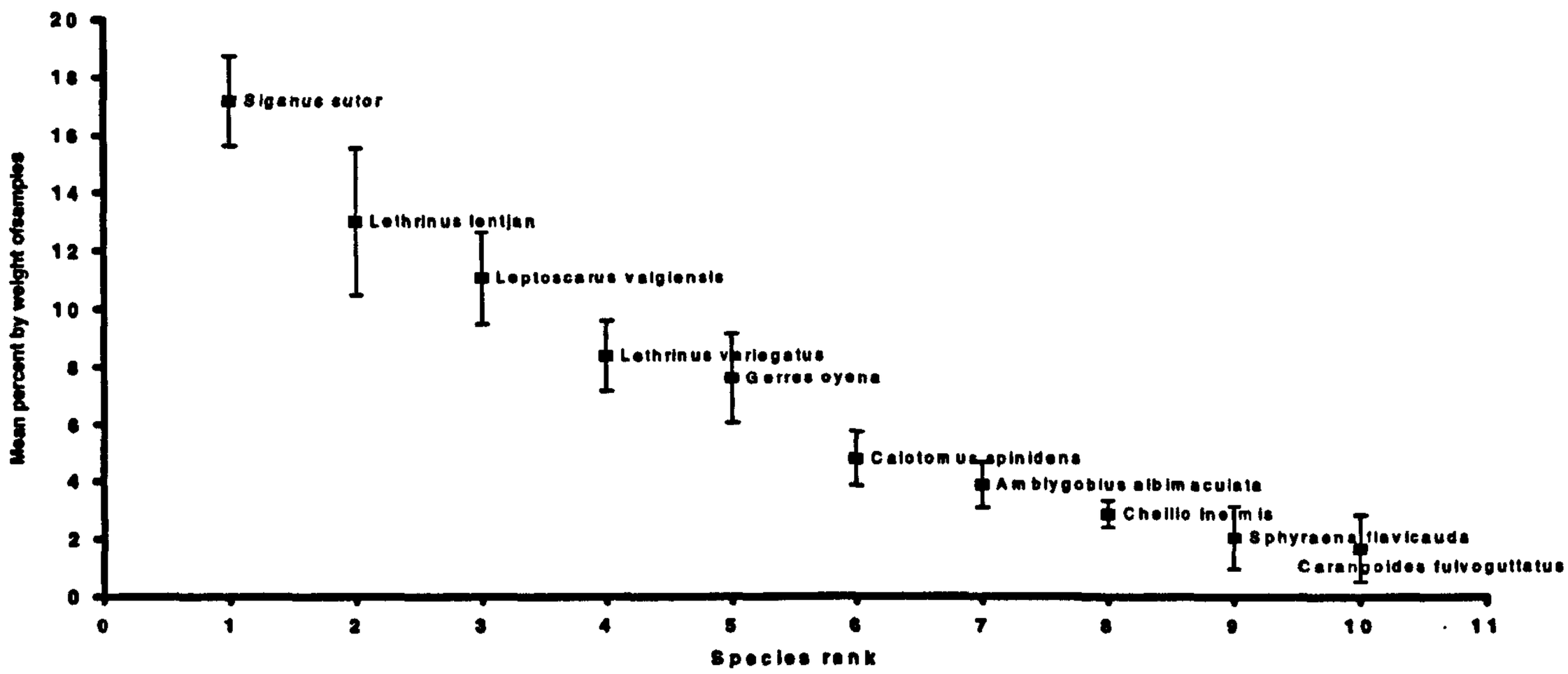


Fig. 8: Species abundance curve for all " coral-associated" sites. Error bars show ±SE.

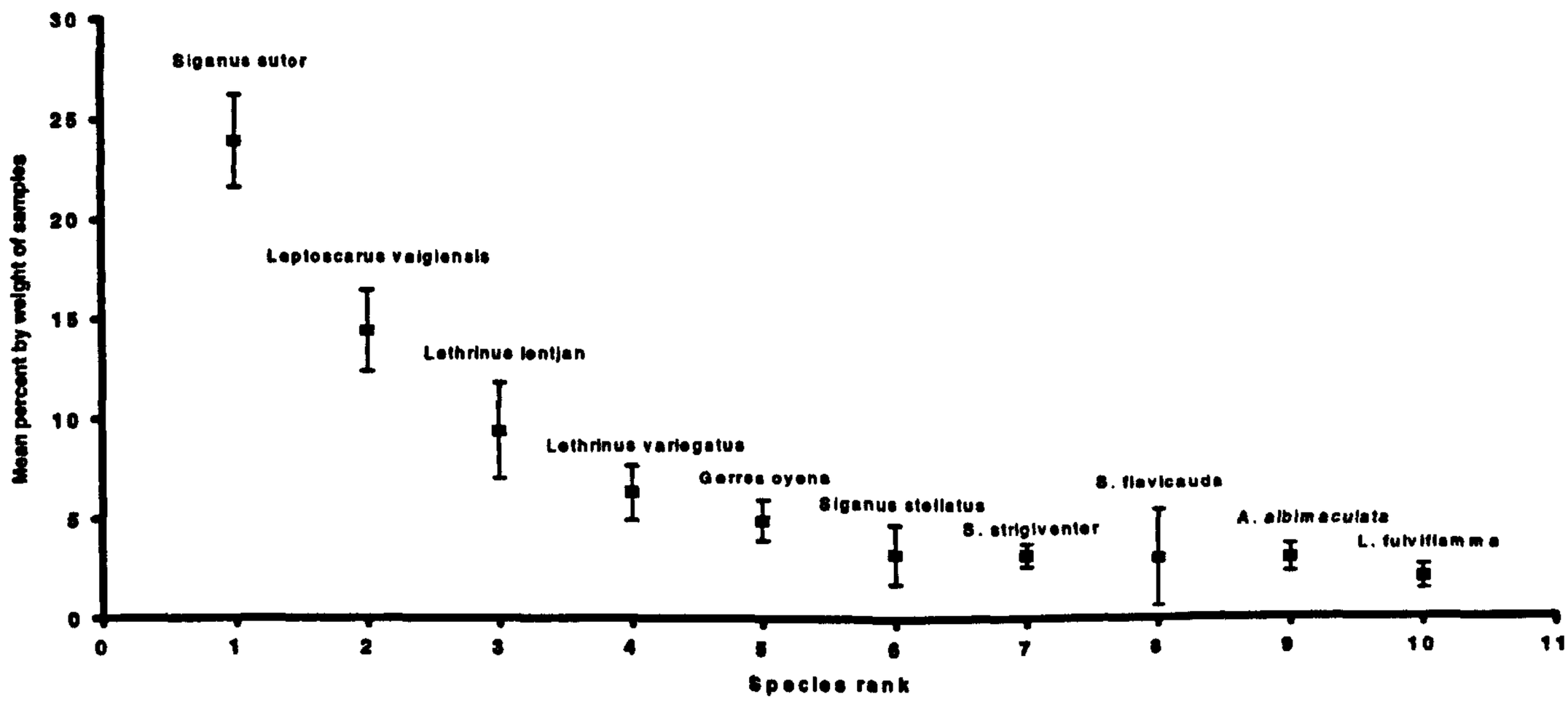


Fig. 9: Species abundance curve for all " mangrove-associated" sites. Error bars show ±SE.

Maria, Kumilamba and Mecute. These large fish seemed to be closely associated with the large coral or rock structures of these sites.

Three coral sites were dominated by *Lethrinus lentjan* in terms of weight: Mecute (23.9%), Santa Maria (23.9%) and Kumilamba (32%). The other three sites were dominated by *Siganus sutor*: Lusino (24.9%), Makome (23%) and Momade Assane (24.2%). Two unusual species occurred in the top five most important species in terms of biomass in Santa Maria – the large pelagic *Carangoides fulvoguttatus* (9.5%) and the usually reef-associated *Diagramma pictum* (6%) (see Table 6).

3. Mangrove-associated sites: Pakilima, Panteramouco, Abujati, Quiutu and Quiwandala

Mangrove-associated sites were dominated by the same three families as the other two site types: Siganidae (27%), Lethrinidae (21%) and Scaridae (17%) and by the species *Siganus sutor* (24%), *Leptoscarus vaigiensis* (12%), *Lethrinus lentjan* (10%) and *Lethrinus variegatus* (6%) (see Fig. 9). These sites had a total of 122 species in 41 families of which 25 species appeared just once. The barracuda *Sphyraena flavicauda* was an important component of samples from mangrove-associated sites, accounting for 4% of fish biomass sampled (see Fig. 9). All but one of the mangrove-associated sites were dominated by *Siganus sutor*: Pakilima (26.9%), Panteramouco (20.7%), Quiutu (31.4%) and Quiwandala (22.9%). Abujati was dominated by *Leptoscarus vaigiensis* (19.1%) (see Table 6).

Species diversity and community structure

There were 82 species that were common to all three categories of site. Seagrass and coral sites had 100 species in common, 95 appeared in both the seagrass and the mangrove sites and 90 in coral and mangrove associated sites.

When rare species were excluded (those appearing less then 3 times in all samples) there were 87 species in the seagrass sites, 117 in the coral-

associated sites and 83 in the mangrove associated sites. There were 63 of these common species that appeared in all three site categories.

Trophic structure

The trophic roles of the 25 most common species are shown in Table 1. These are derived from some stomach-contents analyses, behavioural observations and from the literature. Three of six most important fish in catch were herbivores, and herbivores accounted for over 40% of total fish biomass caught. The herbivore stomach contents that were examined contained large quantities of recognisable seagrass and epiphytic material.

There was a very low proportion of predators in the catch, only three major piscivores were identified among the twenty five most abundant fish – *Sphyraena flavicauda*, *Fistularia commersoni* and *Carangoides fulvoguttatus*. Most fish that weren't herbivores were invertebrate feeders, particularly on crustaceans and other small invertebrates (for example the emperors and the wrasses). The crustaceans consumed by the invertebrate feeders could also be presumed to come from the seagrass habitat (crabs are extremely abundant in the seagrass, in particular spider crabs (Majidae spp.) and box crabs (Calappidae spp.)).

DISCUSSION

Methodology

Tropical fisheries are often highly diverse, particularly those taken from coral reefs (Munro 1996, Jennings *et al.* 1995). Seagrass fisheries have rarely been studied specifically but in a number of experimental fishing programmes high numbers of fish species (150+) have been found in seagrass meadows (Blaber *et al.* 1994, Harmelin-Vivien 1983). Table 7 shows a summary of some of the key studies (mainly experimental rather than fisheries studies) of seagrass fish communities from the literature. The species composition of the Quirimba seagrass fishery does not strongly resemble that of any other study, but for almost every study a slightly different sampling method was used and this had a strong influence on the catch compositions obtained. One study showed that when seagrass beds were sampled using different gears in some fairly distant

Table 7: Selected studies of tropical and subtropical seagrass fish communities, showing location of the study, seagrass species, total number of fish species and families and number of fish sampled, and the dominant fish families in the catch.
*** = site also contained coral communities**
****= site also contained mangroves.**

Location	Seagrass species/ genera	No fish pecies	No. fish families	Dominant families/ species	Sample Size	Reference
N. South Wales	*Posidonia australis*	39	23	Gobiidae, Monacanthidae	902	Burchmore et al 1984
Groote Eylandt	*Cymodocea, Enhalus, Thalassia Syringodium, Halophila, Halodule*	156		Sharks		Blaber et al 1992
		300	85	Haemulidae, Nemipteridae	400,000	Blaber et al 1994
Victoria	*Heterozostera, Zostera*	39	22	Gobiidae, Syngnathidae		Jenkins et al 1997
N. South Wales	*Zostera capricorni*	43		Ambassidae, Teraponidae	17220	Gray et al 1998
Marseille	*Posidonia oceanica*	49	20	Labridae, Sparidae	3301	Bell & Harmelin-Vivien 1982
	Thalassia testudinum	97	36	Gerridae Clupeidae	423kg	Baelde 1990
Burung Island	*Thalassia, Diplanthera*	78	32	Apogonidae	8148	Hutomo et al 1977
Lombok	*Enhalus, Cymodocea & Syringodium*	85	45	Athrerinidae, Engraulidae	1141	Hutomo & Peristiwady 1996
Gazi Bay	Mixed *Cymodocea, Halodule, Thalassia, Thalassodendron.*	75	40	Gerridae, Atherinidae	3601	De Troch et al 1996
Tulear	Mixed, no *Enhalus*	157		Apogonidae		Harmelin-Vivien 1983
Terminos Lagoon	*Thalassia*	121		Engraulidae	21734	Yanez-Arancibia et al 1980
		53	25	Siganidae	1384	Vergara & Fortes 1989
Cape Bolinao	*Enhalus, Cymodocea, Thalassia**	280	53	Siganidae	>4000	Campos et al 1994, Fortes 199?
Southwest	*Thalassia & Syringodium*	43	24	Scaridae, Gobiidae		Martin & Cooper 1981
Swartkops Est.	*Zostera capensis*	39	19	Atherinidae, Clupeidae	62020	Beckley 1982
Negombo Estuary	*Halophila ovalis, Halodule pinifolia***	62	39	Cichlidae, Gobiidae	10287	Pinto & Punchihewa 1996
St Croix	*Thalassia*	57	26	Scaridae, Haemulidae	2534	Robblee & Zieman 1984
Ecofina Estuary	*Thalassia*	94		*Lagodon rhomboides*	82241	Livingston 1984
Fenholloway Est.	*Syringodium*	99		*Lagodon rhomboides*	37582	Livingston 1984

separated estuaries the species compositions found using the same gear in different estuaries were more similar than the compositions obtained from within the same estuary using different sampling techniques (in Blaber 1997). In some studies simple netting was used, but others employed fish poisons (rotenone) or sophisticated drop traps and some were done only by day, others by night as well, so it is difficult to directly compare them. Harmelin-Vivien and Francour (1992) compared trawling and visual census techniques in Mediterranean seagrass beds and found that there were significant differences between the two methods. Visual census gave fewer species but a higher biomass and a larger number of individuals than trawling. Good swimmers and planktivorous fish were better represented by visual census and carnivores, canopy dwellers such as pipefishes and seahorses (Syngnathidae) and benthic species such as gobies (Gobiidae), blennies (Blennidae) and flounders (Bothidae) were better represented in trawls. The difference between the catch composition and fish sizes from the net fishery and the trap fishery in the Montepuez Bay demonstrates the difference that a sampling method can make on the resulting catch composition. *Leptoscarus vaigiensis* was revealed as by far the most dominant species by the trap fishery, whereas in the net fishery it was just one of a number of important species. The flagfin wrasse *Pteragogus flagellifera*, a rare species in the net fishery, was a major component of the trap fishery. To try to interpret the seagrass fish community of the Montepuez Bay through just one or other of the fishing methods would be misleading, as may be the case using just these two methods.

Using traps and seine nets to look at fish community composition was, however, an improvement on using just one method (Harmelin-Vivien and Francour 1991 conclude that it is not sufficient to sample fish in a seagrass bed using only one method, although it does give a relative picture, enabling site comparisons), and species not caught or rarely caught in nets were caught in traps. However, there were definitely components of the fish community that were under-sampled by both these methods. As Harmelin-Vivien and Francour (1991) found, trawling with seine nets does not capture many fast swimmers. We observed large numbers of *Siganus sutor* escaping or evading the net, and large species such as the blue-spotted ray *Taeniura lymna* evaded capture by swimming under the net. Fast pelagics such as jacks (Carangidae) were caught occasionally in the

bay by hook and line and were also seen occasionally on dives but were very rarely captured by net. There may have been a whole suite of large, fast benthic and pelagic predators that were captured very rarely but that formed an important component of the seagrass fish community.

I attempted visual census techniques in the Quirimba seagrass beds but they were abandoned because visibility was poor, currents were strong and very few fish were seen after many hours spent underwater and dive time was a constraint. The majority of common species of fish seemed to be very patchily distributed. They formed large (often on the order of hundreds of individuals), mixed species foraging schools which were seen on about one in ten dives, so on nine out of ten dives virtually no fish were seen. The main species seen in visual censuses were *Lethrinus variegatus*, *Leptoscarus vaigiensis*, *Stethojulis strigiventer*, *Cheilio inermis Pteragogus flagellifera* and *Parupeneus barberinus*. In 6m deep mixed seagrass (mainly *Enhalus acoroides*) and sand, an average of nine species were seen over a 30 minute period of observation in contrast with an average of 53 species seen over coral habitats in the same period of time (ranging from 32 to 80) in Quirimba.

One major problem with using the seine net and trap fisheries to study the seagrass fish community was that we were restricted to daytime sampling. The whole guild of nocturnal fish including large predators and piscivores thought to migrate into most seagrass beds at night was not sampled. Robblee and Zieman (1984) found two distinct assemblages: day time - small permanently resident seagrass species e.g. parrrotfishes, and wrasses and night time - grunts, squirrelfishes and cardinalfishes were the dominant fish. The Quirimba traps fished overnight, but the fish attracted to the predominantly unbaited traps were mainly small herbivores, with a few omnivores. Occasionally predatory fish such as moray eels and small groupers were caught in the traps but this was rare. If the species diversity of diurnal species is compared with the corresponding diurnal component of fish species in other studies the overall extrapolated diversity of the Quirimba seagrass beds including nocturnal migrants is likely to be exceptionally high.

The high diversity of the Quirimba seagrass fish

The most similar study of a seagrass fishery in the literature was a study of a multi-gear, multi-species artisanal fishery in the Philippines that focussed on a seagrass-dominated lagoon habitat (Campos *et al.* 1994). In that fishery 280 species in 53 families were identified and the dominant family was also Siganidae, as it was in this study. The potential number of species in South East Asia is much higher than that for the East African Region so it is interesting that the diversity of a seagrass bed in Mozambique, in the Western Indian Ocean Region, could approach that of a Philippines system. It has been suggested in studies of the diversity of other groups and habitats in the area (Whittington *et al.* 1998) that the Quirimba Archipelago may itself be a centre for biodiversity on the East African coast. One of the main similarities between the habitat fished in Campos *et al.*'s (1994) study and the Montepuez Bay was the mixture of seagrass and coral communities in close proximity. This could be the key to the high number of fish species encountered. When the fishing sites in the Montepuez Bay were divided into habitat categories, the seagrass sites associated with coral communities had the highest number of species of fish compared to those associated with mangroves and those sites surrounded by just seagrass. The Quirimba seagrass beds not only contained small areas of patch reef but were also in close proximity to extensive coral reefs. These included the fringing reefs at Quilaluia and on the east coast of Quirimba and the extensive patch reefs of the Sencar-Quilaluia channel and the dense mangroves of Ibo (See map of habitats in Chapter One). Baelde (1990) found that differences in the fauna of seagrass beds depended on their proximity to other marine habitats. In Baelde's study in Guadeloupe in the Caribbean, mangrove-associated seagrasses were found to provide nursery areas for small juveniles and reef-associated seagrasses were used for foraging by species that shelter among corals for the rest of the time. Baelde found that seagrass beds associated with coral reefs were utilised by fish that were better adapted to avoid predation than those fish associated with mangroves.

Predation, whether from nocturnal visitors to the seagrass bed or from ambush predators during the day, may be an important influence on the ecology and behaviour of the seagrass fish. It may be predation pressure that has led to the multi-species schools that characterise the seagrass fish community. The

species in these schools also adopt a uniform camouflage colouring, their green-yellow bodies, and horizontal yellow stripe, so that although these species all look very different out of the water, underwater in their schools they look very similar apart from slight differences in body shape.

The only other seagrass fish study I have found that produced higher numbers of species than those found in Cape Bolinao (Campos *et al.* 1994) or in the present study was a very large scale study in the Gulf of Carpentaria, Northern Australia (Blaber *et al.* 1994). They sampled day and night by trawling over an area of tens of kilometres and identified 300 species from 85 families. They found substantial differences between catches made during the day and during the night.

Studies on a more similar scale to the present study generally gave much lower numbers of species and families despite many of them including night-time sampling and more efficient fish capture techniques, such as the use of rotenone poison and drop-traps. Dominant species by weight in these seagrass habitats ranged from rabbitfishes in the Philippines (Vergara and Fortes 1989), cardinalfishes in Indonesia (Hutomo & Martosewojo 1977) and Madagascar (Harmelin-Vivien 1983), hammerhead sharks in Groote Eylandt, Northern Australia (Blaber *et al.* 1992) and grunts and porcupine fishes in Mexico (Arancibia, Linares & Day 1980) (see Table 7).

Apogonids (cardinalfishes), one of the major families present in catches from other seagrass areas did not figure prominently in the catch from Quirimba. Numerically the most common species of cardinalfish, *Cheilodipterus quinquelineatus* accounted for 1% of the number of fish caught but only 0.14% of total fish biomass.

Nursery Area Functions

In the Caribbean, the key characteristics of a seagrass bed that make it a good nursery area are: low predation compared to reefs, high structural complexity offering protection to small animals, and a rich food supply provided by plant detritus and associated micro-organisms (Adams *et al.* 1973, Young and Kirkman 1975, Ogden and Gladfelter 1983 in Ogden 1997). Specific studies of

nursery area use in the Caribbean were carried out on the French grunt *Haemulon flavolineatum*. They spend two weeks as planktonic larvae and settle in to seagrass beds at night. After a month or so in the seagrass beds the juveniles move towards the reef (McFarland *et al.* 1985). These fish have a very high post-settlement mortality of over 90% for the first month, but the time spent in the seagrass beds may have a key role in reducing this mortality to allow some recruits to survive (Shulman and Ogden 1987). Birkeland and Amesbury (1988) suggested that nearby seagrass and mangrove habitats improve the likelihood of fishing on reefs being sustainable. Perhaps the close proximity of mangroves and coral reefs to the seagrass beds of the Montepuez Bay not only increases the diversity of species in the fishery, but also improves its sustainability.

The Quirimba seagrass beds do seem to be important as a nursery area, although migration of juveniles was not directly observed. Many of the key species were present in the fishery mainly as juveniles, for example *Lethrinus lentjan*, *Siganus sutor*, *Sphyraena flavicauda* and *Lutjanus fulviflamma*. Juveniles of 5-6cm or more were vulnerable to capture and these small juveniles formed an important part of the fishery. Currents were such in the area to ensure a high turnover of water across the reefs on the east coasts of the Quirimban islands into the Montepuez Bay, allowing good opportunities for the settlement of larvae from a wide area.

Seagrass-based fisheries are often composed of a large proportion of juveniles which is something that is typically a cause for concern in a fishery. However, the high numbers of juveniles have been suggested by some as a potential source of high productivity in a seagrass based fishery. Campos *et al.* (1994) attribute the high annual yield of the Bolinao fishery to the nursery role of the seagrass beds of the reef flat, the high proportion of herbivores – first-level consumers in the catch - and the fast growth and high turnover of the dominant rabbitfish species. By harvesting young fish the fishery may be utilising fish biomass that would otherwise be lost through natural mortality. Bolinao Bay supports a siganid fishery, based on 2-5cm juveniles of *Siganus fuscens*, *S. spinus* and *S. argenteus*. The fish are used to make a fermented fish paste that is regarded as a delicacy. In Bolinao, the juvenile fishery may also be more

economically important than the adult fishery (Aragones & de la Paz 1993). There, indicators of overfishing are becomingly increasingly evident in the form of the preponderance of small fish. *Siganus fuscens*, the dominant fish in the fishery is heavily exploited at all life stages which is a cause for concern, but Campos *et al.* (1994) suggest that as a first order consumer the rabbitfish may be more resilient to overfishing than some species at higher trophic levels. In a situation where adult fish are highly exploited as well as juveniles, a juvenile fishery could be highly damaging, greatly reducing the already small numbers of recruits to the adult habitat. However, in a situation like the one in the Montepuez Bay, where the reefs and reef flats are fished very lightly, the adult population may be able to sustain the high fishing mortality of juveniles. This can only happen if sufficient juveniles reach adulthood and the reefs to reproduce. The key point here for management is that the fishery is not so intense as to virtually eliminate each generation of fish at the juvenile stage so insufficient adults reach maturity to maintain the population and sustain the fishery.

Without long term data it is difficult to say whether the fishery as we see it now is already in decline or whether the fish populations and community structure have already been changed by fishing pressure. In studies of reef fisheries one of the indicators of overfishing is a tendency to catch fish further and further down the trophic scale, or "fishing down the food webs" (Pauly *et al.* 1998) that is being seen in fisheries around the world. Reef fishery catches composed of a high proportion of herbivores and planktivores are thought to indicate an overexploited system where original target species, usually carnivores such as groupers (Serranidae), emperors (Lethrinidae) and snappers (Lutjanidae) have been overfished. Fishers have then targeted less desirable or valuable species of fish, working their way gradually down the food web. What are the effects of overfishing on the trophic structure of a seagrass fish community? In the Montepuez Bay fishery over 40% of the fish biomass comes from herbivores but it is impossible to say what this indicates about the exploitation status of the seagrass beds. Herbivores would be expected to be the dominant trophic group in a habitat composed almost exclusively of seagrass and algae. However, if they are also the species preferentially removed by the fishing methods it is likely that it would be the species fish that have the most generalist diets and

that are adapted to the widest range of habitats that would become dominant, for example benthic detritus feeders such as *Gerres oyena.*

Seagrass fish communities

Seagrass fish communities have a variety of facets: the seagrass-feeding, seagrass-coloured residents such as *Leptoscarus vaigiensis* and *Calotomus spinidens*, *Cheilio inermis* and *Paramonacanthus barnardi*, juvenile reef species such as *Lethrinus lentjan* and *Lutjanus fulviflamma* and visiting adult species that feed or shelter in the seagrass beds. Although the species present may vary greatly between seagrass beds in the Caribbean and various parts of the Indo-Pacific, this combination of species types and life stages and trophic groups could be considered a characteristic seagrass fauna. This distinct seagrass fauna may be diverse in species and form, but this diversity is likely to be increased by the transient fauna of opportunistic and highly mobile species which utilise the seagrass area. Seagrass beds in the Montepuez Bay, as in many other places, form stepping stones of complex habitat, food and shelter between areas of coral communities, between stands of mangroves and between corals and mangroves. They play an important role in fish migrations of many different kinds (daily, season, life cycle, Appeldorn *et al.* 1997) and are so are likely to contain species that have no specific need for seagrass as a food source or shelter but are in transit between other habitats. In the Montepuez Bay there is also a suite of mobile larger species, mainly scarids and some species of wrasse, which are permanently resident and specialised for life in seagrass.

Comparison of seagrass fish diversity and coral fish diversity in the Quirimba Archipelago

" The diversity of fish species in seagrass beds is not nearly so high as coral reefs but seagrass beds provide foraging grounds for many of the coral-reef associated species, and therefore indirectly support coral reef species diversity (McClanahan *et al.* 1994)." Ruwa (1996).

It is impossible to make direct comparisons of reef and seagrass fish diversities as they were studied using very different methods. The diversity of reef fishes in the Quirimba Archipelago was studied in a rapid, superficial way by undertaking 28 half hour fish census dives in which all species seen were recorded. These were undertaken at 8 different islands within the southern Island group of the Archipelago. In addition to more than 14 hours of underwater observation, on the islands of Quisiva, Quirimba, Sencar and Rolas the reef fishery (mainly line and spearfishing with some large marema and gill net catches) was studied and species identified for a total of perhaps 1000 fish over the 26 month study period. All these species were recorded as coral reef species. In total 228 species of fish were identified from coral reefs in this way, and 252 from seagrass beds from the fisheries assessment methods. A total of 388 species of fish were recorded from the Quirimba Archipelago from this combination of methods and habitats. Of these species 92 where found both in seagrass and reef habitats, 136 were found exclusively in reef habitat and 160 were found exclusively in seagrass habitats. The higher diversity of fishes from seagrass habitats than reef habitats is difficult to defend as a meaningful result because of the very different types of sampling and effort. It is nevertheless interesting that seagrass habitats proved so speciose and contained many species not observed on reefs after a not inconsiderable reef study period.

Although the total number of fish species caught in the fisheries exceeded 200, a much smaller number of species could be considered commercially important. Just 5 species accounted for over 60% of catch weight sampled (*Siganus sutor*, *Lethrinus lentjan*, *Leptoscarus vaigiensis*, *Lethrinus variegatus* and *Gerres oyena*) and the 27 species in Table 2 accounted for nearly 90% of total weight of catch sampled. In terms of stock assessment and the sustainability of the fishery it is necessary to focus on a few key species (see Chapter 4). However, in terms of habitat or ecosystem conservation we need to look much more closely at the diversity of species we have found in these seagrass beds. Using the local fishery has proved an invaluable way to sample large numbers of fish from a habitat that is notoriously difficult to study by visual methods, expensive, time-consuming and destructive to study by alternative methods such as box-traps and rotenoning. It is ironic that the diversity of the fish communities of the

seagrass beds of the Montepuez bay has been revealed through the medium of its greatest short-term threat – an intensive fishery. No significant correlations were found between seagrass characteristics, such as number of species or biomass category, and the diversity of fish species. However, this study was done on a large scale, comparing species numbers caught over a large site with seagrass characteristics sampled throughout the site – not an ideal way to detect subtle relationships. However, having revealed this unexpectedly high number of species and families in a habitat not noted for its diversity, it is important that this information is considered in the future management of the area.

Why is the area so diverse?

There are a number of possible reasons for this:

1. **Habitat complexity**: Seagrass beds have a high level of habitat complexity. Like terrestrial forests they provide shelter and refuge at a variety of levels, from the seagrasses such as *Halophila* which grow close to the sandy substrate, to the tall leaves of *Enhalus acoroides* which provide shelter or ambush possibilities to some large species. The sandy substrate on which seagrasses are based also provides options for habitat complexity often through the potential for habitat manipulation. Fish species such as gobies are able to dig burrows in sand and also benefit from the surrounding cover and food supply of the seagrass beds. Mounds and depressions in the sand created by burrowing sea cucumbers also increase the habitat complexity and influence the growth of seagrasses (pers. obs., Brouns & Heils 1985).

2. **Proximity of diverse habitats**: As I have explained earlier many of the seagrass fishing sites were either in close proximity to or contained small areas of coral communities or mangroves. The close proximity of the three habitat types, seagrass, coral communities and mangroves, in the Montepuez Bay may in itself create an opportunity for specialist species from the three habitats to be found within a small area, while generalists able to utilise aspects of all three habitats are also able to thrive. In other studies in the Quirimba Archipelago fish counts were made in a variety of reef other coastal habitats and some of the highest fish species counts came from shallow (5m) patch reefs surrounded by

dense *Enhalus acoroides* and *Thalassia hemprichii* seagrass beds. On a much smaller scale, the diversity of seagrass beds containing the small (10cm diameter) pieces of branching coral, large sponges and sand-associated anemones interspersed amongst the seagrass can contain a broad variety of specialist (juvenile corallivorous butterflyfishes on coral heads, *Amphiprion* spp. on anemones etc) and non-specialist fish. Some of these species may occur on unvegetated sand in proximity to coral or mangrove but the seagrass does provide a additional advantages. These include shelter, substrate stability and an enormous surface area which can be colonised by algal epiphytes, spats of invertebrates and as a substrate for some benthic fish eggs.

3. **Food:** Seagrass beds are an important food source. They provide food for fishes in the form of the seagrasses themselves, epiphytes and other associated algae. There has been a great deal of controversy about the nutritional value of seagrasses and their importance in the diets of herbivores. It has been repeatedly said that seagrasses are low in nutrients and virtually unpalatable. Valentine and Heck's recent review paper (1999) contains considerable evidence supporting the claim that not only is seagrass a viable and nutritious food source, better quality than many species of algae, it is eaten by lots of creatures in significant quantities.

Seagrass as a food source

Numerous sources have claimed that the importance of living seagrass leaves as a food source is extremely limited. This has always seemed surprising and unlikely that so few animals should have adapted to utilise such a plentiful resource. A recent review paper presents persuasive evidence of the true importance of seagrass in the diets of animals, suggesting that "grazing on seagrasses is widespread in the world's oceans" (Valentine & Heck 1999). It was previously thought that seagrasses were not grazed because of their low nutrient content and the indigestibility of their cellulose and that less than 10% of above ground biomass was grazed, with the most important contribution of seagrasses to the marine food chain derived from detritus.

Valentine and Heck present their counter evidence to these theories:

1. The nutrient content of seagrass may be similar to that of algae (Thayer *et al.* 1984)
2. Seagrass detritus contains a lower level of nutrients than living seagrass (Klumpp & Van der Walk 1984).
3. Many herbivorous fish are "extreme generalists" feeding on vegetation in proportion to its abundance (Hay 1997) and seagrass is preferred to many species of algae.
4. Sea urchins consume up to 100% of above ground seagrass biomass in some areas.
5. Where fishing pressure is low herbivorous fish are the dominant herbivores, rather than urchins.
6. Seagrass leaves have been shown to contribute to fish growth in laboratory experiments.

"...seagrass herbivory, although probably reduced in a historical context, continues to represent an important and underestimated trophic pathway in many areas, and not a highly localised anomalous event." Valentine and Heck (1999).

Evidence for seagrass herbivory in the Quirimba seagrass beds

Stomach contents of *Siganus sutor* were full of plant material which was sometimes difficult to identify as seagrass, but in many cases there were recognisable pieces such as whole leaves of *Halophila ovalis* and bites of *Enhalus acoroides* and *Cymodocea*. *Siganus sutor* appeared to have some sort of bright yellow gut symbiont which may have been involved in the digestion of seagrass material (as has been found in surgeonfishes, Fischelson *et al.* 1987).

The stomach contents of *Leptoscarus vaigiensis* were composed of plant material ground to a fine paste, but the colour and texture suggested that this was plant (angiosperm) matter rather than algae. *Leptoscarus vaigiensis* were also seen to feed on *Enhalus acoroides*. At least one in ten large seagrass leaves harvested from the fishery sites had been fed on by fishes or invertebrates (see Chapter 1) (see McClanahan *et al.* 1994).

Which fish are most vulnerable to fishing?

- **Rare, restricted range, site-attached species** such as seahorses (Syngnathidae), seamoths (Pegasidae), ghost pipefishes (Solenostomidae), less common gobies (Gobbled) and cardinalfishes (Apogonidae) that mouth-brood would all be expected to be vulnerable to intensive fishing. Many of these families have non-pelagic larval and egg phases and so are unlikely to have wide distributions on a global scale and do not have the ability to recolonise an area easily once they have gone. The common pipefish species *Syngnathoides biaculeatus* was often caught with large numbers of eggs attached to its underside. Some of these species were very rare in catches. In some cases this would be expected: species like the ghost pipefishes are not common anywhere, but other species would have been expected to be caught more often in the seagrass habitat with which they are associated. For example, the apparent scarcity of seahorses in catches was considered unusual for the area (A. Vincent pers. comm.).
- **Fish with their entire life cycle in the seagrass beds,** as they have no stage at which they are not under pressure from the fishery. This could potentially include *Leptoscarus vaigiensis, Calotomus spinidens,* and other common seagrass species.
- **Fish with one life stage that is massively overexploited** – for example the juvenile stage of *Lethrinus variegatus* is apparently overexploited, particularly in places where suri traps which specifically target juveniles of this species are used extensively (see Chapter 1).
- Large, sometimes slow-moving fish such as pufferfish (Tetraodontidae) which seem to be particularly vulnerable to capture by net fishing and by fence trapping, and which do not seem to recover well when returned to the sea.

How can the fishery be managed to reduce the threat to these species?

Many of the fish listed under the first point above are small fish whose chances of survival could be improved simply by increasing the mesh size of the cod-end. The majority of pipefishes, seahorses, cardinalfishes and small goby species would then escape. Educating fishermen could also help as these fish species are usually fairly distinctive and could quite easily be returned to the sea immediately after capture. The gravid pipefishes that are caught are simply

bycatch so it may be possible to persuade the fishermen that if they see them (they are very obvious with dozens of large eggs stuck to their belly) they should throw them back. Seahorses and seamoths would be more difficult as they are a rare and valuable resource. Fishermen can get the same price for a 5cm seahorse (sold to traders in Tanzania for the Far Eastern market for Chinese medicine) as they can for a kilo of normal fish and it seems to be a way in which individual fishermen can benefit without going through the boat owner (see Chapter 6).

A larger mesh in the cod-end and also in the main net would also reduce the pressure on the seagrass fish in which all lifestages appear in the seagrass and are targeted by the fishery. The small juveniles would no longer be vulnerable to capture. Closed seasons around spawning would seem to be a management possibility to allow adults to spawn but this may be difficult in the major species such as *Leptoscarus vaigiensis* and *Siganus sutor*, herbivores which have protracted spawning (see Chapter 4).

Which fish are preferred or targeted?

- Small fish generally
- High value species such as seahorses and seamoths
- Balistids are favoured but no specific effort is made to catch them.
- Lethrinid (emperors) and siganid (rabbitfish) meat is highly considered.

If small fish are targeted specifically (see Chapter 6) it may be more difficult to persuade fishermen to use larger mesh sizes and also more economically difficult in the initial stages. Neither seine netting nor trap fishing were highly selective fishing methods, though trap fishing was obviously much more selective on the basis of size, only targeting "medium" sized fish. Trap fishing methods had the potential for being made more selective with the use of different baits and entrance sizes.

A very intensive seagrass fishery might lead to the reduction in numbers or even disappearance of species strongly associated with the seagrass – e.g. *Leptoscarus vaigiensis*, *Siganus sutor*, in consequence actually *reducing* the proportion of herbivores in the catch. Species remaining plentiful would

presumably be non-seagrass species that feed in the seagrass beds, e.g. *Gerres oyena* (a sand-associated feeder), lethrinids like *Lethrinus lentjan* (reef-associated crustacean feeder) which can both spend large proportions of time out of the seagrass area.

Factors that may promote the sustainability of the fishery

Although the Montepuez bay fishery seems to be very intensive and the high yield would seem to indicate overexploitation, a number of self-regulatory mechanisms operate in the fishery.

- Firstly, within the fishing area there are a number of small coral patch reefs which are not fished directly because the nets would get snagged. On underwater surveys these small patches of coral appear to be important refugia for fish – although they are small they team with the more mobile fisheries species.
- The intensive seagrass fishery is not paralleled by an intensive reef fishery so the area should continue to be supplied by the reef species juveniles that are so important in the catch, as long enough adults reach the reef to reproduce.
- Although the fishermen use small mesh sizes, their nets are in poor repair and on many occasions when I snorkelled around the net observing the haul perhaps 75% of the potential catch initially encircled by the net escaped through huge holes. The fishermen could be catching a lot more than they do.
- Tide and weather conditions mean that the majority of boats only fish for perhaps half the days available. Boats can't go out in very strong winds, which are fairly common, or torrential rain, and at least four days per fortnight are not fished because there is not enough daylight time around low tide. None of the Quirimban fishermen actively fished at night.

Having said this, the fishing fleet is increasing in size, nets and traps are becoming more readily available and the islands are facing increasing pressure from itinerant fishermen from the next province south, Nampula. The population has increased by 50% in the last ten years and the seagrass fishery is the

obvious source of employment for new residents. Islanders welcome the hoards of visiting fishermen and watch as they catch twice as many fish, so no traditional management guidelines appear to be available to the Quirimbans to protect their resources.

The nature of the seagrass fish community – a diverse assemblage of fish, many of which will move between habitat types – could mean that over-exploitation may not manifest itself in yields for some time. The Montepuez Bay is an area of high water movement, potentially supplied with recruits from large areas of reefs in the Archipelago. This undoubtedly contributes to the high productivity of the area and is likely to reduce the vulnerability of many of the fish species to overexploitation, with the exception of those species discussed above that do not have pelagic larval stages.

The Quirimba Islands are at present considered a potential site for a marine protected area in Mozambique. A programme of protected areas in the Archipelago could prove to be the most effective management option for the seagrass fishery. Protected areas would provide further areas of "refuge" for common species to promote the sustainability of the fishery and for rare species to maintain species diversity. A priority might be to have a Quirimba Reserve in which marine resource use was restricted to Quirimban residents. This would be very complicated to implement but may protect the islanders and their resources from over-exploitation from outside fishermen. If the community with a stake in the future of the Montepuez Bay fishery could be clearly identified it might then be easier to implement small protected areas with the support and enforcement of that community.

The Quirimba seagrass fishery is diverse and highly productive but does need careful management to ensure that it is sustainable. In an interview a seagrass fishermen from the fishery landing beach at Quiwandala said "There will be fishermen at Quiwandala until the end of the world". With the rich, diverse harvest that the seagrass has provided for the people of Quirimba for decades, they have no reason to believe that the seagrass will not continue to provide. It remains to be seen how management can be implemented so that the local fisheries and the incredible biodiversity can both be sustained.

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CHAPTER 4

OBSERVATIONS ON THE BIOLOGY AND LIFE HISTORY OF 5 IMPORTANT FISHERY SPECIES: *SIGANUS SUTOR, LEPTOSCARUS VAIGIENSIS, LETHRINUS LENTJAN, LETHRINUS VARIEGATUS* AND *GERRES OYENA* IN THE QUIRIMBA ISLAND SEAGRASS FISHERY

ABSTRACT

The 5 most abundant fisheries species were selected for more detailed study. They were sampled from fisheries catches and weighed and measured, underwater observations were made of their presence and behaviour in seagrass and coral habitats, and aspects of their biology such as life histories and diets were determined. The five species each had very different life histories in which the seagrass beds of the Montepuez Bay played a different role. Only one species, *Leptoscarus vaigiensis* inhabited the seagrass beds throughout its life. *Siganus sutor* was present in the seagrass beds from juvenile to sub-adult phase, with adults inhabiting the exposed reef flat on the east coast of Quirimba. *Lethrinus lentjan* was only found in the seagrass beds as a juvenile, and large adults were found on the coral reefs on the eastern coast. *Gerres oyena* was found in seagrass beds over a small range of sub-adult to adult sizes, with the large adults observed to be common on the reef flats, but the habitat of juveniles unknown. *Lethrinus variegatus* was found in the seagrass beds from juvenile to small adult. No larger adults of this species were found in any other habitat. The key point made in this chapter is the diversity of life history strategies and habitat utilisation demonstrated by just 5 of the 250 species present and the challenge this presents to the fishery manager. A variety of management techniques are discussed, and the most useful is concluded to be the careful placement of no-take marine protected areas giving protection and improved chances of sustainability to the broadest range of species.

INTRODUCTION

There are few published studies of the biology of many of the tropical marine fishes that form the basis for nearshore artisanal and commercial fisheries. Although many studies of the biology and life histories of coral reef fishes have been published, the majority of these papers have focussed on small, colourful, site-attached species such as butterflyfishes, damselfishes and angelfishes. These fishes may form a part of artisanal fisheries in many tropical developing countries, but they are not the species that form the main biomass of catches. The fish that feed millions of people in the Indian Ocean, South East Asia and the Pacific: emperors (Lethrinidae), rabbitfishes (Siganidae), parrotfishes (Scaridae) and mojarras (Gerreidae) have been relatively neglected, despite the need for biological studies to improve management of the fisheries of species in these families. (Medley *et al.* 1993).

There are probably two main reasons for this neglect and the bias towards studies of small generally non-fisheries species. First of all, the fish subjects of many studies are chosen for the ease with which they can be studied. The majority of the species that form the bulk of tropical nearshore fish catches are schooling, fast moving uninspiringly coloured fish that are difficult to study *in situ,* difficult to rear in tanks and even difficult to identify. Despite the economic importance of these families, very little work has been done on the basic biology of the many species in these families. For example, basic taxonomic distinctions are uncertain in Lethrinidae (emperors), reproductive patterns are only just being determined in some species of Scaridae (parrotfishes) and life history traits such as larval duration and mobility are completely unknown in many species. Knowledge of basic biological parameters such as growth rate, age at maturity, life cycle and mortality are needed for the sustainable management of fisheries. Many stock assessment attempts suffer from the lack biological information on local species. Management strategies that appear to make economic sense fail because one crucial aspect of fish ecology or biology has been overlooked, for example the occurrence of spawning aggregations or seasonal migrations. The primary problem is lack of resources to undertake detailed biological studies. Secondly, when these studies are undertaken the results are often not disseminated, and so are not accessible to other

researchers who need the information for stock assessment. Many such studies are published as internal reports by fisheries institutions and government departments, and in unpublished university theses and do not enter the public domain. ICLARM's FishBase (1996) and their bulletin NAGA are addressing these problems and basic biological information for tropical fisheries species is becoming increasingly available. However, even on FishBase basic biological information for most of the important East African fisheries species is extremely limited and it is always necessary to refer back to the primary literature referenced on FishBase and to check the sources. Thirdly, even if a species is extensively studied in one part of the region, the parameters calculated for that population will often not be applicable to other populations in different locations where they are subject to different climates, different physical and environmental factors and different assemblages of habitat type. Another problem is that so many different species and families are encompassed by tropical artisanal fisheries that even with the resources, and the will, the sheer number of species involved would make this a very difficult task.

Lethrinids, siganids and scarids are all very important fish families in tropical nearshore fisheries and many reef and lagoon fisheries are dominated by one of more of these families. Siganids are the dominant family in the Mecufi spear fishery in northern Mozambique (Loureiro 1998) and in the Bolinao reef flat fishery in the Philippines (Campos 1994). Lethrinids and scarids are the main species in the in Kenyan and Tanzanian trap and net fishery (Watson 1996, McClanahan and Obura 1996, Darwall 1996).

In this chapter I aim to present a review of the literature on the five key species, present qualitative and quantitative observations and data on the occurrence of these species around Quirimba Island (with some information from other islands in the Archipelago where relevant) and some biological data that would be useful in future management of the multi-species fishery of which these five species form an important part.

STUDY SITE

The north of Mozambique experiences two main seasons, the hot wet season from December to May and the cooler dry season from May to November. During the hot, wet season heavy rain falls virtually every day. During the dry season temperatures drop and rainfall is rare during these months. In the dry season strong winds are more common, but cyclones are more likely in the wet or monsoon season.

The Montepuez Bay has a tidal range of over 4m and intertidal flats of over 1km in places. At high spring tides the bay is full of water, covering an area of close to 50km^2, but at low spring tides the area of bay that is filled with water is reduced to as little as 30km^2. Therefore, the area of water available to fish can potentially be almost halved over the course of a day, with potential implications for resident fish populations.

The currents in the bay are strong as the tides change and large quantities of water move in and out of the bay. These surges of water connect areas of reef on the tips of Quirimba, the main fringing reefs on the east coast of Quirimba with the seagrass beds and mangroves of the Montepuez Bay.

METHODS

Lethrinus lentjan, Lethrinus variegatus, Siganus sutor, Leptoscarus vaigiensis and *Gerres oyena* were studied from the seine net fishery in the Montepuez Bay, Mozambique (see Chapter 3). They were sampled randomly from mixed catches, were measured to the nearest 0.5cm and weighed to the nearest 1 gram (up to 200 g) or 5 grams (for fish weighing more than 200g) using a spring balance.

The incidence of these 5 species of fish in fisheries other than the seagrass seine net and trap fisheries was recorded by observing and sampling catches from other fisheries such as the reef flat gill net fishery, occasional reef flat seine netting catches, line fishing and fence trapping (see Chapter 2). Underwater observations of the presence and abundance of the key species were also made using SCUBA in seagrass beds and coral reefs. Mangroves were surveyed for these fish species by snorkelling.

Previous studies of the five key species and other fishes in their families were reviewed to provide background information on the importance of these families and species in world fisheries, on their biology and life history and any other additional information available. The majority of literature reviewed was in the form of papers in journals or reports, but a great deal of information was found using FishBase (Froese and Pauly 1996), ICLARM's CD database of world fishes.

The stomach contents of each of these species were examined from a small sample of individuals. No detailed biological analysis was carried out on the stomach contents or on any other aspect of fish biology because of logistical problems and the lack of any sort of laboratory facilities.

RESULTS

All lengths quoted are fork lengths, with the exception of those for *Leptoscarus vaigiensis* which are total lengths.

Siganus sutor

Qualitative observations in the Quirimbas

Siganus sutor was seen often underwater on the seagrass beds but was never seen on coral areas. The species formed part of the large mixed schools that were common in the seagrass beds, containing juveniles of lethrinids, scarids and mullids. *S. sutor* were sometimes observed to hover vertically over seagrass areas with their heads towards the bottom and their tails towards the surface, and adopted the horizontal yellow body stripe that seemed to be a key feature of fish in these mixed schools. *S. sutor* was the most important species in the Montepuez Bay seine net fishery in terms of biomass of fish and numbers of individuals (see Chapter 3). *S. sutor* in the fishery were generally small, less than 15 cm and many individuals were just 7 or 8 cm long. They were observed to eat seagrass and whole leaves of the small seagrass species *Halophila ovalis* were found in some stomachs examined and pieces of the larger species of seagrass were also recognisable. The stomachs of all the *S. sutor* examined contained bright yellow stomach symbionts to assist the rabbitfish to digest the

course plant material they ate. They also appeared to graze on the abundant epiphytes present on the seagrass, particularly on *Enhalus acoroides*. Full grown adult *S. sutor* were rarely seen in the seagrass beds or in the catches of fishermen in the seagrass beds. However, gill-netters on the reef flat on the east coast of Quirimba regularly caught large *S. sutor* of around 30cm. *S. sutor* were not seen in fisheries catches from coral communities or coral reefs. They were also rarely seen in the trap fishery.

The proportions of *S. sutor* changed very noticeable as they grew: small fish had an extremely compressed body whereas larger individuals had very "fat" bodies. This effect was much more pronounced in *S. sutor* than in most other species in the fishery (the relationship between lengths and weights is shown in Fig. 1).

Quantitative information

Fig. 2 shows the series of length-frequency histograms for monthly samples of *S. sutor* from the seagrass seine net fishery over the study period. In all seagrass seine net sample of *S. sutor* there were three very clear cohorts between 6 and 24cm: one around 10cm, one around 16cm and one around 20cm. These cohorts can been seen most clearly in the monthly samples from 1997 because these samples were collected over a shorter period during the month than those in 1996. There is quite strong evidence of recruitment pulses around June and around October, as small individuals of 7 or 8cm or under become very common in the catch. Based on these observations it is likely that *S. sutor* stay in the seagrass beds for approximately 1.5 years. *S. sutor* began to recruit to the fishery at just 5 or 6 cms and was caught in large numbers at 7cm and above. *S. sutor* began to disappear from the fishery at around 20cm.

Spawning possibly occurred from August to September and around April. Spawning in September is supported by the apparent disappearance of the largest cohort around September, where the 23cm to 26cm cohort disappears and is replace by the 18-20cm cohort as the largest. In the first year the average *S. sutor* attains 14cm and in the second 22-24cm. The largest adult *S. sutor* caught on the reef flats in the gill net fishery must have reached three or

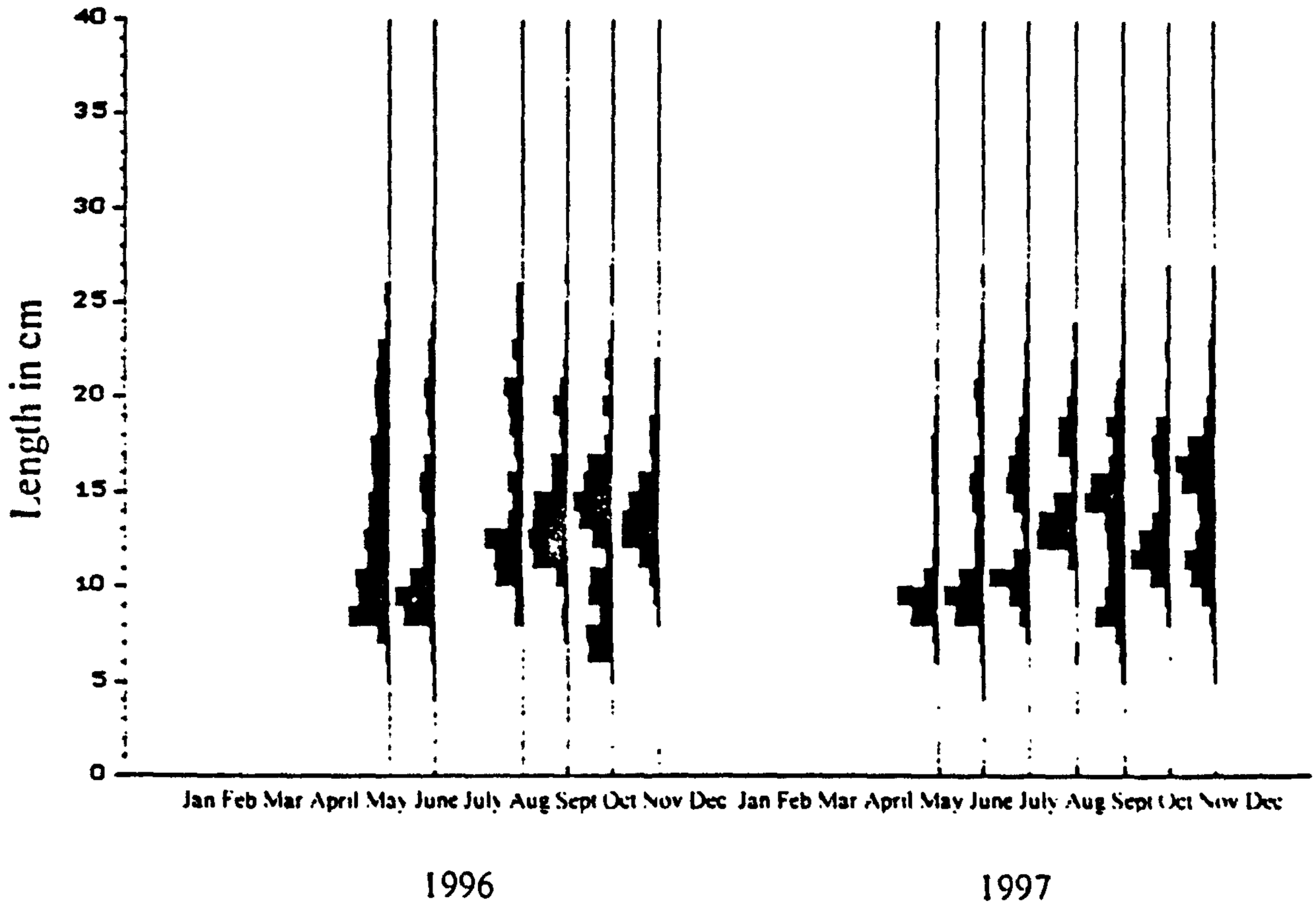


Fig. 1: ***Siganus sutor*** **length-frequency histograms for the 13 months when seine net catches were sampled in the Montepuez Bay. The data was grouped into 1cm categories and the histograms show proportion of fish in the samples in each length category rather than the actual numbers.**

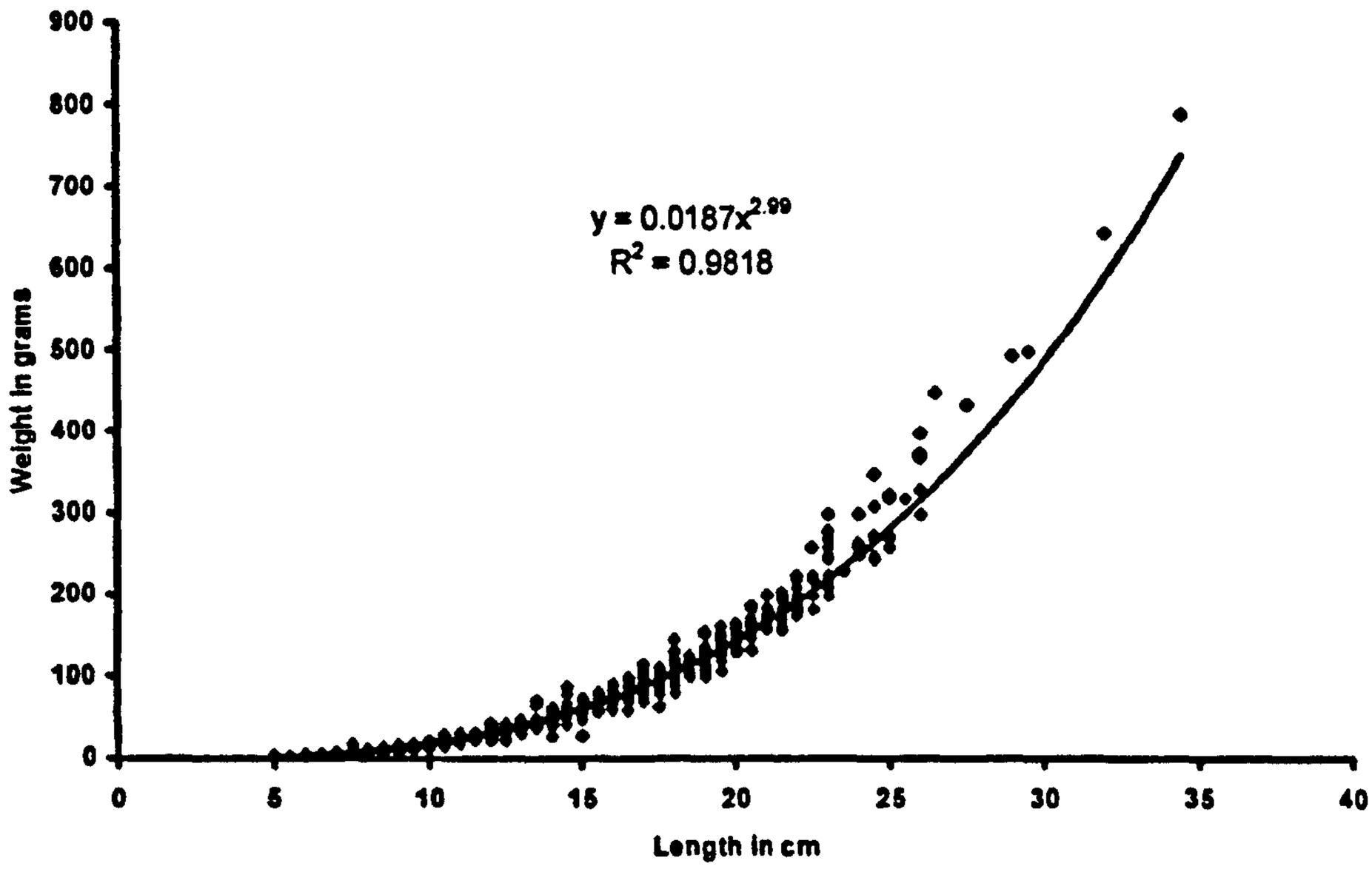


Fig. 2: Length-weight relationship for *Siganus sutor* in the seine net and trap fisheries in the Montepuez Bay. N = 1473.

more years. Fig. 3 shows the life cycle of *S. sutor* suggested by the observations made in this study.

Leptoscarus vaigiensis

Qualitative observations in the Quirimbas

L. vaigiensis were only seen or caught in seagrass areas around Quirimba and throughout the Archipelago. The individuals caught in the seagrass were often adults of over 20cm, particularly those caught in traps. They were seen to feed on seagrass and epiphytes but it was difficult to confirm the main component of the diet from stomach contents analysis because all the plant material was ground into a green paste by their pharangeal plate.

L. vaigiensis species also joined the mixed species schools in the seagrass beds described above. Approximately 10% of *L. vaigiensis* individuals were infected with large (up to 2cm long) isopod parasites living in the mouth, eating away at the "tongue" area and forming a bulbous double-chin effect under the parrotfishes head. This was also described from Kenya by Brown (1975) who said that the isopod only affected males. In this study males and females were both infected but it was mainly larger fish that had these parasites.

Quantitative values for Leptoscarus vaigiensis

Fig. 4 shows the series of monthly length-frequency histograms for *L. vaigiensis* and Fig. 5 shows the relationship between fish length and weight. *L. vaigiensis* was the "key species" in which the widest range of ages and sizes were represented in the seagrass habitat and which was not seen or fished in any other habitat in the archipelago. This species appears to live its whole life in the seagrass beds. All life stages from juvenile (6cm) to large adults (25cm) were present in the seagrass fisheries, and spawning adults were frequently seen. Three cohorts between 7 and 25cm were seen in most months in the seagrass seine net fishery but there was no clear progression of cohorts, which suggests continuous spawning and therefore continuous recruitment to the fishery. Although *L. vaigiensis* of between 20 and 30cm were seen in the traps set on the edges of the Montepuez Bay fishing grounds (eg Kumilamba and Lusino) fairly commonly, they were rare in the seine net fishery. This may be a result of the high fishing pressure on the population. It is highly likely that the *L.*

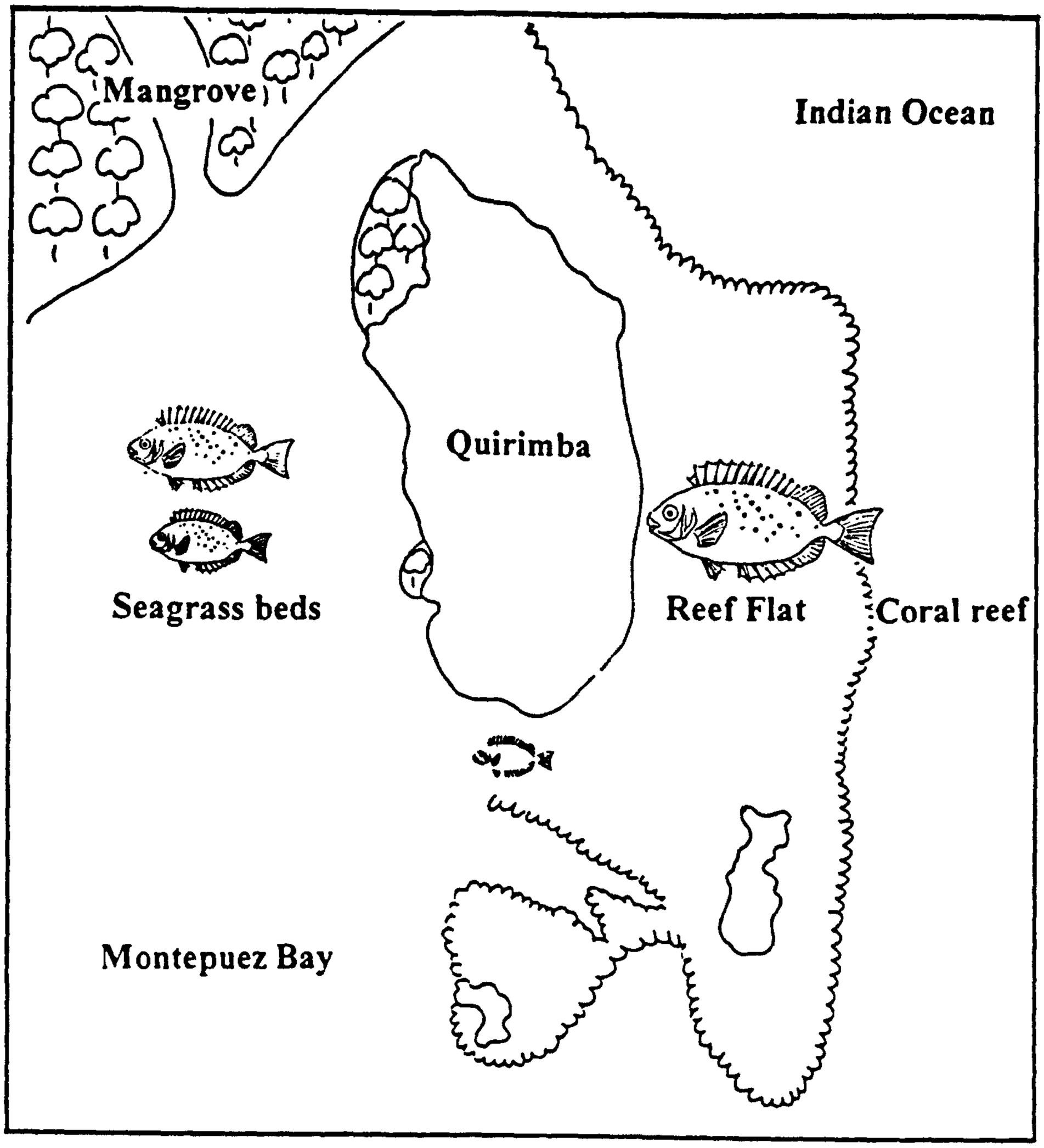


Fig. 3: Map of Quirimba Island and the Montepuez Bay showing the location of the major life stages of *Siganus sutor*.

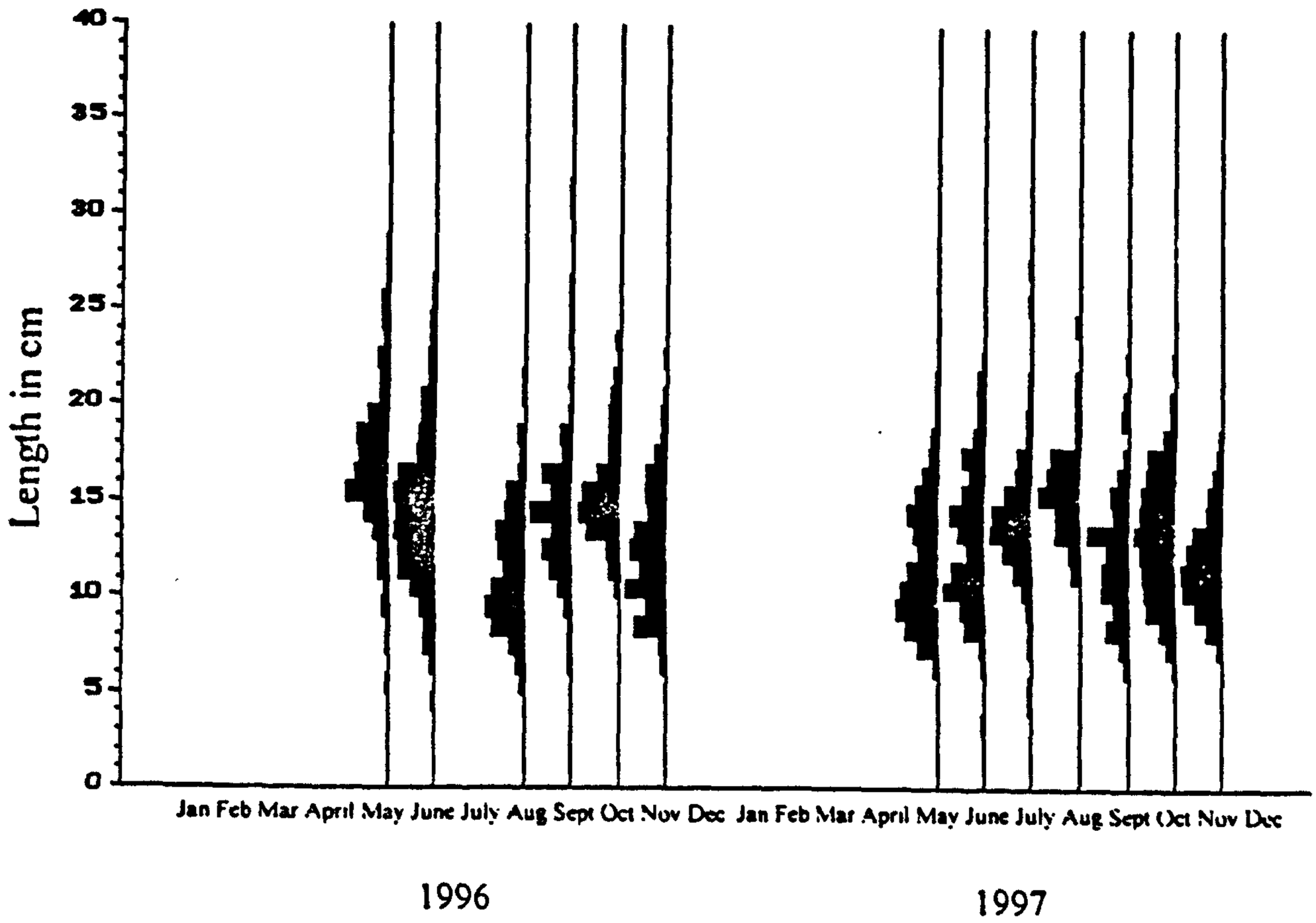


Fig. 4: *Leptoscarus vaigiensis* length-frequency histograms for the 13 months when seine net catches were sampled in the Montepuez Bay. The data was grouped into 1cm categories and the histograms show proportion of fish in the samples in each length category rather than the actual numbers.

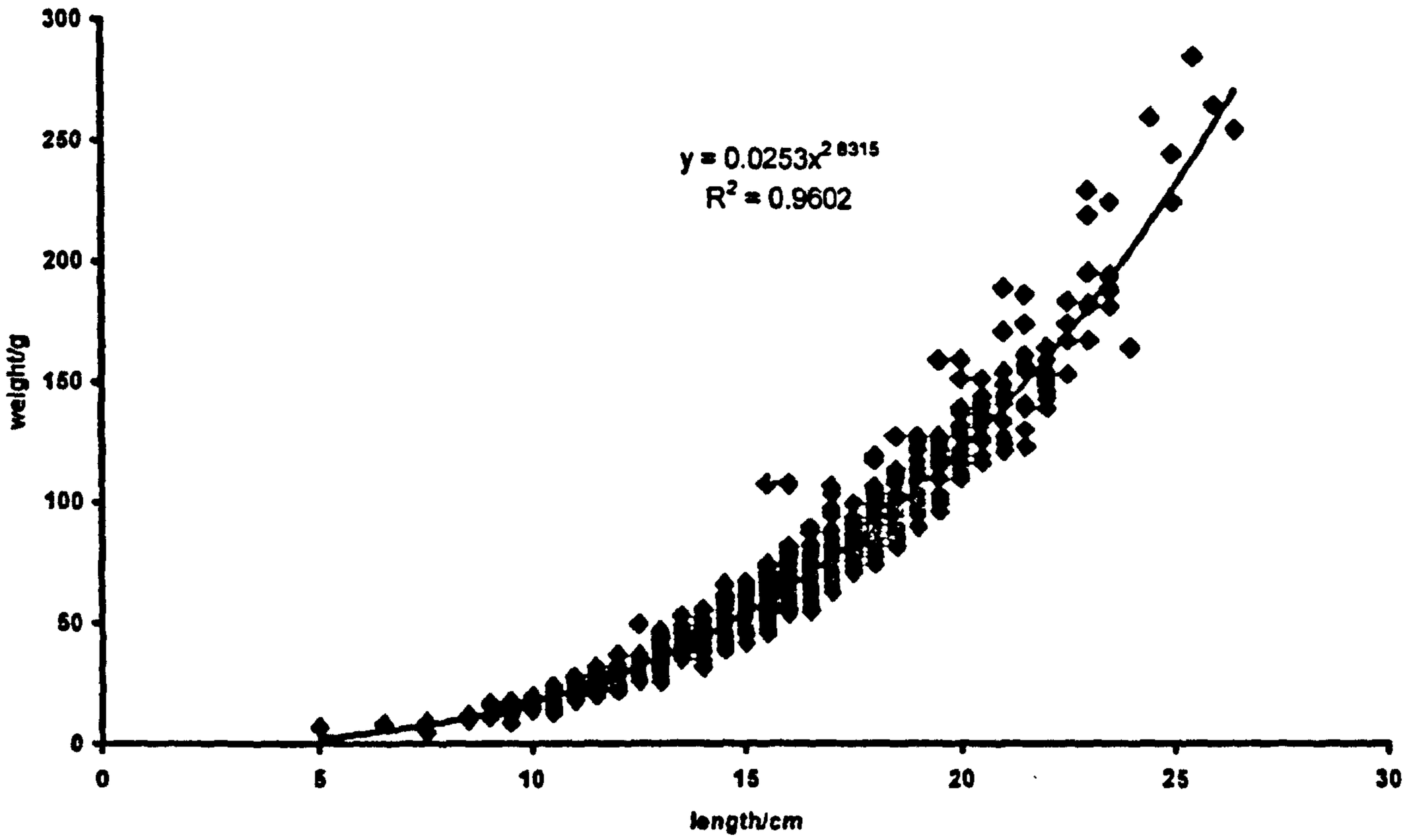


Fig. 5: Length-weight relationship for *Leptoscarus vaigiensis* in the seine net and trap fisheries in the Montepuez Bay, N = 1163.

vaigiensis of the Montepuez Bay spend their entire life cycle with the same large seagrass bed, so the adults are not migrating anywhere but may be suffering from fishing pressure and there may actually be very few fully grown adults left in this population. If *L. vaigiensis* potentially grow to over 30cm but are commonly only reaching 20cm in this fishery before they are captured then there is a real threat to the population. In Fig. 5 it is possible to see that a 25cm fish could weigh double what a 20cm fish weighs. You would therefore expect the larger fish to produce at least twice as many eggs.

Ripe fish ready to spawn (fish handled visibly lost eggs or milt) were observed during September in fish caught in traps. In 149 fish between 12.5 and 22.5cm, 46.3% were shedding eggs or milt – 17.4% eggs and 28.9% milt. The proportion of individuals with ripe gonads was similar for all of those length categories above 12cm.

Progressive cohorts in the length-frequency histograms may be obscured by differences in male and female growth rate as the sex of fish measured was not recorded (because it was not immediately obvious and would have meant compromising speed). Fig. 6 shows the suggested life cycle for *L. vaigiensis* in the Montepuez Bay.

Lethrinus lentjan

Qualitative observations in the Quirimbas

L. lentjan was seen in the seagrass beds and caught there as a juvenile. In bommie areas within the seagrass beds small adults (20cm and more) were seen and caught. Very large individuals are caught by line fishermen in reef areas between Quilaluia and Quirimba. The largest individual recorded caught by line on the reef was 50cm. *L. lentjan* adults were seen in small groups on the reefs of Quirimba and other islands. They were always fairly large, 30cm of more on the reefs. Reasonably large (20cm and over) *L. lentjan* were also caught in *maremas* baited with *Terebralia* shells. The flesh of *L. lentjan* was excellent and was highly regarded by local people. Some fishermen charged higher prices for large *L. lentjan* (see Chapter 6).

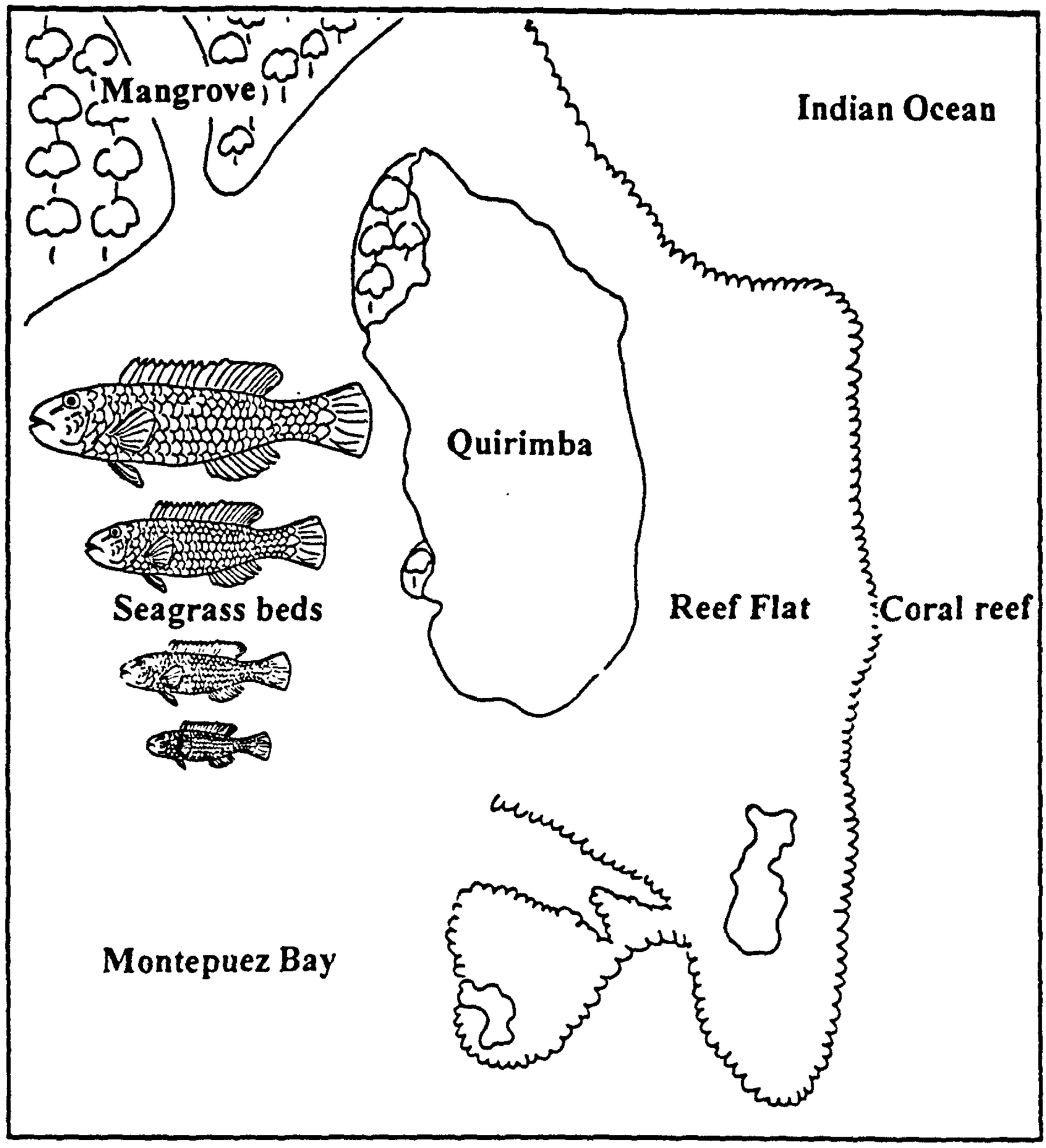


Fig. 6: Map of Quirimba Island and the Montepuez Bay showing the location of the major life stages of *Leptoscarus vaigiensis*.

Small adult *L. lentjan* were most commonly caught in the coral-rich areas of south Santa Maria and Lusino at the southern end of Quirimba. Small (less than 15cm) *L. lentjan* were caught elsewhere in the Bay and were commonly seen in the mixed seagrass schools. From stomach contents analysis, *L. lentjan* were apparently carnivores, with crustaceans, mainly small crabs as their major prey.

Quantitative information

Fig. 7 shows the monthly length-frequency series for *L. lentjan* and Fig. 8 shows the length-weight relationship. *L. lentjan* was present as juveniles and small adults in the seagrass seine net fishery, and were caught as large adults by hook and line fishermen on coral reefs. *L. lentjan* showed at least three distinct cohorts, with four visible in some samples, with most fish falling between 8 and 25cm. When four cohorts were visible they appeared to be at 9cm, 14cm, 18cm and then 24cm. A slight progression of cohorts was visible over the study period and from the length frequency diagrams there appeared to be a pulse of recruitment around April and one around August. This would correspond with spawning around June and October. Individuals disappear from the seagrass fishery at 22-25cm which may be when the mature adults leave the seagrass beds to migrate to the reefs. If there was biannual spawning as the cohort patterns suggest then two year classes were present in the seagrass beds and the *L. lentjan* must migrate to the reefs towards the end of their second year. Adults of as much as 50cm have been caught form the reefs which suggest great longevity after leaving the seagrass beds of over 6 years (Wassef (1991) gives a mean length of *L. lentjan* at 6 years as 39cm, Toor (1967) gives a mean length of 44cm for a 4 year old *L. lentjan*).

The annual growth rate of *L. lentjan* in the first year (up to 12cm) seemed to be little under 1cm per month on average. The growth rate did not seem to slow greatly for the second year as the majority of individuals appeared to reach 22cm or more in the second year of growth. This is in accordance with Toor's (1967) study in India in which the average length of *L. lentjan* at ages one and two years are 17-18cm and 26.5 to 27.5cm respectively. In the Red Sea length at age 1 year was estimated at 11cm, year 2 19.5cm and year 3 26.5cm (Wassef 1991). The life cycle for L. lentjan as suggested by the results of this study is illustrated in Fig. 9.

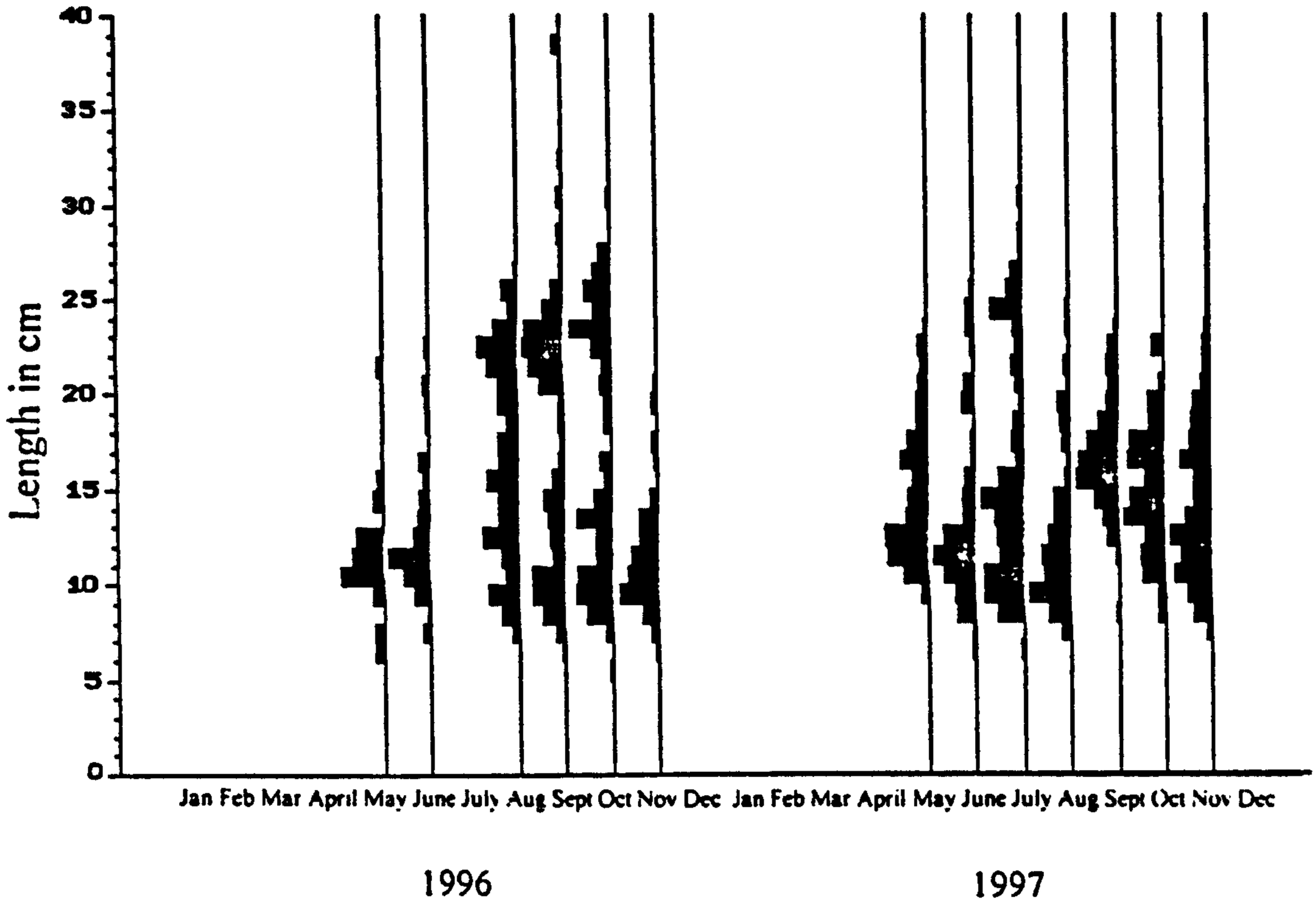


Fig. 7: *Lethrinus lentjan* length-frequency histograms for the 13 months when seine net catches were sampled in the Montepuez Bay. The data was grouped into 1cm categories and the histograms show proportion of fish in the samples in each length category rather than the actual numbers.

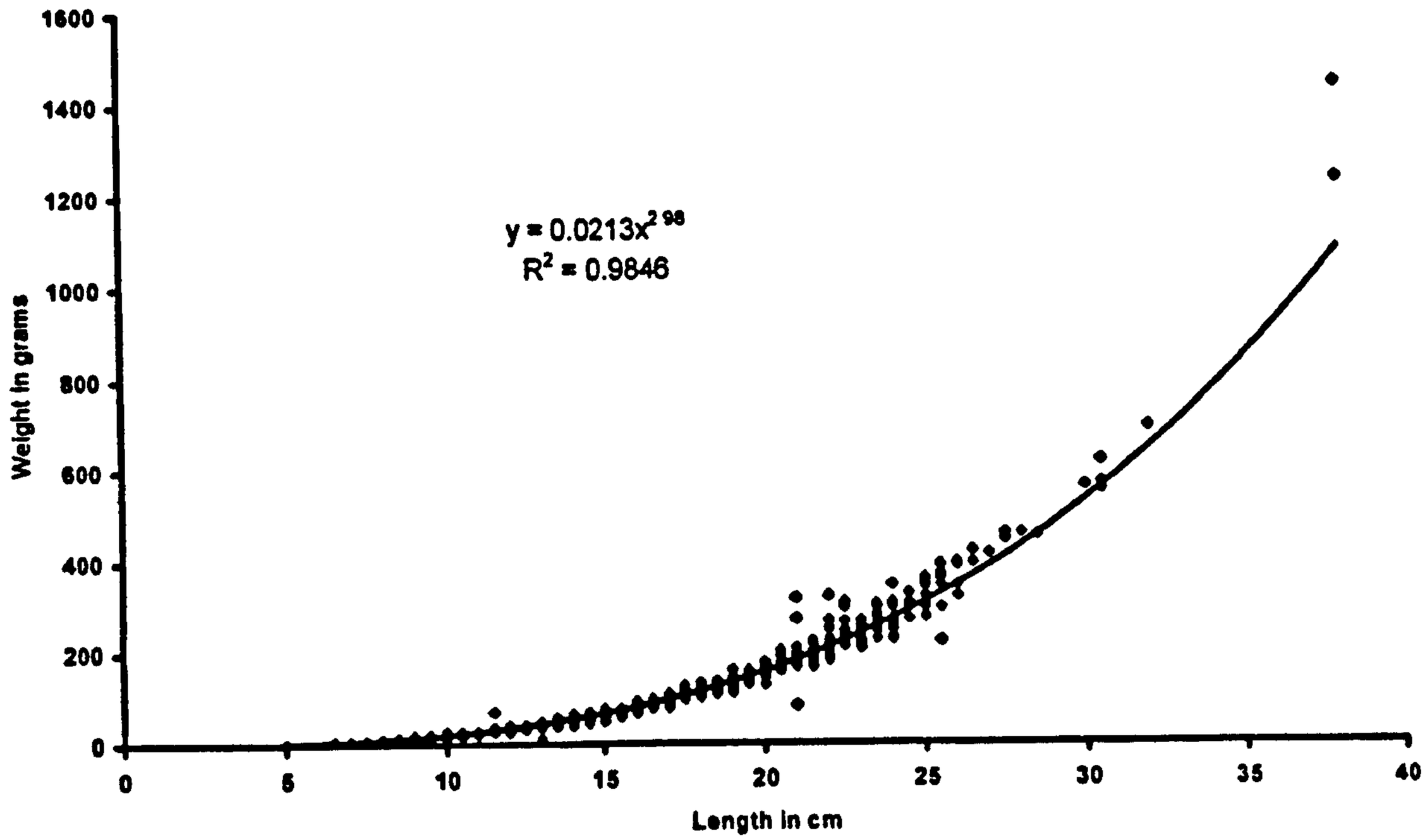


Fig. 8: Length-weight relationship for *Lethrinus lentjan* in the seine net and trap fisheries in the Montepuez Bay, N = 685.

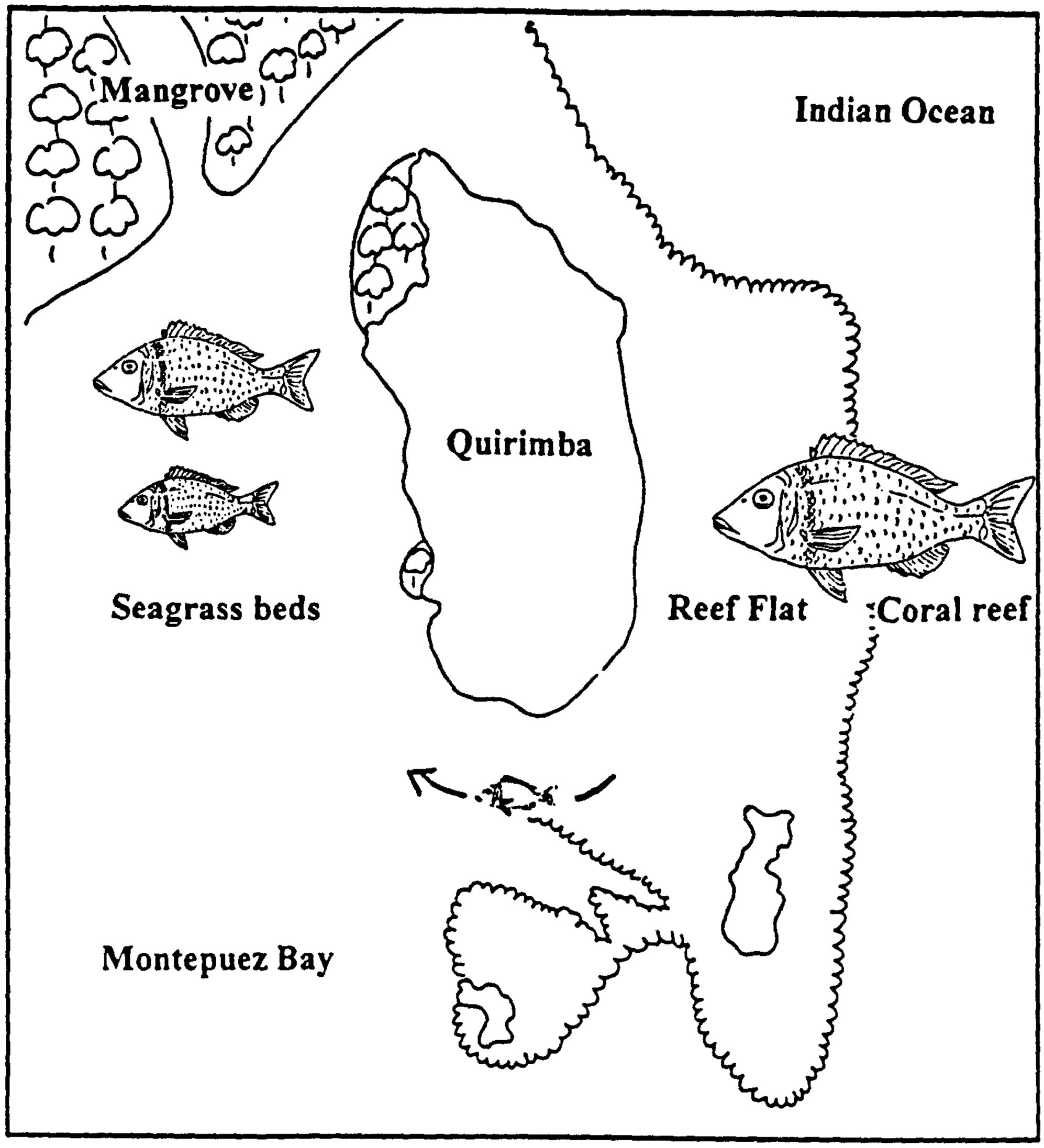


Fig. 9: Map of Quirimba Island and the Montepuez Bay showing the location of the major life stages of *Lethrinus lentjan*.

Lethrinus variegatus

Qualitative observations in the Quirimbas

L. variegatus was on of the most numerically abundant fish in the seagrass fishery. It was also the fish most commonly seen underwater on the seagrass beds, forming the major component of the mixed species schools. Underwater the fish adopted a horizontal stripe through the middle of their body, and their top half appeared yellow. They often hung vertically amongst the seagrass.

L. variegatus were crustacean feeders, and the remains of a variety of crab species were found on analysis of stomach contents. *L. variegatus* of over 13cm were extremely rare in any fishery catch in the Quirimba Archipelago. Occasionally individuals of 15 or 16cm were found in the catches of *suri* fishermen (who specifically targeted *L. variegatus* with small baited traps) and a single 18cm individual was found in the catch of a line fisherman fishing on the reefs of Rolas island, further north in the Archipelago. As this was the only individual of this size to be found during the 16 month study in which over 50,000 fish were sampled, it seems likely that *L. variegatus* of this size and over were extremely rare in the Quirimba Archipelago.

Quantitative observations on *L. variegatus*

At any one time in the seine net fishery only one cohort of *L. variegatus* appeared to be present with lengths from 7 to 12 cm. The mode length for *L. variegatus* was usually 9cm each month, occasionally 10cm. After 13cm the fish seems to completely disappear from the fishing ground, with the exception of a few outliers. There did not appear to be a clear progression of modal lengths, apart from around June to September 1997 (see Fig. 10). After September this cohort disappears from the fishery and a new one appears. There was no convincingly clear evidence of the times for spawning but there was some evidence of pulses of recruitment around June and around September or October. No large adults were present in the fishery, but unlike some of the other species examined here there was no evidence of large numbers of adults in other fisheries or ecosystems so it is a mystery where the fully grown adult *L. variegatus* go, if indeed there were larger adults elsewhere. It could be that the *L. variegatus* live out their entire life in the seagrass beds. The unimodal

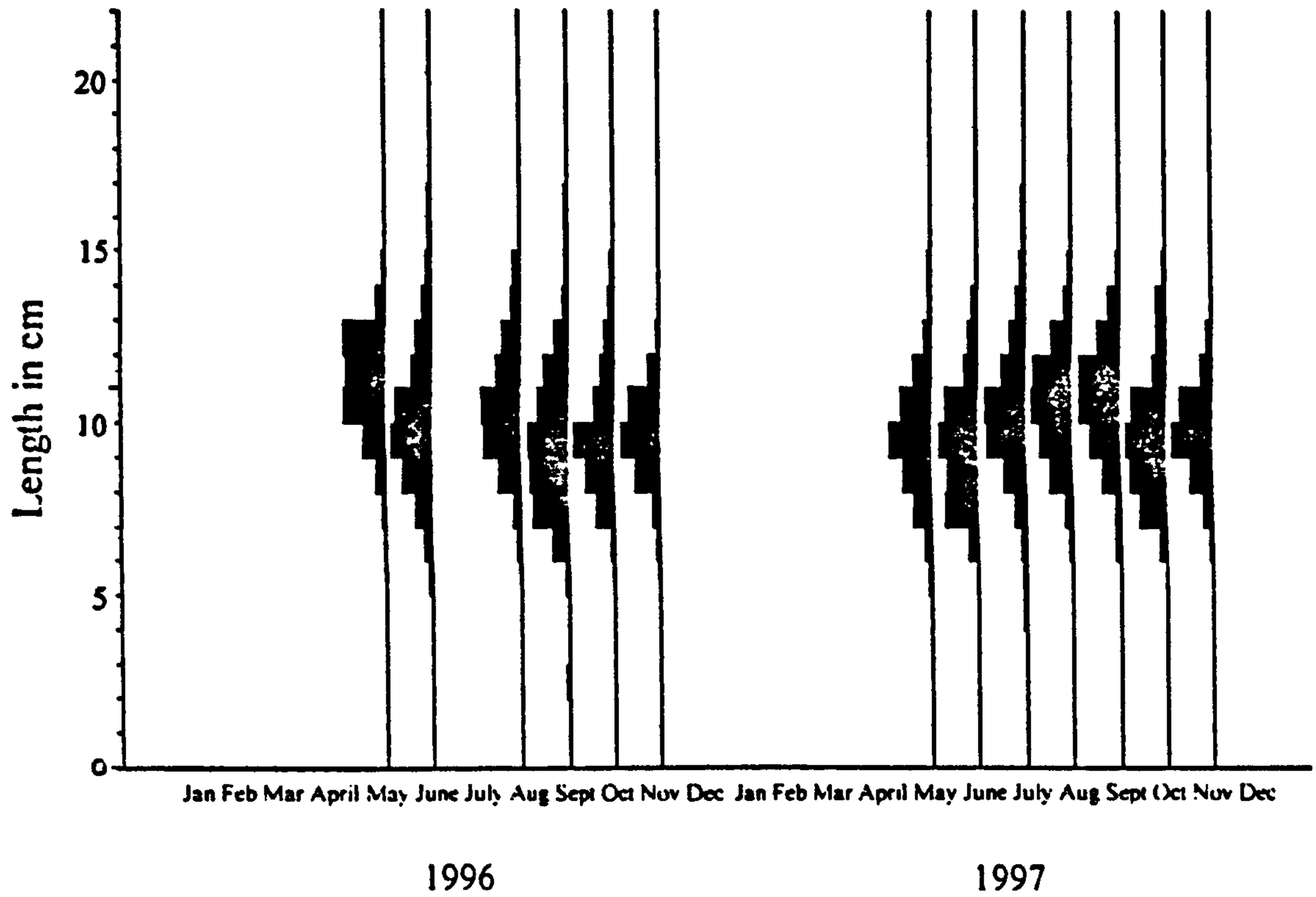


Fig. 10: ***Lethrinus variegatus*** **length-frequency histograms for the 13 months when seine net catches were sampled in the Montepuez Bay. The data was grouped into 1cm categories and the histograms show proportion of fish in the samples in each length category rather than the actual numbers.**

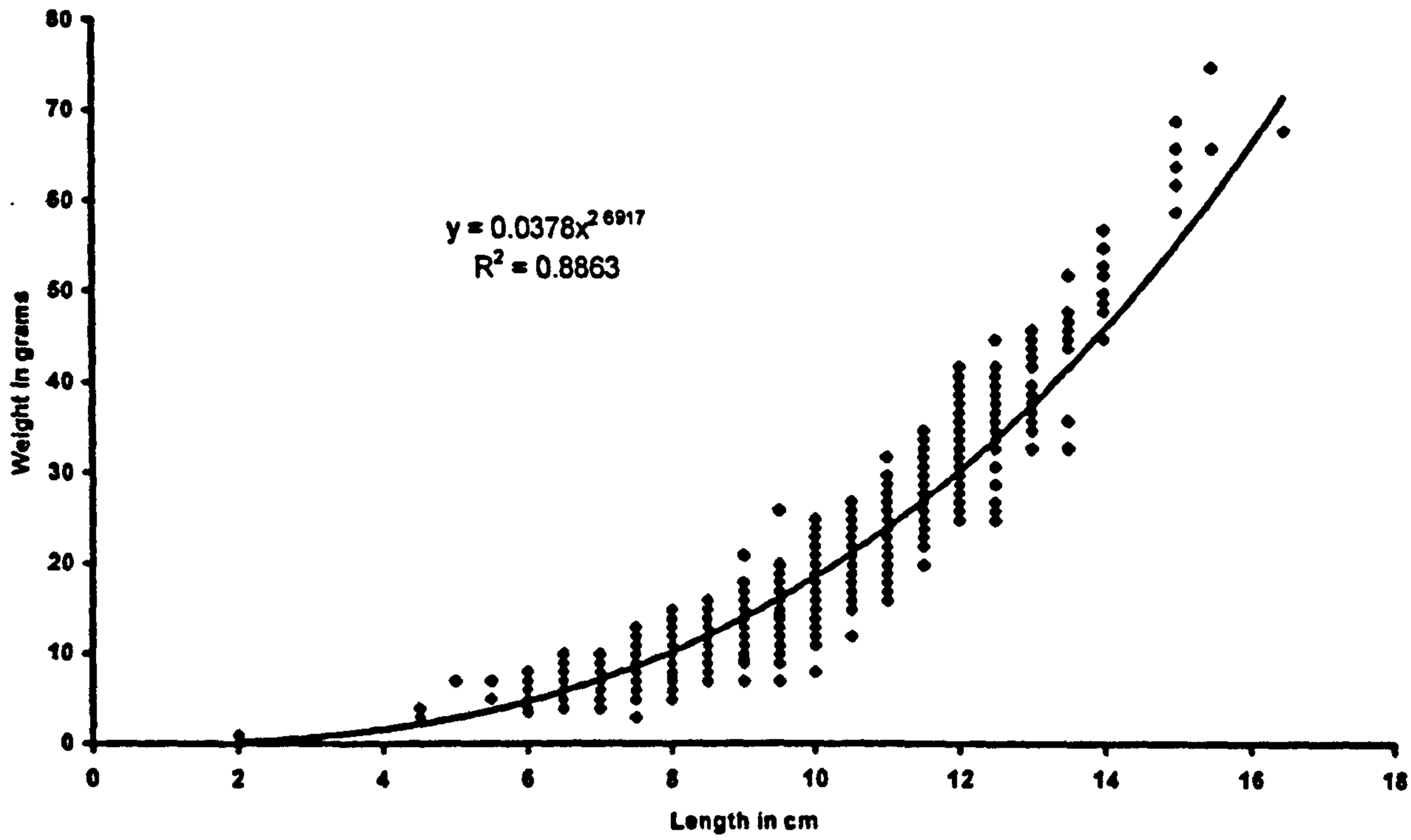


Fig. 11: Length-weight relationship for *Lethrinus variegatus* in the seine net and trap fisheries in the Montepuez Bay, N = 1634.

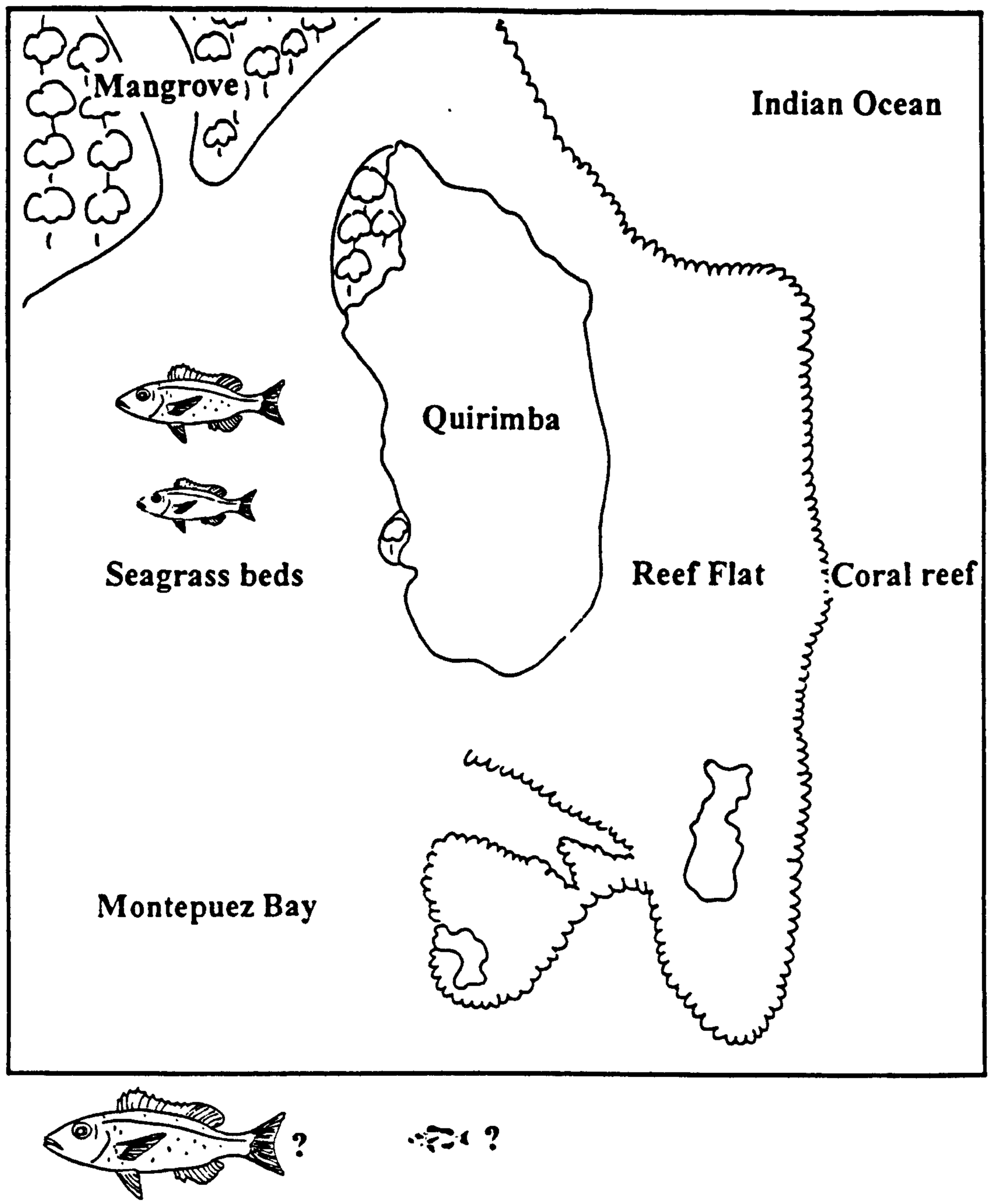


Fig. 12: Map of Quirimba Island and the Montepuez Bay showing the location of the major life stages of *Lethrinus variegatus*. The large adult and the juvenile have been placed outside the map because their location was unknown.

distribution suggests that there was only one year group. For a small species it is possible that it only lives for a year, but it does seem unlikely in view of the much longer life cycles in other members of the lethrinid family. The intense fishing pressure on this species could possibly have led to a significant decrease in the maximum lengths in the population. The maximum adult size could now be 15cm rather than 20cm in this particular exploited population.

Gerres oyena

Qualitative observations in the Quirimbas

G. oyena were often seen underwater in seagrass beds in large monospecific schools of small (around 10cm) fish. They were also caught in schools – in a seine net haul there would either be a large number of *G. oyena* caught as a school or none of the species. *G. oyena* did not join the mixed species school of juveniles in the seagrass beds – these schools were characterised by small, greeny grey fish all looking very similar. *G. oyena* had a very distinctive silver appearance and formed large single species schools. *G. oyena* were commonly caught in gill nets on the reef flat on the east coast of the island and these fish were usually large adults of 20cm and over.

G. oyena were often seen over sand and close to the shore. *G. oyena* fed on small things from sand in seagrass areas with retractable mouths. Nothing immediately recognisable could be found in the stomachs – they fed on a variety of small benthic invertebrates. *G. oyena* flesh was unremarkable and was commonly dried.

Quantitative observations from fisheries data.

G. oyena was common in the seagrass seine net fishery as individuals of around 10cm, common in the reef flat seine net fishery as large individuals of 25cm and completely absent from the seagrass trap fishery (see Chapter 3). In the seine net fishery only one large cohort appeared to be present of between 7 and 13 cm, with the majority of individuals consistently measuring between 9 and 11cm (see Fig. 13). There was no obvious progression of these cohorts over the months as would be expected if there were distinct spawning events so the evidence suggests that *G. oyena* spawned all year round. If this was so then there would be a constant stream (or a monthly pulse) of recruits from the reef

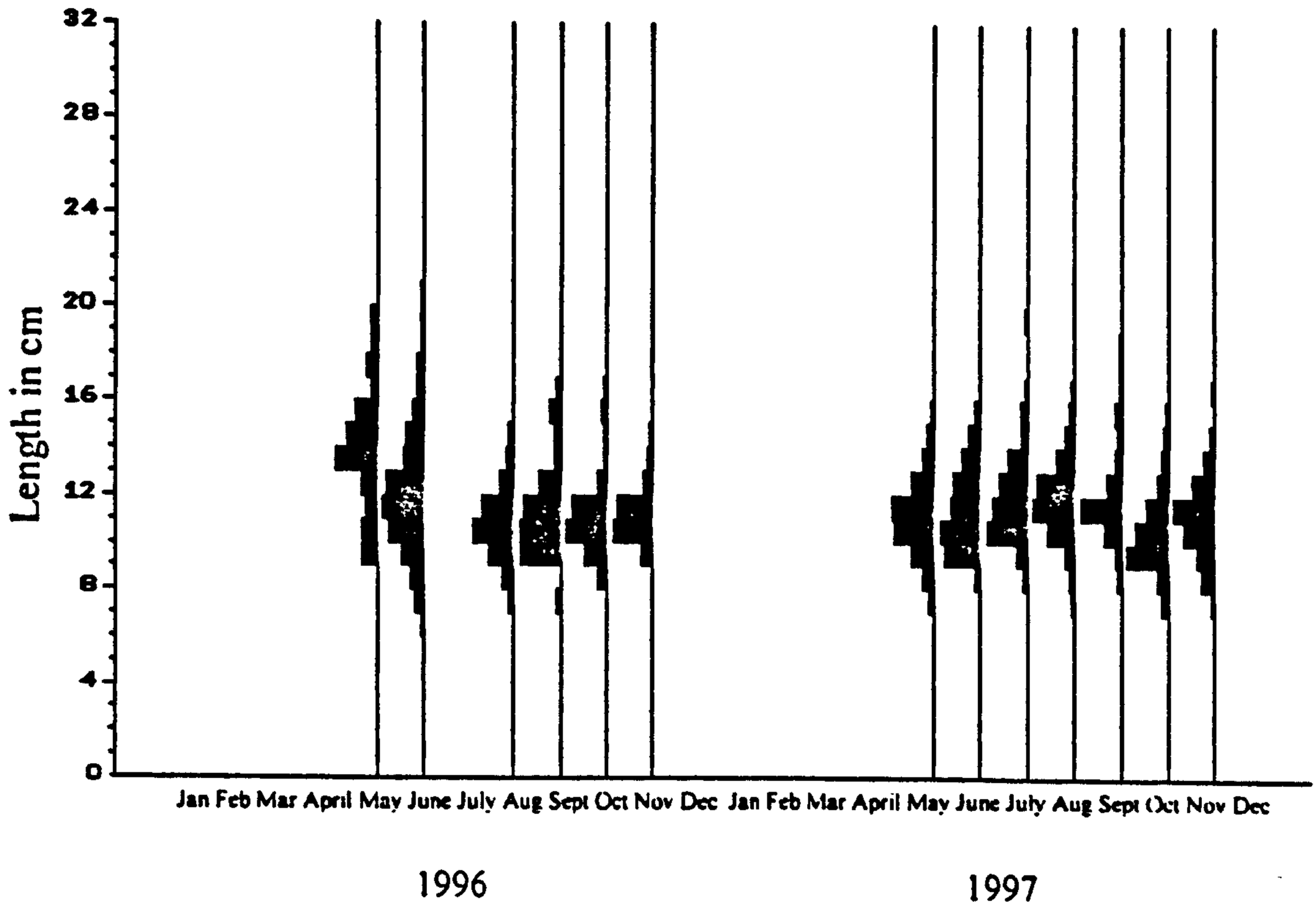


Fig. 13: *Gerres oyena* length-frequency histograms for the 13 months when seine net catches were sampled in the Montepuez Bay. The data was grouped into 1cm categories and the histograms show proportion of fish in the samples in each length category rather than the actual numbers.

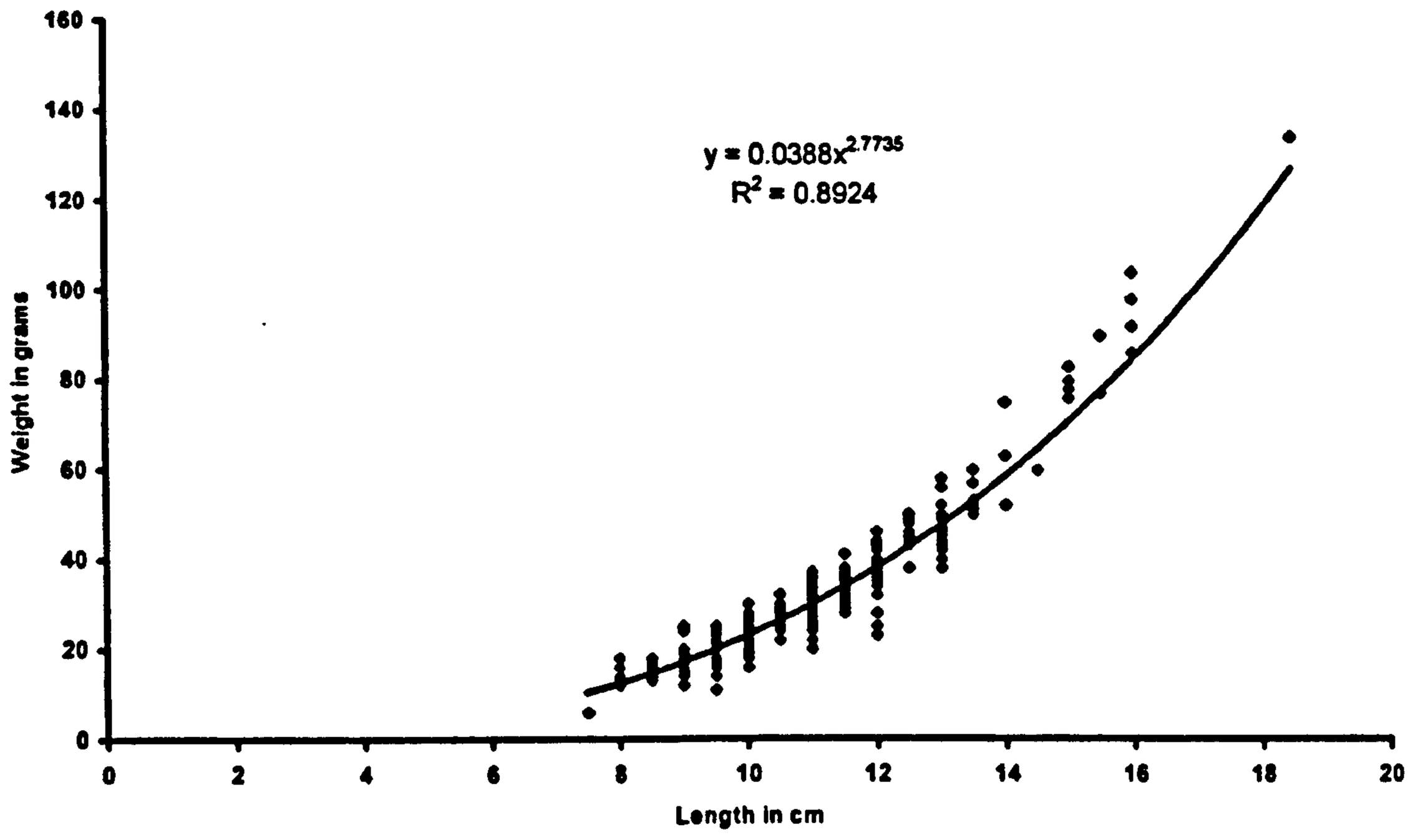
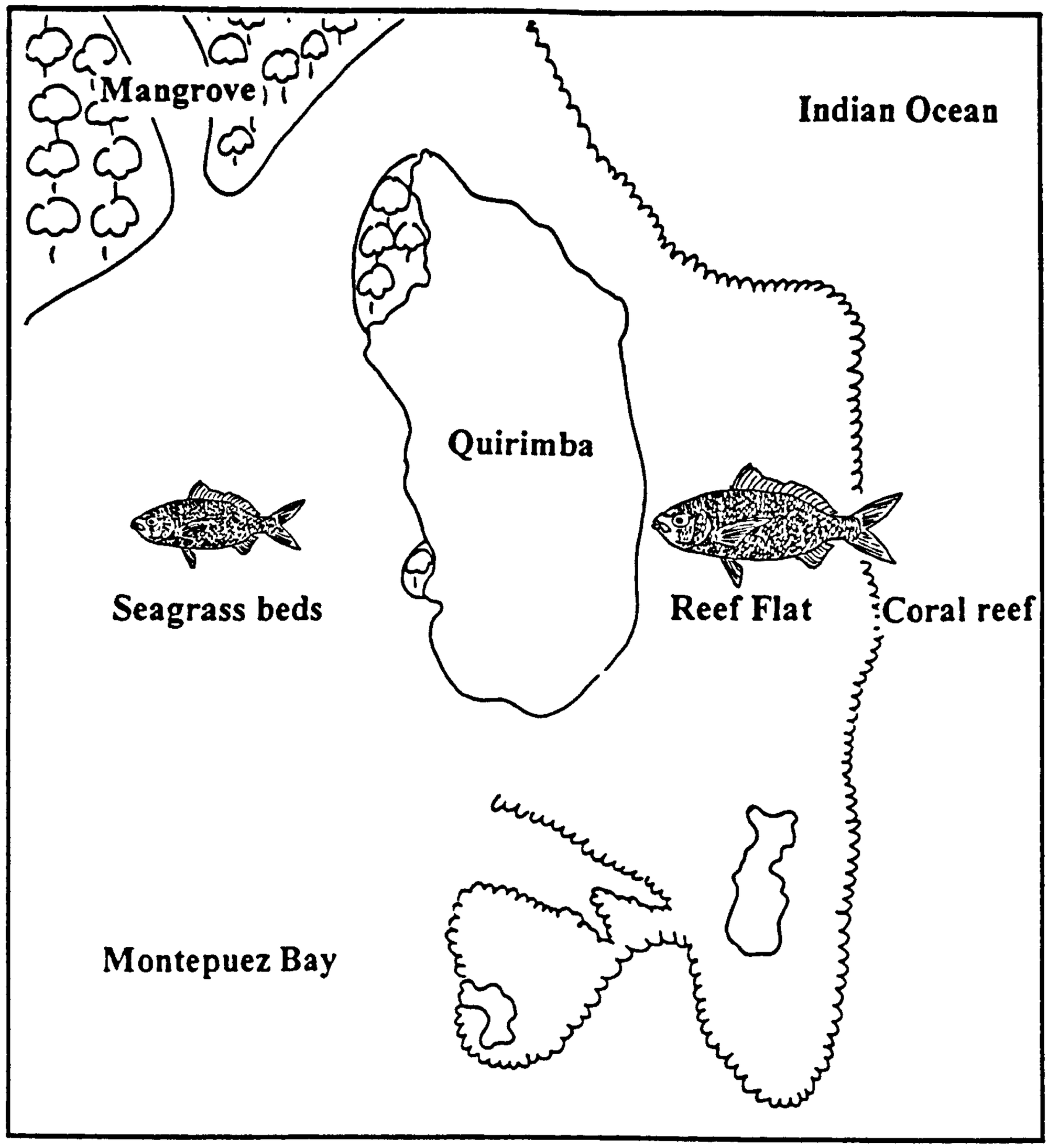


Fig. 14: Length-weight relationship for *Gerres oyena* in the seine net and trap fisheries in the Montpuez Bay. N=431.



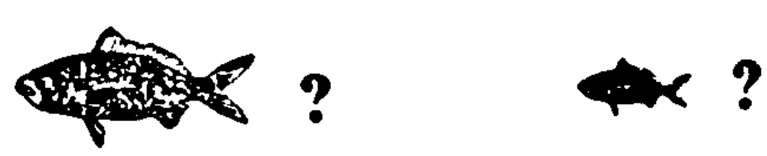


Fig. 15: Map of Quirimba Island and the Montepuez Bay showing the location of the major life stages of *Gerres oyena*. The larvae and the juvenile have been placed outside the map because their location was unknown.

flat to the seagrass beds and also of adults from the seagrass beds to spawning sites on the reef flats. There seemed to be a very clear distinction between these two lifestages – large adults were never caught in the seagrass and small adults of juveniles were never caught on the reef flat, though this could well be an artefact of the fishing gears used. The seagrass cohort of around 10cm must be assumed to be year one fish and the 20cm and above individuals can be assumed to be year 2. As some of the reef flat individuals got as big as 30cm it is likely that there was at least one further year group present on the reef flats. All individuals caught in the seagrass beds looked very similar and the species did not seem to be sexually dimorphic. The modal length varied between 9.5 and 11cm but with no obvious seasonal pattern.

DISCUSSION

***Siganus sutor*: Previous studies on this or similar species**

Siganids are present throughout the tropical Indo-Pacific with the exceptions of Hawai'i and Easter Island. They are also found in the Eastern Mediterranean and throughout this distribution are considered to be a very good food fish (Lam 1974). There are 27 species of siganids in the tropical Indo-Pacific region, with five species occurring in the East Africa region: *Siganus sutor, S. stellatus, S. argenteus, S. corallinus* and *S. luridus* (Woodland 1990).They are an important component of many tropical fisheries, for example in an investigation into the fisheries potential of a reef flat in the southern Great Barrier Reef, Australia, more than 50% of fish biomass was accounted for by two species of siganid (Woodland 1990). According to Smith and Heemstra (1991) up to 60% of "marketable-sized" fishes from shallow reef flats are rabbitfishes. In Kenya, over 50% of artisanal catch is siganids and 95% of the siganids are *Siganus sutor* (Ntiba 1988).

A number of species of siganids are reef-associated and many of these are commonly found in pairs or small schools over reefs (Woodland 1990). However, as herbivores many species are found in algal and seagrass areas and many of these school. Many species of rabbitfish are associated with habitats other than coral reefs – for example out of 10 species studied in the

Philippines seven lived in bays, estuaries, mangroves or rivers at some stage of their life. Of ten species of *Siganus* common in the Philippines, five species had juveniles that spent some time in seagrass beds (*S. argenteus, S. canaliculatus, S. punctatus, S. spinus* and *S. virgatus*). Four species were also found as adults on the seagrass beds *(S.canaliculatus, S. puellus, S. spinus* and *S. virgatus*) (Alcala 1979).

A number of species of siganids are important for aquaculture because of their tolerance of poor conditions and overcrowding, eg *S rivulatus* and *S. canaliculatus* in the Arabian region (Wassef and Hasdy 1997). *Siganus sutor* is very similar to *S. canaliculatus* and *S. fuscescens* and the three species are considered sibling species. *S. sutor* is distributed widely in the Western Indian Ocean, from Mauritius to Knysna in South Africa and possibly as far north as the Gulf of Aden (Woodland 1990). *Siganus sutor* is a common species in East African fisheries from Kenya to Mozambique and Madagascar. *S. canaliculatus* is distributed from the Arabian Gulf, India and the Eastern Indian Ocean area and Western Australia, whereas *S. fuscescens* overlaps its distribution with *S. canaliculatus* and is distributed further East throughout Papua New Guinea and out into the South Pacific. *Siganus rivulatus* is the Red Sea sibling species (Woodland 1990).

Wassef and Hady (1997) studied *S. canaliculatus* in Arabia. This species is common in the Arabian region and is the most common siganid in the Philippines. In the Arabian study *S. canaliculatus* reached sexual maturity at 17cm and spawned at the beginning of their second year in April and May. *S. canaliculatus* was very fecund, producing up to a million eggs per female in a lifetime. Fecundity was found to be much more closely related to fish weight than to fish length.

Johannes (1981) records ten main species of siganid in Palau in the Pacific. He recorded that *S. canaliculatus* lived in the seagrass and mangroves and went out to the reef about a week before spawning, and spawned on the edge of the reef. Apparently this migration was very abrupt, so that one day there would be thousands of adult *S. canaliculatus* in the seagrass and the next day virtually none. Their spawning peak there was between February and June. The larvae

were reported to be pelagic for three weeks then juveniles would begin to appear in the seagrass beds in large schools. They were observed to feed on seagrass during the day.

Siganids are best caught by gill nets or spearfishing (Aragones and de la Paz 1993). They are one of the most important reef resources for artisanal fisheries in Bolinao in the Philippines. There, *S. fuscescens* was found in the seagrass as adult and juvenile. There is an interesting juvenile fishery for which Bolinao is well known. Juveniles of *S. fuscescens*, *S. spinus* and *S. argenteus* of 2 to 6cm long are caught in large numbers from March-May and from August to September. The juveniles appear for 4-5 nights between the last quarter and the new moon. They are captured using bag net, beach seine and fish corral. The fish are ground into a paste and left to ferment for up to a month to produce a local delicacy called *bagoong* for which Bolinao is famous. In Bolinao the juvenile siganid fishery is by far the most important fishery in the area and the economy of the area depends on it. There are concerns with this fishery that species are being increasingly fished as adults as well as juveniles, threatening the future of the fishery (Aragones and de la Paz 1993).

According to Woodland (1990) small juvenile of *Siganus sutor* of around 5cm live in schools of 50 or more in seagrass beds where they browse on epiphytes. Larger individuals form smaller schools of 2-30 individuals in estuarine areas, around rock reefs and on the inner areas of reef flats where they graze continually during the day on seaweeds. *S. sutor* is found mainly in algal and seagrass areas. It grows to a maximum of 45cm which is larger than the other sibling species. This larger size is apparently because of a faster growth rate rather than a longer lifespan (Woodland 1990).

In the case of *S. sutor*, all but the large adults and the very small juveniles were fished heavily. If enough adults can continue to reach the reef flat habitat the fishery may be sustained at some level. The reef flat adults were very lightly fished during the study, so once the adults left the seagrass beds and reached the reef flat they were theoretically subject only to natural mortality with a very low additional fishing mortality. If fishing pressure in the seagrass beds was to increase past a certain critical point then insufficient adults would reach the reef

flats to spawn and to produce new generations of recruits for the seagrass beds and the numbers of *S. sutor* could go into steep decline. On the other hand, if the reef flat gill-netting fishery were to expand, whilst the seagrass seine-netting fishery remained at the level it was at during the study period, although sufficient adults might be reaching the reef flats, they would be increasingly vulnerable to fishing pressure there and many of the adults might be caught before they were able to spawn. This could lead to *S. sutor* declining both in the seagrass beds and on the reef flat, as fewer recruits returned to the seagrass habitat.

To manage the fishery to optimise the sustainability of *S. sutor* I would recommend that as long as the seagrass seine net fishery continues to be the main fishery on Quirimba that the development of the reef flat fishery be discouraged so that there is at least one life stage at which the species is not exploited. With increased exploitation and no management in place at present I would predict that the proportion of *S. sutor* and *L. vaigiensis* would decrease and be replaced by a larger proportion of reef fish juveniles such as *L. lentjan, L. borbonicus* and *L. fulviflamma*, but only if exploitation of adults in reef fisheries does not increase. Proportions of *G. oyena* would also be likely to rise, along with other generalist species not reliant on seagrass or reef habitats.

***Leptoscarus vaigiensis*: Previous studies of this or similar species**

The Scaridae are a very large and diverse family of mainly herbivorous fish that can grow to be very large, for example the bumphead parrotfish *Bolbometopon muricatum* which can grow to well over a metre. Most species are in the genus *Scarus* but the main species in the Quirimba seagrass fishery is *Leptoscarus vaigiensis* which is the only species in its genus. *L. vaigiensis* is smaller than many other scarids, reaching a maximum of 35cm. It is reportedly the only scarid that does not change sex during its life (Smith and Heemstra 1995). Its range is throughout the Indian Ocean and Pacific to Easter Island. *L. vaigiensis* are commonly known as seagrass parrotfish and are well-adapted for life in the seagrass beds. They are green mottled, well camouflaged and adopt a yellow horizontal stripe and a vertical posture amongst the seagrass providing even better camouflage.

A revision of the Sparisomatinae (*Calotomus* and *Leptoscarus*) was produced by Bruce and Randall (1985). They describe *L. vaigiensis* as distributed widely in the Indo-Pacific, from the northern Red Sea to South Africa and East to Easter Island, although it is not present at Hawai'i. *L. vaigiensis* is usually associated with seagrass beds, but where there are no seagrasses *L. vaigiensis* can be found living in macroalgae on hard substrates, for example in the Pitcairn and Tongan Islands. *L. vaigiensis* spawns in groups or pairs over shallow seagrass beds as the tide falls (observed in Aldabra by Robertson *et al.* 1982). This study was also the first to suggest that *Leptoscarus vaigiensis* is the only gonochoristic species of parrotfish. There are some differences between males and females but they are not as extremely different from each other as most other species of parrotfish are. The males have purple spangles on their scales and canniform teeth above the upper dental plate.

L. vaigiensis was the only one of the key species which was definitely being exploited at every life stage with the exception of small juvenile. For true seagrass fish species like this, the overall intensity of fishing in the seagrass beds must also be managed. These species live out their entire lives (with the possible exception of the pelagic larval stage) in the seagrass beds, and are not generally found in other habitats. Other such species in the fishery include the parrotfish *Calotomus spinidens* and the wrasse *Cheilio inermis*. The fishery is already intense and to increase fishing pressure in the Montepuez Bay will threaten these species with no life stage that is unexploited and no nearby stocks on other habitats such as reefs to replenish the seagrass beds with. No-take zones within the seagrass beds of the Montepuez Bay could be a useful management option for *L. vaigiensis* and other such species. No take zones would provide refugia for the some of the population at all life stages, and would thus ensure that more individuals reached maturity, and more adults reached larger sizes, producing exponentially larger numbers eggs (Roberts 1997).

***Lethrinus lentjan:* Previous studies on this or similar species**

Lethrinids are an important fishery species throughout the Indo-Pacific. In the Red Sea and Arabian Gulf lethrinids account for 15-30% of fish catches and are mainly caught by hand-lines. Over 55,000 metric tonnes of lethrinids were caught worldwide in 1987 and 66% of these were caught in the Western Indian

Ocean (Carpenter and Allen 1989). Lethrinids yield a good quality white flesh which is highly regarded. In Mauritius lethrinids account for nearly a third of all fish catches, over 5000 tonnes are caught per year. In Qatar they account for 25% of all catches or nearly 700 tonnes and in Saudia Arabia 17% of catches and 7,700 tonnes. Lethrinids dominated the commercial catch in Fiji (Jennings and Polunin 1995). However, in common with other important species and families in tropical fisheries, very little work has been done on the biology of lethrinids, although such work would obviously be very useful in fisheries management. Even fundamental aspects of the family such as their taxonomy is largely unknown – "Taxonomically, lethrinids are considered one of the most problematic of tropical marine fishes" Carpenter and Allen 1989. In "Smith's Sea Fishes" the lethrinids are described as "a difficult group for systematists" (Smith and Heemstra 1995).

L. lentjan is of considerable economic importance throughout its distribution, from the Red Sea and Arabian Gulf to the South Pacific. In the Arabian area *L. lentjan* was most frequently found at lengths of 23-33cm, in depths of 27-50m. The smallest fish ever found a study of Arabian reef fishery catches was 15cm, and the largest 42cm. Fish of less than 20cm were found to be rare in the commercial catch (Wassef 1991). *L. lentjan* appears be to protogynous – there were more females for the first 4 year groups and then afterwards more males, so there was a possibility of sex reversal in the fifth year (Wassef 1991). Protogynous hermaphroditism has been proved in 8 lethrinid species (Young and Martin 1987). *L. lentjan* was found to have two spawning seasons in the Red Sea (January, and April to May; Wassef 1991), and in India (December to February and June to August; Toor 1967) and one in New Caledonia (September to December; Carpenter and Allen 1989). Size at maturity was estimated at around 30cm.

L. lentjan adults are usually solitary and are found in fairly deep reef and sand areas to 50m, whereas juveniles and small adults are found in loose aggregations in seagrass beds, mangroves and shallow sand (Carpenter & Allen 1989). From traditional knowledge collected in the South Pacific *L. lentjan* was described as predominantly solitary and deep-water dwelling except when

in spawning aggregations in shallow water. Spawning aggregations were only seen in the first half of the lunar month (Johannes 1981).

L. lentjan was only very heavily exploited at Quirimba in its juvenile and small adult stages. Larger adults seemed to be migrating to the reef, and probably spawning there, with the juveniles coming back to the seagrass beds to settle. All reefs in the vicinity were fished at very low levels during the study period, so the adult *L. lentjan* were subject to a low level of exploitation. However, fishing pressure by itinerant fishermen was increasing on the shallow coral communities between Quilaluia and Quirimba, so the species could increasingly become fished as an adult too. A no-take zone or a network of no take zones could also be useful in the management of this species, but areas of both seagrass and reef community would have to be protected. The development of the reef fishery in the surrounding reefs would also have to be monitored closely. As we have seen *L. lentjan* could grow up to 50cm and was frequently seen on the reefs around Quirimba and was the only one of the five key species that could really be described as a "reef fish" (although "what are reef fishes?" Bellwood 1998). It is therefore the only species to fall into the category of fish that are commonly associated with seagrass beds – potentially commercially important "reef" species that grow to a large size that are present only as juveniles in the seagrass beds and migrate out onto the reefs to spawn.

***Lethrinus variegatus:* Previous studies on this or similar species**

In "Fishes of the Family Lethrinidae from the Western Indian Ocean" J.L.B. Smith gives the following description of *Lethrinus variegatus:* "...over the whole Western Indian Ocean juveniles are sometimes abundant in weedy areas, adults apparently solitary, nowhere plentiful, mostly deeper water to 80 fathoms" (145m). Smith also gives a maximum length for *L. variegatus* of 60cm but this seem likely to be the result of misidentification and confusion with another larger species such as *L. microdon*. *L. variegatus* is widespread in the Indo West Pacific – from the Red Sea and East Africa to New Caledonia. It lives in seagrass and algal areas near coral reefs where it feeds on small invertebrates. Its maximum length is more likely to be in the region of 20cm (Carpenter and Allen 1989) making *L. variegatus* the smallest species in the *Lethrinus* genus. The main methods of capture for *L. variegatus* are by beach seines or trawls

and it is regarded as a species of minor importance in the fisheries where it occurs (Carpenter and Allen 1989).

L. variegatus was exploited over a relatively narrow range of sizes in the seagrass trap and net fishery and over similar range, but slightly smaller in the suri fishery. Larger adults were rare in the reef fishery, so its seems that most of the stages of this species beyond small juveniles were exploited. The majority of fish taken in the fishery seemed to form a single cohort – thus the fishery could be seen as exploiting a single recruitment pulse of *L. variegatus*. The species seemed to be highly associated with seagrass beds. Some individuals were caught in coral areas but they were rarely seen on reefs (although Jennings *et al.* (1995) found that lethrinids were always under-represented in underwater visual censuses).

***Gerres oyena:* Previous studies on this or similar species**

Gerrids play an important role in tropical coastal ecosystems. They form an economically important component of the catch in artisanal fisheries and are ecologically important in linking the primary and tertiary trophic levels in the food web (Santos 1997).

Gerrids are a versatile species, mainly associated with sandy areas but also common in estuarine, reef and lagoon areas and are known to enter freshwater (Smith and Heemstra 1995). They feed on small invertebrates picked out of the sand or by sieving sand through their gill-rakers. They are distinctive in their brilliant silver colour. The gerrids are generally small fish, rarely larger than 15cm. They occur in many tropical multispecies fisheries but they do not keep well which makes them less useful in artisanal fisheries. Smith gives five *Gerres* species in the Western Indian Ocean region (Smith and Heemstra 1995).

Gerres oyena is distributed in the Tropical Indo-Pacific as far south as Kosi Bay in South Africa. In Palau two species of *Gerres* similar to *G. oyena*, had lunar spawning cycles around the full moon all year round. During spawning in Palau fish migrate from the sand flats and mangroves where they usually live to the reef edge where they spawn in schools. Fishermen there targeted these spawning aggregations (Johannes 1981).

G. oyena feeding was studied in an intertidal lagoon on the east coast of Zanzibar. *G. oyena* there were found to feed predominantly on meiofauna but also took some larger items such as polychaetes, amphipods, shrimps and crabs. Harpactocoids were found to be the most important component in diets of small individuals to 5cm. Above 5cm the main components of the diet were amphipods, polychaetes and oligochaetes. In seagrass habitats Gerres oyena of 0-10cm were found to select oligochaetes, whereas those over 10cm were found to select amphipods (Ndaro and Ólafsson 1995).

G. oyena was different from all the other key species in that at no point was it reliant on seagrass beds. The species is most commonly associated with sand and can therefore be found equally on reefs, reef flats and in seagrass beds. Populations in the Montepuez Bay were likely to be highly mobile between the seagrass beds, reef areas, coral communities and areas of sand at a variety of depths. Gerrids are also found in mangroves and estuaries (Smith and Heemstra 1995) and can therefore utilise a wide variety of the habitats available in the vicinity of the Montepuez Bay, some of which provide natural refugia from fishing. *G. oyena* and species like it are probably the least vulnerable to the Quirimba seagrass fishery. They are highly mobile and are able to utilise large areas of habitat that are not fished. It is likely that if the exploitation of the fishery continues to increase then the proportion of *G. oyena* in the catch would be likely to increase, as the other more vulnerable species decrease in abundance in the catch. The flesh of *G. oyena* was not inferior to that of the other key species but was known to perish faster than most species of fish, making it less than ideal as the main catch species in a fishery with no refrigeration or other preservation facilities.

Implications for the management of the five key species

L. variegatus

It is possible that in the Quirimbas *L. variegatus* spends its entire lifetime in the seagrass beds and does not grow much bigger than 15cm. If this is the case then the population of *L. variegatus* may be at risk from overexploitation. The entire population was under intense fishing pressure and there were very few

large or full grown adults in the population to form the spawning stock replenishing the population. Small maximum size could be due to fishing pressure and selection for small size at maturity. As the majority of *L. variegatus* that were caught are of 9cm or less an obvious method of reducing the pressure on this species would be to increase mesh sizes of both net and cod-end. An increase to a stretch of no less than 4cm would instantly exclude the majority of the smallest *L. variegatus* from the catch.

If the entire population of *L. variegatus* does indeed exist within the seagrass beds an alternative management option may be to limit fishing around spawning seasons so the maximum number of mature adults were able to spawn before capture. More detailed study of these species would be necessary to clearly identify the spawning season to ensure that fishing was limited around the correct time. Spawning sites would also have to be identified if appropriate. In such a mixed multispecies fishery closed seasons would have to be chosen to benefit the maximum numbers of species. *Suri* trapping, aimed specifically at small (8cm or less) juvenile *L. variegatus* could be posing a grave threat to the population also exploited by the seine net fishery. Very few people were employed in the *suri* fishery, yet because of the small size of the fish captured the numbers of fish involved were high. Management of the Quirimba fisheries should seriously consider the regulation of the *suri* fishery, perhaps even to the extent of closing this very small fishery and offering the *suri* fishermen alternative fishing methods. The most likely alternative would be the permanent closure of a carefully selected area within the bay, allowing year round fishing in 70-80% of the bay.

It is possible that the small *L. variegatus* in the seagrass fishery were juveniles and small adults and that the population was divided between seagrass beds and another habitat, for example a habitat not surveyed in this study such as deep reef or dense mangrove stands. Significant numbers of this species were not caught on the reefs but reef fisheries in the Archipelago were very limited so it is possible that *L. variegatus* existed in other habitats but were not captured. If *L. variegatus* does utilise a variety of habitats then it is at a much lower risk and is much more likely to be sustainable for the fishery. If a reasonable number of adult *L. variegatus* were able to migrate to the reefs where they were virtually

unaffected by fishing then the high fisheries mortality of the adults and young adults may be sustainable. The adults on the reefs would be able to grow to a good size to produce the maximum amount of eggs to replenish populations on the seagrass beds.

Gerres oyena

G. oyena life histories were clearly split between two habitats – juveniles in seagrass and sand areas and adults on the reef flat. They were an important component of the seagrass fishery catch, as one of the five key species but their capture was fairly sporadic. Large schools were sometimes caught but on other occasions the species was absent from catches. The reef flat fishery on Quirimba was small and undeveloped so very few adult *G. oyena* were vulnerable to capture, leaving large adults to grow to good sizes and to produce large quantities of larvae to replenish the juvenile population in the seagrass beds. The obvious source of threat would be if insufficient large *G. oyena* were reaching the reefs to join the adult population to spawn. General methods of fishery management such as a limit on the number of fishing vessels and, in particular, no-take zones encompassing a variety of habitats may be the only way to avoid the capture of unsustainably large numbers of *G. oyena* before they reach the reefs where they spawn.

Siganus sutor

S. sutor was the most important species in the Quirimba seagrass fishery in terms of fish biomass caught and it is therefore of great importance that this species is fished in a sustainable manner. During the study period this species appeared to be at an advantage because its life cycle was divided between the seagrass beds which were heavily fished and the reef flats which were are not. If the adult populations on the reef flat can continue to grow to large sizes and reproduce successfully, the intensive fishing of juveniles and small adults of this species may be sustainable up to a point. Again the key problem at present is to ensure that sufficient adults reach the reef flat to reproduce before they are caught. Spawning seasons have been tentatively put at September and February (although much more study is needed to confirm this). February in the Quirimbas is at the height of the wet season when fishing effort in the Bay is reportedly reduced, and it is also when the majority of agricultural work has to

done in the *machambas* (agricultural plots) on the island. A short fishing ban prior to this when the *S. sutor* are probably in the process of migrating to the reefs might greatly enhance the spawning capability of the fish. This would also have minimal impact on the fishermen, many of whom would prefer not to fish at this time of year anyway and could invest more time in their agricultural work. There was no evidence from this study of the mass migration described by Johannes (1981) from Palau but if this did occur on Quirimba, it would be a stage at which the population would be very vulnerable to exploitation and this would have to be considered for appropriate management. For instance a closed season during the migration or the closing of the main route of the migration to fishers on a seasonal basis.

As has been considered by others (Campos 1994), the harvest of juveniles, if supported by the protection of adults to maximise reproductive output, could be a very productive and sustainable pursuit – harvesting the fish at what could possibly be their time of maximum natural mortality (with the exception of the larval stage) and highest growth rate. There is of course always the risk of harvesting the fish too early when the yield per recruit is still low, leading the loss of potential productivity. If the harvesting of all fish from the very smallest is to continue sustainably a good reliable strategy for maintaining adult populations is necessary. Siganids are well known for their suitability for aquaculture (Alcala 1989), so marine ranching or small scale fish farms for stock enhancement could be to complement fisheries management techniques. *S. sutor* could be reared and released into the seagrass beds or reef flat. If farming *S. sutor* was successful it would also provide a good alternative source of employment for local people to take the pressure off the fishery.

Lethrinus lentjan

Lethrinus lentjan was probably one of the least threatened of all the key fisheries species because, although a relatively wide range of lengths and therefore ages were present in the seagrass fishery, the adults of this species were mainly found on the reefs and in water that was deeper than any common gears used in the Quirimbas could reach. Therefore, although the exploitation level of juveniles and small adults was fairly high, the large adults were largely unexploited. The largest individual of *Lethrinus lentjan*, caught by hook and line,

(a fishing method rarely used around Quirimba), was 50cm, larger than the maximum length for *L. lentjan* given from a number of different sources. The problems for *L. lentjan* are likely to come when fishing pressure on the reefs and reef flats increases. *L. lentjan* flesh is highly valued and is likely to be in increasing demand as the area develops, and as storage and transport capabilities increase, particularly for the tourist market. It may also be an easier species to target using particular gears and baits. So, although *L. lentjan* may be the key species least at risk at the present, it probably has the greatest potential for overexploitation in the future.

Leptoscarus vaigiensis

L. vaigiensis was the only one of the key species to spend its whole time on the seagrass beds and as such was likely to be the most vulnerable to fishing in the Quirimba area. As *L. vaigiensis* was shallow-seagrass associated it did not have access to certain unfished refugia open to other species such as deep reefs (although mangroves were unfished in the area and thus offer a potential source of murky estuarine refugia for *L. vaigiensis*, although the species was not recorded from mangrove areas). Therefore, persistent heavy fishing pressure on *L. vaigiensis* could lead to a collapse in the population. Very few large individuals (over 20cm) of *L. vaigiensis* were seen which may be a result of fishing pressure. The reproductive behaviour of *L. vaigiensis* may make it particularly vulnerable to the seagrass seine net fishery. If this species does spawn in groups or pairs over shallow seagrass areas as the tide falls (Robertson *et al.*1982), then the Montepuez bay at an hour before high when fishing is at its most intense may also be prime spawning time for the species. Fishermen seemed indifferent to the presence of fish which were obviously spawning in their catch and there did not appear to be any traditional management regimes connected with spawning. If *L. vaigiensis* does have all-year round spawning and the spawning grounds are the fishing grounds it could be very difficult to avoid catching an unsustainably large proportion of the spawning fish. Again, the wet season may provide a natural closed season that could benefit populations of *L. vaigiensis*. If net fishing could be maintained at a very low level or completely stopped during a couple of months of the true wet season this may allow a couple of months worth of successful spawning for this species which could be enough to keep the population at a sustainable level.

One possible solution for the problem with this and a number of the other species is to promote trap fishing as an alternative to net fishing. For *Leptoscarus vaigiensis*, *Siganus sutor* and *Lethrinus lentjan* – the three key species which are caught in traps and that are threatened by the depletion of adult numbers to replenish juveniles – traps offer a method of capture which may promote the sustainability of these species. *L. vaigiensis* and *S. sutor* are the two species which are very common in the trap and net fishery. In *S. sutor* which in the net fishery is present from 6 to 24cm, in the trap fishery it is predominantly between 10 and 14cm. This means that there is very little fishing pressure on the first cohort of 7-9cm or on adult *S. sutor* over 14cm. In theory this allows *S. sutor* to reach a reasonably productive size before being harvested, and leaves the adult population virtually unexploited to grow and spawn, and so replenish the seagrass beds.

Similarly, although *Leptoscarus vaigiensis* is harvested at lengths from 7 to 20cm in the net fishery, in the trap fishery it is predominantly caught at lengths between 13 and 19cm (see Chapter 3). This again reduces the numbers of small juveniles caught and would reduce the number of the larger adults caught. Entrance holes to trap could be made fractionally smaller to ensure that the largest adults were not targeted.

CONCLUSIONS

The five species considered in this chapter all have very different life histories, inhabited different habitats at different life stages and each had a very different ecology in terms of diet, behaviour and reproduction. This emphasises the problems of managing a multi-species fishery. Not only did the Quirimba seagrass fishery have a remarkably high number of species (over 250 –see Chapter 3) but even if it is reduced to its five key species for the purposes of devising broad management strategies, the fishery is still composed of a complex combination of species and ecological systems. In each of the main species the fishery exploited a different sector of the population and therefore had an impact on the fish population in a different way.

This more detailed look at the biology of these key species emphasises the diversity of species types that we are dealing with and the problems of managing a multi-species fishery on the basis of the biology of fish populations. It demonstrates a situation in which the use of no take zones presents itself as the most useful tool to use for managing a highly mixed fishery. All manner of combinations of gear restrictions and quotas could be tried but it is highly unlikely that any of these combinations could ensure the sustainable exploitation of the main species whilst conserving the minor species and thus the biological diversity of the fished ecosystem.

Three standard fisheries management options exist:

1. Marine protected areas/no-take zones
2. Mesh size limitations and gear regulations
3. Boat licensing, limits on numbers of fishers and catch quotas.

Some increase in the minimum mesh size for nets would potentially have a positive impact on the fish populations, as during the study period small juveniles were found to be highly vulnerable to fishing. The number of fish, particularly of *L. vaigiensis*, *S. sutor* and *L. variegatus* being caught at very small sizes must give a very low yield per recruit, thus a wastage of potential fisheries productivity. If the mesh for cod-ends was increased to perhaps 3cm stretch many of fish of these key species would not be caught until they had increased their length by just a few centimetres and perhaps doubled their biomass. This may reduce catches slightly at first but the benefits would become evident very soon. Quotas is not an option – individual boats already take a small amount of fish per person per trip (see Chapter 2) – it would not be practical or desireable to decrease this. If mesh size regulations were coupled with protected areas, the juveniles escaping capture would have a potential refuge and would be able to reach maturity and larger adult sizes leading to higher fecundity.

Licensing boats and regulating access to the fisheries grounds, for example limiting the access of itinerant fishermen from outside the district and outside the province would mean that the main users of the fishery would be local

Quirimban people so it would be clearly in their interest to respect the no-take zone allocated themselves and to be involved in their enforcement, preventing visiting fishermen infringing on regulations. The three management options could be used together as complementary techniques. Strategically placed no-take zones would be the main and most important technique, ensuring spatial refuges for the majority of fisheries species. However, some regulation of fishing rights in the areas outside the no-take zones would make the no-take zones easier to enforce – i.e. if the main group of fishers were local and supported the use of no-take zones for their long term benefit.

Marine protected areas, and particularly no-take zones are the ideal management tool for diverse tropical multi-species fisheries (Nowlis and Roberts 1997). Small marine protected areas have found to be effective in increasing fish numbers available to surrounding fisheries in reef areas (Roberts and Polunin 1991). In the highly speciose fishery of the Quirimba seagrass beds, only areas of undisturbed seagrass and reef habitat can provide an opportunity for the full spectrum of species to be fished sustainably in the surrounding area. Marine protected areas have been used successfully as a fisheries management technique for reef fisheries elsewhere in East Africa, which had the same problems of being highly multi-species and involving a variety of gears, and were also dealing with similar species to the present study. In Kenya, a no-take marine park has significantly higher densities of key fisheries families such as lethrinids, lutjanids and serranids than the surrounding fished areas (Watson and Ormond 1994). In Tanzania protected coral sites were found to have 3 times more fish in terms of biomass than unprotected areas (McClanahan *et al.* 1999). In the Philippines there have been numerous examples of small reserves benefiting surrounding multi-species artisanal fisheries. For example the reserve at Sumilon Island where adjacent areas have produced some of the highest known coral reef fish yields since protection in 1974 (Russ 1989). The most important consideration in managing the fishery with marine reserves would be to ensure that the sites were chosen on the basis of sound ecological knowledge to maximise the benefit and minimise the loss of fishing grounds to fishers. The ideal reserve design would obviously incorporate knowledge of the life history, larval dispersal and adult migration patters of all the fisheries species (Nowlis and Roberts 1997) but with over 200

species, or even the 20 or so common species in the seagrass fishery, this ideal is virtually impossible. The advantage of marine reserves over the alternative management strategies is that the maximum number of species are likely to benefit, including that crucial species so often overlooked in fisheries management – man (Roberts 1997).

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CHAPTER 5

A COMPARISON OF FISH CAUGHT IN 3 SPECIES OF SEAGRASS: *ENHALUS ACOROIDES, THALASSODENDRON CILIATUM* AND *CYMODOCEA SPP.* IN THE MONTEPUEZ BAY BY EXPERIMENTAL TRAP FISHING

ABSTRACT

Traps were set in 3 common species of seagrass: *Enhalus acoroides, Thalassodendron ciliatum* and *Cymodocea spp.* using the traditional spacing used locally and the numbers, weights and species of fish were compared. Significant differences were found between the fish caught in traps set in *Enhalus acoroides* and those in *Thalassodendron ciliatum* and *Cymodocea spp.* Traps placed in *Enhalus* gave the highest numbers, weight and numbers of species of fish. Traps were also placed in *Enhalus acoroides* at a variety of different spacings. The optimum spacing between traps placed in lines was found to be 5m, which is the spacing used by local trap fishers. Fish assemblages in the three seagrass species were found to be different. The most commonly caught fish in *Enhalus acoroides* was the parrotfish *Leptoscarus vaigiensis,* in *Thalassodendron ciliatum* it was the filefish *Paramonacanthus barnardi* and in *Cymodocea spp.* it was the snapper *Lutjanus fulviflamma.* The trap fishing strategy used by local trap fishermen (traps places in 5m spaced line in *Enhalus acoroides*) was found to one of the optimum methods.

INTRODUCTION

Trap fishing is an important method for fishing nearshore tropical habitats such as reefs and seagrass beds throughout the Indo-Pacific and in the Caribbean, where traps are the major method used for fishing for reef-associated fishes (Munro 1983 in Recksiek 1991). In East Africa, trap fishing is one of the major artisanal fishing methods used. Traps are used in a wide range of habitats from intertidal pools to 30m reefs. In the Quirimba Archipelago they are used in a range of sizes for different target habitats and species (see Chapter 2). The use of traps for fish sampling and other studies has increased in recent years and

has been used in coral reef and estuarine habitats throughout the tropics (Sheaves 1995).

It has been acknowledged that stands of different seagrass species, even those in close proximity, can support very different fish assemblages (Bell & Pollard 1989) but there have been very few studies comparing the fish communities of seagrass beds composed of different species in the same area (Martin & Cooper 1981). Studies comparing the communities of the same or similar seagrass species in different geographical areas, or comparing faunas of seagrass beds with those of unvegetated or algal areas are more common (Jenkins et al. 1997, Jenkins and Wheatley 1998 – fish, Knowles and Bell 1998 – invertebrates). Knowles and Bell (1998) say that seagrasses are an ideal environment in which to study faunal-habitat associations because the seagrass system is characterised by a range of "microhabitats" with different architecture, chemical composition and persistence in time and space.

STUDY SITE

Traps were set in two adjacent fishing sites at the south of Quirimba Island, Kumilamba and Lusino (see map in Chapter 1). The sites were composed primarily of *Enhalus acoroides* with areas of *Thalassodendron* and *Cymodocea serrulata* and *C. rotundata* (impossible to distinguish from above the surface and hereafter referred to as *Cymodocea spp.*). Trap fishermen choose sites that are rich in *Enhalus acoroides*, but unlike net fishermen they are able to choose sites with small areas of coral as they can fish around them.

METHODS

All trap experiments were conducted with the help of an experienced trap fisherman, Anibal Amade, who constructed the traps and set and emptied them with me. We fished 40 marema traps from an outrigger canoe. Initially I accompanied the trap fisherman on fishing trips to study how traps were normally fished. Traps were set in lines of ten, marked at one end with a stick with approximately 5m between the traps (see Chapter 2 for more details). There were complex rules regarding the angle at which the traps were placed, depending on their alignment with land, with the prevailing currents and other physical factors. Most important was the placing of the traps in areas of dense

Enhalus acoroides. This species of seagrass, *Jani-lala*, was said to be the home for more fish than any other species, in particular the *bonju* or seagrass parrotfish (*Leptoscarus vaigiensis*), a major component of the fishery. It was also said to help keep traps in the same places, the dense leaves preventing the traps being moved by currents and waves.

For each series of experiments 10 replicates of each trap treatment were used. The traps were set at low tide one day and emptied at low tide the next day, giving a soak time of just over 24 hours. The contents of each trap were recorded separately. The fish were measured to the nearest 5mm using a measuring board and weighed to the nearest 2g using a spring balance.

Two different trap settings were investigated:

1. Setting traps at various spacings

The spacing experiment was designed to investigate trap spacing distances to find the optimum spacing arrangement and how this corresponded with the spacing traditionally used by fishermen. Sets of traps were placed in lines with spacings of 1, 2, 4, 5 and 10 metres between them, and also in matrix arrangements of nine traps with 2, 5 and 10m between each trap. All traps in the spacing experiment were placed in *Enhalus acoroides* in the normal way they would be set by a fisherman, except for the spacings.

2. Setting traps in different species of seagrass

The object of this experiment was to investigate the abundance and species composition of fish in three species of seagrasses. Traps were set in lines with 5 metre spacing in areas dominated by *Enhalus acoroides*, *Thalassodendron ciliatum* and *Cymodocea rotundata* and *C. serrulata* (the latter treated as one seagrass category referred to as *Cymodocea spp.)*.

The traps set experimentally were not baited (some fishermen did bait their traps, and caught a larger proportion of carnivorous fishes such as *Lethrinus lentjan* but this was not investigated - the majority of ordinary trap fishermen did not bait their traps).

RESULTS

Trap spacing

The mean numbers, weights and species per trap for each of the 8 spacing treatments are shown in Fig. 1 a-c. Traps placed in lines at increasing distances apart caught increasing numbers and total masses of fish and also increasing numbers of species, up to the 5 metre spacing used by fishermen. At 10 metre spacings mean weight of fish fell to less than that observed with traps spaced in 2 metre lines. Mean weight of fish per trap ranged from a mean of 130g per trap (SE= ±29) or 2 fish (SE= ±0.4) for traps placed 1m apart to 220g of fish per trap (SE= ±31.2) and a mean of 3.5 fish (SE= ±0.3) per trap for traps placed 5 metres apart.

For traps placed in a matrix the same pattern was observed – an increase in the mean number and weight of fish from 2m spacing to 5m spacing, then a decrease for the 10m spaced traps. The values for mean weights and number of fish in the traps placed in a 5m matrix were slightly higher than those for traps spaced in 5m lines (5m line mean weight per trap 220g SE= ±31.2 and 3.5 fish SE=0.3, 5m matrix 243.2g SE= ±65, 4.4 fish per trap, SE=0.9).

The modal value for number of fish per trap in all categories was 0, indicating the high proportion of empty traps at all spacings. In total 30% of traps fished were empty. The highest proportion of traps were empty in the traps spaced 1 metre apart and the lowest proportion of traps were empty in the traps spaced 10 metres apart (see Table 1). 5m spaced traps had a mean of 3.5 fish per trap but 25% of traps were empty, so the mean number of fish per trap, excluding empties, was nearly 5 fish.

When Mann Whitney U tests were performed on pairs of trap spacing data, significant differences were found between the mean number of fish in 1m line spacing and 4m line spacing, 1m line and 5m line, 1m line and 5m matrix, 5m line and 2m matrix, 2m matrix and 5m matrix (see Table 2). In terms of mean weight of fish per trap there were significant differences between traps with 1m line spacing and 4m line spacing, 1m line spacing and 5m line spacing, 2m matrix and 5m line and 2m matrix and 5m matrix. There were significant differences in numbers of species per trap between 5m line spacings and 10m

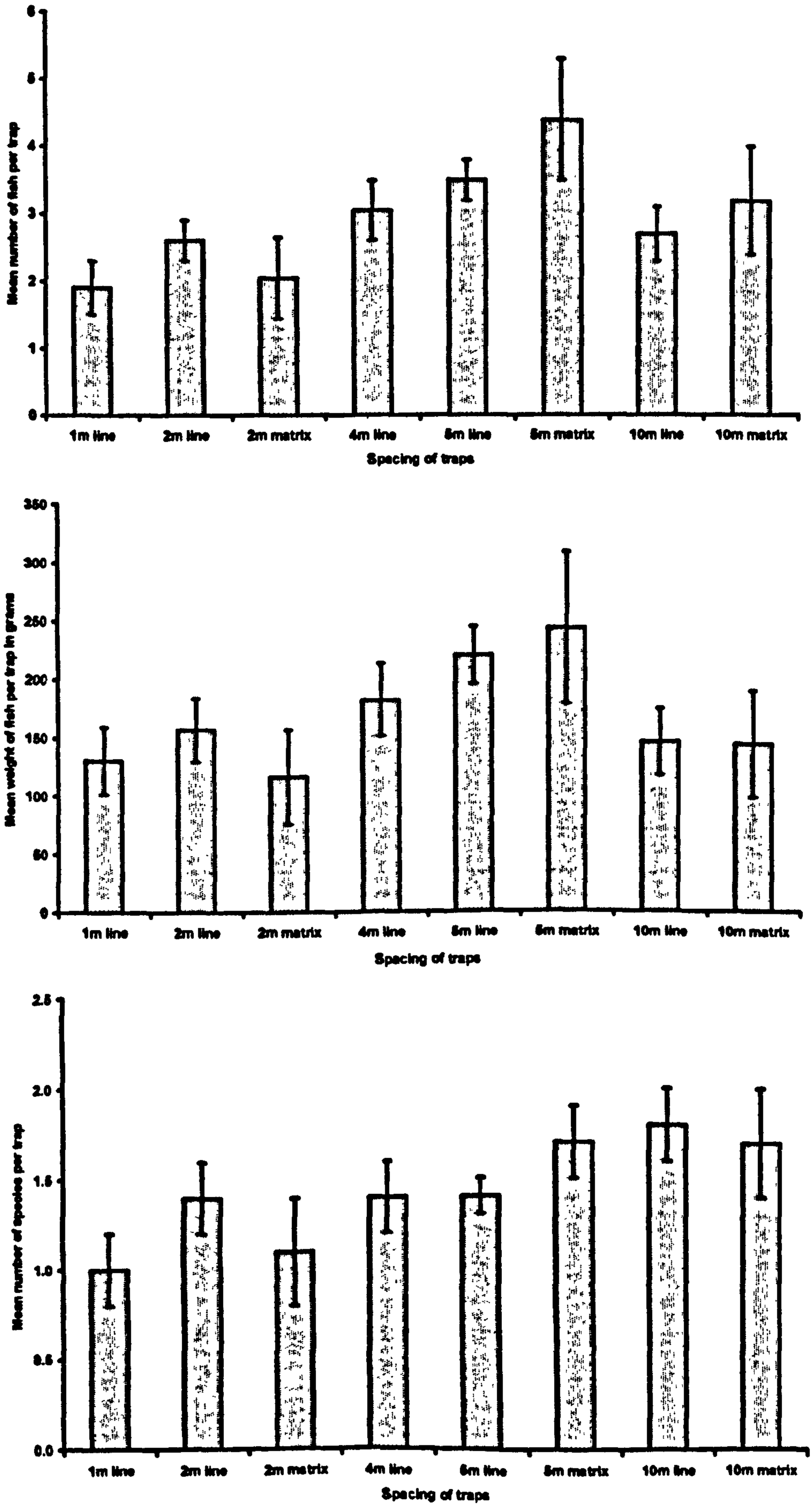

Figure 1: Histograms showing (a) the mean number of fish per trap, (b) the mean weight of fish per trap and (c) the mean number of species per trap for the 8 trap spacing treatments. Error bars show ± 1 SE.

Table 1: A summary table of catches from traps set in the 8 different spacing treatments.

	No.	%	Weight of fish in each trap							Number of fish in each trap							Number of species in each trap						
Trap spacing	Empty	Empty	Mean	Min	Max	N	SD	SE	Mode	Mean	Min	Max	N	SD	SE	Mode	Mean	Min	Max	N	SD	SE	M
1m line	21	42.9	130.5	0	851	49	203.0	29	0	1.9	0	11	49	2.5	0.4	0	1.0	0	4	49	1.1	0.2	
2m line	27	33.8	157.0	0	1102	80	241.0	27	0	2.6	0	12	80	3.1	0.3	0	1.4	0	6	80	1.5	0.2	
4m line	13	26.0	181.7	0	956	50	220.6	31.2	0	3.0	0	12	50	3.1	0.4	0	1.4	0	4	50	1.2	0.2	
5m line	42	26.4	220.2	0	2286	159	310.3	4.6	0	3.5	0	23	159	4.2	0.3	0	1.4	0	6	159	1.2	0.1	
10m line	10	25.0	145.5	0	825	40	180.5	28.5	0	2.7	0	12	39	2.7	0.4	0	1.8	0	6	39	1.5	0.2	
2m matrix	12	46.2	116.2	0	874	26	206.9	40.6	0	2.0	0	12	26	3.1	0.6	0	1.1	0	5	26	1.4	0.3	
5m matrix	6	20.0	243.2	0	1728	30	356.0	65	0	4.4	0	20	30	4.8	0.9	0	1.7	0	4	30	1.2	0.2	
10m matrix	3	23.1	144.0	0	631	13	163.8	45.4	0	3.2	0	10	13	2.8	0.8	0	1.7	0	4	13	1.3	0.3	

Table 2: The results of Mann Whitney U tests to compare fish catches from catches set in the 8 different spacings. Table (a) shows values for number of fish per trap, (b) for the weight of fish per trap and (c) for the number of species per trap. The values marked with a star and underlined had a value of $P < 0.05$.

Number	1m line	2m line	4m line	5m line	10m line	2m matrix	5m matrix
1m line							
2m line	0.196						
4m line	0.038*	0.320					
5m line	0.006*	0.119	0.771				
10m line	0.106	0.654	0.595	0.444			
2m matrix	0.896	0.260	0.081	0.035*	0.148		
5m matrix	0.009*	0.065	0.317	0.359	0.152	0.022*	
10m matrix	0.069	0.298	0.718	0.723	0.395	0.099	0.629

Weight	1m line	2m line	4m line	5m line	10m line	2m matrix	5m matrix
1m line							
2m line	0.383						
4m line	0.009*	0.279					
5m line	0.031*	0.145	0.867				
10m line	0.220	0.572	0.589	0.405			
2m matrix	0.679	0.215	0.059	0.03*	0.139		
5m matrix	0.059	0.221	0.696	0.739	0.343	0.049*	
10m matrix	0.285	0.539	0.945	0.905	0.875	0.150	0.784

Species	1m line	2m line	4m line	5m line	10m line	2m matrix	5m matrix
1m line							
2m line	0.144						
4m line	0.058	0.601					
5m line	0.002*	0.405	0.893				
10m line	0.010*	0.151	0.322	0.281			
2m matrix	0.967	0.288	0.158	0.089	0.048*		
5m matrix	0.008*	0.131	0.280	0.248	0.937	0.038*	
10m matrix	0.045	0.264	0.381	0.384	0.924	0.099	0.978

line spacing, 1m line and 5m matrix, 10m line and 2m matrix and 5m matrix and 2m matrix.

Seagrass species comparisons

The mean numbers, weights and numbers of species per trap for the 3 seagrass species are shown in Table 3 below. The number of traps set in each treatment is also shown. Figure 2 shows the mean values as a histogram with error bars showing standard error. Traps set in *Enhalus acoroides* had the highest mean weight of fish per trap, the highest mean number of fish per trap and the highest mean number of species per trap of all the treatments, followed *by Thalassodendron ciliatum*, followed by unvegetated sand, followed by *Cymodocea rotundata. Thalassodendron ciliatum* yielded less than half the mean weight per trap that *Enhalus acoroides* did, and *Cymodocea rotundata* less than one third.

There were significant differences between *Enhalus acoroides* and both *Thalassodendron ciliatum* and *Cymodocea spp.* in terms of number of fish per trap, weight of fish per trap and number of species per trap, but their were no significant differences between the numbers and weight of fish caught in traps placed in *Thalassodendron ciliatum* and *Cymodocea spp.* (see Table 4 for significance levels from Mann Whitney U tests).

Species Composition

The full species list for traps set in the 3 seagrass species is shown in Table 5. *Enhalus acoroides* had the highest total number of species with 63, followed by *Thalassodendron ciliatum* with 21 and *Cymodocea rotundata* with 20 fish species. Margelef's index was highest in *Enhalus acoroides*, followed by *Cymodocea spp.* and *Thalassodendron ciliatum* The dominant species present in the three seagrass species were notably different (see Table 6). In terms of numbers of individuals all three species of seagrass had only one species in common in their top five species (*Leptoscarus vaigiensis*). This was the main species in the trap fishery and the mean weight and mean number of *Leptoscarus vaigiensis* in each species of seagrass are shown in the Table 7.

Table 3: The mean numbers and weights of fish and numbers of species per trap for the three seagrass species and for unvegetated sand.

Substrate type	Number of traps set	Mean number of fish per trap	SE	Mean weight of fish per trap in grams	SE	Mean number of species per trap	SE
Cymodocea spp.	78	0.9	0.13	68.1	10.8	0.8	0.11
Thalassodendron ciliatum	60	1.6	0.28	84.4	19.3	1.1	0.17
Enhalus acoroides	159	3.5	0.20	220.2	15.4	1.4	0.21
Unvegetated sand	25	1.2	0.26	104.3	28.4	1.0	0.16

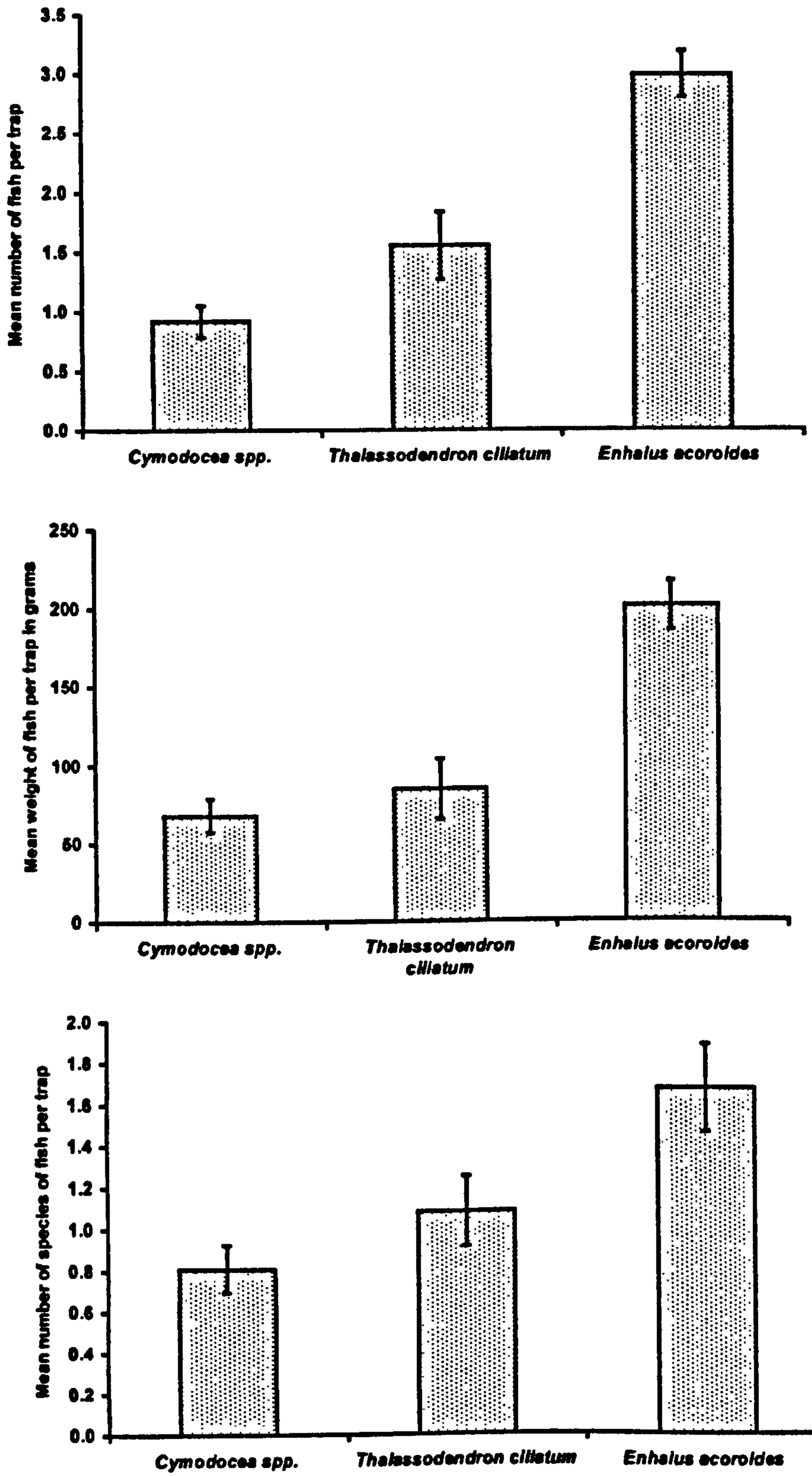

Fig. 2: Histograms showing (a) mean number of fish per trap, (b) mean weight of fish per trap and (c) mean number of species per trap for the three different species of seagrass. Error bars show ± 1 SE.

Table 4: Significance levels of Mann Whitney U tests performed on data from the three seagrass species categories. * * denotes P = <0.05.

Value	Seagrass species in which traps were placed		P	Significance
Number of fish per trap	*Enhalus acoroides*	*Cymodocea spp.*	0.000	**
	Enhalus acoroides	*Thalassodendron ciliatum*	0.003	**
	Cymodocea spp.	*Thalassodendron ciliatum*	0.196	
Weight of fish per trap	*Enhalus acoroides*	*Cymodocea spp.*	0.000	**
	Enhalus acoroides	*Thalassodendron ciliatum*	0.001	**
	Cymodocea spp.	*Thalassodendron ciliatum*	0.662	
Number of species per trap	*Enhalus acoroides*	*Cymodocea spp.*	0.000	**
	Enhalus acoroides	*Thalassodendron ciliatum*	0.007	**
	Cymodocea spp.	*Thalassodendron ciliatum*	0.287	

Table 5: The fish species caught in each of the three seagrass species studied, showing the total number of each species caught, the total weight and the percentage of each species in the total sample in terms of number and weight.

	Enhalus acoroides				*Thalassodendron*				*Cymodocea*			
	No.	%	W/g	%	No.	%	W/g	%	No.	%	W/g	%
Acanthuridae												
Naso brevirostris	1	0.03	6	0.00								
Antennariidae												
Antennariidae sp.									2	2.78	20	0.37
Apogonidae												
Apogon aureus	5	0.14	87	0.04								
Cheilodipterus quinquelineat.					3	2.44	58	1.12				
Aulostomidae												
Aulostomus chinensis	1	0.03	91	0.04								
Balistidae												
Rhinecanthus aculeatus	1	0.03	42	0.02	1	0.81	4	0.08				
Bothidae												
Moses sole	1	0.03	25	0.01								
Chaetodontidae												
Chaetodon auriga	4	0.11	40	0.02	1	0.81	46	0.89				
Chaetodon melannotus	2	0.06	14	0.01								
Chaetodon xanthocephalus	4	0.11	36	0.02								
Dasyatidae												
Taeniura lymna	1	0.03	117	0.05								
Gobiidae												
Amblygobius albimaculata	1	0.03	51	0.02								
Haemulidae												
Diagramma pictum	8	0.23	686	0.29								
Plectorhinchus gaterinus	4	0.11	200	0.08	1	0.81	62	1.20				
Labridae												
Cheilinus oxycephalus	6	0.17	209	0.09	3	2.44	168	3.25	1	1.39	12	0.22
Cheilinus trilobatus	40	1.13	1079	0.45								
Cheilio inermis	17	0.48	1665	0.70	3	2.44	330	6.38	7	9.72	826	15.43
Novaculichthys macrolepid.	4	0.11	156	0.07								
Pteragogus flagellifera	218	6.15	5592	2.35	11	8.94	192	3.71	4	5.56	105	1.96
Stethojulis strigiventer	3	0.08	60	0.03								
Lethrinidae												
Lethrinus harak	9	0.25	420	0.18	1	0.81	27	0.52	5	6.94	423	7.90
Lethrinus lentjan	15	0.42	833	0.35					2	2.78	188	3.51
Lethrinus mahsena	11	0.31	430	0.18	1	0.81	54	1.04	1	1.39	24	0.45
Lethrinus mahsenoides	59	1.66	3158	1.33					6	8.33	415	7.75
Lethrinus obsoletus	14	0.40	606	0.26	1	0.81	38	0.73	4	5.56	332	6.20
Lethrinus variegatus	19	0.54	683	0.29					1	1.39	30	0.56
Lutjanidae												
Lutjanus fulviflamma	143	4.03	6286	2.65	5	4.07	158	3.05	13	18.06	1751	32.71
Lutjanus gibbus	2	0.06	80	0.03								
Monacanthidae												
Paluteres prionurus	1	0.03	8	0.00								
Paramonacanthus barnardi	68	1.92	958	0.40	44	35.77	770	14.88				
Mullidae												
Parupeneus barberinus	164	4.63	8993	3.79	1	0.81	133	2.57	3	4.17	126	2.35
Parupeneus heptacanthus	1	0.03	46	0.02								
Parupeneus indicus	1	0.03	68	0.03					1	1.39	86	1.61
Parupeneus macronema	2	0.06	53	0.02								
Upeneus tragula	1	0.03	124	0.05								
Nemipteridae												
Scolopsis ghanam	15	0.42	564	0.24					1	1.39	33	0.62
Ostracidae												
Lactoria cornuta	1	0.03	10	0.00	2	1.63	23	0.44				
Platicephalidae												
Platicephalus longiceps	2	0.06	789	0.33								
Pomacentridae												
Chrysiptera annulata	11	0.31	121	0.05								
Dascyllus trimaculatus	2	0.06	49	0.02	4	3.25	51	0.99				
Plectroglyphidodon lacrymat.	4	0.11	76	0.03	10	8.13	134	2.59	2	2.78	23	0.43
Pomacentridae sp	5	0.14	79	0.03	3	2.44	59	1.14				

	Enhalus acoroides				*Thalassodendron ciliatun*				*Cymodocea rotundata*			
	No.	%	W/g	%	No.	%	W/g	%	No.	%	W/g	%
Scaridae												
Calotomus carolinus	2	0.06	107	0.05								
Calotomus spinidens	295	8.32	12749	5.37	2	1.63	100	1.93	5	6.94	226	4.22
Leptoscarus vaigiensis	2002	56.49	176020	74.10	24	19.51	2740	52.97	8	11.11	516	9.64
Scarus ghobban	42	1.19	1941	0.82								
Scorpaenidae												
Scorpaenidae sp.	1	0.03	10	0.00	2	1.63	26	0.50	1	1.39	12	0.22
Dendochirus brachypterus	1	0.03	17	0.01								
Serranidae												
Epinephelus flavocaeruleus	2	0.06	755	0.32								
Epinephelus furcatus	1	0.03	158	0.07								
Epinephelus fuscoguttatus	2	0.06	202	0.09								
Epinephelus hexagonatus	1	0.03	218	0.09								
Grammistes sexlineatus	1	0.03	10	0.004								
Siganidae												
Siganus stellatus	6	0.17	151	0.06								
Siganus sutor	281	7.93	9804	4.13					2	2.78	149	2.78
Teraponidae												
Pelates quadrilineatus	1	0.03	90	0.04								
Tetraodontidae												
Arothron hispidus	17	0.48	538	0.23					3	4.17	55	1.03
Arothron nigropunctatus	1	0.03	23	0.01								
Arothron stellatus	1	0.03	62	0.03								
Canthigaster bennetti	10	0.28	54	0.02								
Canthigaster valentini	5	0.14	39	0.02								
Tetrarogidae												
Ablabys binotatus	1	0.03	24	0.01								
Total number of fish	3544				123				72			
Total weight of fish (g)			237552				5173				5352	
Total number of species	63				21				20			
Magalef's diversity index	7.6				4.2				4.4			

Table 6: The five most abundant species in terms of number and weight in (a) *Enhalus acoroides*, (b) *Thalassodendron ciliatum* and (c) *Cymodocea spp.*

Enhalus acoroides Top five species by number	N	%	Top five species by weight	W/g	%
Leptoscarus vaigiensis	2002	56.5	*Leptoscarus vaigiensis*	176020	74.0
Calotomus spinidens	295	8.3	*Calotomus spinidens*	12749	5.4
Siganus sutor	281	7.9	*Siganus sutor*	9804	4.1
Pteragogus flagellifera	218	6.2	*Parupeneus barberinus*	8993	3.8
Parupeneus barberinus	164	4.6	*Lutjanus fulviflamma*	6286	2.6
Others	584	16.5	Others	23700	10.1

Thalassodendron ciliatum Top five species by number	N	%	Top five species by weight	W/g	%
Paramonacanthus barnardi	44	35.8	*Leptoscarus vaigiensis*	2740	53.0
Leptoscarus vaigiensis	24	19.5	*Paramonacanthus barnardi*	770	14.9
Pteragogus flagellifera	11	8.9	*Cheilio inermis*	330	6.4
Plectroglyphidodon lacrymatus	10	8.1	*Pteragogus flagellifera*	192	3.7
Lutjanus fulviflamma	5	4.1	*Cheilinus oxycephalus*	169	3.3
Others	29	23.6	Others	891	18.7

Cymodocea spp. Top five species by number	N	%	Top five species by weight	W/g	%
Lutjanus fulviflamma	13	18.0	*Lutjanus fulviflamma*	1751	32.7
Leptoscarus vaigiensis	8	11.1	*Cheilio inermis*	826	15.4
Cheilio inermis	7	9.7	*Leptoscarus vaigiensis*	516	9.6
Lethrinus mahsenoides	6	8.3	*Lethrinus harak*	423	7.9
Lethrinus harak	5	6.9	*Lethrinus mahsenoides*	415	7.8
Others	33	46.0	Others	1421	26.6

Table 7: The mean number and weight of the most common species in the trap fishery, the seagrass parrotfish *Leptoscarus vaigiensis* in traps set in each of the three seagrass categories.

	Mean number	SE	Mean weight	SE
Enhalus acoroides	1.65	0.15	152.29	14.22
Cymodocea sp.	0.12	0.04	13.24	7.11
Thalassodendron ciliatum	0.40	0.14	45.67	17.12

Leptoscarus vaigiensis accounted for 74% and 61.2% in *Enhalus acoroides* and *Thalassodendron ciliatum* respectively, but for just 9.6% in *Cymodocea*. *Cymodocea* also had the largest proportion of fish not accounted for by the 5 most common species. Over 50% of fish by number in *Cymodocea* were species other than those five most abundant species.

Thalassodendron ciliatum and Cymodocea *spp.* both had *Lutjanus fulviflamma* in their top five species but the remainder of most abundant species by number were different in each species of seagrass. Two species of lethrinid featured in the top five species from *Cymodocea spp.* beds, and a pomacentrid, *Plectroglyphidodon lacrymatus* was important in *Thalassodendron ciliatum*. Numerically, *Thalassodendron ciliatum* was dominated by the filefish *Paramonacanthus barnardi*, whereas in terms of biomass *Leptoscarus vaigiensis* was the most important species. Three species of labrid appeared in the five most important species in terms of biomass in *Thalassodendron ciliatum* – *Cheilio inermis*, *Cheilinus oxycephalus* and *Pteragogus flagellifera*. The main species in *Enhalus acoroides* in terms of numbers and weights were the species found to be common in the net fishery and were also some of the species most often seen on underwater visual censuses: *Leptoscarus vaigiensis*, *Siganus sutor*, *Calotomus spinidens* and *Parupeneus barberinus* (Chapter 3).

DISCUSSION

Trap spacings

The 5m line spacing used by Quirimban fishermen was apparently an efficient method, and one of the optimal spacing arrangements for maximising catches. In the spacing experiment there did not seem to be any benefit in term of increased catch in spacing the traps more widely, and any wider spacing than 5 metres had the disadvantage that it was not usually possible to see the next trap in line when setting the first. Fishermen often lost widely spaced traps. The highest values of catch per trap came from the traps placed in matrix arrangements but this was not a practical option for trap fishermen because setting traps in this arrangement required difficult manoeuvres of the dug-out canoe and involved entering the water to set each trap. It is interesting to note

that number and weight of fish increased progressively with increasing spacing in lines, but that numbers of species per trap was lowest at 1m spacings, remained constant for 2, 4 and 5m spacings and was highest for 10m line spacings.

It was interesting that the weight of fish and number of fish per trap for traps with 10m between them was lower than for 5m spacing. It seems likely that the number and biomass of fish caught in traps at whatever spacing is less to do with some inherent value for fish density, and more to do with how the arrangement of traps may affect the behaviour of the target species. Traps themselves may act as a kind of fish aggregation device, and the manner in which they attract fish could depend on their arrangement. Above 5m spacing there may be a cut-off point where the traps are only seen as individuals traps, not as a group of traps which may attract fish more strongly. The values for both fish number and weight are greater (though not significantly) in matrices than lines for both 5m and 10m spacings. One would expect matrix-spaced traps to have lower catches rather than higher catches because there would be more overlap in the areas available to be fished. This may be the case for 2m line and matrix traps in which line spaced traps do catch a higher mean weight and number than matrix-spaced traps. For traps spaced more than 2m apart the fish aggregation properties of the matrix of closely spaced traps may make overlap effects insignificant.

Seagrass Species

The clear conclusion to be drawn from the traps set in the three seagrass species was that whatever aspect you look at; mean weight of fish per trap, mean number of fish per trap or mean number of species per trap, they are all higher in traps set in *Enhalus acoroides*. All three values were virtually double that found in *Cymodocea spp.* or *Thalassodendron ciliatum*. *Enhalus acoroides* appears to provide a more suitable habitat for the species of fish vulnerable to capture by trap than *Cymodocea spp.* or *Thalassodendron ciliatum*. *Enhalus acoroides* is a much taller seagrass and often grows in very dense stands. *Enhalus acoroides* is the species of choice for fishermen to place their traps and this choice seems to be confirmed as a good one in these experiments. It is interesting to note that in *Thalassodendron ciliatum* (probably the second most

common seagrass in the Montpuez Bay in terms of area covered and biomass, and a large species) the most common fish species numerically was the inedible filefish *Paramonacanthus barnardi.* Filefishes were found to be amongst the most abundant fish families in seagrass beds in a number of studies of tropical seagrasses. For example, in Japan (Nishiwaki and Koike 1980, Kikuchi 1966), Indonesia (Hutomo and Martosewojo 1977), South West Australia (Scott and Dybdahl 1984), New South Wales (Burchmore et al 1984), Florida (Livingston 1975) and the Caribbean (Weinstein and Heck 1979), filefishes (Monacanthidae) were in the top five most abundant fishes in seagrass beds.

There appear to be clear differences in relative abundances of key species between the three seagrass species. It must be remembered that traps only sample a fairly narrow cross-section of species (compare the diversity and catch composition of the trap fishery with the net fishery – see Chapter 3). *Leptoscarus vaigiensis* which accounted for approximately 80% of biomass in the trap fishery catches accounted for just 11% of the net fishery so the trap experiments were likely to have overestimated the importance of *Leptoscarus vaigiensis* in these three seagrass species. Parrotfishes have been found to be the most common species caught in traps in other studies, particularly in the Caribbean (Munro 1983).

Fishermen never placed their traps in areas of *Thalassodendron ciliatum* or *Cymodocea rotundata.* Using the mean catch figures from this experiment, a fisherman with the standard 40 traps, if placed in *Enhalus acoroides* would catch an average of 8.8kg for a days fishing, 3.4kg if placed in *Thalassodendron ciliatum* and 2.7kg if placed in *Cymodocea rotundata*. Placing traps in these other seagrass species would require the same amount of effort as for *Enhalus acoroides*, approximately 4 hours, but the catch per unit effort would be vastly different. In *Enhalus acoroides* the CPUE would be 2.2 kg fish per man hour, whereas for *Thalassodendron ciliatum* it would be 0.85 kg fish per man hour and for *Cymodocea rotundata* 0.67 kg fish per man hour. One point that the fishermen made repeatedly about *Enhalus acoroides* was that this species of seagrass kept the traps in the same place so they were not swept away by

currents and lost. It may be that this species also helped to keep the traps stationary so that fish were not frightened by the movement.

The difficulties I encountered in undertaking this experiment using a traditional fishing method and a traditional boat emphasised the skill involved in trap fishing. To be able to place traps myself that would fish effectively I had to learn a complex series of rules for the way the trap set was weighted and maintained, the angle that the entrance made with the shore and the placing of the trap in relation to currents, sandbanks and other topographical features. In the initial exploratory phase of the experiment whole sets of traps that I had placed at the optimum 5m spacing in the preferred seagrass caught virtually nothing because the traps had not been placed in the correct way.

The angle of the trap in relation to the shore and to prevailing currents was also found to be an important part of trap fishing in Palau (Johannes 1981). There, the long axis of the traps is placed parallel to the prevailing currents which prevents the currents from causing various parts of the trap to vibrate, which is thought to frighten the fish (Nomura 1980).

It is not surprising that the methods of trap setting that gave the highest number and biomass of fish corresponded closely to those used by the marema fishermen of Quirimba. The same design of the marema is seen throughout the east African coast and is also very similar to that used in the Caribbean. The traps are made from natural materials and it is likely that the same design has been used for centuries. Trap fishing, unlike net fishing on Quirimba is a highly skilled occupation which is usually learnt by apprentices from older experts in the art of making and fishing maremas.

In their comparison of fish faunas sampled by beach seine from two species of seagrass in Puerto Rico, *Thalassia testudinium* and *Syringodium filiforme*, Martin and Cooper (1981) found that *Thalassia* yielded a much higher biomass of fish than *Syringodium* (3.15 gm^{-2} per trap set compared with 0.65 gm^{-2}). *Thalassia* was also found to have a higher diversity index than *Syringodium* and the seagrass fish faunas were described as significantly different and not equivalent as fish habitats. Martin and Cooper ascribed these differences to the

higher patchiness of *Thalassia*, substrate type associated with the two seagrass species and "environmental structure imposed by blade morphology". The homogeneity of the habitat was thought to influence fish biomass and diversity with *Thalassia* displaying much higher habitat diversity associated with its higher levels of patchiness. *Syringodium* beds were described as completely homogeneous. *Thalassia* is a larger, flat-leaved species of seagrass, whereas *Syringodium* is a fine, cylindrical species providing a much smaller surface area for colonising epiphytes.

It is possible that the lower biomass and number of individuals and species in the two smaller seagrass species reflected less a difference in fish biomass and numbers in those species and more a difference in the size of fish. Heck and Orth (1980) suggested that lifestage – juvenile or adult – of fish which occupied the seagrass could be related to the surface area of seagrass in relation to the area of bottom covered. They suggest that adult fish are associated with low plant surface area per unit area of bottom, whereas juvenile fish and mobile invertebrates were associated with a range of plant surface areas, including those at the higher end of the range. Traps selectively catch a narrow range of fish sizes so any differences in fish sizes between the seagrass species would be obscured and would only appear as differing abundances of the fish of the size vulnerable to traps.

In Tulear, in the Mozambique Channel, Madagascar, Harmelin-Vivien (1983) compared fish species diversity and richness in three species of seagrass (also present at Quirimba): *Thalassodendron ciliatum*, *Syringodium* and *Halodule*. She found that of these three species *Thalassodendron ciliatum* (the largest seagrass species) had the highest number of species (33) and families (25), the highest indices of species richness and diversity and the lowest index of evenness (equitabilité). *Syringodium*, a small cylindrical-leaved species (see diagrams in Chapter 1) had the next highest numbers of species (29) and families (19) and diversity indices. The seagrass with the least diverse fish community was the small species *Halodule* with 16 species and 10 families. There does seem to be a pattern of increasing fish species with increasing seagrass size.

Although the sample size of traps set in unvegetated sand was small, the higher number and weight of fish and the higher number of species in sand compared to in stands of *Cymodocea spp.* was interesting. The role of the fish trap as a fish aggregation device might be more important in sand where alternative sources of shelter for fishes are not available. The sand areas used in this study were patches of sand of the order of $10m^2$, surrounded by seagrass beds. The highly mobile nature of many of the seagrass fish species make it likely that fish migrate across sandy areas and may be as abundant in these areas as in sparse seagrass beds.

Conclusion

This study showed that there are some key differences between the fish assemblages sampled from three species of seagrass. Fish number, biomass and species all varied between seagrass species and this has important implications both ecologically and for management. In Chapter 3 the high species diversity of fish from the seagrass beds was described, and compared to studies elsewhere. In many other studies with much lower fish species numbers the seagrass beds were composed of just one species of seagrass. The seagrass beds of Quirimba were composed of a mosaic of 10 species, often dominated by *Enhalus acoroides*, but very rarely monospecific except on a very small scale (see Chapter 1). In terms of biomass of fishes *Enhalus acoroides* is evidently important but the overall diversity of the seagrass beds may also depend on this mix of seagrass species and their corresponding diversity of growth forms. It would also be interesting to investigate these fish communities by using much smaller meshes on traps so that small fish in the communities could also be investigated.

Trap fishing is one of the most common fishing methods used by artisanal fishers in the tropics, particularly in East Africa and the Caribbean, and knowledge of the impact of substrate type, spacing and arrangement of traps on catch composition and size is useful in fisheries management but is often overlooked in studies of landed catches. The strategy that the fishermen of Quirimba use for trap fishing was evidently one of the optimal strategies, which is to be expected after what could be centuries of perfecting this fishing technique in the region. One important point for management would be to

emphasise the invaluable knowledge of the fish and fisheries that the local fishermen have. Any future management strategies for the trap fishery must be planned and implemented with the full involvement of the fishers.

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CHAPTER 6

THE PRICE OF FISH AND THE VALUE OF SEAGRASS BEDS: SOCIO-ECONOMIC ASPECTS OF THE SEAGRASS FISHERY ON QUIRIMBA ISLAND, MOZAMBIQUE

ABSTRACT

The economic importance of the seagrass fishery was studies on Quirimba Island through informal interviews, observation and community workshops. Income from the seagrass fishery was found to be the single most importance source of employment and income for men on the island. Many fishers employed in the seine net fishery were young men who received some of the lowest wages on the island. Boat captains and trap fishermen earned a higher daily salary, and the most lucrative role in the fishery was as a seine net boat owner, which required considerable capital investment. Most households on Quirimba were almost self-sufficient in terms of food, through produce grown in allotments and fish caught by the men or invertebrates collected by women and children. However, the need for imported goods such as medicines and the increased availability of consumer items was increasing the pressure on people to earn cash, rather than to maintain their largely subsistence lifestyle. Approximately half the fish caught on Quirimba was sun-dried and sold on the mainland. Boat owners and fish traders would sell fish in bulk in Pemba. Prices for dry and fresh fish were amongst the lowest in Mozambique and had risen little with inflation, whereas prices for dried invertebrates collected by women were high on the mainland. The men's seagrass fishery was therefore the main source of animal protein for subsistence, whereas the women's fishery was more cash-orientated. Quirimba Island was a remote rural community with no tourism or industrial development and poor infrastructure, and therefore very few alternatives to the current reliance on marine resources.

INTRODUCTION

Marine resource use is an important component of the local economy in many tropical coastal areas. The importance of marine resources to a community

depends on the geographic and economic situation of the area: the level of development, the role of tourism and the availability of alternative sources of income (Ruddle 1996a). In areas near international airports and large cities, marine resources can be exported to an international market or sold to tourists and can fetch high prices. In more isolated places without a developed transport infrastructure, marine resources may only be used on a subsistence level in the immediate local area and thus have a much lower economic value (Birkeland 1997, White *et al.* 1994, Lindén and Lundin 1996). However, in such isolated places the local value of marine resources is high because they are often the most important source of income and animal protein.

To manage marine resources it is important to assess the ecological status of the habitats and organisms that are being exploited, and also how the local people use them and their role in the local economy. As the socio-economic structures of coastal communities develop and change, the intensity with which marine resources are exploited also changes. In the past this generally happened on a local or perhaps national level. However, as we enter the twenty first century and the phenomenom of "globalisation" means that few places really are remote or inaccessible any longer. Economic growth and social change in one place can affect the extent to which marine resources are exploited in other parts of the same country, in other countries and even in other continents. For instance, rapid economic growth in Asia has had a direct impact on the sustainable use of marine resources throughout the Pacific, from Taiwan to the Galapagos, with large Asian companies buying live reef fish, sea cucumbers and other marine products to supply the growing Far Eastern markets (Birkeland 1997).

Socio-economic investigations are increasingly being incorporated in biological studies of tropical coastal fisheries (Fiji - Jennings and Polunin 1996, Kenya – Juma 1998, Sri Lanka - Dayaratne *et al.* 1995), as it has become apparent that ecological and socio-economic aspects of resource use must be considered together. Increasing emphasis is being put on the role of user-participation and the use of local knowledge in the management and development of natural resource use in developing countries (Sillitoe 1998, Chambers 1997). However, including an element of "indigenous knowledge" in natural resource projects is

still rare, with just 1.1% of all projects funded by the UK Department for International Development including such research (Sillitoe 1998).

Fishing and other types of marine resource use are typically last resort sources of food and employment for people who have no alternative (McManus 1993). This is one of the reasons that marine resources and particularly those that are easily accessible on foot, are put under such severe pressure in very poor, often highly populous areas. Accessible sheltered areas such as reef flats and seagrass beds often support large numbers of very poor fishermen who can not afford boats (McManus 1993). Seagrasses are therefore often more likely to be intensely exploited than other habitats.

STUDY AREA

This study was conducted as part of the Frontier-Moçambique Quirimba Archipelago Marine Research Programme. Much of the socio-economic data presented here were collected on Quirimba Island, one of the two most densely-populated islands in the Archipelago, during thirteen months over a period of two years (1996 and 1997). Quirimba Island is 6km long by 2km wide. It is situated within a few kilometres of the Mozambican mainland and is part of Ibo District in the province of Cabo Delgado (Fig. 1 in Chapter 1). At low spring tides it is possible to walk between the island and the mainland and also to Ibo Island to the north and Sencar Island to the south. Quirimba has 3000 inhabitants, most of whom live in Quirimba village at the north tip of the island. A few hundred people lived outside the village, the majority in the Kumilamba area in the south of the island (Fig. 2 in Chapter 1).

The History of the Quirimbas

The Quirimba Archipelago has a long and colourful history but there are few existing historical records and the islands have been little studied (Boxer 1963).This is surprising because they were a key part of the Arab and Portuguese Indian Ocean empires and "research on the Quirimbas would surely throw new light on the broad-ranging scope of the Indian Ocean trade" (Davidson 1961 in Boxer 1963). Before the Portuguese arrived in the sixteenth century, the islands were important as prosperous Arab trading posts for ivory and slaves. In the seventeenth century they suffered in the wars between the

Portuguese and the Omani Arabs, and at the end of the seventeenth century the Omanis destroyed most of the buildings in the stone towns on the islands. In the early nineteenth century the islands were devastated by Madagascan raiders (Boxer 1963, Sousa 1960). Unlike Zanzibar, Mombasa, Kilwa or Mozambique Island, the Quirimbas did not continue to exist as important Indian Ocean trading ports or become known for their long histories. The catholic church in Quirimba village (now used as the school) dates back to 1894 and there is also a ruined church, Nossa Senhora do Rozario, that was built around 1580 (Sousa 1960). Santa Maria beach, where the Frontier-Moçambique project was based, was said to be where some of the first Portuguese settlers in the Quirimba Archipelago had lived (Gessner pers. com. – from C.R. Boxer, the historian who visited Quirimba in the 1950s).

Historically the islands seem to have been very productive agriculturally and able to support residents and visiting traders. They were well-placed for trading goods from the interior such as ivory and gold. Ibo and Quirimba were also important centres for the Indian Ocean slave trade. Records from early visitors (mainly Portuguese and British) describe the islands as productive in terms of agricultural produce, goats and of course fish, and a good place to stop for supplies (Boxer 1963, Sousa 1960).

For over four hundred years there were Portuguese inhabitants on the islands and a strong catholic presence, with parish priests on Ibo and Quirimba. Now the residents are virtually all of African or mixed African, European and Arab origin. The coastal people traditionally associated with the coast of Cabo Delgado are the Mwani who speak a dialect of Kiswahili called Kimwani, and were traditionally traders and fishers. The coastal Mwani people are mainly Muslim. They are not as strictly Muslim as many coastal Tanzanian communities and there is still a strong system of traditional pre-Islamic beliefs. Witch doctors or *curandeiros* are important figures in the community and are consulted for a huge variety of problems. The other main group on the island are people of Makua origin, the biggest ethnic group in Mozambique (West 1998) living throughout the northern provinces of the country. A third ethnic group present in small numbers are the Makonde, from the area around the

Tanzania-Mozambique border. The Makonde are known for their skilled wood carving.

Until 1975 Mozambique was under Portuguese colonial rule, with many colonial plantations and factories in the rural north. The Portuguese were strict enforcers of fisheries regulations such as mesh size regulations and in colonial times there were regular incinerations of illegal nets on Quirimba (J. Gessner pers. comm.). In 1975 Mozambique gained independence and the 17 year civil war started. The civil war was fought predominantly in the ordinary villages of rural Mozambique and the ordinary people of Cabo Delgado province suffered brutal guerrilla warfare. Tens of thousands of people became *deslocados,* refugees within their own country, fleeing villages that were being destroyed. Many of the *deslocados* fled to the coast, and in particular the islands, because the guerrillas would not cross water and so would not pursue refugees to the islands. This influx of people from the mainland led to an increase in population on the coast (Massinga and Hatton 1997) and on the islands (J. Gessner pers. com.) and a greater mix of ethnic groups. Many of the refugees were Makuas and some were Makondes from the northern Mozambican interior.

In the years since the end of the civil war in 1992, Mozambique has gained a level of stability and the present government is progressing in rebuilding the political and economic structure (Macia and Hernroth 1995). The Human Development Index of the country as determined by UNDP has risen over recent years, but Mozambique is still the world's ninth poorest country (UNDP 1998). Development is now happening very quickly in all sectors of Mozambican life, from tourism to heavy industry. However, the Quirimbas have been somewhat neglected. They are over 2000km from the national capital Maputo and difficult to reach and therefore are rarely visited by politicians and other decision makers. Infrastructure is poor and there are few opportunities for the people of the Quirimbas to be represented or heard at a national level.

METHODS

Socio-economic data were collected on Quirimba using several methods:

1. Informal interviews with fishermen on fishing trips, at landing sites and in the village.

2. Formal interviews with boat owners.
3. Accompanying fishers on fishing trips that employed all major methods.
4. Visiting fishers' households, talking to families and observing daily routines.
5. Informal workshops in the village with fishers.

A number of Quirimba fishers and other residents were key advisers for this study. They were interviewed at length on numerous occasions, suggested other people to talk to, took me to their houses and the houses of family and friends to learn more about life on Quirimba, and showed me their allotments (*machambas*) and their other daily work. The information presented in the results is therefore assembled from a large number of mainly informal interviews a wide spectrum of people in the community. The key informants are acknowledged at the end of this chapter.

Some biological information about the women's invertebrate fishery was collected in the first year of the project and has already been presented in Barnes *et al.*, (1998). Additional social and economic information about these fisheries was collected through informal discussion with women in the village, by accompanying them fishing and through two workshops. Workshops were organised with the local OMM (Organizaçao da Mulher Moçambicana – Mozambican women's organisation) representative in the village. The workshops were conducted in Portuguese, Makua and Kimwani. Most women in Quirimba were illiterate and many did not speak Portuguese so it was important to use visual methods that were accessible to all participants.

RESULTS AND DISCUSSION

Quirimba during the study period (1996-97)

Quirimba village has a good system of water pumps from wells throughout the village. There is a medical clinic staffed by a trained nurse, but no doctor, a small school, a market selling a very limited range of goods, a few small shops and a bakery. The houses in the village are fairly large (2 to 4 rooms), and well built with a mangrove structure filled out with mud and rock. Most have traditional *mecute* (woven coconut palm) roofs but there are some stone or cement houses with corrugated iron roofs. The houses have large yards where

cooking is done and also small toilet and washing shelters. There is no sewerage system in the village. A few houses have shelters with a "long-drop" style toilet but many people still use the beach or mangrove area for solid waste. There is no electricity supply to the village. A few residents have oil-powered generators for their homes, used for a few hours each day. There is a mosque in the village for the predominantly Muslim community.

In Kumilamba in the south of the island, the residents have *machambas*, small allotments used for mainly subsistence agriculture. Houses in Kumilamba are of less permanent nature than those in the village, and generally smaller (typically just one room). The people who live in the *machambas* have easy access to their agricultural land but they are 6km walk from the village where they have to go to get drinking water. Also, many children who live in the *machambas* do not go to school because the nearest school is in Quirimba village. Most households on the island have a *chamba* where they grow sweet potatoes, cassava, papaya, corn and beans. The land tenure system was informal and slightly vague at the time of study and appears to be entering a process of modernisation and formalisation. Many families have plots which their family had farmed for years which they think of as their own but have no legal documentation. Others have cleared bush and scrub by slash and burn to claim the newly cleared land as their own.

A large area of the middle section of the island is covered in a coconut plantation owned by farmers of German origin whose family have had a plantation on the island since the beginning of the century. The plantation provides jobs for about 80 people as labourers, guards and processing workers. The coconuts are produced for the copra market. The plantation owners also rear cattle to sell in Pemba. There is also a local herd of cattle owned by a number of people in the village. The cattle graze in the coconut plantation.

Although people on Quirimba are fairly self-sufficient in terms of everyday requirements such as food, water and building materials, many people make the trip to Pemba, the provincial capital, to sell produce for a small cash income, to receive medical treatment and to buy household goods such as cooking pots and clothes. Three motor boats sporadically provide transport for the day-long

journey from Quirimba to Pemba. It is also possible to go to Quissanga on the mainland on the other side of the Montpuez Bay by dhow, then go by road to Pemba but this often takes even longer and is more expensive.

Types of marine resource use (see Table 1 for summary)

The main fishing methods on Quirimba Island are seine netting and *marema* trapping in the subtidal seagrass beds, the collection of invertebrates from the intertidal seagrass beds and a variety of smaller scale fisheries and resource collection on the coral reefs and in the mangroves. These fishing methods are described in Chapter 2. The marine resources captured by these methods can be put into three categories based on their use:

1. Locally consumed resources

The majority of fish caught locally are consumed locally by fishers and their families or by other local people had trade goods or services for them.

2. Locally sold resources

Some fresh fish and shellfish are sold locally. There is no fish or seafood market in the village as such – buyers usually go to the beach where fish or shellfish that have been collected that day are landed. Dried produce is occasionally sold between Quirimba residents on a casual basis.

3. Resources sold outside Quirimba

Large quantities of dried fish are sold off the island in two main ways. Firstly, island-based traders buy fish from fishermen, particularly trap fishermen, accumulate a large quantity of dried fish, then sell it in the market in Pemba or in markets elsewhere in Cabo Delgado province. They buy fish, often a lot of *Lethrinus variegatus* and *Leptoscarus vaigiensis,* for 3000Mts per kilo wet weight, and sell it for 15-20,000Mts dried (12,000Mts was equal to approximately US$1 during the study period, so traders paid US$0.25 per kilo for fish and sold it for US$1.25-1.67). This seems like a large profit but in fact the dried fish will have lost up to three quarters of its wet weight through drying, gutting and cleaning. Net fishing boat owners also buy fish to sell on the mainland. They have an arrangement with their boat's crew whereby they either buy the majority of fish caught at a reduced price or they pay their crew a

Table 1: Marine species exploited on Quirimba Island with method of capture, user group, habitat captured from, market and use for the species (from personal observation and interviews and workshops with fishers).

Scientific name	Common name	Kimwani	Method of capture	User group	Habitat	Market	Use
Fish							
Siganus sutor	African whitespot rabbitfish	Safi	Seine, gillnet & marema trap	Local men	Seagrass and reef flat	Local Mainland/Pemba	Eaten fresh Dried
Leptoscarus vaigiensis	Seagrass parrot	*Bonju*	Marema trap & seine	Local men	Seagrass	Local Mainland/Pemba	Eaten fresh Dried
Lethrinus variegatus	Variegated emperor	*Sololo*	Suri trap and seine net	Local men	Seagrass	Local Mainland/Pemba	Eaten fresh Dried
Gerres oyena	Blacktip mojarra	*Sala*	Seine net and gillnet	Local men	Seagrass and reef flat	Local Mainland/Pemba	Eaten fresh Dried
Lethrinus lentjan	Pink ear emperor	*Njana*	Seine net	Local men	Seagrass and coral	Local Mainland/Pemba	Eaten fresh Dried
Large reef fish e.g. Acanthurids, Scarids			Gill net, spearfishing	Itinerant fishermen	Coral reefs	Mainland	Dried
Carangidae	Jacks	*Njohwe*	Fence trap, line fishing	Local men, itinerants	Open water, seagrass, reef	Local	Eaten fresh
Molluscs							
Octopus vulgaris	Octopus	*Mweza*	Stick, hook	Local women	Reef flat	Local	Eaten fresh and dried
Barbatia fusca	Ark shell	*Ombey*	Hand	Local women	Intertidal sand and seagrass	Mainly mainland/Pemba	Dried
Pinna muricata	Pinna shell	*Macaza*	Hand	Local women	Intertidal sand and seagrass	Mainly mainland/Pemba	Dried
Pinctada nigra	Oysters	*Mbari*	Hand	Local women	Intertidal seagrass	Mainly mainland/Pemba	Dried
Pleuroploca trapezium	Tulip shell	*Korne nlume*	Hand/collected on net or trap fishing trips	Men	Seagrass	Operculum sold in Tanzania	Animal eaten fresh
Chicoreus ramosus	Murex	*Makome*	Hand/collected on net or trap fishing trips	Men	Seagrass	Operculum sold in Tanzania	Animal eaten fresh
Terebralia palustris	Mangrove whelk		Hand	Men/children	Mangrove/intertidal flat	None	Used for baiting traps
Echinoderms							
Holothuriidae	Seacucumber	*Megajojo*	Hand	Local finfishermen and itinerants	Seagrass and intertidal	Export	Dried for food
			Mask and canoe	Local finfishermen and itinerants	Seagrass and shallow reef	Export	and medicinal uses
			SCUBA	Itinerant fishermen	Reefs	Export	
Crustacea							
Panulirus spp.	Crayfish		Hand/spear/hook	Local fishery/some itinerant/tourist	Reef	Pemba	Restaurants
Scylla serrata	Mangrove crabs		Hand	Local fisherman	Mangrove	Local European	Eaten fresh
Portunus pelagicus	Swimming crab		Hand/bycatch in traps	Children/trap fishermen	Intertidal flats, shallow water	Local	Eaten fresh
Reptiles							
Chelonidae	Turtle	*Assa*	Incidental catch in net	Local and itinerant	Reef and seagrass	Local	Eaten fresh

certain wage and receive the majority of the fish as their share of the operation. They dry this fish and accumulate it in storage until they have enough to make the trip to Pemba to sell it.

The other main route to sale for Quirimban fish is through fishermen from the mainland who come to Quirimba and the other islands in the Archipelago to fish. A small proportion of these fishermen are from villages on the nearby mainland such as Mahate and as far south as Pemba. Many of them have been coming to the Quirimbas to fish for many years. Most are farmers in the wet season and fish the Quirimbas in the dry season. The dried fish supplements their family's diet of maize and cassava, and can also be sold for cash to buy any goods that the family can not produce themselves, such as clothes, cooking oil and medicines.

The majority of the visiting fishermen are from the next province south, Nampula, and have only been fishing the Quirimbas in large numbers for a few years (from interviews with Nampula fishermen and Gessner pers. comm.). These fishermen are in a similar situation to those described above – they have agricultural work in the wet season and come to the Quirimbas in the dry season to catch fish to dry and take back to eat over the wet season and to sell. Traders also come to Quirimba to buy dried fish which they said is "better quality" than the fish they can buy in Nampula. These traders deal in hundreds of kilos of fish which they drive down to Nampula.

4. Cash commodities for export

The only really lucrative commercially driven fishery on Quirimba is the sea cucumber fishery. In the mid 1990s a large commercial sea cucumber fishing operation based in Pemba was active in the whole of the Quirimba Archipelago. The operation was run by a Chinese export company who processed the sea cucumbers and exported them to the Far East along with other commercially valuable marine resources caught locally such as shark fin. At the end of the study period this fishery had temporarily ceased. At least one Tanzanian sea cucumber fishing operation was active in the Archipelago, using SCUBA gear. Traditionally local fishermen collect sea cucumbers by snorkelling, so limiting the depth range over which they are vulnerable. Ordinary net or trap fishermen

who collect sea cucumbers while they are fishing can sell them individually to traders for up to 1000Mts (less than US$0.10) each. Other incidental catches that can be sold to traders include seahorses for which a fishermen can get 5000Mts (US$0.40) for a 7cm individual and the opercula of some shells which can be sold by the kilo for 150,000Mts (US$12.00) or individually for a few hundred meticais. These traders sell these resources on in bulk across the border in Tanzania to be sold on to the Far East.

The prices for fish caught in the seagrass and coral reef fisheries of Quirimba were remarkably consistent. Fresh fish were sold for a set price of between 4000 and 5000Mts per kilo. Occasionally large, good quality lethrinids caught in baited traps or by hook and line were sold for a higher price (reportedly up to 10,000Mts per kilo) because of the good quality of lethrinid flesh. Otherwise, everything from a kilo of 7-10cm *Lethrinus variegatus* or other small fish, to a kilo of a large jack (Carangidae) or snapper (Lutjanidae) caught in a fence trap was sold for around 4000Mts. 5000Mts per kilo of fish was the standard price for fish throughout rural coastal Cabo Delgado. The same price was charged in the rural Mecufi district south of Pemba, where 5000 meticais was quoted as the lowest price of fish in Mozambique (Loureiro 1998). Set prices are common for a variety of commodities in northern Mozambique, from shellfish to sweet potatoes.

The only way to preserve fish on Quirimba is to dry it in the sun. This is done on drying racks outside houses in the village. Dried fish was sold on the mainland for between 15 and 20,000Mts per kilo. Small fish are dried closed (*fechado*) and were sold for 15,000Mts per kilo and larger fish are dried open (*aberto* – like a kipper) and sold for the slightly higher price of 16,000Mts. per kilo. Dried fish often have a slightly "off" taste which does not prevent their sale or consumption. Occasionally seagrass parrotfish (*Leptoscarus vaigiensis*) die in the *marema* traps, and are retrieved in a partially rotted state. These fish are not discarded and are dried as normal and sold for consumption. The highest prices, some exceeding 25,000mts per kilo were given for dried fish sold in villages a long way inland. The prices of fish and marine invertebrates on Quirimba are shown in Table 2, along with a selection of other local prices for comparison. Note the high prices per kilo of fresh invertebrates (10-15,000Mts)

Table 2: Prices paid on Quirimba Island for fish, agricultural produce and other goods, their source, mode of production and how they are made available to the community. Prices are shown in the local currency of Mozambican meticais and US dollars.

Item	Cost on Quirimba Meticais	Cost on Quirimba US$	Source	Mode of production/exploitation	Market
Fresh fish/kg	3 to 5,000	0.25-0.40	Local	Caught by men	Sold direct at landing site
Dried fish/kg	12 to 15,000	1.00-1.25	Local	Caught by men	Sold from home
Squid/kg	3,000	0.25	Local	Caught by men	Sold direct at landing site
Octopus/kg fresh	5,000	0.42	Local	Caught by women and men	Sold direct at beach
Dry	16,000	1.30			
Pen shells fresh/kg	15,000	1.25	Local	Collected by women	Sold direct at beach
Ark shells fresh/kg	10,000	0.83	Local	Collected by women	Sold direct at beach
Oysters/kg	12,000	1.00	Local	Collected by women	Sold direct at beach
Mangrove crab/kg	5,000	0.42	Local	Collected by men	
Sweet potato/kg	2,000	0.17	Local	Grown in machambas	Sold in machambas
Cassava leaves/kg	5,000	0.40	Local	Grown in machambas	Sold in machambas
Peanuts/kg	4,000	0.33	Mainland		Sold in village market
Coconut (each)	1,000	0.08	Local	Machambas and plantation	Sold in village market
Onions/kg	25,000	2.08	Mainland	Imported	Sold in village market occasionally/Quissanga market
Eggs (each)	1,000	0.08	Local	From chickens kept in village and machambas	Sold from home
Bread flour/kg	10,000	0.80	Mainland		Sold in village shop
Maize flour/kg	6,000	0.50	Mainland/local	Maize from machambas	Sold in village shop
Rice/kg	10,000	0.80	Mainland		Sold in village shop
Papaya (each)	500-2,000	0.04-0.16	Local	Grown in machambas	Sold in machambas
Mango (each)	100-1,000	0.01-0.08	Local	Machambas and in plantation	Sold in village market seasonally
Sugar/kg	20,000	1.60	Malawi	Imported	Sold in village shop
Condensed milk	15,000	1.25	Maputo/ South Africa	Imported	Sold in village shop
Chicken each	15-25,000	1.25-2.08	Local	Reared in village or in machambas	Sold from home
Capulana (sarong – 2 pieces)	40-80,000	3.33-6.66	Maputo/ Tanzania	Imported (cheapest from India)	Sold in village shop
T-shirt	10,000	0.80	Mainland	Imported	Sold in village market occasionally
Trousers	20,000	1.60	Mainland	Imported	Sold in village market occasionally
TB medication	40,000	3.33	Mainland	Imported	Sold at village clinic

compared to that of fish (3-5,000Mts), and also the high price of imported goods such as sugar (20,000Mts per kilo) and onions (25,000 per kilo).

The different economic levels of marine resource use in the Quirimbas

Marine resource collection in the Quirimba Archipelago can be divided into a number of categories depending on the level of investment needed by the fisher:

1. Little or no personal investment

The main group in this category are the crew of the seine net fishing boats who need to make very little investment to start fishing. Some have their own strong shoes to protect against urchins, others have their own masks but the majority have neither. Young boys go straight into the seine net fishery and strangers to the island are also free to enter this fishery.

The women's invertebrate fishery requires very little personal investment, needing only a bucket or other container. Women collect invertebrates from the intertidal at Santa Maria and Pantopi, and also make trips on boats out to exposed sand banks at low spring tides. Young children who collect small species of mollusc from the upper intertidal, and women who collect these shells for occasional meals can also be included in this category.

2. Moderate personal investment

Trap fishermen need a dug-out or plank-constructed canoe with two outriggers (worth between 100,000 and 800,000Mts, see Table 3), 30 to 50 (usually 40) *marema* traps, weights (stones collected locally), "hippo fat" to waterproof the boats, a pole for punting and bailer. The total cost for trap-fishing equipment ranged from a minimum of 220,000Mts (US$18) for a second-hand dugout canoe and 30 traps, to over 1,000,000Mts (US$83) for a large plank-constructed canoe and 40 traps. The average initial expenditure was probably around 300,000Mts for a standard canoe and 160,000Mts for 40 traps, a total of 460,000Mts (US$38). *Maremas* also have to be replaced every few of months. The average salary for a days formal work in Quirimba, for example on the coconut plantation or as an ordinary fisherman was 10,000Mts (US£0.83 - see

Table 5). Most of this small salary was needed for food and other necessities and saving was not an option for most ordinary people on Quirimba.

Weeks could pass when a fisherman could not go fishing because of the weather, because of problems with the net or the boat, or because of illness so any money saved would be used then. Unforeseen expenses included money for medicines for the fisherman himself or a member of the family, for example treatment for an elderly relative with TB might cost 40,000Mts (see Table 2). Quinine and Aspirin for malaria also had to be bought fairly frequently. Most people grew their own staple foods such as maize, sweet potatoes and cassava in their *machambas*, so for most people food was rarely a problem.

Groups of women from the district of Mecufi, south of Pemba, were reported to come to Quirimba every year and fish in the shallows of the reef flat in front of the village using large capulanas (the patterned cotton wrap worn by local women and with dozens of other uses). This method of fishing for very small fish is found throughout the region (Comores - Dahalani 1997; Tanzania – Andersson and Ngazi 1998). Some village women said that the reason they did not do this type of fishing was that it required a special large *capulana* that they couldn't afford. This type of fishing therefore requires a level of investment difficult for Quirimban women who have few opportunities for earning cash.

Gill nets were used by a few groups of people for fishing on the reef flat on the east coast of Quirimba. These nets are shorter than seine nets and a lot cheaper. Three people are needed to do gill netting so either all contributed to the cost of the net or one person bought it. The gillnets on Quirimba were all owned by ordinary families.

3. A large initial personal investment

The main group in this category were the seine net fishing boat owners. The same person usually owned the net and the boat which together could be an investment of over 6 million meticais (US$500, see Table 3). These boat owners were the entrepreneurs of Quirimba. They had the largest stone-built houses and were amongst the only people to own motorbikes and other major consumer items. Some of the boat owners also had other business concerns

Table 3: The average costs of the major items of gear for seine net and *marema* trap fishing.

Item	Cost in meticais	Cost in US$	Source
Seine net - new	5-10 million	417-833	Imported
Seine net - 2nd hand	3 million	250	Imported - bought in Pemba
Fishing boat 3-4m	2-3 million	166-250	Made on Quirimba with wood from the mainland
***Marema* trap**	4000 (need 40)	0.33 (13.20 for 40)	Bamboo panels from the mainland
Canoe - dug-out	100,000-400,000	8-33	Made on Quirimba
Canoe - timber	400,000-800,000	33-67	Made on Quirimba

apart from trading fish; some had shops in the village, others traded across the border in Tanzania.

The stories of how fishing boat owners made the money to initially buy the fishing boats varied. Some were local men who had worked their way up from being a fisherman crewing a large seine net fishing boat, to trap fishing, to buying their own large boat. A few had family money from land ownership, others had come from the mainland specifically to fish.

The seine net fishing boats were built in Quirimba village with wood imported from the continent. A three metre boat cost from 2 to 2.5 million meticais (around $200). A four metre boat cost around 3 million meticais. One of the boat owners interviewed had bought his current fishing boat for 1.5 million 4 years ago. The nets were bought on the mainland, usually in Pemba. A new net complete with floats, weights and ropes reportedly cost 10 million meticais but all the boat owners interviewed had bought their nets second hand for around 3 million meticais. They expected the nets to last for 10-15 years. Various systems of payment were used on the fishing boats. Some of the boat owners paid their crew 4000Mts per kg of fish caught and said their catch could range from a few kilos to a few hundred kilos. The pay per trip for the crew worked out at 10,000Mts per fishermen and 14,000Mts for the captain, and some small share of the catch, usually 1kg. The owners also had to pay four or so people to clean the fish. They were usually paid one kilo of fish or 4000Mts each day. (See Table 4 for salaries for the various fishing jobs on Quirimba and Table 5 for the costs and earnings in the seagrass trap and net fisheries).

Economic gain from fishing (see Table 5)

1. Net fishing

The average daily catch per boat was 75kg (see Chapter 2). If this was sold at 4000Mts per kilo it would be worth 300,000Mts (US$24). Out of this the boat owner paid an average of 8 crew 10,000Mts each, the captain 14,000Mts and 5 people 4000Mts to clean the fish. This would give a total daily expenditure of 114,000Mts, making a total profit of 186,000Mts (US$14.90) Boat owners had responsibility for maintaining boats and nets, buying new ropes and other

Table 4: The major forms of employment on Quirimba, average time worked, salaries and location of the work.

Employment	Hours worked	Days worked per month	Daily salary Meticais	Daily salary US$	Annual salary Meticais	Annual salary US$	Location
Trap fisherman	4 hours	22-24	15,000-40,000	1.25-3.33	4-10 million	333-833	Montepuez Bay
Net fisherman	5 hours	18-20	10,000	0.83	2,160,000	180	Montepuez Bay
Net fishing captain	5 hours	18-20	14,000	1.17	3,024,000	252	Montepuez Bay
Net fishing boat owner	Various	Various	111,000	9.25	23,976,000	1998	Montepuez Bay
Work in machamba (mainly subsistence)	Various - seasonal	Various – could be whole day	Food				Machambas (Kumilamba)
Worker in coconut plantation	8 hours	6 days a week	10,000	0.83	3,138,600	262	Plantation
Fish processor	1-2 hours	18-20 (same as net fishers)	4,000	0.33	864,000	72	Quiwandala
Intertidal invertebrate collector	3 hours	6-8 days around spring tides	20,000 +	1.67	1,680,000	140	Santa Maria, Saja etc
Making bread and cakes to barter for fish	Various	18-20 (same as net fishers)	Fish				Quiwandala
Trader	Various	Various	Various				Quirimba, Pemba, Tanzania

Table 5: Summary of average values for various aspects of the seagrass trap and net fisheries. The exchange rate used was US$1 to 12,000 meticais.

	Trap fishing	Net fishing
Mean daily catch per boat	7kg	75kg
Total daily catch for fleet	280kg	2250Kg
Mean value of daily catch	21,000-35,000 meticais US$1.75 - 2.91	225,000-375,000 meticais US$18.75-31.25
Initial expenditure	Boat 300,000mts, US$25 Traps 160,000mts, US$13 Total 460,000mts, US$38	None for individual Fishermen
Crew wages	-	8 crew at 10,000mts per day total 80,000mts, US$6.67
Captain wages	-	14,000mts, US$1.17
Processors' wages	-	5 processors at 4000mts/US$0.33 per day total 20,000mts/US$1.67
Total daily expenditure	3000mts*/US$0.25	114,000mts/US$9.5
Mean daily profit for boat owner	21,000-35,000 mts US$1.75 - 2.91	111,000-261,000mts US$9.25-21.75
Total daily value of catch for fleet	630000-1400000mts US$52.5-116.67	3,375,000 – 11,250,000mts US$281.25 - 947.5
Days fished per year	264	216
Total annual catch	60 tonnes	440 tonnes
Total annual value of catch	180-300 million meticais US$15000-25000	1320-2200 million meticais US$110000-183333
Total annual catch for both methods	1500-2500 million meticais US$125,000-208,333	

materials, so some money would go towards this. Ropes in particular needed replacing regularly, perhaps once a year. Around neap tides some boats catch just 25kg of fish, worth 100,000Mts. which is less than the daily expenditure calculated above. Occasionally, when things went wrong and the sail broke or the boat ran aground the crew would come back with no fish and presumably on these days everyone would go home empty-handed.

Other boat owners organised the fishing in a different way. They took a certain amount of fish every day as their share and the value of the rest was divided between the crew with the captain getting slightly more. In this case it was in the interest of the crew to catch more fish to increase their wage but there did not seem to be an inclination for fishermen on boats run this way to work harder to maximise their earnings. The boats that seemed to work the most efficiently were those with small crews of five or so (see Chapter 2). They had to work harder than larger crews to haul the nets but they often seemed more efficient at getting their boats out, catching the fish and returning to port. Many of the boats with large crews of 12 or more seemed to be primarily a social occasion that just happened to result in something to eat and some money.

2. Trap fishing

The average daily catch per fisherman for trap fishing was 7kg, an average daily earning of 28,000Mts, nearly three times the average salary as a labourer or as fishing crew. Trap fishermen fished alone and cleaned their own fish and so had no expenditure on a day to day basis. If fishermen could sell their catch fresh in the village they would get 4,000Mts whereas if they sold it all in one go to a fish trader they would only get 3000mts. per kilo (21,000mts. for an average catch) but they could organise this in advance and would be guaranteed to sell it all on the day they caught it. Trap fishermen usually retained about 1kg of their catch for their own consumption. Very few trap fishermen dried their own fish.

Socio-cultural aspects of fish use on Quirimba

Fish was highly valued as food on Quirimba. Although some species were favoured for their taste, particularly lethrinids and siganids, all edible species fetched a similar price. Fish was often used for barter. Small fish (around 10cm)

caught by net fishermen were bartered for bread rolls or peanut biscuits made by local women, which they brought out to the boats as they came into the landing site at Quiwandala at the end of the day's fishing trip. The women who made these biscuits were usually single or had husbands who were not involved in fishing. There was an inflexible exchange rate of 4 small fish (often variegated emperors or three-ribbon wrasse) for one biscuit. Fish was commonly shared between family and friends in the complex Quirimban "kinship" networks (discussed below). Fish were also commonly given as gifts or in exchange for other goods or services.

The small size of the fish eaten was very striking. The capture and consumption of small fishes that would be considered "trash fish" in many places is a common feature of some tropical artisanal fisheries (Pauly 1979, Gayanilo & Pauly 1997). As Munro (1996) states "unless a fish is actually poisonous, there is apparently no such thing as a trash fish in many impoverished developing countries". People on Quirimba utilised extremely small fish that would have been discarded elsewhere, for example 5cm long butterflyfishes, emperors and damselfishes. Fish was usually added to stews containing coconut milk, chillies and sweet potatoes. The small fish could add flavour and add nutritionally in terms of animal protein, but did not significantly increase the cooking time. Firewood was always in short supply on Quirimba and collecting wood, whether from the mangroves or from scrub-land or from around the *machambas*, was hard work done mainly by the women. Small fish could be cooked quickly and required much less fuel than large fish.

There were some unusual uses of fish and fish products. Box-fishes (Ostraciidae), not eaten in many places because of skin toxins, were well-liked in Quirimba. They were stuffed with rice and cooked directly in the fire, their tough skins protecting the flesh from burning. Other toxic fish such as scorpionfishes (Scorpaenidae), catfishes (Plotosidae) and most pufferfish and tobies (Tetraodontidae) were discarded but some large pufferfishes were retained for sale to Makua people in Pemba and Nampula. Some Makua people eat these fish and know the special methods for preparing them to avoid fatal poisoning.

Fishing traditions

Fishing communities all over the world have long traditions and complex systems of beliefs and superstitions (Ruddle 1996b), from the South Pacific (Johannes 1981) to the Isle of Man (pers. obs., Manx Heritage Foundation 1991). In southern Kenya, where the habitats and fishing methods are similar to those used on Quirimba and the coastal people have a broadly similar cultural history with strong Arab influences, strong fishing traditions still exist (McClanahan *et al.* 1997). There were few traditions associated with fishing in Quirimba but it was difficult to ascertain whether this was because there had been a complex system of beliefs which had gradually disappeared or whether there had never been such a belief system. The seine net fishermen did not seem to have any traditions or superstitions directly associated with fishing apart from a vague concept of "luck". One fisherman sometimes wore a seamoth fish (Pegasidae) round his neck as a talisman to bring luck. Seeing dolphins during fishing was considered good luck. On the other hand, fishers in some parts of Kenya still hold ritual ceremonies and have sacred sites at sea where offerings are made to spirits to improve fishing. These rituals are gradually being lost, in many instances because Islam is increasing in strength and the younger generation of Muslim fishermen see the traditional rituals as against Islam. Although there has been a lot of population movement around the Kenyan coastal area, it probably does not approach the large scale migration of people around the north of Mozambique as a consequence of the war. McClanahan *et al.* (1997) said that in Kenya rich and elaborate cultural traditions of coastal management have "decayed in recent times as Islamization of the culture has occurred". This may also be the case to some extent in Quirimba.

There were a number of traditions associated with eating fish or other marine products. When dugongs were caught, and they were fished in the area up until the last 10 or 20 years, they had to be taken to the mosque for blessing before they were eaten. Dugong meat was given to pregnant women to make their babies "beautiful". Other fish species were by tradition not eaten by pregnant women because they were said to harm the baby. (In a place where a large proportion of women lost babies at late stages of pregnancy and where infant

mortality was high it was not surprising that there were a lot of superstitions surrounding pregnancy and the health of the unborn baby.)

Although there was no formal system of rules and traditions for fisheries management, conflicts within and between user groups were rare. There were a number of potential sources of conflict – between trap fishers and net fishers using the same fishing sites, between local Quirimban fishermen and fishermen from Quissanga on the mainland side of the bay, and between Quirimban fishermen and Nampula fishermen. There were also many opportunities for theft and for "cheating". Seine nets, perhaps the most valuable possessions on Quirimba were always left anchored in the water off the fish landing site overnight and were never stolen during the study period. Traps were rarely stolen or emptied by people other than their owner. In interviews trap and net fishermen were asked if theft was a problem and about conflicts between user groups but none of those interviewed expressed any concerns. Most net fishermen tried to avoid fishing over areas containing traps or lifting nets over traps although some were reported to take the fish out of traps caught in their nets. Trap fishermen did not come into conflict over sites fished or empty the traps of other fishermen. Dynamite fishing, that has in the past been a serious problem in coral areas of Southern Tanzania just across the border (Guard & Masaiganah 1997), has not been witnessed in the Quirimba Archipelago.

In southern Kenya, McClanahan *et al.* (1997) found that where old traditions of respect for sea spirits and customs for behaviour at sea had been lost, theft from set nets and traps and of the nets and traps had increased. This implies that without the specific superstitions in place that were feared by all sectors of the community, people (in that case mainly the younger people to the anger of the elders) would behave without respect for others. It was therefore remarkable how rare conflicts were on Quirimba, where religious and superstitious beliefs seemed to be disjointed and did not form a coherent code of living and where people of a range of different backgrounds, ethnic groups and beliefs were living in the shadow of a 17 year civil war. One of the reasons for the high levels of trust and low incidence of conflict may have been the strong sense of "kinship". People had large networks of extended families and friends with whom they shared food and exchanged help and services. Many people

married more than once (some ordinary Quirimban fishermen had up to three wives, each living in a different household) and had siblings with different sets of parents, linking together disparate parts of the community. This type of complex kinship was also reported from southern Mozambique (Gengenbach 1998). Parents often do not bring up some of their own children, but entrust them to relatives who may not have children. This complex network of kinship in a community of 3000 meant that anti-social behaviour such as stealing from other peoples fishing gear would, firstly, be likely to be witnessed by a member of the community and secondly, might well affect the "kin" of the thief. Theft was remarkably rare on Quirimba and most thieves came from outside the island; for example large scale coconut theft in the plantation was almost always done from boats from the mainland.

The main sources of conflict during the study period were land disputes and land-use issues such as the problem of one person's goats grazing on another person's crop. These were taken to the district administrator to resolve. Land disputes are an acknowledged problem in post-war Mozambique (Gengenbach 1998, West 1998). All land in Mozambique belongs to the state, and officially can only be acquired on 50 year leases (Massinga and Hatton 1997). In most cases in rural areas formal leases were not issued and land ownership or the right to farm the land was an informal arrangement. During the war displaced people often took over land left by others who had moved elsewhere because of the conflict. The gradual return of refugees to their homes, "rural resettlement" has led to serious land disputes in many parts of Mozambique (Gengenbach 1998). The current administration system of Quirimba seemed to be in the process of change. Unlike Tanzania, a few hundred kilometres to the north, local elders and chiefs did not make the important decisions, and the whole system of village elders that was in place before independence does not exist anymore. This was rooted in the decision of the new FRELIMO government at independence in 1975 to abolish the system of chiefs in Mozambique (West 1998). Traditional local hierarchies of elders were replaced by the system of a Provincial Governor and a District Administrator (or Chef de Post).

The strongest tradition adhered to by virtually all Quirimbans, whether of Mwani or Makua origin, was the belief in the power of witch-doctors and witchcraft.

Most people had a little sewn up cotton packet that they wore round their neck or kept in a pocket containing a good luck charm from a witch-doctor. People with illnesses went to a witch doctor for treatment before they went to the clinic and spells were bought for a variety of reasons, from protecting property against theft to giving people energy. There were well known witch doctors in the area, such as Tanzoor on Quisiva Island, and well-known thieves who had powers of witchcraft to help them. However, none of these beliefs were related to the sea and it seems likely that many of them were brought from mainland villages and Makua traditions and superimposed over whatever belief system existed previously in the Quirimbas. It is possible that the Mwani people never had the strong belief system found in some other fishing communities. Many of the communities with the strongest belief systems are isolated island communities such as those in the Pacific (Ruddle 1996b), where communities had strong cultural and linguistic identities. The Quirimbas have been invaded, colonised and formed an important part of trade routes for Arab and Portuguese traders for over 500 years. This, together with the large scale destabilisation caused by Portuguese colonial rule until 1975 and then the 17 years of civil war that followed directly after do not make for a community with a strong sense of identity or the preservation of tradition. The current isolation of the Quirimba Archipelago is a modern phenomenon.

Total value of the fishery

Total annual catch for net fishing was estimated at 440 tonnes which would be worth 1320 million meticais US$110,000 (at the minimum price of 3000Mts per kilo), and for the trap fishery 60 tonnes, worth 180 million meticais or US$15,000. The total value of the seagrass fin fishery (not including the women's invertebrate fishery) of the Montepuez Bay was therefore estimated at 1500 million meticais or US$125,000 (1997 exchange rates) per year (see Table 5). About half of this, 750 million meticais or US$61,560, went directly back into the local economy in the form of wages to fishermen and fish processors. The area of seagrass fished by the Quirimba fleet was estimated at around 35km^2 (see Chapter 1). If the total annual value of fish caught was US$125,000, then the minimum annual value per square kilometre of seagrass was estimated at US$3570.

Approximately 400 people on Quirimba Island were employed in the seagrass fisheries. The annual individual wages for those involved in the fishery range from 864,000Mts (US$72) for fish processors, 2,160,000Mts (US$180) for ordinary fishing crew, 3,024,000Mts (US$252) to 7,392,000Mts (US$616) for trap fishermen. Boat owners could in theory earn from US$1458 to US$4698 annually. Whether they actually did this was unclear – the boat owners themselves were not clear about the kind of annual profit they made, and it is likely that a lot of the "profit" went back in to maintaining boats and gear.

A provincial and recent historical context

In 1986 a beach seine could be purchased in Cabo Delgado for the equivalent of 2731 kilos of fish. In 1994 this had risen to 66915 kilos of fish (Republic of Mozambique State Secretariat of Fisheries. 1994b.). In the present study, the 1997 price of a new seine net was given at between 5 and 10 million meticais. Using the lowest price it was possible to get for fish on Quirimba, 3000Mts, this was the equivalent of between 1667 and 3333 kilos of fish. Using the maximum price for fish, 5000Mts this was the equivalent of 1000 to 2000 kilos of fish, more akin to the 1986 relative prices than those in 1994. The price of fish has not risen much since 1994 but the prices of nets have evidently fallen as supply networks to the area have improved. In the eighties the price of fish in Cabo Delgado was kept artificially elevated, the price of fish decreased nine-fold since 1986 from US$3.37 for a kilo of fish in Pemba to just US$0.39 in 1993. (During the eighties ordinary people in Pemba did not eat local fish, but ate fish imported from around Africa – there was a notorious poisoning incident from freshwater fish – M. Carvalho pers. comm.). Fishermen in the area have very low financial incentives and little access to new gear, precluding anything more than subsistence fishing (Republic of Mozambique State Secretariat of Fisheries. 1994a) and also face the storage and transportation problems mentioned above.

National per capita consumption of fish was estimated at 5.1kgs per year in 1994 (Republic of Mozambique State Secretariat of Fisheries. 1994b). It is likely that per capita consumption of fish on Quirimba greatly exceeded this national value. Fishermen and their families shared about 1kg of fish per fishing day. Each person ate approximately 100g per day on fishing days (16 days per

month), giving 1.6kg per month and a minimum of 19.2kg of fish per year. In addition to this dried fish was also often eaten on the non-fishing days.

In 1989 Cabo Delgado had 4539 fishermen accounting for 0.7% of the working population, the same proportion of fishermen in the population as was seen on a national scale. Quirimba Island had between approximately 400 fishermen (Chapter 2) in a population of 3000, so fishermen there accounted for at least 10% of the population and a much higher percentage of the working population. Between 1989 and 1994 the number of fishermen nationally increased from 52,000 to 80,000 and a similar increase would be expected in Cabo Delgado. This increase has mainly been attributed to the displacement of the population towards the coast because of the civil war (Republic of Mozambique State Secretariat of Fisheries. 1994b, Massinga and Hatton 1994). With this migration there has been a disproportionate increase in the numbers of people living off subsistence fishing, often the only source of food and employment to displaced people. The pressure on artisanal coastal fisheries has been particularly intense because although there was a surge of people to the coast in the 1980s and early 1990s, there was no accompanying development of the local fishing industry or related diversification of activities. This situation is described as having led to the local population and the refugees collectively "mining rather than husbanding" the littoral resources (Hatton and Massinga 1994).

Employment opportunities and salaries

Workers on the coconut plantation or in other daily employment worked 6 days a week all year, a total of 312 days per year. Their potential annual salary would be just over 3 million meticais. or US$260, significantly higher than that of the net fishermen (see Table 5). However, fishing crew had up to 10 days off per month to do other work such as on their *machambas* and some were able to supplement their income from net fishing with other types of fishing, for example spear-fishing. Jobs in the coconut plantation were limited, but many people claimed to prefer fishing to plantation work. Fishing may have been chosen despite the less regular income for social reasons. On the fishing boats there was an atmosphere of co-operation and everyone regardless of age or experience appeared to be treated equally (with the exception perhaps of the young boys who start off as apprentices and have to do some of the unpleasant

jobs). Although the hauling of the fishing nets was extremely hard work, much of the time spent out fishing was spent sailing between fishing sites when fishermen talk, sing and seemed to enjoy themselves. The coconut plantation, the only source of formal daily employment on the island offered regular work that did not depend on the weather or the state of a leaky boat. It also offered extra benefits such as the opportunity to buy some foodstuffs cheaper and some free medical treatment. However, the plantation was run by white farmers of European origin and there was some historical resentment of working for white plantation owners, with the memory of ruthless Portuguese plantation and sisal factory owners still fairly recent. The parents of some of the young fishermen were employed by the Portuguese in this way before Independence.

Fisheries elsewhere in the region, in Tanzania, the Comores and Seychelles for example, have developed as local economies have expanded. Fishermen have left traditional fishing methods behind to use outboard engines and more sophisticated gears. The fishermen of Quirimba did not use outboard engines on their boats. The fishing boat owners on Quirimba appeared to have been earning enough to potentially be able to buy boat engines in the future, although it wasn't something any of them talked about doing. The main obstacle to this may not have been so much the cost (although this is likely to be extremely high – import tax of 300% is commonly charged on certain imports and the cost of transporting a boat engine from South Africa to the north of Mozambique may also be enormous) but the availability. If no-one was importing engines to Pemba, which was the case during the study period, no-one will be able to buy them. Much larger sums of money than the local boat owners have access to would be needed for actual importing numbers of engines from South Africa.

Another reason for the lack of engines may have been that even with engines it would not necessarily be efficient to fish on the outer reefs instead of in the seagrass beds. Weather conditions in the area were very changeable and it was often not possible to anchor the project's research boat off the outer reef of Quirimba to do survey dives. It was regularly not possible to get the boat out onto the east coast of the island at all because of strong winds and rough seas. Traditional sailing dhows were almost certainly better suited to fishing in the

shallow seagrass beds than boats with outboard engines. There was thus no incentive to "develop" fishing techniques.

Social structure of the fishing fleet

The crews of seine net fishing boats were a mixture of ages, from young boys of 12 or less to older men in their 50s and 60s. However, the majority of fishermen were young, aged between 15 and 25. Many young men came to Quirimba as refugees from the fighting in inland villages during the war. Many came as children and fishing had been their only job, even though it was not an option that was open to their parents in the inland villages they came from. In some more developed fishing communities, for example in the Seychelles (Wakeford *et al.*, 1998) or in parts of the Caribbean (J. Hawkins, pers. comm.) most of the fishermen are from older generations whereas the young men try to avoid fishing and try to get better salaries for modern, cleaner jobs. In Quirimba there was clearly no lucrative alternative to fishing so it remained the most common job for young men. Some of the Quirimban fishermen left fishing to work as traders across the border from Mtwara in Tanzania to Moçimboa on the Mozambican border, or as crew on boats that did this run, but this was often temporary or seasonal work.

Older men were more likely to be trap fishermen. Trap fishing was a skilled method of fishing requiring an apprenticeship. It was difficult to learn and required a large investment in terms of learning the skills involved in making and maintaining traps and setting them. If someone bought, assembled and set some traps without guidance from an expert they could quite literally catch nothing. In the first year of study there were signs that trap fishing was in decline. The fishery was dominated by elderly men and very few young men seemed to be going into the trap fishery. However in 1997 marema traps became available locally. Instead of fishermen having to make a special journey to the mainland to buy traps, they could buy them in Quirimba village. There was a sudden increase in people buying traps, and even people who did not have a boat to set them from started making traps.

The division of fisheries work between the sexes

Women never worked in the seagrass seine net or trap fisheries as fishers but provided the main labour force in the processing of the fish from the net fishery. The idea of a woman involved in either of these two fisheries was completely unacceptable to men and women interviewed. Men cited the weakness of women as a reason, although Quirimban women regularly carried 30 litre water barrels from one end of the island to the other, felled mangroves, carried the wood long distances and did most of the heavy agriculture work. Men also cited women's inability to swim. There was a traditional reluctance to teach girls to swim even though they were likely to spend a lot of time on boats, and I was told by a number of different people that women often drowned in boat accidents. The women interviewed did not have any aspirations to fish in the trap or net fishery but when pressed did suggest that economic factors made it impossible to consider trap fishing. In Tanzania a clear distinction was made between women's territory and men's for marine resource collection (Mtwara - M. Guard pers. comm.; Bagamoyo – Semesi *et al.* 1998). Women fished in water up to waist deep water. In deeper water, where a boat would be needed, men took over. In some Tanzanian coastal communities these designated areas led to conflicts of interest in the community and to members of the same family working against each other over these rights. In Kwale District, Kenya, there was a similarly inflexible division of labour with men fishing and felling mangroves and women collecting invertebrates, growing food and collecting firewood. Men there maintained that this was because women weren't strong enough to do the "men's" work, whereas women maintained that the reason they didn't do this work was financial (Juma 1998).

There were a few options for catching fin fish open to women. They could do the *capulana* fishing (mentioned previously), they could catch fish that had been trapped in intertidal pools as part of intertidal gleaning and they could empty their family's *luwando* or fence trap. Women collected three main groups of invertebrates in the intertidal seagrass beds of the Montepuez Bay:

1. *Mbari* (*Pinctada nigra*)

Mbari were collected at low spring tides from the stalks of the large seagrass species *Enhalus acoroides*. They were sold for fresh consumption and also dried for sale on the mainland.

2. *Macaza* (*Pinna muricata*)

Macaza were also collected at low spring tides from intertidal areas of sand and the seagrass *Thalassia hemprichii*. The majority of the animal was discarded and only the small adductor muscle was retained to eat.

3. *Ombe* (*Barbatia fusca*)

Ark shells were collected on the intertidal flats and in *Thalassia hemprichii* at low tide, the women skilfully detecting their presence beneath the surface of the sand using their toes. Ark shells were also either consumed fresh locally or dried and sold in Pemba.

Some other invertebrates were collected by women and men. *Makome* (*Chicoreus ramosus* – murex shells) were one of the few invertebrate species routinely collected by men. They were collected incidentally by trap and net fishers in the seagrass beds. Abandoned *marema* traps appeared to provide a good aggregation device for murex shells. Some fishermen also specialised in *makome* fishing, using canoes and paddling out to deeper seagrass sites to dive for the shells. Shells caught in deeper water by full time murex fishermen were much bigger than those caught incidentally by other fishermen. Murex shells were used in a variety of ways. The animal was cooked in the shell for immediate consumption, the opercula were sold by the kilo to Tanzania and the shells were burnt on large pyres with other shells to make lime for painting houses. Despite the large size of many of these shells there was no evidence of their use in the curio trade.

Kome nlume (*Pleuroploca trapezium* - tulip shells) were collected almost entirely incidentally in other fisheries. They were sometimes eaten but their main value was for their opercula, which were also sold by the kilo to Tanzania. A remarkably wide variety of other molluscs were caught by children. These were mainly small molluscs that are found higher than the level of low spring tides and even those found near the top of the beach and in small areas of

mangrove. The value of these shells appeared to be solely to supplement the diet of the family and none were sold. Women who are not normally involved in invertebrate collection also collect these species on a casual subsistence basis.

Many of the intertidal invertebrates such as *mbari* (oysters), *macaza* (pen shells) and *ombe* (ark shells) were mainly found at the low tide level and so were only accessible at low spring tides, just 3 or 4 days per fortnight. This meant that women who collected these molluscs had a less regular income than net fishermen but their catches on these few days were often more valuable than a days net fishing. Women could also fit a range of activities around the tidal cycle. Some women collected octopus and other organisms associated with the exposed reef flat on the east coast of Quirimba around neap tides, then moved round to the lower littoral species around tides closer to springs. During completely unsuitable tides (high neaps) women worked on their *machambas*. Some women also collected the higher littoral molluscs during these tides, such as *Strombus sp.*.

Alternative sources of income

On Quirimba the main alternative source of employment was subsistence agriculture. Most people on the island were involved to some extent in agriculture, tending a *chamba* to provide their family with papaya, sweet potato, cassava and beans. Most agricultural activity took place in the wet season (November to April) but many people were involved all year round. The food available in the local market very limited and imported shop-bought food was prohibitively expensive, so most people relied on food grown in their *machambas* for the bulk of their food, with fish or shellfish providing the animal protein. The *machambas* were constantly being expanded into the few remaining areas of forest and scrub by slash and burn clearing methods. On Inhaca Island in southern Mozambique this method has produced land that is high in nutrients for the first year of cultivation but that soon becomes poor in nutrients and becomes impossible to cultivate after 15 years (Serra King 1995). Erosion is also a problem in land cleared by slash and burn, and this may be something that will impact on the coastal habitats. The cash economy was very limited so there were few shops and it was virtually impossible to buy a meal or cooked food of any kind in the village, so there were few opportunities in service

jobs. This situation may be typical of a largely cashless economy for poor rural Mozambicans. In Tanzania many rural areas are much more developed and there are more opportunities for jobs with regular salaries and cash (Andersson and Ngazi 1998). Street food is common and provides an extra employment opportunity. There was no tourist industry mainly because of the inaccessibility of the island and the lack of basic infrastructure.

The gender roles in the fishery at Quirimba were fairly typical of those found in tropical artisanal fisheries around the world. Women throughout East Africa, South East Asia and the South Pacific glean intertidal flats for invertebrates and the fishery for fish is dominated by men (find more general E. Africa reference, Juma 1998 – Kenya, Bailey and Pomeroy 1996 – South East Asia, Matthews and Oiterong 1995 - Palau). Although the biology of the women's invertebrate fishery was not included in the present study and can be found in Barnes *et al.* (1998), the socio-economics were studied to some extent. Women collected the three main species of mollusc on the intertidal (mainly *Thalassia hemprichii*) and upper subtidal seagrass beds (mainly *Enhalus acoroides*).

The community on Quirimba utilised a wide variety of resources. Although seine net fishing in the seagrass beds was the main single employer, most households used a wide range of sources of subsistence food and additional income, typically a mixture of men's income from fishing by net or trap, food from the *machambas* grown predominantly by women, invertebrates gleaned from the seagrass intertidal by women and some additional invertebrates collected by children. Consequently, although many people were involved in the seagrass-based fish and invertebrate fishery very few people, except maybe some boat owners, were entirely reliant on the seagrass fishery. As Bailey and Pomeroy (1996) found in SE Asia, households and therefore communities reliant on a wide range of resources that changed with seasons and with changing weather conditions were much more adapted to cope with long term changes in the availability of resources. The use of a wide variety of resources by people in coastal communities was also found in Tanzania. On Mafia and Zanzibar (Unguja) islands only 11% of people interviewed relied on a single source of income, with most people combining their main source of income, some sort of fishing, with small-scale agriculture (Andersson and Ngazi 1998).

On Quirimba most people did combine some sort of marine resource use, whether fishing or invertebrate collection with subsistence agriculture. However, within the invertebrate fishery a change was taking place. The molluscs: *Pinctada nigra*, *Pinna muricata* and *Barbatia fusca* were originally collected by women as a subsistence commodity that was eaten locally. In the community workshops the women who collected them reported that in the last few years the prices they could get for them in Pemba had risen sharply as demand for dried seafood increased. It was therefore much better to sell them on the mainland rather than eat them themselves or sell them on Quirimba. Others in the community associated this change in use of invertebrates with a decline in their numbers and said that it was virtually impossible for an ordinary Quirimban person to afford to buy these preferred species of shellfish. The shellfish produced by the women were therefore the main commercial product of ordinary people in Quirimba, whereas the fish caught by the trap and net fishermen, although also forming an important commodity for the boat owners and for dried fish traders, was the main source of subsistence food for ordinary households on Quirimba. In Tanzanian coastal communities a similar pattern has been observed with an increase between 1993 and 1998 of the local consumption of fish and vegetables and the complete disappearance of intertidal invertebrates in local diets. There too prices have increased because of combination of increased demand because of growing populations and the developing tourism industry and increased scarcity as marine resources are overfished (Andersson and Ngazi 1998). The situation in Tanzania is perhaps ten or more years ahead of what was recorded in Quirimba in terms of economic development. Cabo Delgado is one of the least economically developed provinces in Mozambique (Hatton & Massinga 1994). In Inhaca Island, southern Mozambique the invertebrates collected by the women are eaten by the family and it is the fish that is sold for cash (Wynter 1990) perhaps reflecting the close proximity of a tourist market for fish and the national capital.

Integrated coastal zone management in northern Mozambique.

A comprehensive review of integrated coastal zone management can be found in the proceedings of a national workshop on integrated coastal zone management in Mozambique (Lundin and Lindén eds. 1997). The only example

of integrated coastal zone management in Cabo Delgado province is that of the Mecufi Coastal Zone Management Project (Massinga 1997).

Along with the other East African and Western Indian Ocean Island States who signed the "Arusha Resolution on Integrated Coastal Zone Management in Eastern Africa (including Island States)", Mozambique has pledged to develop and implement integrated coastal zone management (ICZM) programmes. Within the main government department involved in coastal zone management, MICOA (Ministry for the Co-ordination of Environmental Affairs) there is now a Coastal Zone Unit with specific responsibility for coastal management issues. Active coastal zone management has largely been restricted to some large marine protected area projects in the southern sector of the country, for example the Inhaca Island marine park, the Bazaruto Archipelago marine protected area and the Xai-Xai Integrated Coastal Area Management project. However, projects are gradually being developed throughout the country, for example the Mecufi Coastal Zone Management Project just south of Pemba or the Island Management project on Isla de Moçambique which are currently in progress. City Coastal Zone Management Projects are also planned for the city of Nacala in Nampula Province and the city of Beira in Sofala province.

Having only emerged from the civil war in 1992, Mozambique has the difficult task of reconciling coastal zone management programmes with the need for rapid development of large areas left by the war without even the most basic infrastructure and facilities. It also has to address the problem of a population which during the civil war gravitated towards coastal areas. Many refugees have remained and are now settled in their coastal lifestyles. It is estimated that more than 40% of the Mozambican population live in coastal districts (MICOA 1997). The pressures on coastal resources are manifold: increased populations through migrations, through the natural increase in population that is being experienced throughout the region and also increased exploitation of resources by outside user groups such as foreign fishing fleets and recreational users (Hatton 1995).

Itinerant fishermen

Small numbers of itinerant fishermen from local mainland villages have fished seasonally in the Quirimbas, but in the five years preceding the study increasing numbers of fishermen from Nampula started coming to Quirimba and other islands in the Archipelago. They inhabited the islands in groups of tens to hundreds of fishermen on a seasonal basis, usually staying between three and six months during the dry season. These fishermen said that they have been forced to fish in the Quirimbas by the depletion of their own nearshore fish stocks. Nampula has indeed had a much more intensive artisanal fishery sector than Cabo Delgado. In 1994 there were reportedly 180 beach seines in the Province of Cabo Delgado and 10,882 in Nampula. The coast of Nampula is about 50% longer than that of Cabo Delgado but it had a seine netting intensity 600% greater (Republic of Mozambique State Secretariat of Fisheries. 1994b). Fishermen working for companies in Nampula fished with an intensity and a commercial intent that was very different from the Quirimbans' subsistence approach. Nampula fishermen returned to their home towns with boats full of the dried fish and invertebrates they had collected in the Quirimbas, part of which they kept for their families over the wet season and part they sold commercially in Nampula. Fishermen from Nacala (provincial capital of Nampula) were recognised as a major component of the fishing industry in the Macomia district, further north from Quirimba (in Ibo district) (Wilson *et al.* 1996).

Up to the end of 1997 no active regulation of fishing activity in the Quirimbas was in place. Far from trying to control the systematic depletion of their marine resources themselves, Quirimban fishermen were welcoming the invasions of Nampula fishermen despite the gradually emerging problems of wells running dry, traps being caught in the nets of the visiting fishermen and other small but significant signs of potential impending conflict. Possible reasons for the Quirimbas welcoming behaviour include a desire to maintain contact with people from a more developed part of Mozambique. One local fishermen said he enjoyed the company of the Nampula fishermen because they were more educated in Islam then most local people and he found them interesting. The Quirimban fishing community also seemed to be a very open, welcoming

community generally (the way they welcomed this study is a good example), maybe an extension of the "kinship" idea addressed previously.

Highly mobile fishing fleets are not unusual in the East African region and have led to conflicts elsewhere. For instance, in southern Kenya, itinerant fishermen from Pemba Island in Tanzania, having reputedly depleted their own fish stocks, fished in traditionally managed reef areas against local management regulations (McClanahan *et al.* 1997). In Tanzania, iceboats from Dar es Salaam fish right the way down the coast of Tanzania, often using dynamite and other damaging methods.

One of the problems with this situation of over-exploitation by itinerant fishers in the Quirimbas is that, for the purpose of future management or legislation, it will be very difficult to say who is a Quirimban resident and to whom the marine resources of the Quirimbas actually belong. During the war people were forced to move around a lot to escape the intense fighting in rural areas. Some refugees stayed where they fled to, others have moved back to their home villages. Many people have also continued to move, whether between different opportunities to work or between partners or family members displaced throughout the area. There is also a lot of movement between towns and rural areas. Much trading is done by boat, so as well as the movement of people between the islands and mainland towns and villages there is an additional group of people who are continuously moving up and down the coast between ports from Nampula to Mtwara in southern Tanzania. The Mwani people of the coast are historically fishers and traders and the trading is still an important part of coastal culture.

It seemed to be difficult for people on the islands to think of the surrounding marine resources as theirs. The majority had moved around so much in their lifetime that the idea of having to move on again because of resource depletion did not seem as serious as it perhaps may have seemed to a more settled community. One fairly typical fisherman interviewed on Quirimba Island was just 24 years old but had already moved numerous times and had changed his fishing method on each occasion. He had moved from freshwater fishing as a boy in an inland village, to line fishing from a coastal village, octopus fishing on

Quisiva, through a variety of other locations and fishing methods to trap fishing on Quirimba. He had family members on four of the other islands and in numerous villages in the mainland. To him the idea of having to leave Quirimba because the "fish had run out" was not distressing at all. The threat of fish or invertebrates running out was not normally considered, and one interviewee said "There will be fishermen at Quiwandala [the main fish landing site] until the end of the world".

Threats to sustainable resource use

There were probably three main threats to sustainable resource use in the area:

1. Population growth:

Coastal populations throughout Mozambique are on the increase. In the past 10 years the population of the Quirimbas has been increased by a higher birth rate and by refugees. Quirimba Island had a population of nearly 3000 but no provision for waste management. A growing population will inevitably put increasing pressure on the marine resources. The need for firewood from mangrove areas and for fish to provide protein in local diets will increase. The pressure to exploit resources for sale outside the community to bring in much-needed cash for medicines and other manufactured goods will increase and these communities may already be exceeding sustainable levels of exploitation.

2. **Influx of visiting itinerant fishermen** from outside the local area: this was a recent phenomenon and had only really become a major impact on the islands since the beginning of the 1990s (Gessner pers. comm.). It is likely however that the numbers of itinerant fishermen and the intensity with which they fish will increase as the pressures on fishery and other resources in their home villages and towns increases and more people seek the reputed wealth of resources in the Quirimbas. The commercial fishing sector is also likely to grow to feed the expanding tourist market.

3. **The difficulties of controlling and managing resource use and development**: The Quirimba Archipelago is such a remote area and has been neglected for a long time in terms of infrastructure, development and effective law enforcement. There was a low official authoritative presence in the area and no officials in the capacity of marine resource protection and management.

Fishing gear regulations were not enforced and most people were not even aware of their existence. The local administration system did seem to be improving, but even local administrators with the best intentions for the protection of resources and the implementation of legislation are unlikely to have the time or resources to do very much about it on their own.

Because of the lack of official intervention there was great potential for unscrupulous outsiders exploiting the marine resources of the islands to the detriment of the needs of the local people (Massinga and Hatton 1997). The sea cucumber and shark fin fisheries run in the Archipelago by large companies for export to the Far East are a good example of this. Middlemen exporting these commodities are likely to have made a lot of money but very little was paid to the local people involved. In both cases the methods of extraction were so intensive that the potential for local people to exploit these resources sustainably in the future may already have been lost. Local fishermen reported that sites where they once skin-dived for abundant sea cucumbers now not have any at all. Sharks were also a rare sight now throughout the Archipelago.

Many foreign business people are interested in exploiting some resource or other that they have heard is abundant in the Quirimbas, from crayfish to the opportunities for tourism. Their attitude seems to be that the resources of the Quirimba Archipelago are there for the taking and it is unlikely that anyone will interfere actively. It is important that the rights of the Quirimban residents to their resources are established. Once they are assured, people of the Quirimbas can begin to take responsibility for the protection or guardianship of those resources before the whole lot is sold to a South African businessman as a theme park or dried and sent to the Far East as an aphrodisiac.

4. Indirect threats to the marine ecosystems

An important new growth industry in the north of Mozambique was forestry and with two major rivers entering the sea in the vicinity of the Archipelago the potential for the indirect impacts of siltation of reefs, seagrass beds and mangroves was great. As with all other development in the remote north of the country, logging of coastal forests was difficult to monitor and control and it is likely that illegal logging was a serious problem in the area. Large areas of old

forest were logged and this was likely to lead to increased erosion leading to silt being washed down river and into the sea around the Archipelago. Slash and burn agriculture is widespread on the mainland and this will also lead to increases in soil erosion and potential siltation problems. Coral reefs are particularly susceptible to the effects of heavy siltation but seagrasses too are unable to tolerate high levels of sedimentation with low light levels (Bach *et al.* 1998).

Management implications and problems

The three major threats identified above do not feature strongly in the concerns expressed by the residents of the Archipelago. The majority of the threats have yet to manifest themselves in the form of dramatic decreases in fish or invertebrate catches. The fishermen did not complain about the outside fishermen using their fishing sites but did complain about the high prices of fishing gear. The main concern of women was that with the growing demand for their dried shellfish products in Pemba and other mainland towns, the favoured species of shellfish were becoming an unaffordable luxury. The majority of people interviewed who were resident permanently in the islands seemed satisfied with the present situation. They had access to agricultural land to grow basic foods such as sweet potatoes, cassava and papayas and they supplemented this diet with fish and shellfish.

On a day to day basis people throughout the Quirimbas suffered through lack of basic health care. Paying for medicines was often difficult in a virtually cashless economy. Minor injuries and illnesses often went untreated and led to more serious conditions and the long term loss of income. For example a fishermen on Quirimba with a small infected sore did not receive treatment, the injury became more serious and he was unable to fish for a period of months, inflicting hardship on himself and his family. Malaria and tuberculosis are both common potentially life-threatening illnesses, and both can be controlled using medicines that are cheap by western standards, but even the most basic treatments can be prohibitively expensive. There will be an increasing pressure on the people of the Quirimbas to find ways of earning cash so that they can deal with these emergencies and also so that they have the freedom to buy the consumer goods that are becoming available.

There are 4 basic needs to begin to address the potential problems in the Quirimbas:

1. Education

The general level of education is very low, particularly for women. Boys generally receive a few years of education and learn to read, write and speak Portuguese. Many girls are educated for less than one year and remain illiterate. It is important that all children are educated to a standard where they are literate and are able to access educational materials and the media. Children should either be given a firm grounding in Portuguese (whilst it is ensured that local languages and cultures are not suppressed), or educational materials, radio programmes and newspapers should be produced in local languages, particularly Kimwani which is the main island language and is marginalised at present. It would of course be ideal to give children both of these opportunities. If people were given the opportunity to reach a higher level of education the ecological and economic arguments for them to conserve their own resources may be more easily communicated. A higher level of education may also offer people the opportunity to find employment other than fishing and invertebrate collection, and would make people more employable in service industries that will accompany the development of tourism. Literate, Portuguese speaking Quirimban residents could then by employed in the inevitable tourist developments, rather than imported labour from the cities as has happened elsewhere.

2. Legislation

The ever-increasing numbers of itinerant fishermen in the archipelago needs to be regulated in some way. On some of the smaller islands in the Archipelago every available space is covered with their makeshift shelters. All are there both to catch fish to sustain their family over the wet season and also to make a profit selling their fish inland. Without some sort of limits or regulation this component of the fishery could lead to the decline of the fishery. This problem may be one that has to be addressed at its source, in the majority of cases in Nampula, and is therefore in essence a political problem requiring political will

to solve. Social or environmental problems that have forced these fishermen to look outside their province for additional income on such a huge scale need to be addressed within the province. The use of unacceptably small mesh sizes, in some cases even finer material such as sacking, and other fishing gear infringements also need to be addressed. Active fisheries monitoring in the islands is definitely required.

3. Research and Monitoring

More research is needed into the sustainability of the resource use methods currently in use and into potential alternative use of resources. A great positive step would be the establishment of a marine research centre on one of the larger islands. A large GEF (World Bank Global Environmental Facility) loan has been allocated to the northern Mozambican coastal area and there are currently plans for a marine station at Pemba to the south of the Archipelago or in Moçimboa da Praia to the north (S. Bandeira pers. comm.). This would give scientists who are based in Maputo a good base from which to conduct research and perhaps most importantly to monitor changes and developments in the area and their impact on the marine ecosystems. At present there is no scientific monitoring. For example, the inaccessibility of the area and lack of marine scientists have meant that the status of the Quirimbas coral reefs during 1998's catastrophic coral bleaching events remains unknown. The establishment of a marine research centre would also play an important role in the education programme. Such a centre could serve as a base for training environmental educators and provide educational facilities for schools and community groups, and an opportunity for local people to actively participate in research and decision-making.

4. Implementation

To implement any gear regulations it would be necessary to provide financial and practical help to fishermen to help them purchase more favourable gear types. The education programme must instil in the island residents the idea of the marine resources of the Archipelago as theirs to conserve and use sustainably now so that they will continue to provide food and employment to their children and grandchildren. In this way, enforcement of legislation could come in part from within the community. Only in the role of guardians of their

own future resource use will the people of Quirimba be motivated to participate in management. The training of local people as environmental educators to work in schools and with fishers on a long term basis would be one way of developing environmental awareness in the area and would also overcome the language problem mentioned earlier. An integrated programme of education, research in close co-operation with local people, legislation to protect vulnerable resources and to prevent destructive practices, and a long term programme of implementation and monitoring is needed.

How would possible changes in fishing patterns affect the economy?

One potential management option would be to move away from seine netting as the main fishing method and increase trap-fishing. Each seine fishing boat covers a large are of *Enhalus acoroides* on each trip and the small trap fishing areas required by individual trap fishermen would be much smaller than the available area. How would an increase in trap fishing and a decrease in net fishing affect the people involved? From an economic point of view everyone employed in the seine net fishery, with the exception of the fishing boat owners, would have a higher income if they were employed as trap fishermen (after the initial expenditure on boats and traps). Net fishermen could potentially earn double their salary as trap fishermen. They would also catch less fish per person so if the same number of men were involved in the fishery, the total fishing intensity would drop (trap fishermen catch an average of 6.7kg per trip whereas net fishermen catch an average of 9.4kg per person per trip – even taking into account the extra days fished by trap fishermen, less fish would be caught) so putting less pressure on resources. There would however be some problems with this change in fishing strategy. There would be the initial problem of fishermen being able to raise the capital to buy a canoe and traps. Trap fishermen also had an outlay of about 160,000Mts every few months, for replacing their traps. This worked out as an expense of approximately 3350Mts per fishing day. If fishermen moved from net fishing to trap fishing this would restrict the business of the seine net boat owners. As the net fishing boat owners were the only businessmen on the island, if they were to lose their livelihood it could have a negative effect on the overall development of the area. Boat owners invested money from fishing in other local businesses such as shops and market stalls. These provided employment for members of the

owners' families and other local people, and provided a service. Each boat owner provided a reliable income for anything from five to twelve fishermen and also part time income for the women and children who cleaned fish.

Conclusions

1. Fishing was the single most important source of food and employment on Quirimba Island, along with subsistence agriculture and the women's invertebrate fishery, but the majority of people and households relied on a combination of marine resource use and agriculture.

2. There was a hierarchy of earnings in the seagrass fishery in Quirimba:

   Boat owners>trap fishermen>boat captains>boat crew.

3. Net fishing was the biggest single source of employment on the island and yielded the lowest wages of jobs for young men. Net fishing may have been preferred to better paid trap fishing or plantation work because it was sociable, flexible and seemed to be enjoyable.

4. Small fish may have been preferred for social and economic reasons. They could be used easily for barter and were easy to cook, dry and sell.

5. There were remarkably few conflicts between the users of marine resources.

6. Seagrass beds were the main habitat to be exploited on Quirimba and therefore the most valuable habitat to the community.

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explaining the workings of the Quirimba fisheries and introduced me to many other fishermen, including reef flat gill netters. Saidi Ndiki, an older gill net fishermen was interviewed on a number of occasions about this fishery. Capitains Ibrahimo, Manueli and Jabira from the seine net fishery provided a great deal of useful information. Oscari, Zaidu and Momadi from Santa Maria were key informants on the fisheries. For general information on the economics of life on Quirimba Awaje Shale and her family were very helpful. The workshop with the invertebrate fishers was organised with Fatima Mussa and other women from OMM in the village.

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FINAL DISCUSSION

A brief summary of the work presented in this thesis

In Chapter 1 I described the seagrass beds of the Montepuez Bay and how they corresponded with the major fishing grounds used. The seagrass beds were highly mixed but overall the bay was dominated by the largest species of seagrass *Enhalus acoroides*. Fishing sites with high seagrass biomass were found to give high fish catch per unit effort. This suggested that the seagrass habitat and its composition was an important factor in the high fisheries productivity of the area.

In Chapter 2 the fishing methods and catches were described. The two main fishing methods were seine net fishing which is potentially damaging to the seagrass habitat and trap fishing which does not appear to directly damage the habitat. Fishing patterns were strongly associated with tides and fishing only took place during daylight, so there were a number of days every tidal-cycle when no fishing took place. Both fishing methods focused on *Enhalus acoroides*. Fishing was intense within the main fishing grounds with trap fishers and seine net fishers in close proximity.

In Chapter 3 the large number of species encountered in the fishery were described and their ecological roles considered. The number of species was unprecedented for a seagrass fishery. Many of the species were herbivores and apparently fed on seagrasses or their associated epiphytes. Many others were juveniles of species associated with coral reefs. The diversity of life-histories and forms within the catch was remarkable. This emphasised the value of the seagrass beds as sources of high biological diversity but also suggested that some of the less common species may be at risk as their the fishery depletes their populations.

In Chapter 4 I looked at the biology of five key species in the fishery. This emphasised again the variety of life-histories in the target species and the management difficulties in trying to sustain the fishery and conserve species and populations of the broad spectrum of fish.

In Chapter 5 the trap fishing experiments showed significant differences between the fish species caught in *Enhalus acoroides* and in the other large-leafed species of seagrass. Some species of fish appeared to be associated with the less common species of seagrass, suggesting that to maintain fish species diversity it is important to maintain seagrass species diversity. The experiments also showed that the trap spacing regimes used by the fishermen we indeed the most efficient in terms of maximising catches, emphasising the extent and importance of local knowledge.

Chapter 6 showed the great contribution that seagrass-associated resources made to the economy of Quirimba and how the sustainable use of the seagrass fishery resource is imperative for the people of Quirimba. I also showed that currently the fishery is unmanaged and fishers do not anticipate problems with the fishery, although pressure from itinerant fishers is increasing at an alarming rate.

The Importance of seagrass fisheries

Although the importance of seagrass fisheries is not widely acknowledged, those who work at a local level with fishers in small less developed coastal communities are well aware of how important seagrass fisheries are under those circumstances. In the Egyptian Red Sea, in Kenya, Tanzania and in the Comores small-scale seagrass fisheries are an important part of local economies (N. Galal pers. comm., J. Uku pers. comm., pers. obs., Y. Dahalani pers. comm.). Seagrass beds in the Arabian Gulf have been acknowledged as one of the most important habitats economically and more than 500 species of animals were identified associated with them (Basson *et al.* 1977). Seagrasses are a very important habitat for fisheries in southern Mozambique too. On Inhaca Island net fishing and intertidal gleaning in the seagrass provide the most significant source of protein on the island and in Maputo Bay, seagrasses are under threat from intense invertebrate harvesting techniques (Bandeira 1995). However, the problem is with public perceptions of the importance of seagrass beds and most crucially the perception of office-based coastal managers and politicians. If seagrasses continues to be seen as a secondary habitat to coral reefs then they will not receive the conservation management they require and will be lost at increasing rates. Shallow seagrass

flats are particularly vulnerable to land-infilling and dredging to change the shape of the coastline, particularly for airports and other coastal developments. A seagrass bed is often seen as an easy sacrifice for the sake of a valuable coastal development project. A World Conservation Monitoring Centre (WCMC) project is planned to produce a report on the world status of seagrasses (E. Green, pers. comm.). This kind of document may be one way to highlight the threats to seagrasses and their ecological and economic importance in a medium that will reach managers and decision-makers. It is important that the health of seagrass beds is linked in the minds of decision-makers with economically important fisheries. In areas of coastal development in the Red Sea the perturbed seagrass communities are dominated by early coloniser species such as Halophila spp (Price *et al.* 1988). Changes in seagrass species like this could have a very detrimental effect on fish communities. Halophila are tiny, delicate, cress-like species which offer little cover or food to fish communities.

This study has shown that seagrass beds have a diverse and distinctive fish fauna, with 252 species in more than 50 families. The invertebrate and algal diversity were beyond the scope of this study, but were also high, thus contributing to a very diverse system that should be valued for its biodiversity alone. In addition, this study found the importance of seagrass beds in the juvenile life stages of a number of species of emperor, rabbitfish and parrotfish which are of great commercial importance elsewhere in East Africa, and are becoming increasingly important in the Quirimbas as fishing intensifies.

Marine protected areas for management

In Chapters 3 and 4 marine protected areas were suggested as one of the best possible management options for the multi-gear, multi-species seagrass fishery, single-species management techniques rendered useless by the variety within the fished community. From a conservation point of view marine protected areas could ensure that rarer species that are vulnerable to fishing have refuges, so that local population extinction is avoided. Marine protected areas could attract tourists and maintain habitats in good condition for them to enjoy, bringing money into the area.

But how could marine protected areas directly benefit the people as well as the fish of Quirimba?

There is increasing evidence that marine protected areas can not only make fisheries sustainable and prevent the decline of heavily exploited fisheries, but that they can also enhance stocks beyond previous expectations (Roberts 1995). Some examples of successful MPAs in Africa include Chumbe Island Coral Park in Zanzibar (McClanahan *et al.* 1999) the Kisite Marine National Park, in Kenya (Watson *et al.* 1997, McClanahan *et al.* 1999). In the De Hoop Marine Reserve in South Africa the CPUE of 6 species recovered 10 years after the reserve was established (Bennett and Attwood 1991) and in the Tsitsikamma National Park in South Africa fish numbers and population structure recovered within the protected area (Buxton and Smale 1989). Marine protected areas have repeatedly been suggested as particularly suited to the scenario of highly diverse multi-species fisheries. Such fisheries are notoriously difficult (if not impossible) to manage using the "traditional" fisheries management tools like permits, quotas, maximum sustainable yields. Most of these methods were designed to manage single species stocks in temperate waters. Multi-species stocks present a range of difficulties. As I demonstrated in Chapter 4, even looking at a selection of 5 of the 252 species in the fishery resulted in a disparate array of life history features requiring very different management strategies if each were to be addressed individually. When the diversity of body forms and life histories of all the species in the Quirimba seagrass fishery are considered the true nature of the management dilemma can be appreciated. Rare in the fishery and probably rare locally too are the unusual fish species such as seahorses (Syngnathidae) and seamoths (Pegasidae). The conservation importance of these families has only recently been highlighted and the have a possible role as attractive species to highlight the loss of seagrass habitat (Vincent 1995). These species seem to be very site-attached and so may therefore be more vulnerable to local extinction than most of the fishery species with pelagic larval stages.

In a situation such as in Quirimba it is very important to consider the habitat composition of proposed protected areas. Good reef sites are commonly selected as protected areas, but it is essential to ensure that sufficient areas of seagrass

and mangrove are also protected. These protected habitats also need to be sufficiently linked for at least some of the fish in the protected areas to go through some of their life cycle there.

In an overall protection and management plan for the Quirimbas, it seems practical to select uninhabited areas to protect some of the less impacted habitats and biodiversity. But, it is also very important to protect areas within the more heavily exploited populated islands. One protected area that I would suggest would be the southern end of the Montepuez Bay, including the deeper area to the west and a proportion of the shallow mixed coral and seagrass area to the east (see Fig.2 in Chapter 1) and part of the mangroves to the south. At the time of study the protection of mangrove areas did not seem pressing – they were very rarely fished and mangrove cutting was happening at low intensity. However, as development of the area accelerates and the size of the local population increases, mangrove use, particularly for fuel and building, is likely to rise. Protected areas therefore also need to include mangroves.

Local participation

The major omission in the Darwin/Frontier Quirimba Archipelago Marine Research Programme was the involvement of the local community. The project was seen as a preliminary biological data collection, so consultation with local people on future management was outside the brief of the project and was to be arranged at a later date by researchers from the university and ministries in Maputo. However, if the area is to be managed in any way, if there are plans for tourist development or fisheries commercialisation then the local people have to be consulted at every level. Socio-economic data needs to be collected on all aspects of marine resource use and subsistence living on Quirimba. The needs of the community have to be ascertained and their voices have to be heard alongside the voices of politicians and hotel developers. As was demonstrated in the trap experiment, local knowledge of the fishery is very valuable. There may not be a strong, ancient traditional knowledge system, but the people of the Quirimba live largely from marine resources and small-scale agriculture and are therefore more

knowledgeable about their needs and limitations than any researcher from outside the area could be.

If the Quirimban people agreed that it was in their interest to protect some part of the Montepuez Bay to benefit fisheries and to conserve species and habitats at a local level, they could be involved at a number of levels. Elsewhere, fishers have become very competent and knowledgeable guides and park enforcers. In the Brazilian Sea Turtle Project in Brazil, children who would normally have left education and gone into employment at a very early age have been recruited as "mini-guides" to teach tourists about turtle conservation and to assist biologists in their research. They earn money and are also educated in marine conservation issues, which heightens their awareness and that of their families and the wider community (Vieitas *et al.* 1999). Education is an area that is particularly under-developed in the Quirimba Archipelago. Many girls receive virtually no formal education at all and any programme that incorporated education in sustainable development and marine conservation would be of great benefit to the community.

In Inhambane in central Mozambique a co-management system has been used in the artisanal and semi-industrial fishery. The fishermen's association makes all the decisions about closed seasons and the issuing of licenses. The combination of empowering the fishers to make the decisions about their fishery and strong social pressures for all members of the community to conform with regulations make the scheme very successful (Kristiansen and Poiosse 1996). This approach could be used in the Quirimbas but would have to be accompanied by an education programme making fishers more aware of the implications of over-fishing, habitat damage and loss of species.

Coastal populations are growing, more and more people are turning towards fishing as a last resort source of income. One solution is to encourage this but to find ways of diversifying fish resource use, such as providing boats with engines or other technological improvements that allow fishers to utilise different habitats such as deeper waters and offshore reefs. This can be used to decrease over-exploitation of previously used resources – e.g. coelacanth fisheries in the Comores (Bruton and Stobbs 1991). Moffatt *et al.*'s (1998) concept of "the reality of

the stomach" came out of the "Experiences in local and community ICZM" workshop in Zanzibar in 1998, expressing the importance of poverty alleviation through economic development in coastal management. This really goes back to the concept of fisheries management often being the provision of alternative livelihoods for fishermen in heavily exploited areas. Tourism and related activities are probably the most common alternative livelihoods to fishing in many tropical coastal areas. Tourism is sometimes state-supported but is most often private business and as Moffat *et al.* (1998) pointed out, one of the big coastal sustainable development and conservation hurdles is that scientists and NGOs (non-governmental organisations) involved in biodiversity conservation projects have a reluctance to involve private investors. Private business has often been regarded as the bête noire of conservation, with a reputation for putting short term profit over long term sustainability. This reputation has been deserved in many cases, but sustainable tourism is increasingly being practised as business people begin to see the long term sense in looking after the resources they are exploiting in their tourist activities. At the higher priced end of the tourist market consumers are becoming better informed and more discerning in the kind of holiday they chose, so it pays for tour companies to be ethical. Ecotourism outfits or strictly sustainable tourism tend to be found in remoter places with small clientele willing to pay huge prices.

Quirimba and other islands in the Quirimba Archipelago have the potential for development as exclusive, environmentally aware, sustainable resorts as are found elsewhere in East Africa, and in the Caribbean. These resorts are designed to make a minimal impact on the environment and also to benefit the local community through employing local people, training them and using local produce when it is prudent to do so. High cost tourism can bring money and alternative sources of income into the area without introducing the more negative sides of tourism such as uncontrolled development, excessive production of waste and use of limited local water supplies.

However, any decisions about this kind of development must be made in close co-operation with the local community. In many places such projects providing alternative incomes for fishers have not worked because many fishermen want to fish – it is more than a job, it is of social and personal importance. Fishing is an

independent, often self-employed source of income in which the fisher has self-respect that may not be the case as a waiter (MPA workshop). The alternative is the co-management and development of the existing fishery, dealing with the problem of the increase in itinerant fishers which is perhaps the biggest threat to all the fisheries in the Archipelago

Shifting baselines and ecology

In any study of marine fish communities at the end of the twentieth century it is imperative that an ecologist considers the "shifting baseline syndrome" (Pauly 1995, Sheppard 1995). This is the idea that we can not take any habitat or fish population as an example of a "pristine" or even near-pristine state. After 500 or so years of human exploitation, that has accelerated rapidly into the twentieth century, no habitat is in its original form and all have changed as a result of human impacts, even in some of the most remote areas. Many ecosystems in the vicinity of human habitation are thought to have undergone massive phase shifts because of the loss of key elements of the ecosystem through human exploitation. One of the major examples of the "shifting baseline syndrome" can be found in Jackson's 1997 paper which looked at historical records of Caribbean marine ecosystems and particularly the records of large marine vertebrates such as manatees, turtles and monk seals. Jackson found that these large vertebrates, now rare, were once so abundant that they formed the keystone species in reef and seagrass communities. The loss of these key grazers was never compensated for by the small grazing fish and invertebrates, and thus the seagrass and algal habitats have completely changed since then.

This has serious implications for modern ecological studies of reefs and seagrass beds. If there is such compelling evidence for a complete change in major tropical marine ecosystems in the Caribbean, it is very likely that a similar thing has happened throughout the tropics. As we saw in the historical background to Chapter 6, the southern Islands of the Quirimba Archipelago were important ports 4-500 years ago. A number of the key Portuguese settlement sites were based around seagrass beds, for example Santa Maria beach on the Montepuez Bay where the first European settlers on Quirimba were supposedly based (J. Gessner, pers. comm.).

The trap experiments investigating the fish assemblages in Enhalus, Cymodocea and Thalassodendron showed that seagrass species composition does have an impact on the species composition and biomass of fish available for capture. This would suggest that it is not enough to ensure that seagrass beds are not removed, the species composition also needs to be maintained to continue to support fisheries productivity and species diversity.

Conclusion

Only the total annual yield of finfish was estimated in this thesis but the invertebrate harvest could be almost as much again – the intertidal seagrass areas are extensive and productive. The value of the Bay in terms of the number of livelihoods sustained in whole or part by fish resources in the Bay is very high. The diversity and productivity of the Quirimba seagrass fishery found in this study suggests that the management of the Montepuez Bay area, for sustainable resource use and for the conservation of the rich habitats and diverse species assemblages, is a priority. Equally importantly though, it emphasises the importance of a habitat and a fishery that may not be valued as highly as it should be. Shallow sheltered seagrass beds throughout the tropics sustain many poor coastal communities. Seagrass beds are at threat from coastal development and pollution and increased fishing pressure, and they must be given the same level of scientific attention as coral reefs have been given in the past decade. Coastal managers and decision-makers need to be aware of their ecological and economic importance. Seagrasses are rich, diverse and an important habitat for fisheries that must be conserved and managed sustainably throughout the tropics.

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