AN ASSESSMENT OF THE KENYAN COASTAL ARTISANAL FISHERY AND

IMPLICATIONS FOR THE INTRODUCTION OF FADs

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EMMANUEL KAKUNDE MBARU

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ABSTRACT

The marine fishery in Kenya is predominantly small-scale and artisanal with about 11,000 fishers intensely fishing near shore coastal reefs using minimally selective fishing gears. A large majority (88%) of fishers use outdated equipment such as basket traps, beach seines, hand lines (hook and lines), fence traps, gillnets, spearguns and cast nets. Handmade canoes propelled by paddles (kasia) or sail power are used to access offshore waters, while only a few fishers have motorized boats. Although fishers along this coast know and express the potential of offshore fishing, most of them are disempowered and unable to access any of the largely untapped offshore pelagic resources.

Using a unique dataset from four distinct coastal areas: Funzi-Shirazi bay area, Diani-Chale area, Mombasa-Kilifi north coast area and the Malindi-Ungwana bay area, containing species level length frequency catch data from the multi-gear and multi-species fishery, abundance of specific species, gear use comparisons in various regions, catch per unit effort and total catch estimate over a nine year period (2001 – 2009) were evaluated. Despite high diversity in the fishery, five species (*Lethrinus lentjan, Siganus sutor, Leptoscarus vaigiensis, Lethrinus harak and Parupeneus macronemus*) represented over 75% of the catch. A total of 11 legitimate gears were observed in this coastal artisanal fishery with basket traps (42%) being the most popular. Fishers along the Mombasa-Kilifi area predominatly used beach seines while those in Diani-Chale, Malindi-Ungwana bay and Funzi-shirazi bay predominaltly used spearguns, gillnets and basket traps, respectively. Apart from gillnets, a general declining trend for most of the gear types was observed since 2004. Beach seines recorded the lowest (20.9±0.2 cm) mean length while gillnets recorded the highest (34.2±0.3 cm). The highest catch (~26,000 metric tons) came in 2001 and

the lowest (~15,000 metric tons) in 2005. The highest number of fishers was observed in 2008 while 2009 recorded the highest (4.8±2.3) mean number of hours per outing. The mean annual CPUE per region ranged from (1.5 kg.fisher^{-1}.hr^{-1}) in Diani-Chale to (1.0 kg.fisher^{-1}.hr^{-1}) in Malindi-Ungwana bay. Making use of questionnaire data, the attitudes towards offshore fishing strategies, FADs in particular, were evaluated. Some communities (about 25% in every location) were not even aware of FAD fisheries. With the imminent introduction of a FAD fishery in Kenya, it was concluded that, for this fishery to realize its full potential, training on FAD fishing techniques has to be done.

Finally, effective management is necessary if small-scale fisheries are to continue providing food security for many poor coastal communities. Gear-based management in Kenya, although under represented and under studied, has the potential to be adaptive, address multiple objectives, and be crafted to the socio-economic setting. Management effectiveness in near shore fisheries has generally been evaluated at the scale of the fish community. However, community level indicators can mask species-specific declines that provide significant portions of the fisheries yields and income. This thesis seeks to identify ways in which the Kenyan artisanal fishery can be sustained and managed from within coastal communities, giving them the resources and education to effectively improve their lives. The introduction of a offshore FAD fishery and hence access to offshore pelagic species provides an opportunity to not only alleviate pressure on coastal resources but also to empower coastal communities and contribute to the growth of Kenya's national economy as a whole.

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CHAPTER 1: GENERAL INTRODUCTION

1.1 The Kenyan Coastal Fishery

Kenya has a coastline of about 640 km stretching from 1º 30'S at the Somali border to 5º 25'S at the Tanzanian border (Maina, 2012). Although the Exclusive Economic Zone (EEZ) covers 200 nautical miles from coastline (FAO, 2009), the coastal artisanal fishery largely operates within a narrow continental shelf confined to a small strip of 2.5 to 3.0 nautical miles (McClanahan and Mangi, 2004; Samoilys et al., 2011). This region is largely dominated by fringing coral reefs, which occur within 12 nautical miles of the coast (Fondo, 2004). Some of the rich inshore grounds within this strip include the Funzi-Shirazi bay, the Diani-Chale area, Malindi-Ungwana Bay, the North Kenya Bank and the Lamu Archipelago (Maina, 2012). Along this coastline, changes in monsoon weather patterns sometimes limit fishing ability especially during the period of May to August (South-east monsoons) when the sea is rough (McManus, 1996; McCLanahan and Mangi, 2004; Morison, 2004). Most fishing activities take place between September and April (North-east monsoons) when the sea is calm (Mbaru et al., 2010, 2011). Although the Kenyan EEZ was extended from 200 Nm to 350 Nm in 2009 (FAO, 2009; Fig. 1.1), marine fishery production is still enormously exceeded by the Kenya's freshwater fisheries with the marine fisheries only contributing to about 10% of the total annual fishery production (Gomes, 2012). The marine sub-sector's annual potential of between 150,000 – 300,000 metric tons and contributes to around 0.5% of the country Gross Domestic Product (GDP) yearly (DoF, 2010). These apparent low yields have been associated with the use of rudimentary fishing technology within the heavily fished near shore areas (Muthiga and McClanahan, 1987). The incapacity of the local fishers venturing into the offshore waters has subsequently resulted into under-

exploitation of deep-sea fishing areas which are believed to be richer in pelagic stocks (FAO, 2009).
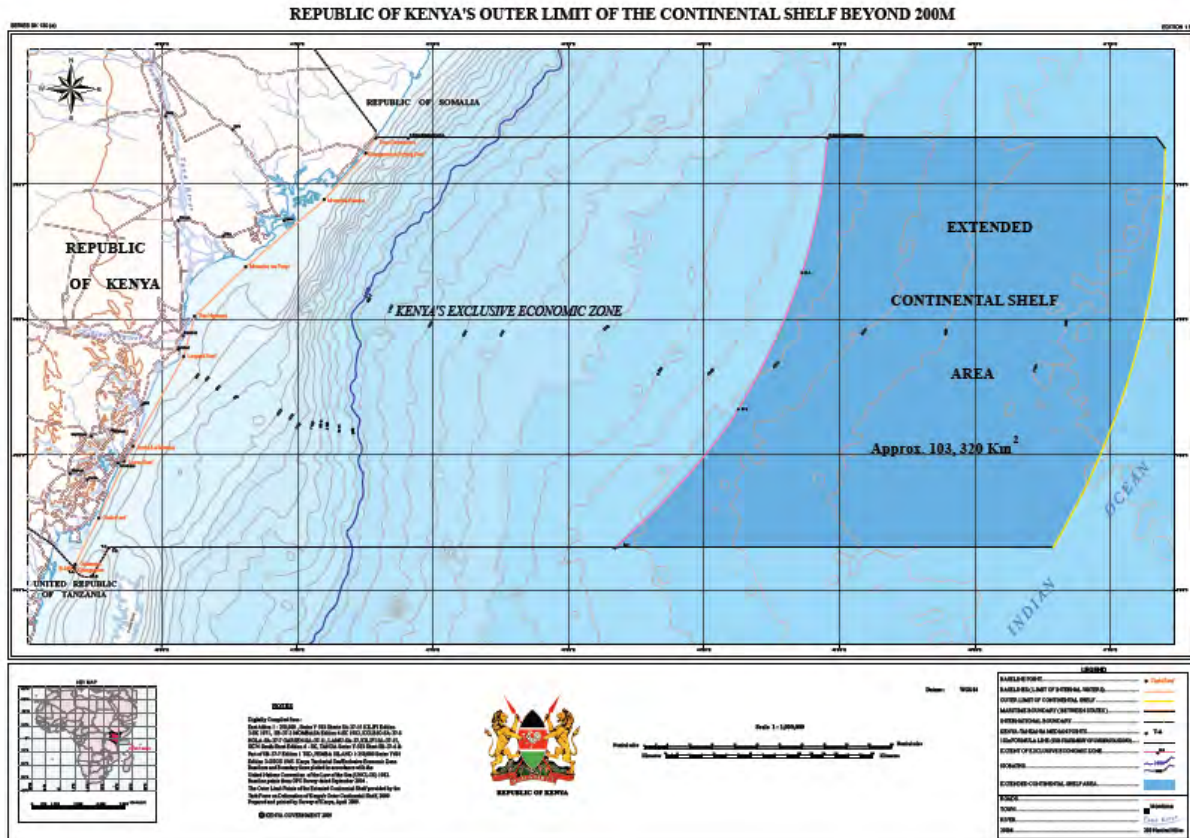
Figure 1.1. An official map showing the Kenyan 200nm and the 350nm extended EEZ.

Consequently, Kenyan marine fisheries have historically received much less research and management attention (Muthiga and McClanahan, 1987; Obura, 2001a; DoF, 2004; Fondo, 2004). Nevertheless, the importance of this sub-sector cannot be underestimated as it supports about 80,000 fishers directly (UNEP, 2006), and about 800,000 individuals (processors, traders and other service providers) indirectly (DoF, 2010). Over the survey period (2001-2009) eleven different gear types were used in the coastal fishery both on the reef and even beyond the reef. These include basket traps, gillnets, spearguns, hook and lines, beach seines, longlines, trolling,

ringnets, castnets, fence traps and scoop nets. A detailed description of each gear type is given in Chapter 2.

1.2. Management

Kenya was one of the first developing countries to enact legislations that established Marine Protected Areas (Melleret-King, 2000). Currently nine MPAs (including five no take marine areas) have been established under the Wildlife Act Cap 376 of the laws of Kenya. From 1968 when the first MPA (Malindi Marine Park) with total area of $6.3km^2$ was established, another eight MPAs were established and gazetted. These include the Watamu Marine National Park with a total area of $10km^2$, the Malindi-Watamu Marine National Reserve ($245 km^2$), the Kisite Marine National Park ($28 km^2$), the Mpunguti Marine National Reserve $11 km^2$, the Kiunga Marine National Reserve ($250km^2$), the Mombasa Marine Park ($10km^2$), the Mombasa Marine Reserve ($200km^2$) and the Diani Marine National Park ($75 km^2$) (Wells et al., 2007). From this, about 9% of the Kenyan reefs are fully protected from fishing and fishing related activities (Wells et al., 2007). Apart from these MPAs, there are about ten Community Conserved Areas (CCAs) in the marine sector established by the Wildlife Conservation Society (WCS), four of which enjoy full compliance (McClanahan, 2010). Apart from the MPA management approach, four additional fisheries management plans are at different stages of development (Maina, 2012). These include; the Prawn Fishery Management Plan 2010 (Legal Notice 20), the draft Lobster Fishery Management Plan, the draft Aquarium Fishery Management Plan and the draft Ringnet Fishery Management Plan.

1.2.1 The Prawn Fishery Management Plan (PFMP), Legal notice 20 of 2010

This is the first functional marine fisheries Management Plan (MP) adopted under the Fisheries Act covering shallow and deep water prawn species. It provides several management measures to ensure a biologically sustainable and economically viable prawn fishery. The prawn fishery covered in this Management Plan is concentrated in the shallow coastal waters around Malindi-Ungwana Bay. Between 4 and 20 semi-industrial trawlers have been trawling in the bay for the last three decades before closure of the fishery in September 2006, concentrating on the deltas of the two rivers. Semi-industrial trawlers target the shallow water prawns and land on average 400 metric tons annually (Mwatha, 2002). The major fishing methods covered in this Management Plan include the stern trawl, single vessel otter trawl and paired beam-trawl. Other fishing methods are the prawn seining and the use of cast nets by artisanal fishers. The aim of this MP is to ensure job creation, wealth, national revenues and foreign exchange earnings, fish products and protection of the prawn fishery and habitat in the long term. To ensure equitable sharing of benefits, it recognises the need to empower local people to utilise the prawn fishery using artisanal technology and employment of local people in semi-industrial prawn fishery. The plan recommends for the establishment of a Community Trust Fund (CTF) whose benefits shall be distributed through the beach management units (BMUs).

1.2.2 The Marine Aquarium Fishery Management Plan (MAFMP), of 2010

The aquarium fishery had been under subsistence practice since the 1970s and expanded to attain commercial significance in the 2000s. However, due to the significance of the marine aquarium fishery in Kenya, starting the year 2009 a total of eight (8) marine aquarium fish dealers are currently fully operational (DoF, 2009). All operators use a total of 130 aquarium fishers who comprise of both gogglers as well as divers mainly dealing with exportation of aquarium finfish, invertebrates and live rocks. They also own a total of 10 fishing vessels although a number of

them are using hired vessels for their operations. According to the 2009 marine exports summary, an annual total value of US$202,000 (7.6 metric tons-mt) for marine finfish, US$36,000 (2.7 mt) for marine invertebrates and US$7,200 (16.9mt) for live rocks (DoF, 2009). The Ministry of Fisheries Development through the Provincial Director of Fisheries, Coast, initiated a process of drafting this management plan. Its commercialization has exerted enormous pressure on coral reef fishes and has resulted to a myriad of complains from the fisher community. The purpose the fishery Management Plan is to develop a vibrant ornamental industry that provides sustainable and equitable benefits to all while conserving the long term ecological integrity of the targeted species along the coast of Kenya.

1.2.3 The draft Lobster Fishery Management Plan (LFMP), of 2010

The commercial exploitation of lobsters occurs along the entire Kenyan coastline. The main fishing grounds are in the north, around the islands of Lamu, Manda, Pate and Ziwayu; (Mutagyera, 1984). The ground considered likely to have commercial potential is located directly offshore from Ungwana bay; where a mean biomass of 330 tonnes has been determined for an area of 66 nm^2 (226 km^2). An overall biomass of 1,177 tonnes (whole weight) was determined as occurring on a trawlable area of 2,133 nm^2 (7,316 km^2). The potential yield from this ground, from the product of half the biomass and an assumed value for the natural mortality coefficient, has also been estimated to be 140 tonnes (Onganda et al., 2011). The broad objective of this Management Plan developed by the Ministry of Fisheries Development is to ensure the continuation of a biologically sustainable and economically viable fishery thereby providing benefits to Kenyans in terms of creation of employment, wealth, national revenues, fish products and certification of the lobster fishery to meet and maintain the Marine Stewardship Certification (MSC) standards (Maina, 2012). Since the draft Management Plan only covered areas within

Lamu, there has been a view that the draft LFMP be expanded to cover the whole Kenyan coast. This is to also fulfill the Marine Stewardship Council (MSC) certification requirement. In response to the concerns within the lobster fishery industry, and the high value of the trade, the Ministry of Fisheries Development selected this fishery for a pre-assessment for MSC certification. The fishery is currently in process of the fishery improvement process.

1.2.4 The draft Ring net Fishery Management Plan (RFMP) of 2012

Ringnet fishing is defined as the use of long continuous stretches of netting of varied lengths from a minimum of 200 meters to a maximum of 300 m long, varying widths of a minimum of 30 meters and a minimum mesh size of 2 inches. This management plan covers all ringnet fishery activities in the marine fisheries waters of Kenya as described in the Maritime Zones Act. The plan shall cover small pelagic species and reef associated species targeted by ringnets but excludes reef fish species. Extrapolations from existing data sets gives a minimum estimate of 500 -700 metric tonnes being landed annually by ringnet operations in Kenya, having an estimated annual landed value of approximately Ksh 60 – 84 million (DoF, 2011). The broad objective of this plan is to ensure an ecologically sustainable pelagic fishery that provides long term socio-economic benefits to Kenyans in terms of food security, job creation and national revenues; and promote co-management in the sustainable use of ring nets. The specific objectives of the Management Plan are to regulate the harvesting of pelagic fishes, develop mechanisms to enhance responsible exploitation of pelagic fish stocks; improve the net income for fishing community and national revenues; develop regulations and mechanisms to enhance enforcement and compliance for ecosystem management and initiate long term monitoring and implement demand driven research for the pelagic fishery. The latest draft of the RFMP (Feb

2012) has been subjected to peer-review. The Management Plan is expected to be circulated again widely and presented to the public for further comments.

1.3. Stakeholders

The management of the marine fisheries in Kenya involves various stakeholders (McClanahan, 2011). According to the Fisheries Act (Cap 378 of the Laws of Kenya), the exploration, exploitation, utilization, management, development and conservation of fishery resources is provided by the Department of Fisheries (DoF). Research on the fisheries resources is conducted by the Kenya Marine and Fisheries Research Institute (KMFRI) while other conservation and management roles (especially the Marine Protected Areas management) are played by the Kenya Wildlife Service (KWS) as stipulated in the Wildlife (Conservation) Act (Cap 376). Apart from KMFRI, other non-governmental organizations (NGOs) are also licensed to conduct research and several multi-institutional and multidisciplinary projects have been implemented through public - private partnerships. Additionally, the Kenyan coastline falls under the jurisdiction of the various local authorities (Municipals and County Councils) which also address matters of human development and environmental sustainability (Gomes, 2012). Experience and knowledge from the fishers also contribute towards management of the local fisheries. Since 2006, the DoF introduced community based management (co-management) where fishers were organized into beach management units (BMUs). This decentralized approach allowed for stakeholder co-management of natural resources with the DoF at the local level (Obura et al., 2008).

1.4. Exploitation Strategies

The Kenyan coastal fishery is a multi-species, multi-gear and multi-vessel operation with inconsistent and irregular effort throughout the year (McClanahan, 1998; Gomes, 2012). The

fishery has expanded with an increasing number of participants in the industry (Ochiewo, 2004). In addition, due to financial disempowerment and a lack of resources, environmental degradation of fishing grounds has tremendous effect on the industry. As a result of the increased number of fishers, almost all of whom use inappropriate nets and gears, inshore fishing areas are being destroyed, which in turn decreases productivity and the economic livelihood of local communities (Cinner et al., 2008). Local fishers cite a significant decrease in catch. This has perpetuated the decline of the inshore environmental and economic resources. Contributing to the perplexity of the situation, offshore marine resources are abundant and vastly underutilized by the local fishers (Ruwa, 2011). But local fishers are disempowered and unable to develop these vast offshore coastal marine resources that have been largely underutilized (FAO, 2009). They lack adequate equipment—boats, engines and nets, the ability to preserve and process their products and the basic infrastructure to successfully market their catch in national or international markets (Gomes, 2012). Fishers and dealers lack the educational and management resources to effectively organize themselves in order to sustain and remain in control of what could be a profitable industry. Under current circumstances, subsistence inshore fishing drives a cycle of poverty along the coast that inhibits the development of a sustainable fishing economy. In addition, the coastal fishing industry has been largely neglected by national and international investors and by the Kenyan government as a whole.

Overexploitation of the tropical fisheries by small scale fishers (malthusian overfishing) and degradation of near shore areas has led to severe changes in the fisheries ecosystem along the Kenyan coast (McClanahan et al., 2008). Efforts to overcome this are now geared towards shifting of the fishing effort from the nearshore fisheries towards offshore pelagic fisheries

(SWIOFP, 2007). Suggestions regarding changes in resource exploitation approaches provided the framework for the development of alternative fishing techniques (e.g. Fish Aggregating Devices - FADs).

FADs are man-made structures set to float at desired locations in the open sea to aggregate pelagic fish thus rendering their capture easier (Benivary, 2009). The FADs vary in shape and size, and can be either anchored or drifting (Franco et al., 2009). Anchored FADs in particular were first recorded in Malta, Mediterranean Sea, during the 17th century (Dempster and Taquet, 2004). In Indonesia and the Philippines, fishers started to use FADs in the early 1900s (Anderson and Gates, 1997). Typically they can be bamboo rafts, strings of fishing floats or metal cylinders, all with appendages (branches, ropes, or disused netting) suspended beneath to provide shelter for small fish. In some cases, fishers have tied together floating natural logs and bamboos to act as FADs. Anchored FADs are set in position by use of an anchor and a mooring line, whereas drifting FADs are deployed without mooring lines (Franco et al., 2009). In the Kenyan case, the intention is to use anchored FADs (AFADs) since it has been proposed that anchored fish aggregating devices (AFADs) can more easily attract pelagic fishes because of the sounds produced by their anchoring chains or the influence of current on the mooring ropes (Freon and Dagorn, 2000). Among the benefits of FADs include: 1) *Increased availability of pelagic species:* FADs bring the fish to the fishers, 2) *Reduced search time and reduced fuel consumption:* Searching for schools of fish takes time and consumes a lot of fuel. Fishers can spend more time fishing, 3) *Reduced fishing pressure on inshore and offshore bottom-fish resources:* Relocating fishers from the bottom-fish resources to offshore pelagic fish and 4)

Increased safety for fishers: FADs aggregate fish but also aggregate fishers thus increase fishers's safety.

In order to place these alternative fishing techniques in context, this study firstly conducted a baseline retrospective analysis of the marine fishery in terms of catch, effort and participation of fishers over time (2001 – 2009). In this section (see chapter 3), a time series analysis on the status of the Kenyan marine fishery was performed by presenting the differential statistics of catch abundance, mean lengths, estimated annual catches and CPUE for different gears and regions over a 9-year period, with a focus on sustainable management interventions for local fisheries. Since success of these new fishing programs is highly dependent on the perceptions and support from the local resource users, attitudes of the local fishers (both recreational and artisanal fishers) in light of the potential use of FADs were investigated not only to strengthen the knowledge base for the implementation of an ecosystem approach to fisheries (EAF) but also for the purposes of setting up a sustainable FAD fishery. This was necessary to ensure consistency between the FAD fishery development framework and the needs of local fishers and their current practices (Lucas et al., 2009) as there were no other inclusive FAD fishery programs in existence within Kenya for the present project to follow.

1.5 Research Aims and Thesis Structure

Fishing in coral reef lagoons is one of the main sources of expendable income and animal protein for coastal people of Kenya (Glaesel, 1997; Melleret-King, 2000). Yields from these lagoonal reef fisheries have been declining (McClanahan and Mangi, 2001). Such declines have been attributed to an increase in effort and competition for dwindling resources (Glaesel, 1997, 2000; McClanahan et al., 1997). Methods of fish capture may also influence this change as some methods introduced in the past few decades, such as seine nets, spears and trawlers, are

commonly disapproved by traditional fisheries elders (McClanahan et al., 1997). Given the current concern to achieve sustainability of marine fisheries this project was aimed at initiating new methods of fishing such as the use of fish aggregating devices (FAD) as well as to ensure healthy and productive fisheries. FAD fishery is meant to relocate fishers from the heavily exploited lagoon areas to the open sea, with a view to increasing their catch rate and concurrently reducing fishing pressure in the lagoon and to increase the supply of fish on the domestic market. FADs represent a win-win opportunity for fishers and coral reef conservation. Fishers' current incomes will not be reduced, and there is the potential that their incomes will increase both in the long and short term, through increased catch prices and increased ecotourism who would like to snorkel around FADs.

Other studies provided evidence that fish at FADs is density-dependent; therefore by aggregating fish, FADs can result in high retention of larger, high-value target fish. FADs can make fishing a more sustainable livelihood. There are ~15,000 artisanal fishers in Kenya, and ~800,000 individuals (family members, processors, traders and other service providers) whose income depends indirectly on fishing. Increasing their access to pelagic resources increases the likelihood that these jobs can be preserved and improved. Perhaps more importantly, FADs can make fish consumption more sustainable, which is critical to the approximately 500 million people globally who depend on fish as their primary source of protein.

The aims of this thesis are:
- To assess the trends in catch, effort and participation of the marine fisheries in Kenya
- To assess the socioeconomic aspects of fishing communities along the Kenyan coast

- To utilize the social survey to provide a qualitative and quantitative interpretations of the perceptions of the fishing communities towards new fishing techniques and in particular FADs

This thesis has been structured as a series of standalone chapters and a short description of each of the five chapters is given below.

Chapter 1 provides the general background of the Kenyan coast, its geographical position, territorial coverage of the Exclusive Economic Zone (EEZ), current fisheries management plans operationalized and those in different stages of development, various stakeholders involved in the management of the fisheries resources as well as a summary of the exploitation strategies. The general aims and objectives of this thesis are also provided in this chapter.

Chapter 2 describes the general methods used in gathering the fishery data. A brief overview of the Kenyan coast including a description of seasonal currents, monsoon winds is given as part of the introductory section. A description of the four major coastal regions including each of the fish landing stations where sampling was carried out is also included. This chapter also provides a description of the fishery survey methods i.e. fish landing studies and catch recording criteria that was followed during sampling including a description of each fishing gear sampled.

Chapter 3 gives the spatial and temporal trends for each gear use over the 9-year period. Species composition, size composition of catch, estimated annual catches, annual effort and catch per unit effort in the four coastal regions over the 9-year period is provided. Information on fisher demographics and diversity is also provided.

Chapter 4 provides attitudes of the local fishers (recreational and artisanal) in light of FADs as an alternative fishing technique. Perceptions towards these structures including willingness of the local fishers to accept and join this fishery as well as the perceived effects of FADs on the livelihoods were examined. Various indicators that relate to success of FADs such as fishing patterns, individual income and expenditures, market influences and resilience were also examined.

In Chapter 5 the major findings of the research are synthesized in the form of a general discussion and management recommendations are provided.

CHAPTER 2: METHODS AND MATERIALS

2.1. Study Site

The Kenyan coastline is about 640 km long and lies within 1.75-4.65ºS and 39.18-41.22ºE (Figs. 2.1 and 2.2). The coast is characterized by a narrow continental shelf except for the northern parts where it extends to about 60 km offshore (Newell, 1959). The coastal currents are monsoon driven and comprise of the East African Coastal Current (EACC) which flows from south under the influence of the south east monsoon (SEM) across the equator and along the Somali Coast into the Arabian Sea during the northern summer from June to September (Newell, 1959; Johnson et al., 1982).
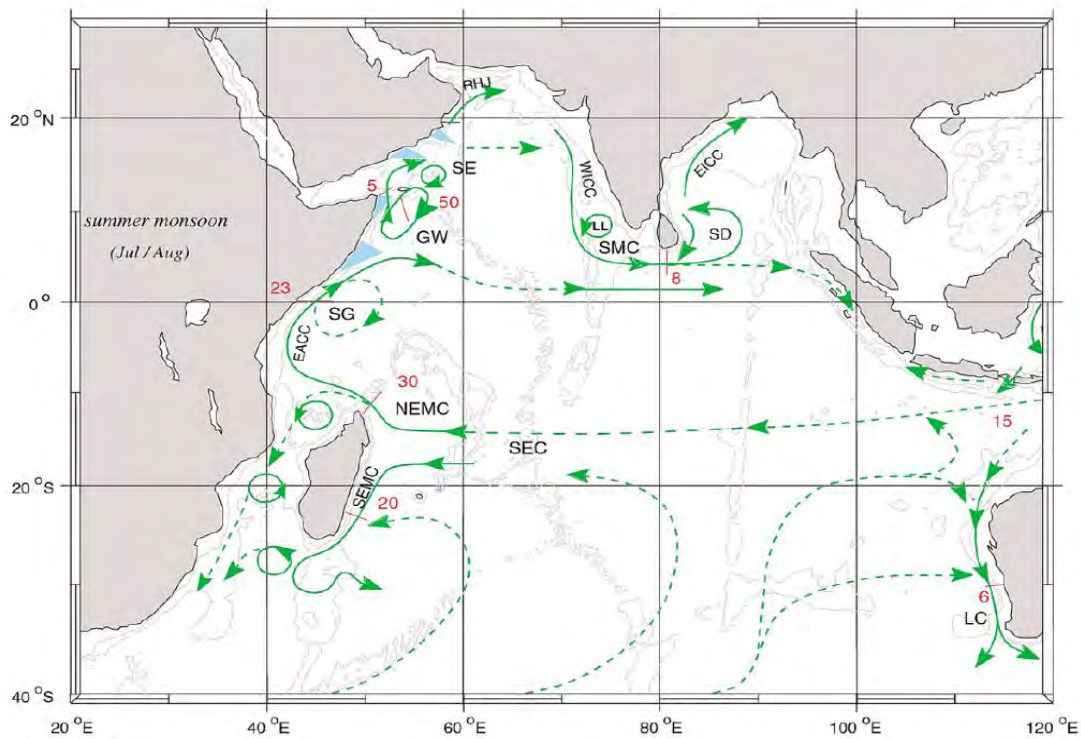
Figure 2.1. A schematic representation of ocean current branches during the Southwest Monsoon, including some choke point transport numbers (Schott and McCreary, 2001).
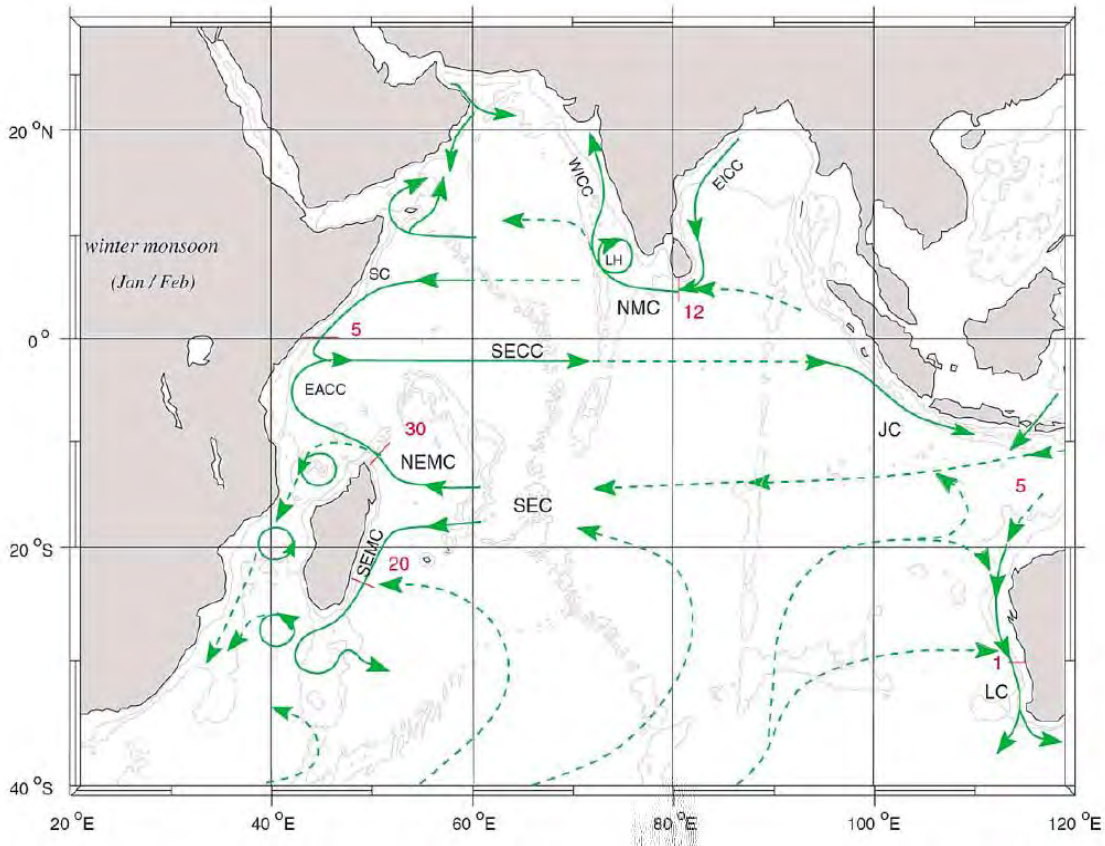
Figure 2.2. A schematic representation of ocean current branches during the Northeast Monsoon, including some choke point transport numbers (Schott and McCreary, 2001).

During the northern monsoon, the EACC is weakened and deflected eastwards where it meets the south-flowing Somali current (SC) off Kipini and Lamu areas (Schott and McCreary, 2001). The flow of these currents, the seasonal changes in wind and ocean patterns and their subsequent confluence is thought to influence migration and distribution of fish, as well as fishing patterns along the Kenyan coast (Brakel, 1984; Jury et al., 2010). Other, studies have also shown that variation in oceanographic parameters like salinity, sea surface temperature

(SST), and chlorophyll also affect distribution of fishery resources (Newell, 1959; Johnson et al., 1982; Jury et al., 2010).

2.2. The Coastal Fishery Survey Area

Twenty-nine major and about twenty other minor sites were surveyed along a 300-km stretch of the Kenyan coast between Vanga and Kipini in the extreme south and north respectively (Fig. 2.3). For ease of description, the study area was divided into four main broad areas; Malindi-Ungwana bay area, Mombasa-Kilifi north coast area, Diani-Chale area and the Funzi-Shirazi bay area. These four regions form the richest fishing grounds along the coastline where majority of the artisanal fishers are concentrated (Agembe, 2010). Study sites were chosen since they were the most active beaches within the region with a high concentration of artisanal fishers and qualitatively represented a typical coral reef, lagoon-based fisheries of Kenya with a variety of fishing gears and vessels in use.

Five major fish landing sites Kipini, Jetty, Mayungu, Mambrui, Malindi among others were situated within the Malindi-Ungwana bay area while landing sites that fell within the Mombasa-Kilifi area included; Nyali, Msanakani, Reef, Kenyatta, Marina, Mtwapa, Kanamai Bureni, Vipingo, Kijangwani, Kuruwitu, Kilifi and Watamu. Seven major sites (Chale, Mgwani, Mwanyaza, Mvuleni, Mwaepe, Tradewinds and Tiwi) fell within the Diani-Chale area while four major fish landing sites (Vanga, Shimoni Msambweni and Gazi) were situated within the Funzi-Shirazi bay area (Fig. 2.3).
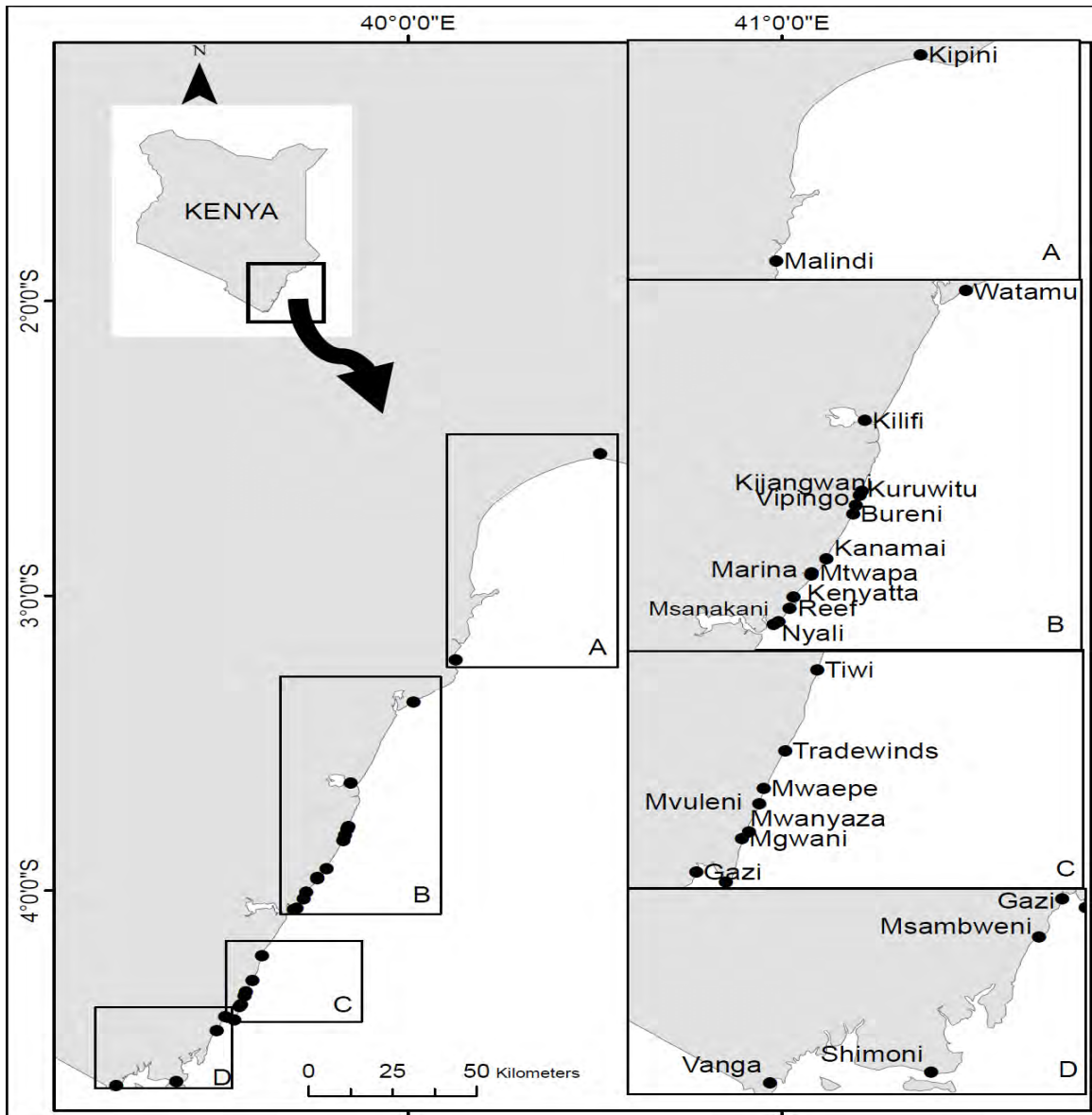
Figure 2.3. Spatial distribution of major fish landing sites across the four coastal regions: A - Malindi-Ungwana bay, B - Mombasa-Kilifi area, C - Diani-Chale area and D - Funzi-Shirazi bay.

2.2.1. Malindi-Ungwana bay area

The Malindi-Ungwana bay is located between the latitudes 2° 30'S and 3° 30'S, and the longitudes 40° 00'E and 41° 00'E covering a coastline of about 200 km long (Fig 2.4). The region

extends from Malindi through Ras Ngomeni in the south to the Tana River mouth at Kipini further north. Five major landing sites (Kipini, Jetty, Mayungu, Mambrui and Malindi) and several minor sites were situated within this region (see Fig 2.4).
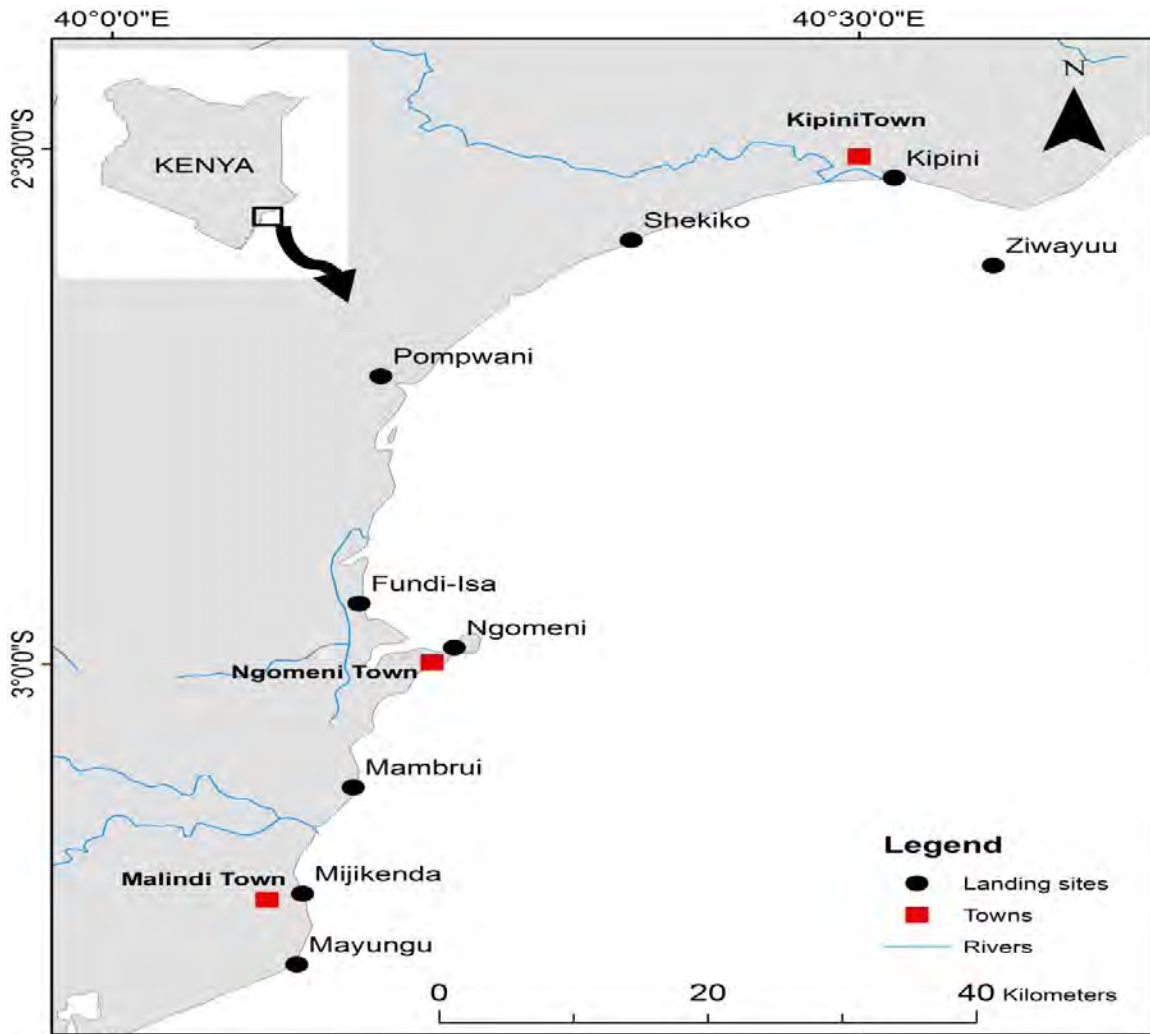
Figure 2.4. Map showing the fishery landing sites and other coastal features within the M-U survey area.

The bay is shallow with a mean depth of 12m at high spring tide at 1.5nm from the shore and 18.0m at 6.0nm which increases rapidly to 100m after 7 nm from the shore and generally decreases northwards. The continental shelf is wide and extends between 15 and 60 km off shore

(Fulanda, 2003). A few places, particularly south of the bay, have scattered rocky and coral reef substrate with terrigenous sediments from the rivers dominating the bottom of the bay (Fulanda, 2003). This region is believed to be the richest shellfish and finfish fishery area in Kenya with its unique topography of the continental shelf in the bay and the inflow of nutrient rich fresh water from the rivers Sabaki and Tana.

For the last 30-years, several semi-industrial trawlers (4 to 20) operated in the bay (Fulanda, 2003), but a ban was imposed on trawling in September 2006. However, the government has since lifted the ban since 2009 (Munga et al., 2010). Conflicts between the trawlers, the small scale artisanal fishers and conservation agencies were main issues surrounding the contravention of the Fisheries Act. Other issues included destruction of fishing gears of small scale fishers by the trawlers, wastage of fish, by-catch and alleged killing of other non-target species especially the turtles. This Act now limits trawling to 5nm offshore after the resumption in 2009.

2.2.2. Mombasa-Kilifi north coast area

This region is situated within the geographical coordinates 04º.06'-03º.36'S and 39º.69'-40º.01'E bordering the second largest city (Mombasa) in Kenya (Fig. 2.5). Apart from Mombasa whose population (according to the 2009 Population and Housing report) is over one million, Mtwapa and Kilifi form part of the other major towns. The population growth rate in Mombasa (>4.03 %) is the highest within the Kenyan coastal region (Munga et al., 2010). In terms of fish landing sites, this region has the highest number (13) of landing sites including Msanakani, Kilifi, Watamu, Kuruwitu, Bureni, Marina, Nyali, Kijangwani, Reef, Kanamai Mtwapa and Kenyatta. Most these landing sites are located on shore from a lagoon protected by fringing reefs and majority of the fish caught are associated to coral and seagrass habitats (McClanahan and Mangi 2001). The sub-region in Watamu (further north from Kilifi) form a continuous protected

coastal area where the Watamu Marine Park and reserve are situated (Gomes, 2012). Among the key coastal resources within this sub-region which lies about 120 km northeast of Mombasa (3º.13'S, 40º.07'N) include mangroves, open woodland, sandy beaches, coral reefs, creeks sand dunes and open ocean.
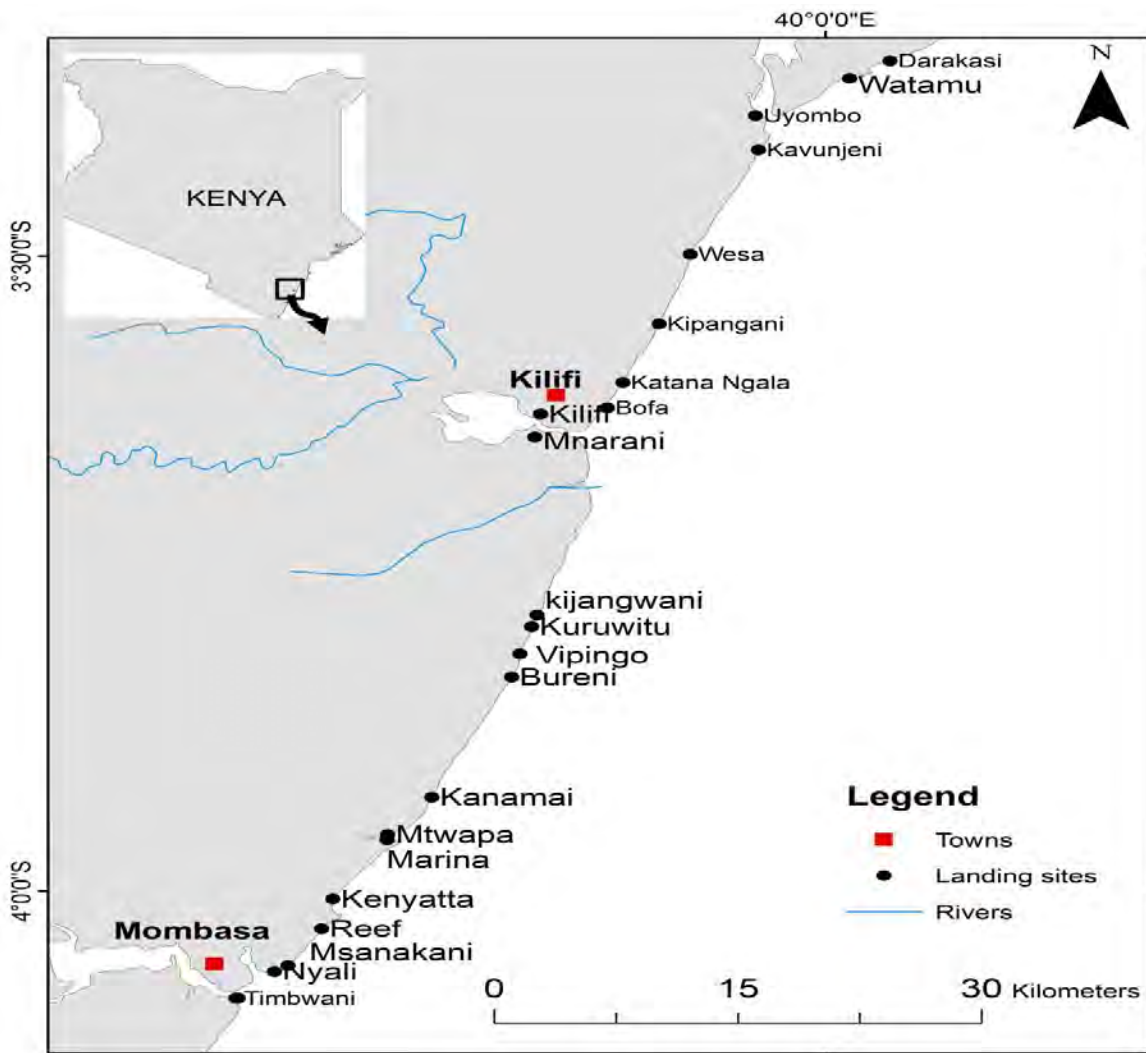
Figure 2.5. Map showing the fishery landing sites and other coastal features within the M-K north coast survey area.

2.2.3. Diani-Chale area

Diani-Chale area is located in the south coast in Msambweni division of Kwale County within the geographical coordinates 04º.44'-04º.22'S and 39º.54'-39º.61'E (Fig. 2.6). The catch assessment work was limited to the coastline from the confluence of River Mwachema to Mwanyaza. This area has seven landing sites namely Chale, Mgwani, Mwanyaza, Mvuleni, Mwaepe, Tradewinds and Tiwi. Fishing in this area is mostly inshore to the outer edges of the fringing reef, in waters generally not exceeding 20 m depth (Maina, 2008).

Figure 2.6. Map showing the fishery landing sites and other coastal features within the D-C survey area.

There are two locally registered beach management units (BMUs) at Mwaepe and Kinondo-Chale. The locals are dependent on fishing, agriculture and tourism which are largely seasonal and some are highly influenced by rainfall. This area is of great beauty and blessed with many economically valuable natural resources and numerous tourist attractions. In 1995, Mwaepe fish landing site in Diani was selected by the local community as a site specific initiative to demonstrate the Integrated Coastal Area Management (ICAM) process in the region using the Jomo Kenyatta Public Beach as a 'model' (Oluoch and Obura, 2008).

2.2.4. The Funzi-Shirazi bay area

The bay covers an area of about 150 km^2 which extends from Msambweni to Vanga at the Kenya-Tanzania Border. This region lies between latitude 4°30' - 4°35'S and longitude 39°22' - 39°27'E in the south coast region of Kenya (Fig. 2.7). The coral reefs in the shallow water lagoons are extensively covered with mangrove forests and seagrass beds in the intertidal areas. The hinterlands are underlain by 'Mto Mkuu' formation of Upper and Lower Cretaceous of the post Karoo systems (Ohowa et al., 1997) while the water zone sediments located in the lagoons consists of mud and silt in the backwater zones. The bay is typically situated on a low-lying coastal plain (below 30 m contour) and is one of the rich inshore grounds within the Kenya's EEZ in terms of fishery and marine biodiversity. Coral limestone of the Pleistocene age with lagoon deposits originating from land and sea forms the main bottom substrate (Nguli et al., 2011). Tidal regimes, river discharge, exchange of water, nutrients and carbon inter-link the critical ecosystems of the bay whose morphology is largely influenced by the Pemba and Wasini Channels. Within the complex, there are several rivers (more conspicuously Ramisi and Mwena) whose catchments extend to Usambala-Pare Mountains in Tanzania and the Nzombo-Shimba Hills entering the complex through Mamuja and Vikurani Creeks, respectively. Within the

Funzi-Shirazi creek lays Mamuja, Vikurani and Uvinje as the three main creek systems from the upper mangrove forest. Within this bay also lies the Funzi Island at the mouth towards the South eastern zone of the complex. Just like the rest of the Kenyan coast, the bay is influenced by the flows both the East Africa Coastal Current (EACC), as well as the Somali Current. The area is adjacent Kisite-Mpunguti Marine Park and Reserve, where a lot of tourism activities take place as a result of the diversity of coral reefs, marine species, extensive mangrove areas and sea-grass beds.
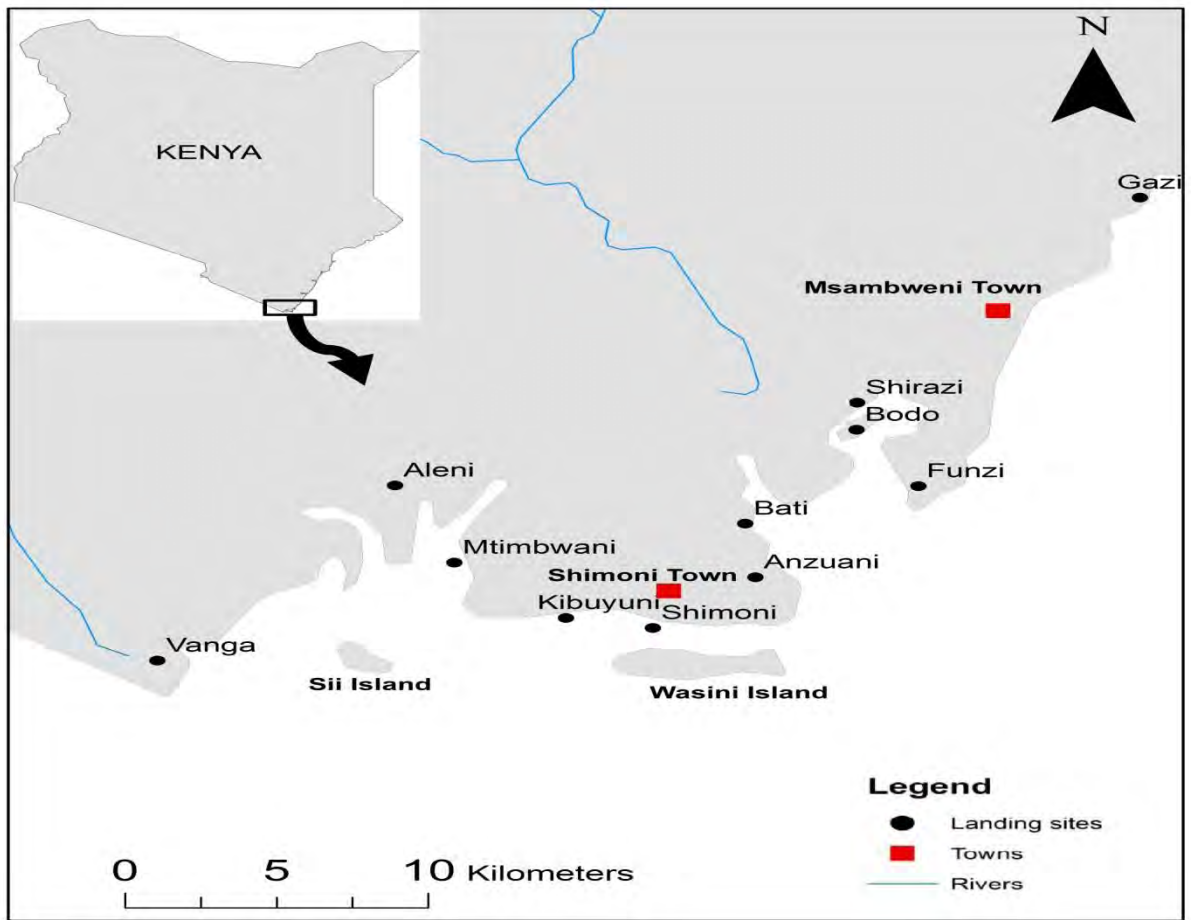
Figure 2.7. Map showing the fishery landing sites and other coastal features within the F-S survey area.

2.3. Fishery Survey Methods

2.3.1. Fish landing studies

The survey represented an access point survey conducted on foot by 21 survey personnel deployed at the various landing sites. Eighteen of these who were observers (trained by KMFRI) were permanently deployed at the landing sites while three scientific observers randomly visited the sites to record additional data on the fish landed. Of the 18 onsite observers, three were deployed at each Msambweni, Vanga, Shimoni and Diani, two were based at Malindi, while Gazi, Lamu, Kizingitini and Kiunga each had one observer. Most of the sites with more than one observer had landing sub-stations; for example, Msambweni had *Mwaembe* and *Mkunguni* as landing sub-stations. Out of the 18 onsite observers, six observers based in Msambweni, Vanga and Shimoni were the most instrumental in providing data from the surveys whilst the scientific observer data was dominated by sites inadequately covered by the onsite observers but also provided supplemental data from the sites actively enumerated by the onsite observers. Sometimes, the onsite observers provided the fish catch data by common names. However these names were easily interpreted into scientific names by the experienced scientific 'taxonomic' observers who had a common knowledge of the fishery. Moreover, during their field visits, the scientific observers collected similar information that verified the species names (Smith and Heemstra, 1986; Lieske and Myers, 1994). To define bycatch, this study adopted Alverson et al., (1994) definition where both discarded plus incidental fish catch were categorized as bycatch. More importantly, information on bycatch was given as 'general information' known for these gears and no data was presented.

2.3.1.1. Catch recording by onsite observers

The onsite observers were present at the landing station every fishing day, before the arrival of boat landings. The observers stayed at the landing sites until the entire landing process was concluded and then recorded the date, total number of boats, area fished, boat type, number of crew, gear used, mesh size (for nets), time in, time out, total landing (kg) and the catch composition on FORM A (see appendix 1). Additional information was obtained from a sub-sample of the catch and included weight of the sub-sample, total number of fish in sub-sample, species composition of sub-sample, weight and total length (cm) of each individual and the sex of 5 to 10 individuals of the same species from the catch (cm), and were recorded on FORM B (see appendix 1). The entire catch of invertebrates (octopus, sea cucumber, lobster etc) were identified by common names and numerated. A brief description of the vessel type and fishing gear used was also noted. These catch recording variables were selected due to their consistency with local fishers' knowledge and practices as well as catch monitoring needs. Fishers usually keep some of the less marketable species for home consumption (Glaesel, 1997) and, therefore, sampling market catches alone would bias the actual catch and reduce estimates of the number of species caught. All recorded data forms were submitted to KMFRI for processing.

2.3.1.2. Catch recording by scientific observers

The scientific observers recorded the same criteria as onsite observers except that they visited each site between 1 - 8 times per month. Fish landed were measured to the nearest centimeter (total length) using a fixed marked ruler on a flat board. If possible every individual fish landed was measured. When catches were large, care was taken to measure a representative sample of every size class (including small, medium, and large) for each species. After each day the data

was entered from the sheets or slates into the database. The slates were not erased until necessary and after data entry had been checked, the data sheets were filed and kept. Dates on which the patrols were conducted were selected randomly to ensure representative coverage. There was no stratification of the number of patrols conducted per month, but similar intervals of sampling were maintained within this randomized block design to detect long-term catch trends. Although all patrols by both observers were conducted during daylight hours, these results do not exclude catches attributed to night-time fishing activities as fishers returning from their overnight fishing were also intercepted by the observers.

2.3.2. Description of gear used in inshore fishery

Over the survey period (2001-2009) six main gear types were used in the coastal fishery. Although the different gear types varied considerably in their spatial use, they were used in all habitats both on the reef and even beyond the reef. A description of each gear type is given below.

i) Basket traps

Basket traps represent a traditional fishing method used in Kenya and other parts of the western Indian Ocean (Samoilys et al., 2011). These traps are popular since they retain most fish that enter, resulting in a catch with a high species composition (Munro, 1983). They are usually handmade by local fishers with a split of bamboo or metal frame, but recently some fishers have adopted the use of wire, arguing that glittering metal mesh enhances fish attraction (Abdulrahman, personal communication). The entry is down curving with interwoven reed strips forming hexagonal patterns that surround the frames. Traps come in different sizes with the smaller ones having an approximate volume of 0.2 m^3 (mesh sizes of 3 cm) while bigger traps

have an approximate volume of 0.8 m^3 and about 5 cm mesh size (McClanahan and Mangi, 2004) to 1-6 traps per canoe with an average of 2 fishers as crew.

Figure 2.8. A typical handmade basket trap deployed on a shallow reef (A) and a trap being repaired (B).

Trap fishers in Kenya use a mixture of plant and animal bait (seagrass, algae, crushed sea urchins, brittle stars and molluscs) as bait, although studies by Munro (1983), confirmed that this bait may not influence trap effectiveness. During fishing, traps are usually lowered to the bottom

of the seabed with ropes attached to small floats or plastic bottles that serve as surface marker buoys. Deployment of traps in the lagoon is done from canoes or outrigger sailboats carrying up to 4-fishers (Fig 2.8). Once deployed and held on the bottom by large stones, traps are usually left overnight (24-hr soak time) and contents (captured fish) are checked and removed on the following day (Glaesel, 1997). Studies by Stewart, (2007) and Johnson, (2010) indicated that traps typically target high-value fish such as rabbitfshes, groupers (Siganidae, Serranidae) and snappers (Lutjanidae), but they also have high bycatch of key herbivores parrotfish (Scaridae) and surgeonfish (Acanthuridae) and other non-target species butterfly fishes (Chaetodontidae). When removing the catch, the trap is raised; catch removed, bait replenished and then reset in the same place or sometimes nearby depending on the catch. Captured fish are kept alive ensuring a fresh and high quality yield. Traps made from bamboo rafts are biodegradable and can minimize the scenario where fish are ecologically trapped by lost fishing gears i.e. ghost fishing. No specialized training is required in making and deploying traps making them inexpensive. However traps may cause damage to coral reef if dropped on reefs (Samoilys et al., 2011). In addition, trap fishers sometimes use live coral heads to weigh traps on the bottom.

ii) Gillnets

Gillnets represent another common gear that can be used both in the inshore as well as the offshore waters (Samoilys et al., 2011). They comprise of a single nylon multifilament net with varying mesh size and thickness. The inshore nets are usually 20-50 m long, 1.5 m high with a diagonal mesh size of 1-4 inches (2.5-11cm). The offshore gillnets are up to 90 m long, ~8 m high with a mesh size of 2-5 inches (5-12 cm). The weight of the multifilament (string weight) ranges from 24 to 36 lb (10.9-16.3kg) and 9 lb (4kg) for the offshore and inshore nets respectively.

Figure 2.9. Fishers removing captured fish from a gillnet (A) and gillnets being pulled off board at a landing site (B).

The system also includes a series of 1 kg lead weights fastened at the bottom and 10 – 15 floats fastened on top. A gill net team consists of 2 to 5 fishers working with two net sections attached

end to end. They spread the net by walking in opposite directions from the centre marked by an indicator buoy. To scare fish into the net, a fisher hits the water from several locations as the others circle in towards the net's central mark. Once trapped, fish become entangled in the netting by their operculum and entrap themselves further as they try to escape. The net is later hauled into the boat after several hours with its catch.

Gillnets may also be set at the surface or in mid-water to fish passively. In terms of fish targeted, gillnets target a wide variety of benthic and demersal species including emperors and lobsters. They also catch tunas and kingfishes when set in the pelagic zone. Gillnets are also well known for the large numbers of bycatch including sharks, turtles, dolphins and other marine mammals (Samoilys et al., 2011). Depending on how they are used gillnets can be categorized as either anchored or drifting. The drift nets are usually deployed from motorboats or canoes propelled by sail power mostly in the offshore waters beyond the reef or in deeper lagoons. The net is either kept connected to the boat as they drift together or set at the surface and left to drift freely with the current.

iii) Hand line/Hook and line

Hand line fishing involves the use a single monofilament nylon line with one or more steel baited hooks and without a fishing pole or rod. Occasionally a steel trace (thin wire) is used between the mainline and the hook to prevent fish or sharks biting through the nylon trace. To sink the line, stones or lead weights are attached. Reels made of polystyrene, wood or plastic are used to wind up and store lines. A variety of bait is used, including pieces of crabs, worms, octopus or squid. Hook and line is employed from a drifting or stationary canoe with 1-3 fishers who are usually

very mobile. Generally, small hooks are used for benthic species in nearshore tropical ecosystems.

A

Figure 2.10. An outrigger canoe used for fishing with hook and lines/handline (A) and simple hooks displayed by fishers (B).

During fishing, the baited hooks are left to sink just above the seabed allowing the fish to take the bait. Fish are thereafter hauled to the surface. This gear is common among children walking along the reef flat at low tide from shore. The fishing lines have a breaking strength of 30-120 lb (13.6-54.4 kg), hook size range of ~3/0 (large) to 25 (small) with either a 'j' or circle shaped hooks. Hook and line fishers mostly target snappers, groupers, mackerels and emperors (Samoilys et al 2011), although the target is usually determined by the size of the hook and line strength. They have very minimal bycatch as most species that take the bait are edible and fetch high market prices. The prefferd fishing grounds include coral reefs, reef edges/slopes, rocky areas, channels and offshore areas to ~40m maximum depth. Hand line fishing causes minimal damage to the ecosystem except when fishers cut coral heads in search of worms for bait. A significant impact to the habitat may occur when the monofilament line becomes entangled in corals and the non-biodegradable line is cut. Again when small hooks are used, there is a high possibility of capturing juveniles (Samoilys et al., 2011). This gear is fairly selective in terms of species and size for the more aggressive predatory fish (higher trophic level); however, some herbivores also take baited hooks (Samoilys et al., 2011). It also provides high quality fish since higher trophic level fish generally have high quality flesh. Catch quality will decline if not brought to shore quickly as ice is rarely used. Unwanted fish can be returned alive to the sea, but this is rare as most species are eaten or used as bait.

iv) Spears/Speargun

Spears or spearguns are 1.8–2.2 m long and made of sharpened wooden poles or tubular metal used to impale fish or blunt poles with a detachable end section of firm but flexible wire that is projected by a rubber strip. These handguns are usually accompanied with a separate steel harpoon with a sharpened tip propelled by rubber strips. Spear fishers usually snorkel with a face

mask or small goggles on the surface while hunting for the fish and invertebrates, impaling them by hand or projected from a rubber strip.
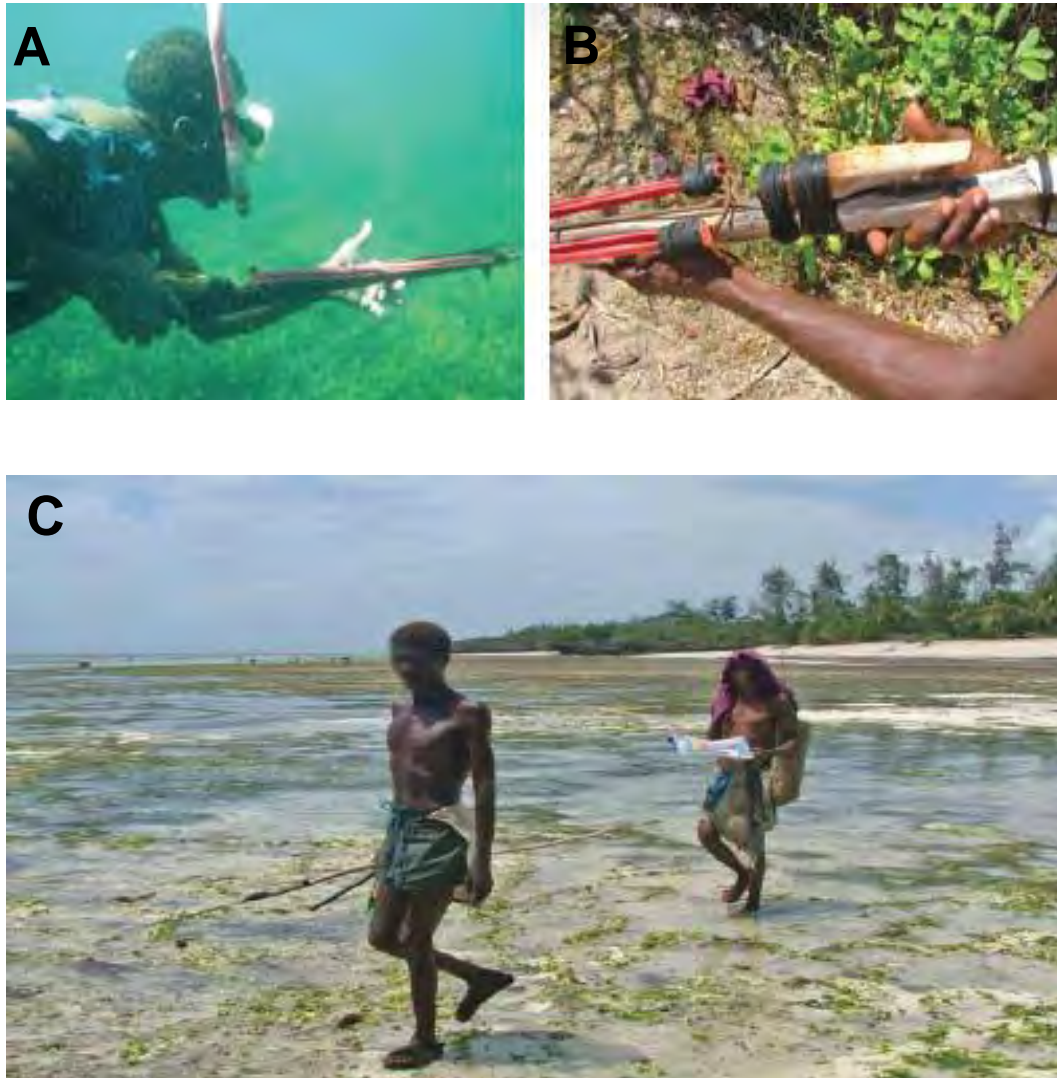
Figure 2.11. Spears in use; active fisher with snorkels targeting fish in water (A), use of spear gun fisher demonstration (B), fishers returning with harpoons "mkodzo" from a fishing trip (C).

Although this gear was declared illegal on 9th November 2001, Kenya Gazette Notice No. 7565 Vol.CIII. No. 69 this gear is still in use. Fishers mostly use this gear to target octopus, parrotfishes, groupers and lobsters. In terms of habitat, the preferred fishing grounds are shallow

waters nearshore within coral reefs. Although no bait or bycatch history is associated to this gear, spears sometimes damage corals when they miss the target. They have a lot of contact with live corals with high rates of trampling on reefs which can cause reef degradation.

However spears have the lowest juvenile capture compared to other near shore artisanal gears (Samoilys et al., 2011). Just like other artisanal gears, spear guns have a very low initial input cost for fishers. The gear is also highly selective for species. One other common spear is the harpoon (mkodzo) which is basically a steel rod sharpened at one end but without a wooden handle. Sometimes a pointed wooden pole without a metallic tip is used. These harpoons range from 1-2.5 m in terms of length. Fishers use these spears to target relatively slow moving invertebrates such as octopus as well as slow moving fishes like ray fishes and moray eels (Samoilys et al., 2011). They are mostly used in coral reef related habitats especially exposed reef flats and shallow near shore waters. All these spear like gears remain illegal.

v) Beach seines

Beach or reef seine nets are robust multifilament nets created by joining six or more small mesh (2.5 cm) nets, each 25 m long and 3–4 m deep with variable but small mesh size. The nets are supported by a float line and weighted foot rope. Coral stones or lead weights (7.5 · 6 · 1.75 cm) are tied at 0.3 m intervals along the bottom of the foot rope and a section of larger mesh netting on each wing corrals fish towards a smaller mesh size net. A team of 8- 25 fishers are used to haul the net ashore.

Figure 2.12. Fishers actively fishing with seine nets; a group of fishers pulling the seine net (A),

fisher scaring fish into the net (B), and a typical beach seine catch (C).

Once the mouth of the beach seine is ~5 m across, team members enter the enclosed area, spread out a sardine net (smaller mesh size) and scoop up the fish into the vessel or they drag the net onto the beach. The contents are dumped into a dugout canoe and the crew moves to another location to repeat the procedure. Beach seines are frequently deployed from the beach, but are also deployed further offshore using canoes and are even used on the windward side of the reef during calm periods. Dimensionally, these nets are usually 100-200 m long and 3-4 m deep. Parrotfishes, rabbitfishes, sardines halfbeaks and emperors are among the most common fishes targeted by beach seine fishers while reef lagoons, seagrass habitats and occasionally offshore reefs are the preferred habitats. Triggerfishes and surgeon fishes are among the bycatch fishes mostly captured by this gear (Samoilys et al., 2011). Beach seine nets are responsible for a high take of juvenile fish and have the highest discard rate as most of the catch is inedible or sometimes absolutely worthless. If not used appropriately, beach seines crush and dislodges corals reducing habitat topographical complexity. It is also linked to high rate of direct coral damage per unit catch and unit area. Although no operational costs or fishing skills are required for crew members, this gear was declared illegal through the Kenya Gazette Notice No. 7565 Vol.CIII. No. 69 of the 9th November 2001 due to its impacts to the ecosystem.

   vi) Fence trap

Fence traps are stationary semi-permanent traps set in the intertidal zone. They are usually made of mangrove stakes, plaited mats or palm fronds with mid ribs tied tightly together. Some usually include a barrier (utanga) made of mangrove poles but most fishers nowadays add nylon netting to increase the effectiveness and lifespan of the fence. Fence traps are set perpendicular or at an oblique angle to the shore to trap fish on the ebbing tide, particularly during spring tides. The semi-circular or spiral form at the end of the fence trap prevents the fish from escaping as the

water level falls. They are checked after 1-2 days for trapped fish are subsequently taken out using spears or simply by hand. Stakes are placed at 5 m intervals and fitted with palm fronds tied tightly together at intervals of <1 cm.

Figure 2.13. Active fence traps set permanently in the intertidal zone.

Netting type of less permanent fence traps use several pieces of 1.5 x 30 m meshed material placed at 5m intervals. These traps mostly target sardines and other fish swimming close to the beach. The fishing grounds are sheltered areas including sea grass beds, bays, small creeks, edges of mangrove and channels. Their installation cost is very low as they utilize materials that are biodegradable. Their impacts to habitat, fish populations as well as bycatch history are still undetermined.

vii) Longline

This is an introduced fishing method which is basically a single monofilament nylon line which is buoyed in a horizontal position and often anchored. A series of vertical short nylon snoods (leaders, sidelines or traces) with baited hooks are attached at intervals. They are usually deployed offshore from a motorized boat. The end of the line is set with a buoy and sometimes an anchor and the baited snoods are run out. To avoid hooks tangling underwater, snoods are spaced along the mainline at a greater distance than the snood length. The longline is set to fish for up to four hours. The main line is usually short ~200 m long while the snood lengths vary depending on depth of water although their length rarely exceeds 20 m. The snoods are usually attached at >5 m and <100 m intervals depending on water depth. Squids, milkfish, sardine, whole or sliced small fish and other artificial lures are used as bait. Long lines usually target pelagic fishes like kingfishes, sharks, swordfishes, sailfishes, marlins, tunas and dolphin fishes. They are also known to capture seabirds, whales, and turtles as bycatch (Samoilys et al., 2011). They are set near the surface in offshore waters causing minimal damage to the habitat. However, longlines catch most of the vulnerable and endangered large predators including sharks.
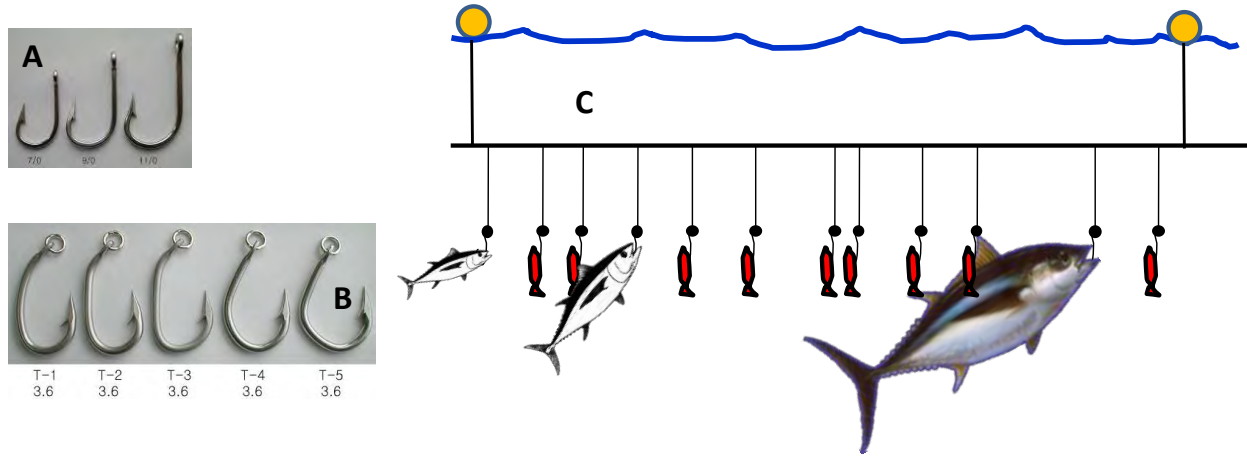
Figure 2.14. Accessories for longline fishing gear; J-shaped hooks (A), Circle hooks (B), and a complete set of a long line gear (C).

viii)   Ring net (purse seine)

A ring net is a multifilament nylon mesh that encircles a school of fish, usually in the deep sea waters outside the reef. Ring nets are usually deployed from either a single vessel or a 'mother' vessel and a smaller support vessel kept up wind or current during hauling to prevent the vessel from drifting into the net. Fishers using a ring net make use sight observations or tell-tale surface activity of the fish or birds feeding in fish to locate surface schools while sub-surface schools are detected by SCUBA divers through underwater diving or by snorkeling. The net is rapidly lowered once a school of fish is sighted and trapped fish are encircled by closing the bottom of the net using a threaded foot rope through metal rings in a process called 'pursing'. Rapid lowering of the net is aided by the use sand filled gunny bags that act as sinkers to minimize escape of fish below the net. The net is usually kept off the bottom by underwater divers to reduce net damage. Pulling the surface of the net ensures that the net ends are brought together. With a vessel crew of 15 - 40 fishers, this gear is intended for offshore pelagic fishes such as

tunas at >50 m depth but it could capture demersal fishes like snappers when deployed in depth <20 m outer reef slopes, in bays and deep lagoons while dolphins, turtles and lobsters comprise of some of its by catch (Samoilys et al., 2011).

Figure 2.15. Ring net in use; a team of fishers deploying a ring net (A) and a ring net suspended by a string of light buoys (B).

Apart from bycatch issues, ring nets can be highly damaging to bottom substrates when deployed in sea beds that contain living corals and sea grass. Corals can be affected further through increased sedimentation when sand filled sacks employed as sinkers are poured into the sea. In terms of fish populations, ring nets can remove an entire spawning aggregation when used to target aggregations of demersal fish. This could have severe implications on fish recruitment for the affected species. The small mesh sized nets could catch a high proportion of juveniles and discards with no sale value.

   ix) Prawn seine nets and Cast nets

A prawn seine is a monofilament nylon net attached to mangrove poles or wooden bars at either end operated with two long ropes fixed to each end. Sometimes, the monofilament nylon line of cast nets are made in a circular format with weights attached around the edge. These nets comprise of three parts: the upper section or net band, the middle section with conical shaped net mesh and the weighted lower section. A foot rope is used to close the net during retrieval. The net is deployed on foot by dragging it in shallow waters towards the beach. The prawn seine net is usually held open by the two mangrove poles and is towed through the water from the end ropes by 1-3 fishers while cast nets are usually operated from a canoe while drifting with one end attached. These nets may also be set or tied in mangrove channels to trap prawns as the tide ebbs. They can also be deployed from a canoe or boat or when wading onto a shoal of fish. Cast net could also be thrown or cast to spread out into a circular shape as it hits the water surface. Once the weighted edge has sunk to the bottom, its landline is pulled which closes the net into a sack to trap the fish. The net is then pulled slowly back to the fisher. These nets are usually 1.8 x 20 m long. The circular nets are of ~15-18 x 8-10 m in terms of length. Their diameter varies from 3-7 m with a typical variable weight of 6.6-11 lb (3-5 kg).

Figure 2.16. Typical models of cast nets; fishers prepare to go fishing with cast nets (A) and a cast net hanged for repairs (B).

Light bait may be used to attract the fish within the cast nets range even though they mostly target sardines sprats, silver biddy and prawns is deployed in shallow brackish waters. They have bycatch of juvenile sharks, tiger-toothed croaker, invertebrates such as crabs and lobsters

(Samoilys et al., 2011). Their fishing grounds habitats include bays and seagrass beds. The nets can also be set across channels and estuaries within the intertidal zones. Other areas are sheltered areas in mangrove creeks and coral reef lagoon habitats. If used in corraline areas, cast nets may abrade corals. When small mesh size nets are used within river mouths and intertidal zones, cast nets may potentially increase juveniles catch even though their main target species are small fish anyway.

x) Scoop net/Hand net

These are small hand operated nets held open by a metal frame with an extended metal or wooden handle. The bag net does not exceed 2 m in any dimensions but usually much less while the handle is usually not longer than 2.5 m.

Figure 2.17. Typical model of a scoop/hand net.

When using scoop nets, the net is usually drawn through the water towards the fish and then lifted up sharply to 'scoop' fish. Fishers use these nets to target mullets, sardines, prawns and lobsters mostly in shallow surface waters and rocky reef areas. Occasionally, fishers use octopus to scare lobsters out of their holes into the 'bag' scoop net. They are normally operated by one fisher, mostly from the shore on foot; or from a boat; or when diving for lobsters. Their impacts to the habitat, fish populations and bycatch are all yet to be determined. Additionally, scoop nets are used in the aquaculture sector to transfer fish from the wild into small scale aquaculture ponds and to make pond to pond fish transfers.

xi. Trolling

This gear comprises of a nylon monofilament main line or lines attached to either an artificial lure or a baited hook and towed through surface waters. Usually double or triple hooks and a wire trace are used. The troll-line is actively towed through surface waters from the stern of the vessel – either motorized boat or a sail powered canoe. Outrigger poles are used if there is more than one line in order to spread the lines widely and prevent entanglements. Occasionally down riggers are used to troll the main line and the lures at certain depth. The weight of the main line ranges from 90 -130 lb (40.8-60 kg), the preferred hook size is 3/0 hooks while lures range from ~9 cm to 14-15 cm in length. The bait used is usually artificial lures (see above Fig. 2.17b), fresh fish (squid or octopus) either whole or cut. Target species are mostly the large pelagic tunas, mackerels, kingfishes, dolphin fishes, sailfishes, marlins among others (Samoilys et al., 2011). The preferred fishing grounds include offshore waters beyond the fringing reef and sometimes in the deeper lagoons (DoF, 2008). Trolling is the preferred method of the recreational deep sea sport fishers in Kenya.

Figure 2.18. Trolling with a boat; mackerel fish used as bait (A), outboard engines used during trolling (B), rod and line gear used to troll bait behind the boat (C, D).

CHAPTER 3 – DESCRIPTION OF THE KENYAN COASTAL FISHERY

3.1. Introduction

Fisheries are spatio-temporally dynamic and characterized by transformations in stock biomass (Pauly and Watson, 2003). Consequently, monitoring these changes is essential for appropriate management actions (Tesfamichael and Pauly, 2011). In recent years, long term catch and effort data have been used for preliminary assessments of the status of populations needed for fisheries management (Caddy and Gulland, 1983). These retrospective analyses have not only been useful for historical purposes, but have also formed the basis for restorative actions, future exploitations

purposes and provided an accurate assessment of the impact of fishing activities on marine ecosystems (Scott and Clapham, 2004; Pitcher, 2005). Consequently, increased fishery knowledge resulting from these assessments has improved decision making fisheries management (Tesfamichael and Pauly, 2011). Long term trends could provide key indicators of the health of a fishery (Pauly et al., 1989) while fish lengths data could give an idea of the well being of the fishery (McCLanahan and Mangi, 2004) as fish size is closely associated fish condition factor. Besides being a useful index in the assessment of fish abundance, information on catch per unit effort (CPUE) can also assist in the determination of Maximum Sustainable Yield (MSY) and potential yield (Mbaru et al., 2011). To help minimize the problem of shifting baselines in fisheries assessment, a time series data reaching far into the past is better (Pauly, 1995). To date, various procedures have been put in place for fisheries assessment (Pauly and Watson, 2003) and those involving the analysis of fisheries catch records from various fisheries agencies or any other sources with direct or indirect clues of fisheries information have been preferred (Tesfamichael and Pauly, 2011).

Prior to this study, the Kenyan coastal artisanal fishery had not been studied well enough (Jennings and Pollunin, 1996) and as a result managers and scientists are still confronted with difficulties of choosing the right tool to manage fishery resources (Hicks and McClanahan, 2012). One of the most frequent problems encountered during fishery assessments in Kenya was the institutional funding instability of most fishery agencies. For example, the Department of Fisheries (DoF) has been collecting fisheries catch data for at least four decades including conducting fisheries Frame Surveys (FS) every two years, but recently, the 2010 FS could not be done due to financial resource shortage (Mueni pers comm.). Furthermore, effective management

of the already existing data, as well as its proper use has not been achieved. Therefore, it can be argued that the management decisions implemented by the Department of Fisheries have lacked sufficient scientific background. Quite a number of programs have also been developed to assess fish catches in the coastal region; none of which fully met the diverse multi-species and multi-fleet requirements of this artisanal reef fishery. Indeed, this may explain the reported conflicts in the status of the Kenyan artisanal fishery (Muthiga and McClanahan, 1987; Obura 2001a; DoF 2004; Fondo, 2004). Since the Kenyan coastal artisanal fishery is increasingly becoming important, there is need to conduct a more accurate and reliable description of this fishery for corrective management purposes. However, the necessity to properly manage this fishery could not be stressed further without considering the specific tools required and those that are available, often involving the analysis of the complex catch and effort data resulting from this multi-faceted fishery (Muthiga and McClanahan, 1987). The aim of this study was assimilate and explore data collected by the Department of Fisheries on Kenya's near-shore fisheries over a nine year period. A thorough analysis was performed in order to (i) describe the species composition, (ii) length frequency distribution of key species, (iii) quantify catch and effort, and (iv) get an idea of where most fishing pressure occurs. Since the data was, and is still being collected in a participatory manner that is consistent with the fisher's knowledge and practices, these findings fit well in the development of modern ecosystem based approach to fisheries management interventions.

3.2. Materials and Methods

The demographic characteristics and spatio-temporal dynamics of the Kenyan coastal fishery were assessed using data collected during several dedicated short-term surveys and from the

long-term Frame Surveys (FS) conducted by the Department of Fisheries. An explanation on how each criteria/variable was enumerated/calculated is given below.

3.2.1. Fisher demographics and diversity

For the purpose of this assessment, a fisher was simply defined as any person who actually goes to the waters to fish (DoF, 2008). A dedicated two-month survey (February/March 2010) was conducted in eight major fishing villages selected from the four coastal regions to assess the demographic profile of the fishery. In order to capture higher diversity of fishers and boost the robustness of the results, interviews were carried out during *Kasi kazi*-North East Moonsoon (NEM), which is the main fishing season at the coast. During this period the ocean is calm offering favorable conditions even to artisanal fishers who do not have powerful fishing crafts. About 30 to 40 fisher surveys per landing site were conducted depending on the population of the fishing village. Selection of active fishers was random based on a list provided by the local fisheries representatives. A systematic sampling design at the landing sites was adopted where a sampling fraction of every i^{th} fisher (e.g. 2nd , 3rd , 4th) selected was determined by dividing the total fisher's population per site by the sample size (Henry, 1990; De Vaus, 1991).

3.2.2. Gear sampling

As explained in Chapter 2, a fishing gear was defined as any device used to capture fish from the water. It may be a net, a hook, any type of trap, be it traditional or modern, plus all the accessories that go with it. Fishing gears recorded included gillnets, longlines, hook and lines, beach seines, prawn seines, reef seines, cast nets, hand lines, monofilament, trawl nets, scoop nets, ring nets; trammel nets, trolling lines, spear guns, harpoons and baskets traps, fence traps. Although the fishery was found to be multi-gear, five main gears were considered for analysis.

These were spear guns locally known as (bunduki), basket traps (malema), hook and lines (mshipi), gill nets (jarife) and beach seines (juya). The rest of the gears were all grouped in the 'other category'. Spatial and temporal data from the Frame Surveys enabled the calculation and comparisons of gear abundance and percent catch contribution for the four coastal regions over the nine-year study period.

3.2.3. Species and size composition of catch

Analysis of the data collected during the Frame Surveys was performed to produce relative abundance (expressed as a percentage) and size structure by gear, year and region. Numbers of individuals per species caught and recorded on a wet-weight basis enabled the calculation of the abundance proportions. One-way ANOVA comparisons were used to test for differences in mean lengths using the each of the three fixed factors i.e. year, gear and region. When overall significance was found then pair-wise comparisons were computed using Tukey–Kramer honest significant differences (HSD) test to determine which gears were different (Sall et al., 2001). Changes in fish size in terms of mean lengths (average length per species), by gear, over the nine-year period and across the four coastal regions was also presented. To investigate these spatial and temporal changes in species composition and size structure, the five most dominant species that represented over 75% of the total catch landed were selected for analysis from the entire list of species; all reported variances in the means being standard errors (SE).

3.2.4. Catch, effort and catch per unit effort (CPUE)

Total fishing effort was calculated for each day as E_{td} following the formula: $E_{td} = E_m/W_m$, where E_m is the mean number of fishers recorded by each month and W_m represent the number of survey days in that month. Individual fisher effort (E_i) was calculated as the absolute duration (i.e. the difference between a fisher's departure and arrival time from the landing site) of each outing (in hours). Total daily fishing effort (E_{td}) at each landing site was calculated by taking the mean effort of all interviewed fishers (n) and multiplying it by the total number of fishers (N) for the ith day, and expressed as follows:

$$E_{td} = \left(\frac{\sum_{i=1}^{n} E_i}{n} \right) \times N \quad \text{[Equation 1]}$$

Monthly effort was then calculated by summing the total daily effort values for each day that fishing took place during the ith month. Annual effort was calculated by summing all monthly (Jan – Dec) effort values for a given year. To enhance precision in the results, the study utilized the actual numbers of fishers utilizing a particular gear to calculate the total effort per gear type.

The catch per unit effort (CPUE) per gear type was calculated using:

$$CPUE = \frac{\sum_{i=1}^{n} \frac{C_i}{E_i}}{n} \quad \text{[Equation 2]}$$

, where C_i is the observed catch as number or mass (in kg) of fish caught by the ith group of fishers interviewed, E_i is the observed fishing effort for the ith group of fishers interviewed, and n is the number of fisher outings recorded throughout the survey period. The adopted unit for CPUE was kg.fisher^{-1}hour^{-1}. Total catch (C_{total}) for each year (or each survey area) was calculated by multiplying total estimated effort (expanded version of Equation 1) by overall CPUE (Equation 2).

3.3. Results

3.3.1. Fisher demographics

During the two month survey, which included 22 survey days, a total of 95 fishers from the artisanal sector were interviewed. The vast majority of participants (92.6%) were male ranging from 32 to 40 years old (mean = 37.4 years) (Table 3.1). The majority of participants (96.8%) were local residents living in the nearby villages adjacent to the fish landing site, while 2% were from other areas of Kenya and a further 1.2% originated from Tanzania. The mean number of years of formal education of all respondents was 8-years, and ranged from 6-years to 9-years.

Majority (66.3%) of participants had only a primary education, 17.9% had secondary education, 1.1% college education, while 14.7% had no education at all. As household heads, fishers had on average five dependents although this ranged from three to seven (Table 3.1) while the level of

experience (years fishing) was 16 years across all sites. From the list of names, Islam was the dominant religion overall for all sites, but Christian were majority in some individual sites.

3.3.2 Fishery access mode and gear type utilization

Most of the fishers accessing the Kenyan coastal fishery used canoes propelled by sail power (15.2 %), or paddle (39.4%) while only a few (9.8%) used motorized boats (Table 3.2). Most significant is that 31.3% of the participants were foot fishers who claim to go fishing without any equipment other than a pair of snorkels and masks.

Table 3.1. Demographic characteristics of the Kenyan artisanal fishery, including gender, mean age, average number of years of formal education, mean number of dependents the mean number of years active as a fishers (experience) and nationality (origin). Values given as Mean±SE (SE = Standard Error).

Categories	Bofa	Kilifi central	Kuruwitu	Mnarani	Roka	Takaungu	Uyombo	Wesa	All sites
Male (%)	75	100	92.3	100	88.9	84.6	100	100	92.6
Age (yr)	38.6±11.1	39.0±11.3	39.4±10.9	38.1±11.0	39.3±13.1	33.4±9.3	41.0±11.8	31.4±9.1	37.4±3.8
Education	5.7±1.3	8.0±1.0	8.8±0.5	7.0±1.3	7.6±1.6	8.0±0.8	7.5±0.7	7.5±1.2	7.5±0.4
Dependants	4.8±0.9	3.2±0.5	5.8±0.9	5.3±1.2	4.6±0.7	3.9±0.9	6.5±1.0	5.4±0.6	4.9±0.3
Fishing experience	14.9±3.6	20.8±3.2	18.3±3.2	15.6±3.0	13.0±1.9	16.0±2.6	16.8±2.4	12.8±2.4	16.1±1.0
Migratory (non-local) (%)	0	0	15.4	0	0	0	0	8.3	3.2

Table 3.2. Average number of crew size, mean percentage use of various propulsion methods from the different site.

Location	Average Crew Size					Propulsion Methods (%)			
	Canoe (%)	Dhow (%)	Motorboat (%)	Swimming (%)	.	Engine	Paddle	Sail	Nil
Bofa	13.6(54.5)	0.0	0.0	0.0	.	0.0	50.0	0.0	50.0
Kilifi	3.0(33.3)	12.3(33.3)	3.0(33.3)	0.0	.	58.3	25.0	16.7	0.0
Kuruwitu	3.3(30.0)	5.5(20.0)	3.0(20.0)	1.0(10.0)	.	15.4	38.5	0.0	46.2
Mnarani	2.0(66.7)	3.0(16.7)	3.0(16.7)	0.0	.	25.0	66.7	0.0	8.3
Roka	6.5(22.2)	0.0	0.0	1.0 (75.0)	.	0.0	16.7	0.0	83.3
Takaungu	2.2(38.5)	5.0(7.7)	0.0	1.0(15.4)	.	7.7	61.5	0.0	30.8
Uyombo	2.6(38.5)	10.8(30.8)	0.0	0.0	.	7.7	53.8	7.7	30.8
Wesa	3.6(91.7)	4.0(8.3)	0.0	0.0	.	0.0	0.0	100	0.0
All sites	4.3(47.8)	8.8(14.1)	3.0(9.8)	1.0(12.6)	.	14.1	39.4	15.2	31.3
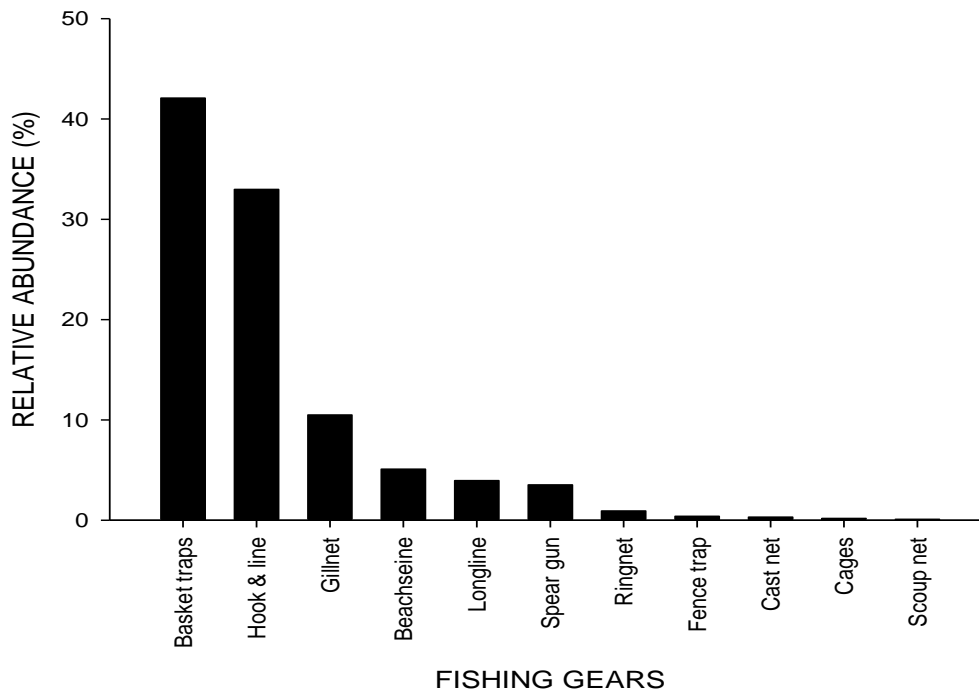
Figure 3.1. Gear type utilization in the Kenyan coastal fishery between 2001 and 2009.

A total of 11 legitimate gears were observed in the coastal artisanal fishery, with basket traps being the most popular (42%) fishing gears across the four regions (Fig. 3.1). Fence traps, cages, cast nets and scoup nets accounted the least with less than 1% altogether (Fig. 3.1). Regionally, there were distict patterns observed (Fig. 3.2). Fishers along the Mombasa-Kilifi area predominatly used beach seines (43.3%) while those in Diani-Chale, Malindi-Ungwana bay and Funzi-Shirazi bay predominaltly used spearguns (33.6%), gillnets (61.8%) and basket traps (45.3%), respectively (Fig. 3.2). A higher diversity of gears was found in Funzi-Shirazi bay where a total of 11 gears were used (Fig. 3.2d). Malindi-Ungwana bay had the lowest diversity with only five gear types used (Fig. 3.2a).
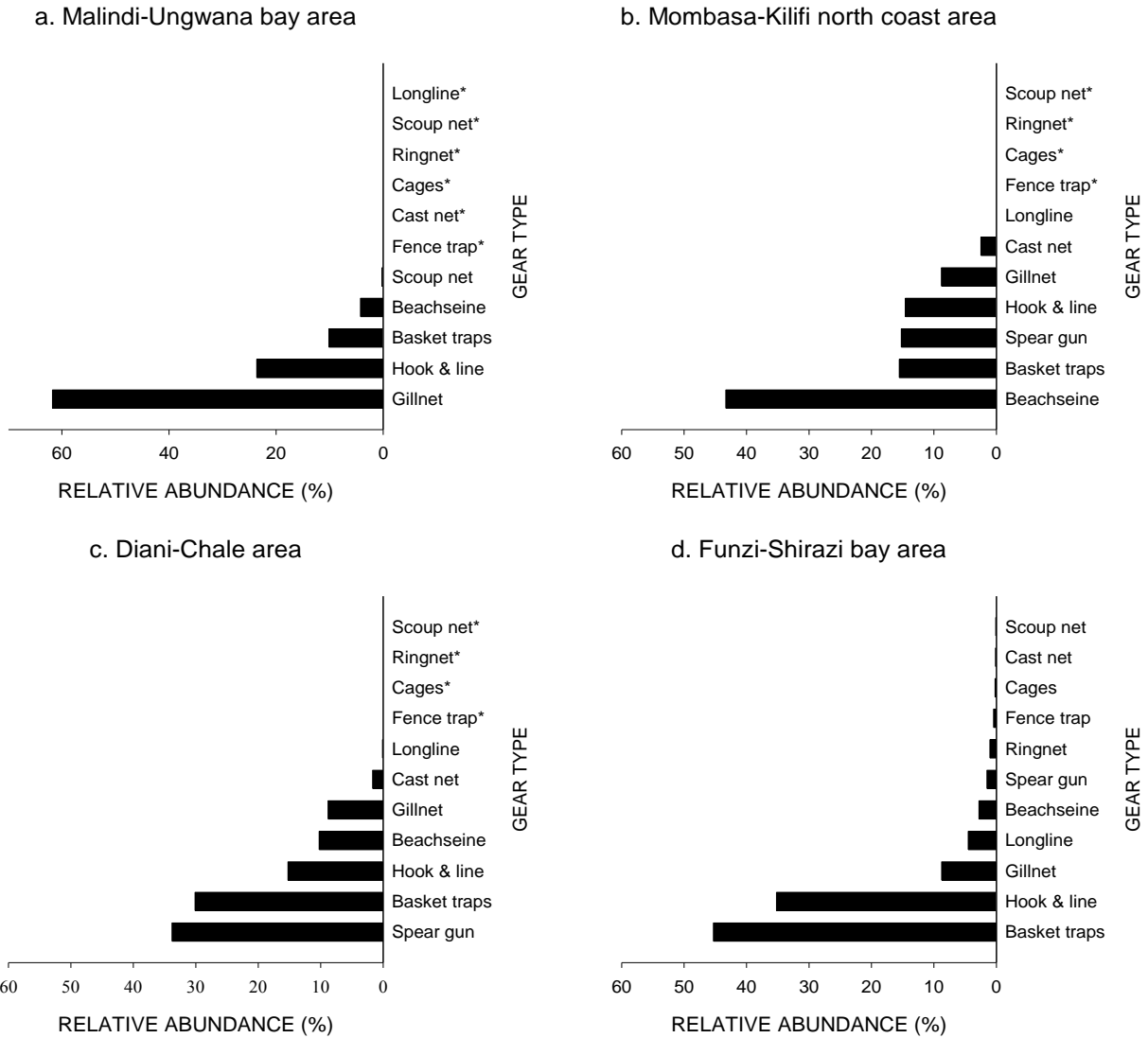
Figure 3.2. Gear type utilization in the four coastal regions, Malindi-Ungwana bay (a), Mombasa-Kilifi (b), Diani-Chale (c) and Funzi-Shirazi bay (d), between 2001 and 2009 (*denotes gear absence in the region).

Apart from the dominating beach seines along the Mombasa-Kilifi area (43.3%), other gears (basket traps, spearguns and hook and line) had almost equal dominance (~15%), while gillnets (8.8%), cast nets (2.5%) and longlines (0.04%) remained unpopular in this region (Fig. 3.2b). An almost equal proportion of basket traps (30.1%) and spearguns (33.8%) was also observed in

Diani-Chale (Fig. 3.2c) and similarly in Funzi-Shirazi bay for hook and lines (35.2%) and basket traps (45.3%) (Fig. 3.2d). Apart from Malindi-Ungwana bay, the distribution of gillnets by region during the surveys showed a constant popularity of ~9% (Figs. 3.2). Ring nets, with slightly over 1.0% popularity were only observed in Funzi-Shirazi bay (Fig. 3.2d).

3.3.1.2. Trends over time

Apart from gillnets which fluctuate without a clearly defined trend, a general declining trend for most gear types was observed since 2004 (Figs. 3.3). There was a sharp increase in the use of gillnets from 2008 (Fig. 3.3b), while the rest of the gears showed substantial reductions in terms of abundance since 2003 (Figs. 3.3). Over the nine year period gillnets were highly used in 2009 (Fig. 3.3b). Although beach seine remain illegal in Kenyan marine waters, its use was still rampant (Fig. 3.3d). During the nine year period, beach seines increased steadily from 2001 until 2003, after which they started to decrease (Fig. 3.3d), but since 2008, this illegal gear showed a slow increasing trend again (Figs. 3.3d). Nonetheless, beach seine is not the only illegal gear; speargun which was also banned alongside beach seines in 2001 was also seen to be used throughout the study period (Fig. 3.3e). Unlike beach seines, spearguns have continued to decline substantially since 2001 (Fig. 3.3e). Hook and lines were also used throughout the study period (Fig. 3.3c). The highest number of hook and lines (29.4%) were observed in 2003 with the least (1.7%) in 2009 (Fig. 3.3c). They decreased steadily from 2003, with a doubling increase in 2004 to 2005 (Fig. 3.3c). Basket traps on the other hand have shown a declining trend since 2002 where 20.4% fishers used them (Fig. 3.3a). From 2006, less than 10% of the local fishers use basket traps with only 4% recorded in 2009 (Fig. 3.3a). The total number of gears designated as others (shark nets, scoop nets, harpoons, ring nets, longlines, cast nets, fence traps, cages and handpicking) also declined substantially (Fig. 3.3f). Interestingly, gear abundance for all the

gears encountered increased steadily after the inception of the continuous catch assessment (CAS) surveys in 2001(Figs. 3.3).
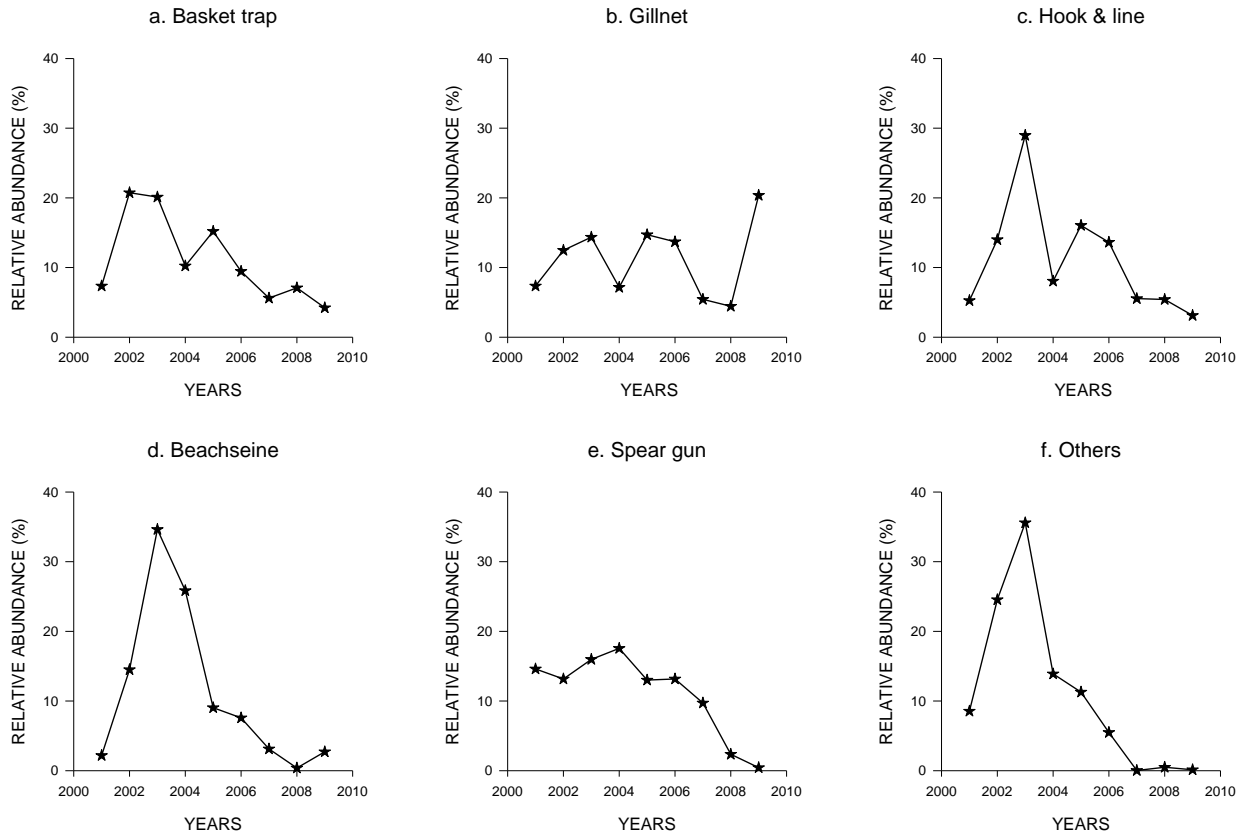
Figure 3.3. Trends in the utilization of different gear types, basket trap (a), gillnet (b), hook and line (c), beach seine (d), spear gun (e) and others (f), in the Kenyan coastal fishery between 2001 and 2009.

3.3.1.3. Catch – species composition

The Kenyan coastal artisanal fishery comprised of at least 365 species representing about 130 families. Due to the high number of species encountered, analysis presented on species composition was based on the top 40 species, with the list of the top 40-species presented in Table 3.3. These 40-species were represented by 17 families with Lethrinidae being the most

diverse family (6 species), while Psettodidae, Siganidae, Sphyraenidae, Clariidae and Chirocentridae had one species each. Siganidae represented by only one species *(Siganus sutor)* was the most dominant (38.7%) in terms of weight, while Gerridae and Psettodidae were the least dominant families. Of the 52,052 fish captured, five species (*Paupeneus macromemus, Leptoscarus vaigiensis, Lethrinus mahsena, Lethrinus lentjan, Siganus sutor*) from three families (Scaridae, Lethrinidae, Siganidae) respectively made up 75% of the catch in terms of weight.

Table 3.3. Top 40-species captured in the Kenyan coastal artisanal fishery.

Family	Species name	Species mean length (cm)	Family mean length (cm)	Relative abundance (% of numbers)	
				Species (%)	Family (%)
Acanthuridae			31.9		2.2
	Acanthurus nigrofuscus	15.3		0.2	
	Acanthurus triostegus	15.4		0.6	
	Naso brachycetron	41.1		1.4	
Carangidae			68.9		3.2
	Caranx hippos	41.5		0.3	
	Caranx ignobilis	80.4		2.4	
	Caranx sexfasciatus	40.4		0.2	
	Decapterus macarellus	27.5		0.3	
Clupeidae			9.1		1.7
	Pellona ditchela	14.3		0.2	
	Sardinella longiceps	8.6		1.6	
Gerridae			17.2		0.2
	Geres oyena	17.2		0.2	
Haemulidae			26.5		0.7
	Plectorhinchus gaterinus	26.4		0.4	
	Plectorhincus flavomaculatus	26.7		0.3	
Labridae			21		0.9
	Anampses caeruleopunctatus	19.1		0.2	
	Cheilinus trilobatus	19.6		0.3	
	Cheilio inermis	23		0.4	
Lethrinidae			22.8		28.2

Table 3.3. cont

Family	Species name	Species mean length (cm)	Family mean length (cm)	Relative abundance (% of numbers) Species (%)	Relative abundance (% of numbers) Family (%)
	Lethrinus crocineus	28.9		1.2	
	Lethrinus elongatus	25.4		0.3	
	Lethrinus harak	24		5.3	
	Lethrinus lentjan	21		7.3	
	Lethrinus mahsena	28.1		4.5	
	Lethrinus nebulosus	20.1		9.7	
Lutjanidae			22.7		4.2
	Lethrinus lentjan	36			
	Lutjanua lutjanus	18		0.2	
	Lutjanus campechanus	24		2.5	
	Lutjanus fluviflamma	17.6		1	
	Lutjanus sanguineus	26.7		0.6	
Mullidae			27.1		4
	Parupeneus barberinus	19.6		0.3	
	Parupeneus macronemus	27.7		3.7	
Psettodidae			43.4		0.2
	Psettodes erumei	43.4		0.2	
Scaridae			24.6		10.1
	Calotomus carolinus	18.1		0.6	
	Leptoscarus vaigiensis	25.1		9.3	
	Scarus ghobban	18.8		0.2	
Scombridae			43.8		3.0
	Rastrelliger kanagurta	24.6		1.9	
	Sarda orientalis	54.7		0.8	
	Thunnus albacares	57.8		0.4	
Serranidae			29.6		0.8
	Epinephelus andersoni	29.6		0.8	
Siganidae			27.8		38.7
	Siganus sutor	27.8		38.7	
Sphyraenidae			36.1		1.1
	Sphyraena barracuda	36.1		1.1	
Clariidae			34.8		0.3
	Clarias meladerma	34.8		0.3	
Chirocentridae			52.3		0.3
	Chirocentrus nudus	52.3		0.3	

Consequently, this study focused on these five species and explored their fine scale parameters including abundance (Figs. 3.5 and 3.6), mean lengths (Figs. 3.7, 3.8 and 3.9), total catch estimates (Figs. 3.13 and 3.14) as well as the CPUE indices (Fig. 3.16).

Among these five dominant species, the shoemaker spinefoot / rabbitfish (*Siganus sutor*) was the most abundant species, which was consistently captured in Malindi-Ungwana bay (68%), Funzi-Shirazi bay area (50%), along the Mombasa-Kilifi area (31.3%) and in Diani-Chale (28.3%) (Figs. 3.5).
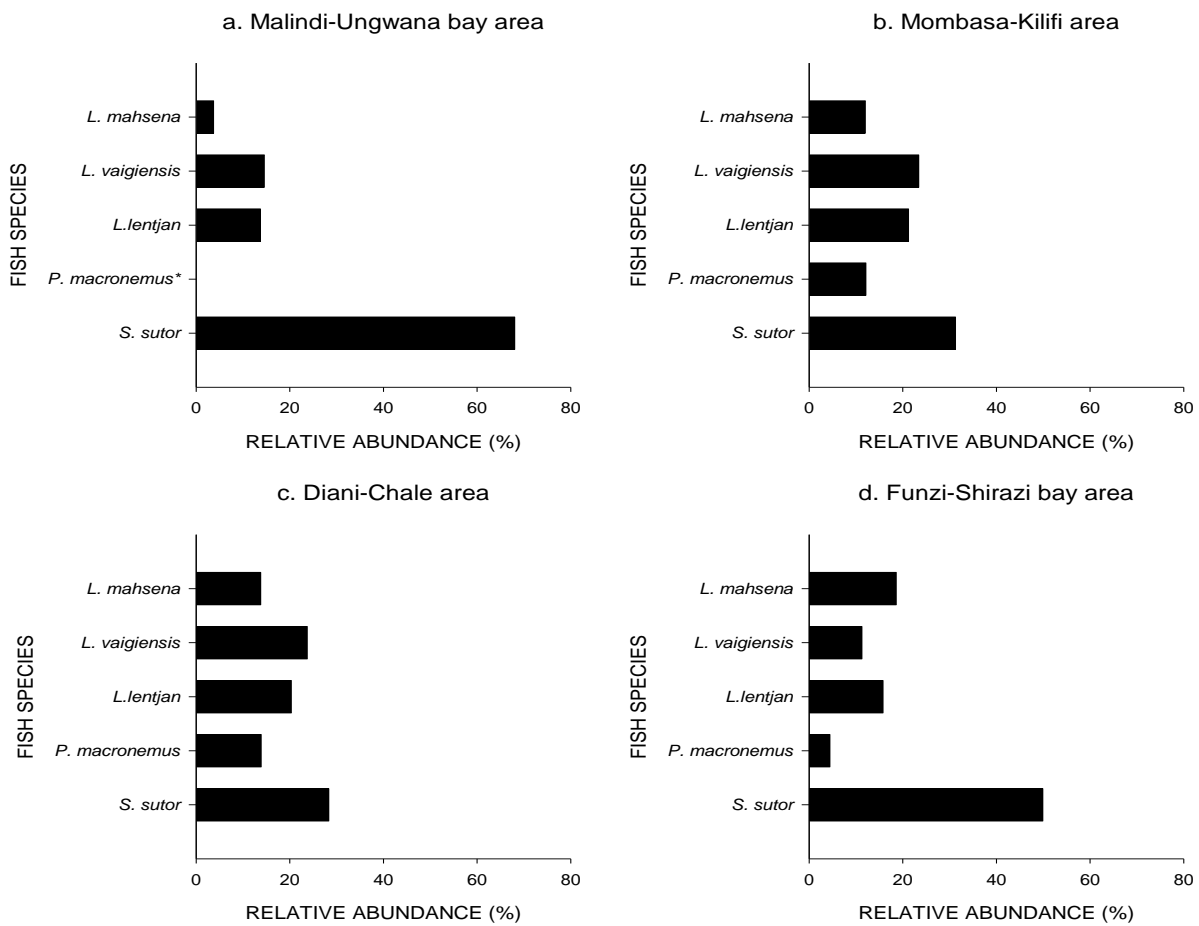
Figure 3.5. Relative abundance of the five most dominant species in the four coastal regions, Malindi-Ungwana bay (a), Mombasa-Kilifi (b), Diani-Chale (c), Funzi-Shirazi (d), between 2001- 2009.

Although *P. macronemus* was one of the dominant species, it was notably missing from the Malindi-Ungwana bay (Fig. 3.5a). It is within the same region that *S. sutor* had the highest abundance of about 68% (Fig. 3.5a). There was little overlap in the species abundance along the Diani-Chale area, with most of the species contributing between 15% to 30% of the total catch (Figs. 3.5c).
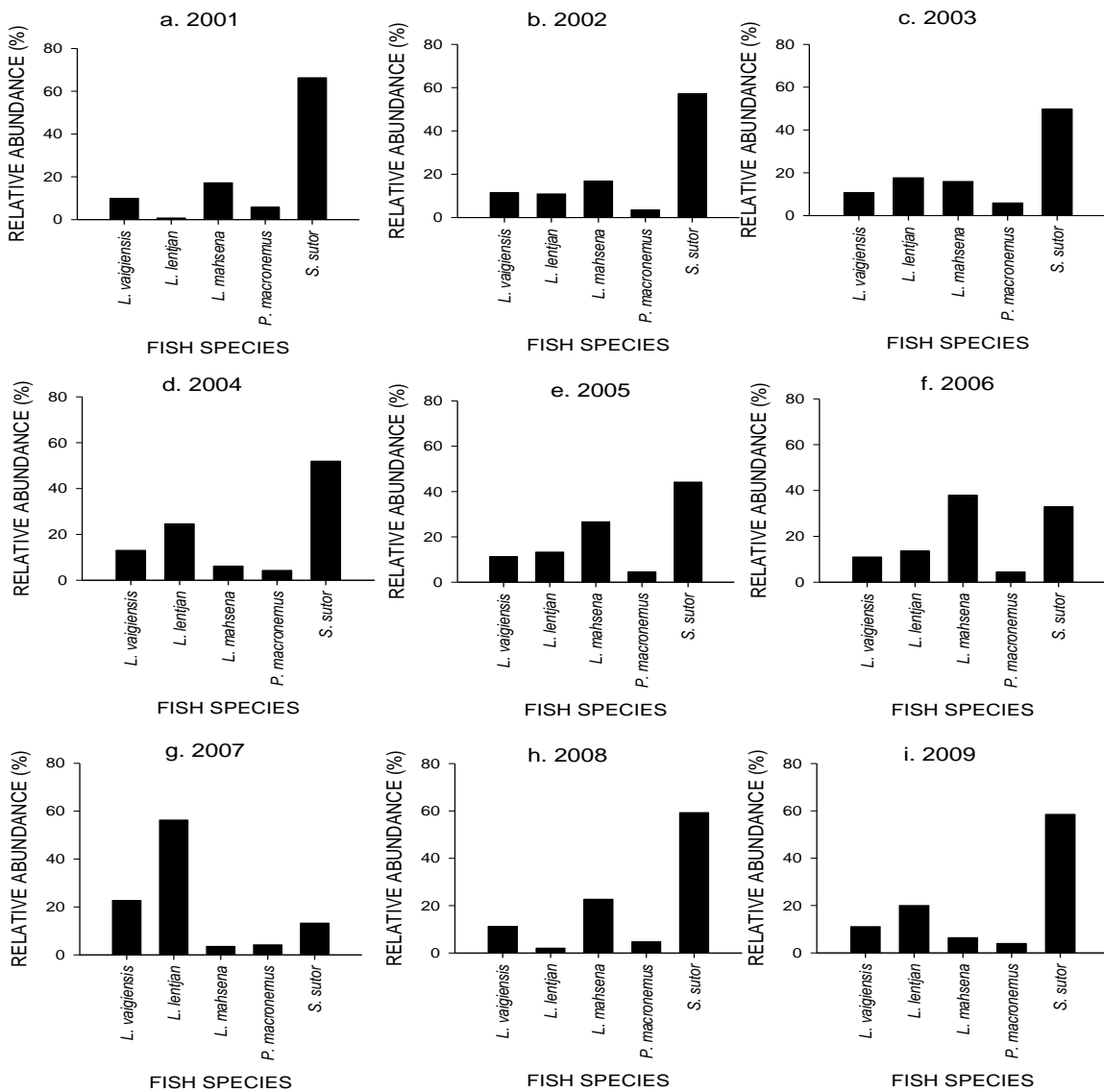
Figure. 3.6. Temporal abundance patterns of the five most dominant species in the Kenyan artisanal fishery over the 9-year, 2001 (a) – 2009 (i), study period.

S. sutor was consistently dominant over the study period (Figs. 3.6) with the maximum percent dominance (66.3%) observed in 2001 and the minimum (13.2%) in 2007 (Figs. 3.6). In 2007 when the catch numbers for *S. sutor* were at their lowest point (13.2%), there was a substantial increase (56.3%) from (18%) from the previous year for *L. lentjan* (Figs. 3.6) during the same year. Opposite trends were observed in almost all the other years where an increase in dominance for *S. sutor* suppressed the dominance of *L. lentjan* and vice versa where any decrease in *S. sutor*, Lethrinids flourish (Figs. 3.6). Among the five species analyzed, *P. macronemus* was generally the least abundant over the nine year period and therefore chronologically ranked fifth behind *L. vaigiensis, L. lentjan, L. mahsena* and *S. sutor* (Fig. 3.4; 3.6).

3.3.2. Catch – size composition

Gear-wise, beach seines recorded the lowest mean length (20.9±0.2 cm) among the 5-main gears investigated while gillnets recorded the highest (34.2±0.3 cm) (Fig. 3.7). Although basket trap was the most dominant gear in this fishery, the mean length of species caught by this gear (26.2±0.1 cm) were just slightly above the two illegal gears, beach seines (20.9±0.2 cm) and spear guns (22.8±0.2 cm) (Fig. 3.7). Mean lengths for fish captured by beach seines and spear guns were significantly smaller ($p<0.05$) compared to fish captured by other gears described in Table 3.3. Conversely, fish captured in gillnets were significantly larger ($p<0.05$) compared to other gears (Table 3.4). Interestingly, no significant difference ($p>0.05$) was observed between catches from the two illegal gears (beach seines and spearguns) in terms of their mean length (Table 3.4).

Table 3.4. Results of the one-way ANOVA and a pair-wise comparison (Tukey–Kramer HSD) of each of the gears for the mean length (X, $P < 0.05$; NS, not significant).

[Fishing gears]	Basket traps	Beach seine	Gillnet	Hook and line	Others	Spear gun
Basket traps	-	X	X	NS	NS	X
Beach seine	X	-	X	X	X	NS
Gillnet	X	X	-	X	X	X
Hook and line	NS	X	X	-	NS	X
Others	NS	X	X	NS	-	X
Spear gun	X	NS	X	X	X	-

Spatially, the mean lengths of fish in Diani-Chale ranged from 20.5±0.5 cm (speargun) to 18.3±0.2 cm basket traps (Figs. 3.8). In Funzi-Shirazi bay, most of the species captured by almost all the six-gears had a higher mean size compared to the other regions particularly catches from gillnets which recorded the highest mean length 37.2±0.4 cm (Fig. 3.8d).
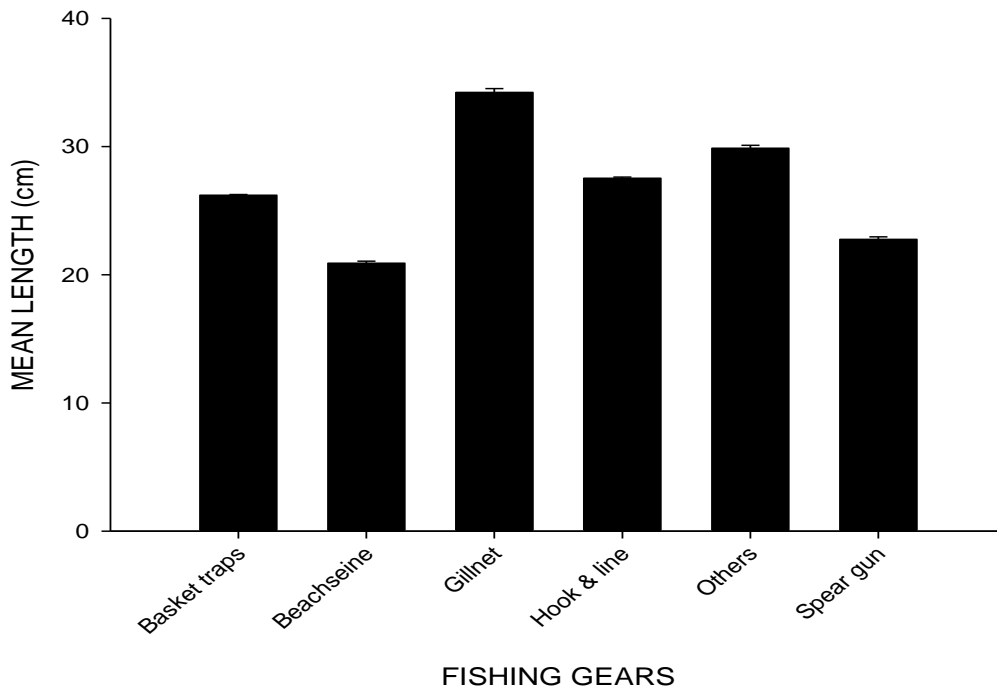
Figure. 3.7. Mean length (±SE) for the five main gear types over the 9-year study period.

Beach seines yet again captured the lowest mean size 23.8±0.2 cm even in this region (Fig. 3.8d). Mombasa Kilifi area where beach seining was more prominent, the highest mean size was 19.7±0.4 cm (spear gun) just ~2 cm above the 17.4±0.3 cm for beach seines while the lowest mean length 17.4±0.3 cm was recorded from the combination of 'other' gears (Fig. 3.8b). Malindi-Ungwana bay showed a substantial difference in terms of mean length per gear with hook and lines recording the highest 30.2±1.1 cm while basket traps recorded the lowest mean length 22.3±0.4 cm (Fig. 3.8a).
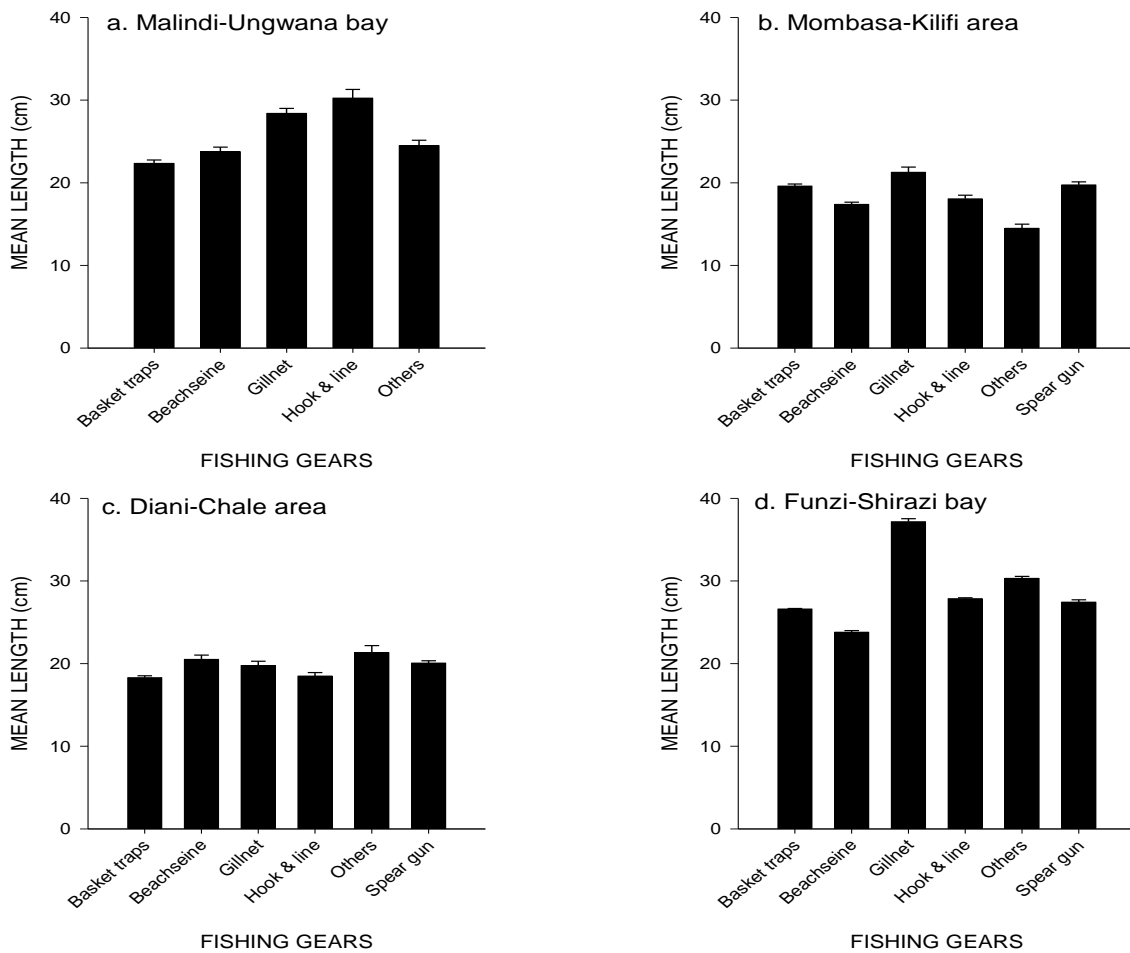
Figure. 3.8. Mean length (±SE) of the five most dominant species in the four coastal regions, Malindi-Ungwana bay (a), Mombasa-Kilifi (b), Diani-Chale (c) and Funzi-Shirazi bay (d), over the 9-year period.

The size structure over time for the most dominant species did not show any major changes, although higher mean sizes were observed in 2001 and the lowest in 2006 (Fig. 3.9) showing some overall reduction in fish sizes during the six year period (Fig. 3.9). For the 5-species, the highest mean size 31.6±0.4 cm was observed in 2002 (*P. macronemus*) and the lowest 18.6±0.2 cm in 2005 for *L. lentjan* (Fig. 3.9). Generally, the 2-Lethrinid species had the lowest mean lengths compared to the other 3-species (Fig. 3.9). In the last two years of sampling 2008 and 2009, the mean length of *P. macronemus* remained above 30 cm, while *L. vaigiensis* had the lowest mean length 20±0.3 cm in 2009 (Fig. 3.9). Mean length of fish captured in 2001 and 2002 were significantly higher (p<0.05) compared to the rest of the other years (Table 3.6). Significant smaller fish were captured in 2004 and 2007 with clear significant differences observed when their lengths were compared to the rest of the other years (Table 3.6).

Table 3.5. Results of the one-way ANOVA and a pair-wise comparison (Tukey–Kramer HSD) of each of the years for mean length (2001-2009).

[Years]	2001	2002	2003	2004	2005	2006	2007	2008	2009
2001	-	NS	X	X	X	X	X	X	X
2002	NS	-	X	X	X	X	X	X	X
2003	X	X	-	X	NS	NS	X	NS	NS
2004	X	X	X	-	X	X	NS	X	X
2005	X	X	NS	X	-	NS	X	NS	NS
2006	X	X	NS	X	NS	-	X	NS	NS
2007	X	X	X	NS	X	NS	-	X	X
2008	X	X	NS	X	NS	NS	X	-	NS
2009	X	X	NS	X	NS	NS	X	NS	-

X-difference significant (p<0.05), NS-difference not significant

No significant differences were however noted between catches of 2001 and 2002 (p>0.05), this was similarly observed when catches in 2004 and 2007 were compared in terms of their mean lengths (Table 3.6).
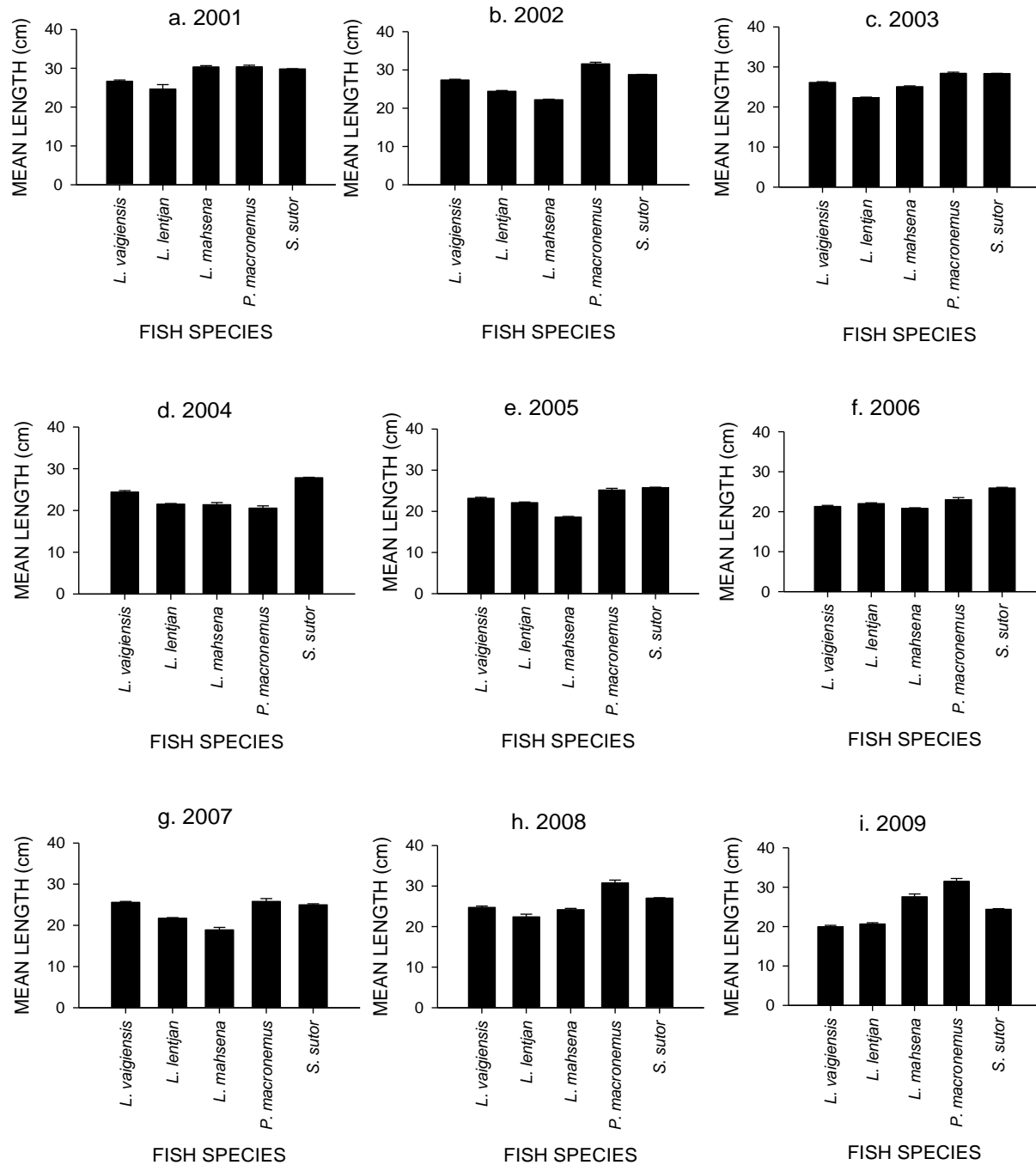
Figure 3.9. Mean length (±SE) per species for the five most dominant species over the 9-year, 2001 (a) – 2009 (i), study period.

In terms of gear type, beach seines again recorded the lowest mean sizes compared to the other gears. This was more prevalent especially for *P. macronemus* (Fig. 3.10). Although the overall trends did not show substantial differences, slight differences were noted; for example the highest mean size 28.1±0.8 cm in gillnets was observed for *P. macronemus* (Fig. 3.10e) while the lowest 14.9±0.5 cm was observed for the same species in beach seines (Fig. 3.10d). The results of the total length measurements for the 5-dominant species per gear are shown in (Fig. 3.10).
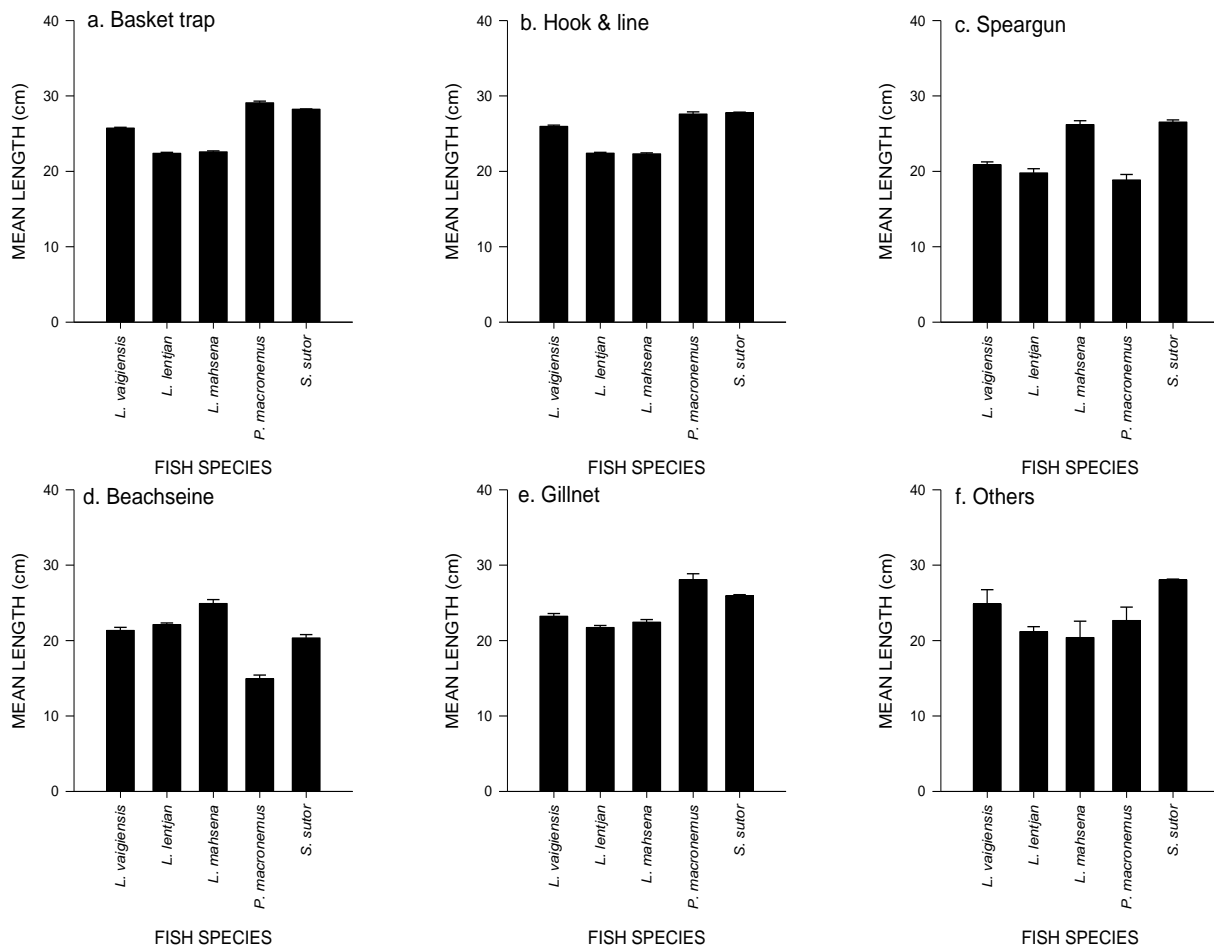
Figure 3.10. Total length measurements for the five most dominant species per gear type, basket trap (a), hook and line (b), speargun (c), beach seine (d), gillnet (e) and others (f).

3.3.3. Total effort and catch

The total estimated annual catch per year was derived from the total enumeration of all fishers. Actual numbers of all fishers were derived from the Fisheries Department Frame Survey (FS) statistics conducted along the coast in every two years. A three year average window was used to estimate the total number of fishers for each consecutive year. From the analysis, results showed fluctuating trends over the 9-year period (Fig. 3.11). The highest catch (~26,000 metric tons) came in 2001 and the lowest (~15,000 metric tons) in 2005 (Fig. 3.11). Additionally, after the lowest catches recorded in 2005, catches started to increase steadily up to (~22,000 metric tons) in 2007 when they started to decrease again to (~21,000 metric tons) in 2008 and (~17,000 metric tons) since 2009 (Fig. 3.11).
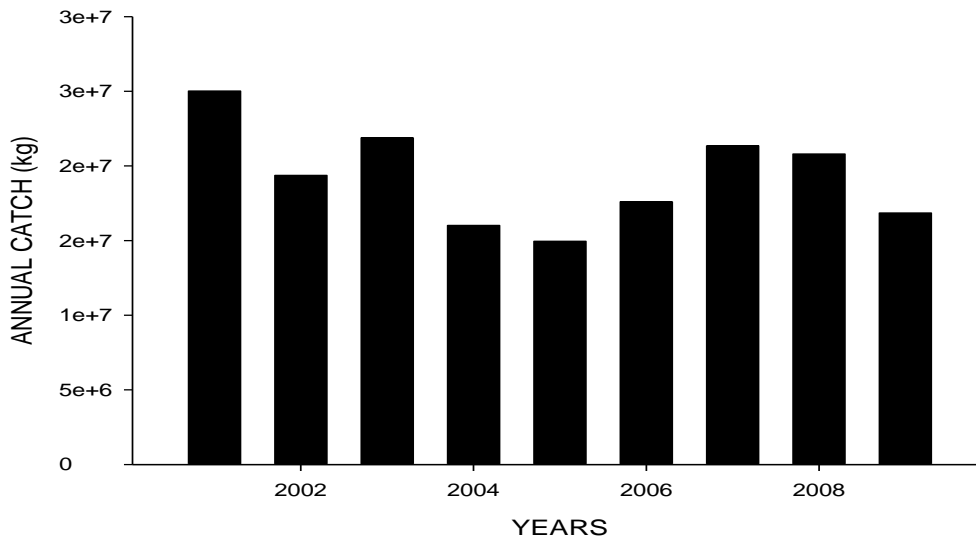
Figure 3.11. Total estimated annual catch over the nine year period.

The highest number of fishers was observed in 2008 while 2009 recorded the highest (4.8±2.3) mean number of hours per outing (Table 3.6). In 2002, only a mean number (2.3±1.3) hours were

spent by fishers during their fishing operations which was the lowest over the period of study (Table 3.6).

Table 3.6. Fishers effort from the landing sites over the 9-year study period.

Years	Total number of fishers (mean=10373)	Number of fishers per outing per boat (mean=2.7±2.1 S.D)	Number of hours per outing per boat (mean=4.3±1.8 S.D)
2001	9973	2.4±1.4	4.6±2.2
2002	10018	2.3±1.3	4.5±1.9
2003	10783	2.8±2.2	4.5±1.9
2004	9017	2.7±2.3	4.7±1.9
2005	9636	2.9±2.5	3.9±1.4
2006	10254	3.2±2.5	3.8±1.2
2007	11166	3.0±2.7	4.0±1.1
2008	12077	2.9±1.5	3.9±0.8
2009	10430	2.6±1.1	4.8±2.3

While comparing the estimated total catch separated to regions, the total annual catch from the two bays was substantially higher compared to the other two regions (Fig. 3.12).
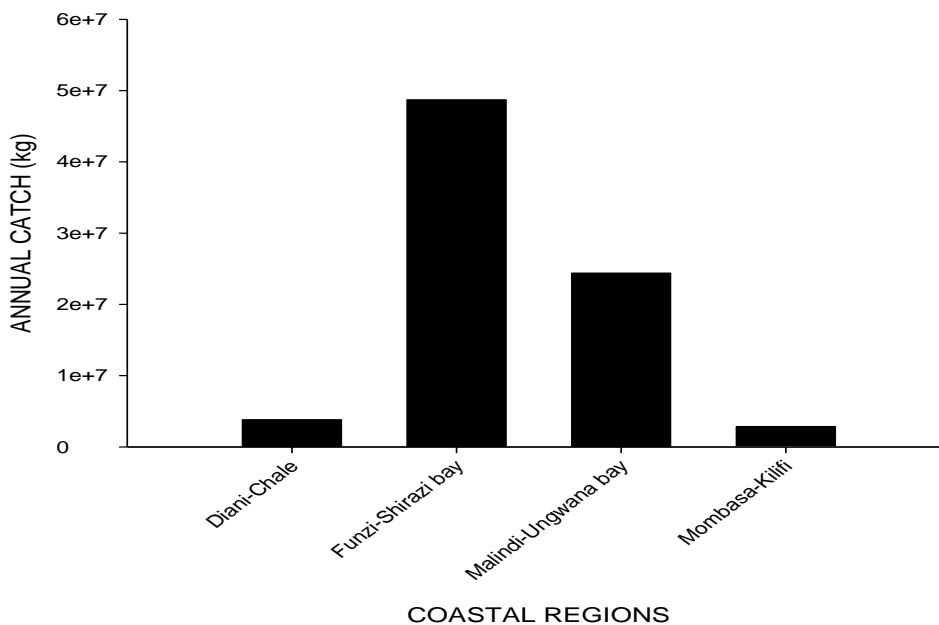
Figure 3.12. Estimated total annual catch per region (*e+{number} represents zeros avoided).

Funzi-Shirazi bay (~49,000 mt) and Malindi-Unwana bay (~25,000 mt) displayed the highest annual catch respectively (Fig. 3.12). The Mombasa-Kilifi area had the lowest catch (~3,000 mt) followed by the (~4,000 mt) Diani-Chale area (Fig. 3.12). In terms of species per region, mixed trends were observed again between the 4-regions (Figs. 3.13). Apart from *L. mahsena* (~3,600 mt), Malindi-Ungwana bay displayed the lowest catches for three of the four species (*L. vaigiensis* (~1,500 mt), *L. lentjan* (1.92 mt), *S. sutor* (2,100 mt)) compared to the other regions (Fig. 3.13a). The highest catch per species was observed for *P. macromenus* (13,900 metric tons) and *L. vaigiensis* with over (~13,400 metric tons) per annum in Funzi-Shirazi bay (Fig. 3.13d).
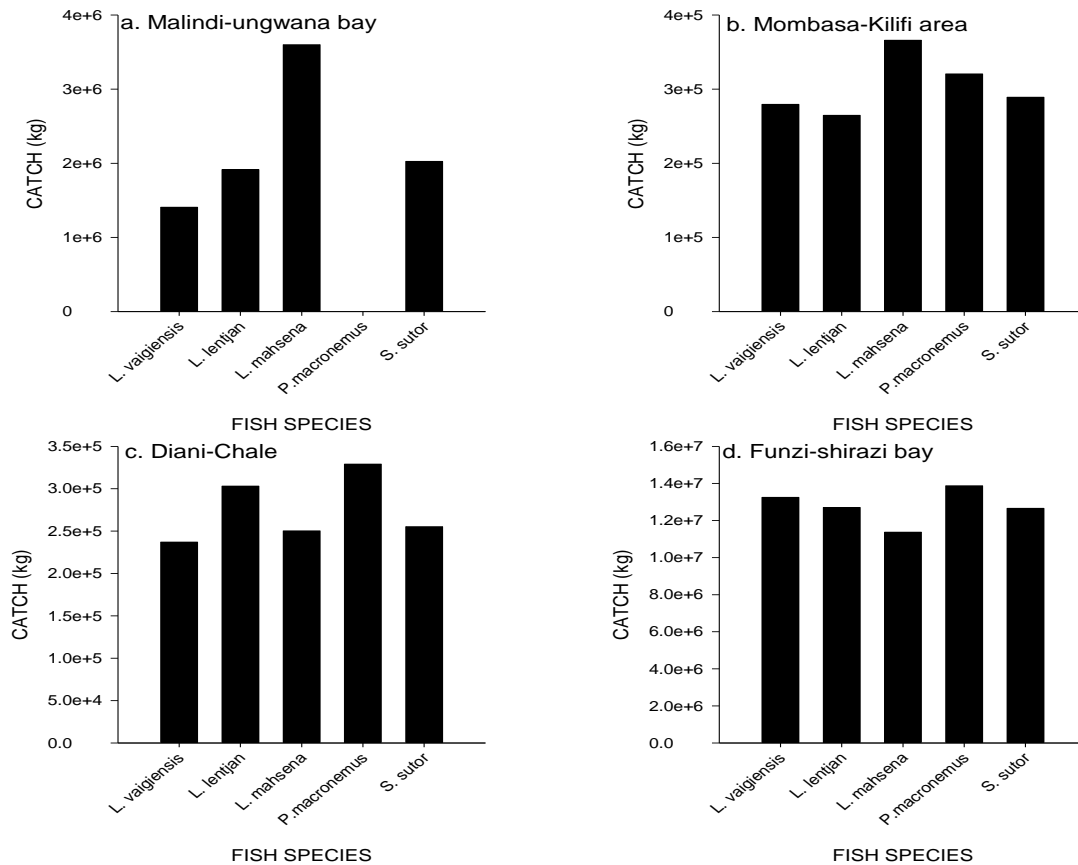
Figure 3.13. Estimated total annual catch separated to species in the four coastal regions, Malindi-Ungwana bay (a), Mombasa-Kilifi (b), Diani-Chale (c) and Funzi-Shirazi bay (d) (*e+{number} represents zeros avoided).

Overall, all the 5-species displayed almost similar annual quantities ranging from ~14,600 metric tons for *P. macronemus* to ~15,700 metric tons for *L. mahsena.* The other three species showed a total of (15,200 mt) *L. lentijan,* (15,200 mt) *L. vaigiensis* and (15,300 mt) for *S. sutor* (Fig. 3.14).
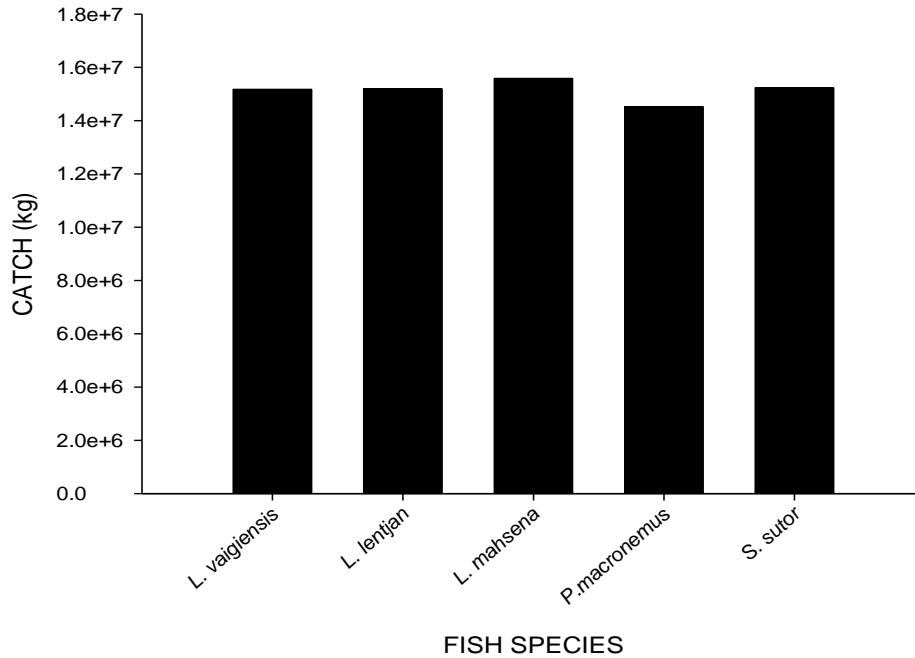
Figure 3.14. Total annual catch averaged over 2001 – 2009 by species for the entire Kenyan coast (*e+{number} represents zeros avoided).

3.3.4. Catch per unit effort (CPUE)

The mean annual CPUE per region ranged from the highest (1.5 kg.fisher^{-1}.hr^{-1}) in Diani-Chale to the lowest (1.0 kg.fisher^{-1}.hr^{-1}) in Malindi-Ungwana bay (Fig. 3.15). Funzi-Shirazi bay (1.2 kg.fisher^{-1}.hr^{-1}) and Mombasa Kilifi region (1.15 kg.fisher^{-1}.hr^{-1}) had almost similar values (Fig. 3.15).
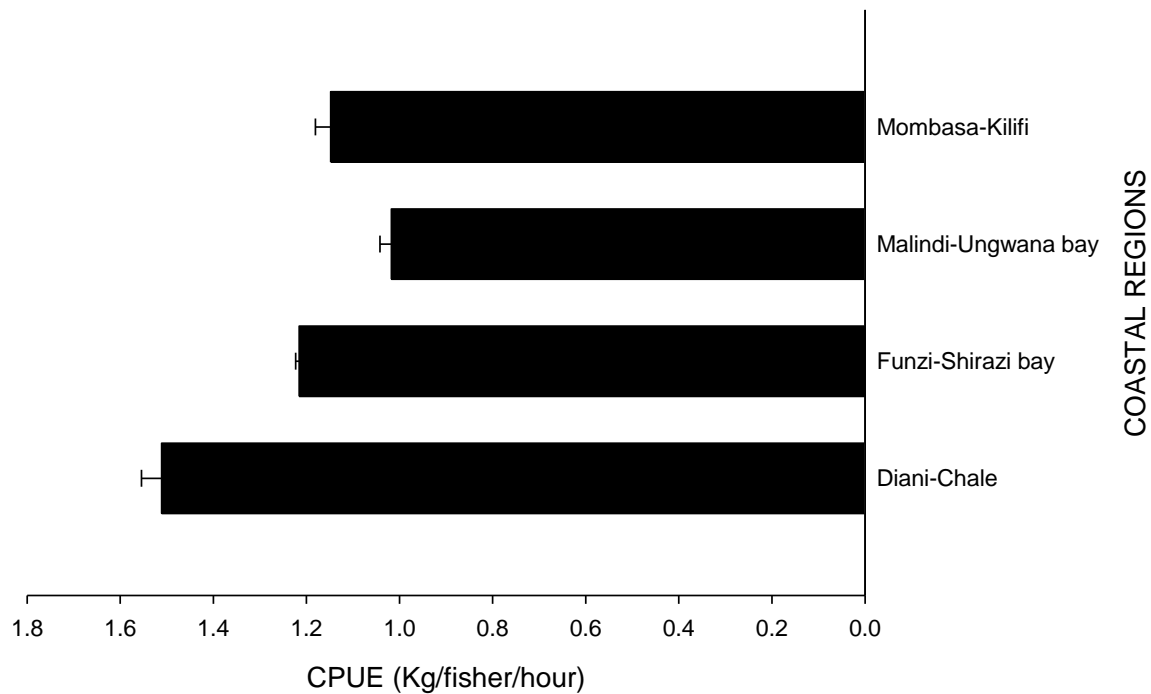
Figure 3.15. Catch per unit effort (CPUE) in the four coastal regions.

With regards to species, Funzi-Shirazi bay showed an almost constant CPUE across the 5-species while varying trends were observed for the rest of the regions (Fig. 3.16). Again, Malindi-Ungwana bay displayed the lowest CPUE values for the 5-species compared to the other regions more in particular for *L. mahsena* (0.7 kg.fisher^{-1}.hr^{-1}) (Fig. 3.16a). CPUE values per region showed a fairly constant trend with a slight variation from the overall mean CPUE 1.23±0.01 kg.fisher^{-1}.hr^{-1}. However, the highest and the lowest mean CPUE ranged from 1.12±0.05 kg.fisher^{-1}.hr^{-1} in Mombasa-Kilifi area to 1.42±0.06 kg.fisher^{-1}.hr^{-1} in Diani-Chale area (Table 3.7).
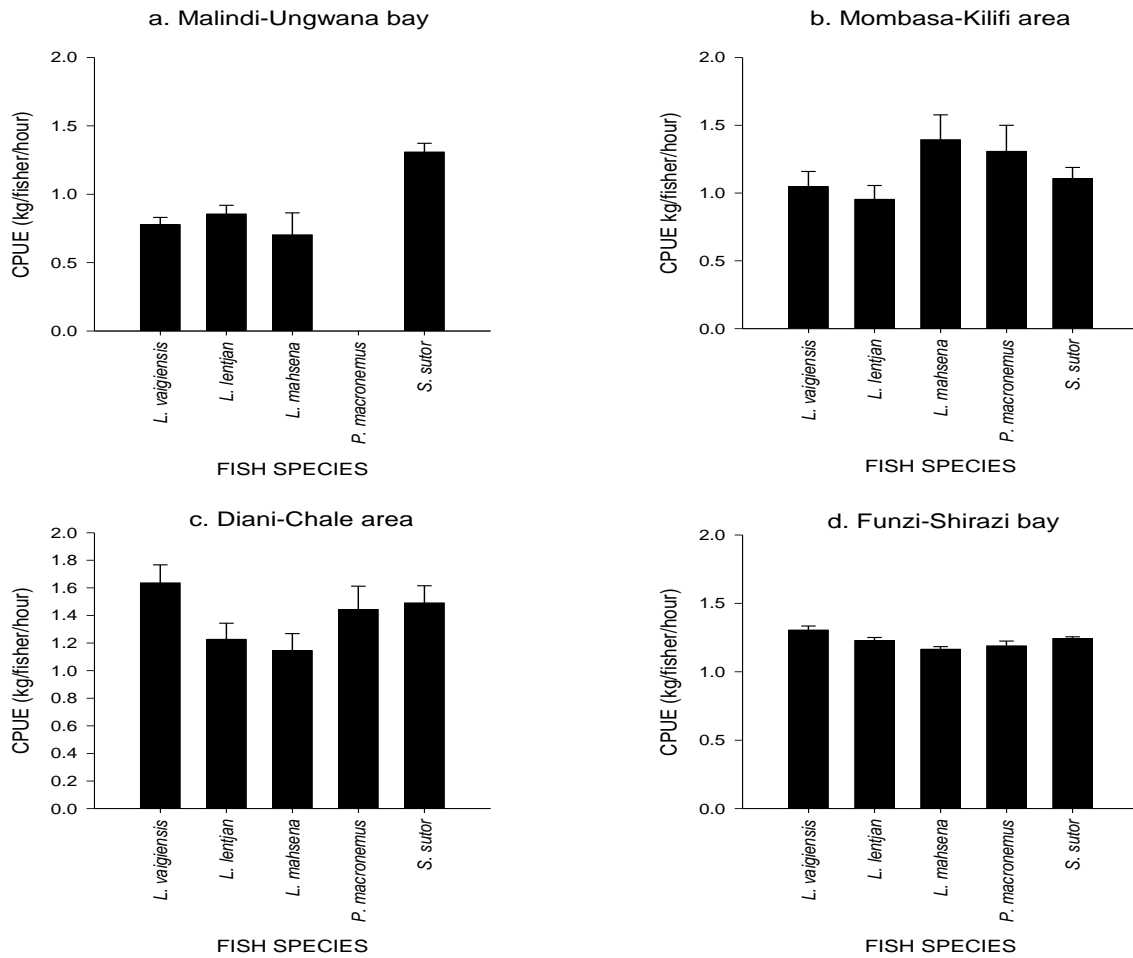
3.16. Species-specific CPUE in the four coastal regions, Malindi-Ungwana bay (a), Mombasa-Kilifi (b), Diani-Chale (c) and Funzi-Shirazi bay (d).

Table 3.7. CPUE (kg.fisher^{-1}.hr^{-1}) for the six main gear types per region as well as all regions combined.

| Fishing gears | Coastal regions | | | | |
	Diani-Chale area	Funzi-Shirazi bay	Malindi-Ungwana bay	Mombasa-Kilifi area	All coastal regions
Basket traps	1.76±0.11	1.17±0.01	1.70±0.11	2.14±0.16	1.19±0.01
Beach seine	0.39±0.04	1.01±0.04	2.38±0.28	0.35±0.02	0.87±0.03
Gillnet	0.38±0.04	1.76±0.05	0.83±0.03	0.54±0.07	1.57±0.05
Hook and line	1.22±0.13	1.22±0.02	0.82±0.08	1.51±0.15	1.22±0.02
Others	0.44±0.11	1.20±0.04	0.15±0.01	1.00±0.33	1.20±0.04
Spear gun	1.84±0.12	1.56±0.07	0.09±0.12	2.09±0.19	1.69±0.06
All gears	**1.42±0.06**	**1.23±0.01**	**1.15±0.05**	**1.12±0.05**	**1.23±0.01**

A general decrease in CPUE over time is apparent with the highest CPUE values (1.5 kg.fisher^{-1}.hr^{-1}) observed in 2001 (Fig. 3.17). Again in 2007, slightly higher CPUE values (1.3 kg.fisher^{-1}.hr^{-1}) were observed after which CPUE started to decline steadily to about (1.0 kg.fisher^{-1}.hr^{-1}) in 2009 (Fig. 3.17).
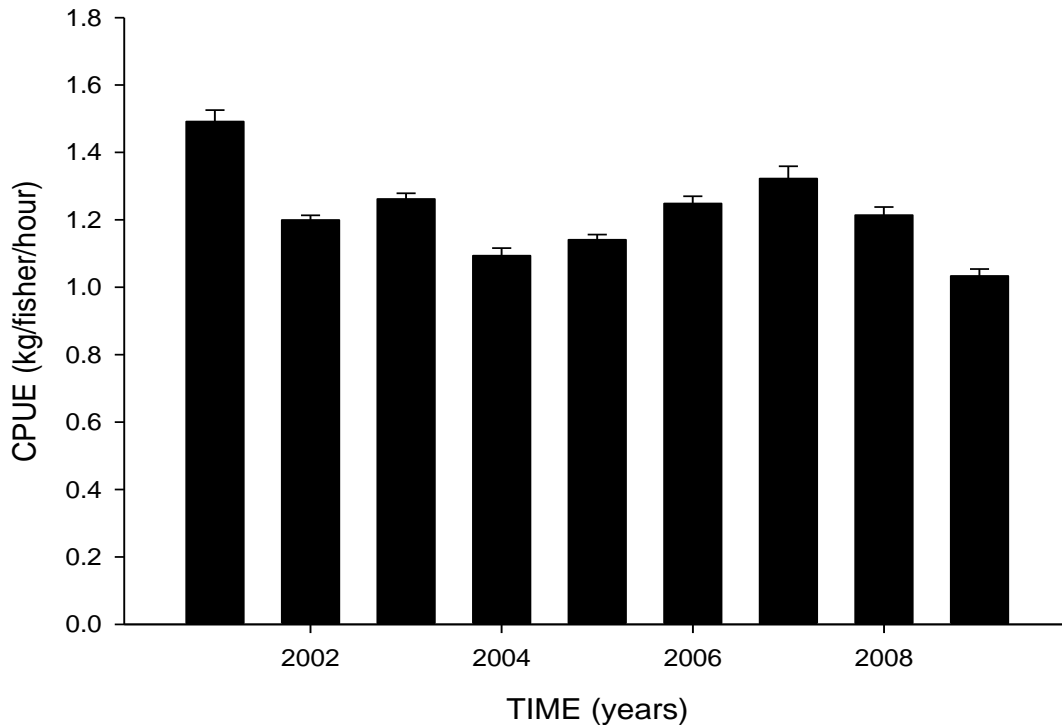
Figure 3.17. Annual CPUE over the 9-year study period for the entire coast.

3.4. Discussion

3.4.1. Demographics and diversity

Similar to global trends, the majority of the fishers in the Kenyan coastal fishery were men. This is common a scenario along the African coastline as this activity generally takes participants away from home and is physically demanding. For instance, several studies conducted along the South African coastline on fisheries resource utilization recorded less than 9% as the

composition of women participating in fishing this activity (Cowley et al., 2009). Similar results were documented with records from the southern pacific community showing a minimum of 3% of women involved in fisheries (SPC, 2008). When considering the mean age of the fishery participants (37.4 years), their involvement in the fishery (16 years on average) and the mean period of their formal educational training (8 years), it suggests that most of the fishers enter the fishery after dropping out of primary school. It is possible that subsistence fishing not only offers the main source of protein but is also a major employment opportunity in the informal sector for the poverty stricken households along the coast (DoF, 2010). Furthermore, joining this fishery is rather simplified by the fact that only Ksh 100 or ($0.9) is needed to secure a fishing license (DoF, 2008). The dominance of local fishers in the selected regions shows to a great extent how proper development and management of the fishery would impact the local communities both socially and economically (Cinner and Aswani, 2007). Taking population movement as an indicator of people's confidence on the local resources (Cinner and McClanahan, 2009), the low numbers of immigrant fishers to some extent casts some doubt on the amount of fishery resources available to attract immigrant fishers. It will be interesting to see how demographics will shift in terms of population movement of immigrant fishers once proper management measures are in place.

It was not surprising that majority of the participants had only primary education, with 14.7% having no education at all, since at this level it is difficult to secure formal employment in Kenya. This could further explain why many unemployed youth opt for fishing. Moreover, since most of these respondents were parents with a mean number of ~five dependants, they had a duty (as household heads) to provide for their families. This could also be a major factor that compels fishers to stick to the open access fishery in order to earn a living. With regards to religion, only

Christianity and Islam were found to be the most dominant with the later being more dominant since the coastal region itself has more than half of its population comprised of Muslims according to the 2009 population and housing report. Either way, no major issues (apart from religious fasting), were noted as a result of differences in religion nor did religious believe play any role in the general fishing behaviour along this coast.

3.4.2. Fishery access mode

Although the fishery is dominated by non-motored vessels, there are deliberate efforts towards increased use of motorized canoes and outboard engine boats (DoF, 2012). Infact, there has been increased percentage composition from only 1.6% and 2.1% as reported by Pauly et al. (1989), Obura (2001b), McCLanahan and Mangi (2004) to 3.3% according to the preliminary results from the Kenya Coast Development Project (KCDP) funded Frame Surveys (FS) conducted in mid 2012. This could reflect the attempts being made by the local fishers to fish in the deeper, unexploited waters (Maina, 2012). This further shows a slight shift in fishing technology since the use of motorized canoes is also associated with the use of more effective gears such as long lines (Mbaru, 2011). Since majority of the sport fishers land a minimum of about 20 kilos a day, this combination might lead to an increase in the quantity of fish landed especially to those fishers utilizing these vessels (see chapter 4).

3.4.3. Fishing gears

3.4.3.1. Basket traps

For various historical and management reasons there were differences in the gear use at each of the four regions over the 9-year period. However, basket traps were commonly used in all four

regions (Fig. 3.1). The dominance of basket traps is not only a common scenario in Kenya but basket traps are both responsible for the majority of fish captured in the Caribbean and around the world (Gobert, 1998; Mahon and Hunte, 2001). The primary reason for their popularity can be ascribed to the low-tech, low-cost and effectiveness of this gear type (Johnson, 2010). Basket traps can easily be handmade by local fishers using locally available raw materials (e.g. bamboo rafts) that can be obtained at a low cost or at no cost at all. This low-technology gear can be used by foot fishers or deployed from a small boat or canoe propelled by paddle or sail power. No training is required on the use of this gear and the overall operation and maintenance costs are also low. However, traps can only target a limited number of species mostly reef associated species rendering their effectiveness low (Johnson, 2010). As a result, the use of basket traps has decreased over the years (Fig. 3.3). This trend is similar to that of the frame surveys (FS) by the Fisheries Department where it has been reported that traps decreased substantially from 5,224 in 2006 to 3,169 in 2008 (DoF, 2008). According to the 2008 FS report, basket traps were a common gear in the larger Kwale district which includes the Funzi-Shiazi bay where the highest numbers of basket traps (Fig. 3.3) were observed. The use of basket traps is restricted to shallow sheltered areas, particularly coral reef lagoons that are subject to heavy fishing pressure and increased competition (Mbaru and McClanahan 2012, unpublished data). Consequently, catch rates have declined and are currently low. Similar trends were reported by Obura (2001b) and McCLanahan and Mangi (2004), who revealed that 56% of basket trap fishers obtained an approximate yield of only 3.1±0.86 kg per day. Because of the high levels of bycatch and other non-target fish such as flounders, damselfishes, filefishes and butterfly fishes as documented by Johnson (2010), their popularity have reduced significantly (Stewart, 2007). Currently traps in the Caribbean and Antilles are modified with escape gaps to reduce bycatch and achieve

sustainability in the near shore reef fisheries which supports livelihoods for the riparian communities (Johnson, 2010). Similar work was done in Kenya as an advancement of different successful case studies in three different areas (Mbaru and McClanahan 2012). The original experiment in Curaçao was designed to test the effect of a proposed and recently enacted regulation that requires 20 x 2.5 cm escape gaps in fish traps (Johnson 2010). The Curaçao regulation was based on a similar regulation in Bermuda where escape gaps were required in lobster traps for the purpose of allowing reef fish to escape. The Bermuda regulation was never scientifically tested and the only escape-gap experiment used a 9.0 x 3.3 cm gap size and showed large reductions in catch quantity relative to controls (Munro et al., 2003). Collectively, these experiments indicate that the global implementation of escape gaps would be a significant step towards decreasing ecological impacts and increasing the sustainability of artisanal fisheries. Therefore, it is proposed that the continued use and dominance of basket traps in certain areas is related to the production and maintenance cost incurred (Glaesel, 1997), rather than their effectiveness in capturing fish.

3.4.3.2. Hook and line/ Handlines

The popularity of hand-lines can also be ascribed to the low costs involved in using this gear type. Most fishers make use of a single twine on which baited hook(s) is/ are attached while some include a stick onto which multiple hooks are attached. Due to their low investment cost, they were used in all studied regions (Fig. 3.2); a trend that was similarly observed during the FS in all the districts along the Kenyan coastline (DoF, 2008). From the 2008 FS report, the highest number of hand lines (1,463) was observed in Msambweni district within the larger Kwale County; similarly in this study, the Funzi-Shirazi bay region within the same administrative unit displayed the highest numbers of hook and lines compared to the other regions (Fig 3.2). Fishers

from this region are known to be to explore efficient fishing gears ranging from traditional to the modern hooks and lines to increase their competiveness. It's a region that is dominated by fishers and fishing is believed to be the main source of income with each household believed to have at least one fisher (Wanyonyi et al., 2003). Although hook and lines are responsible for a significant portion of the catch, they also potentially compete with other common gears, such as seine nets, gill nets, and spearguns within the same fishery that has suffered from declining productivity (Obura and Wanyonyi, 2001). Unlike beach seines and gillnets which catch more than ten different species per day, this gear only catch less than four or five species in a single fishing day (McCLanahan and Mangi, 2004). Consequently, this might have reduced the competitive nature of this gear with the continued use of illegal gears like spearguns and beach seines. This could explain why this gear has continued to decline since 2005 (Fig. 3.3), probably fishers shifting to other types of gears to enhance their catch. Similar declines were reported by fisheries department where numbers of hand-line recorded in the 2008 FS were fewer than the previous two frame surveys of 2004 and 2006 respectively (DoF, 2008). Despite their continued reduction, handlines are believed to have the most distinct selectivity as they target larger carnivorous species with high mean trophic level (McCLanahan and Mangi, 2004).

3.4.3.3. Gillnet

Gillnets of different lengths and mesh sizes are used in the Kenyan coastal fishery and variations are used depending on size and species targeted (McCLanahan and Mangi, 2004). They can be operated either actively (drifting gill nets), stationary by setting it in the water column (set gill net) or drift whereby the net is moved by the water currents (drift gill net) (DoF, 2008). Due to their versatility and effectiveness, it is no wonder that gill nets were popular in this artisanal fishery (Fig. 3.1; Fig. 3.2; Fig. 3.3). The substantial increase from 2008 should however be

attributed to the fishing communities from Malindi-Ungwana bay where this gear was found to be more prevalent (Fig. 3.2, Fig. 3.3). Given that this region is well known for large pelagic fishing activities, it is believed that fishers in this region prefer gillnets to which are fairly efficient to target large pelagic fishes like tunas, marlins, swordfishes, kingfishes, dolphin fishes as well as sharks (DoF, 2008). However, if findings in terms of mesh sizes used in this fishery as reported from the annual fisheries statistical bulletin of 2008 is anything to go by, then selectivity of this gear in terms of mesh sizes used should be checked. The most common mesh size was 6 inches (~18 cm) with 1,219 nets followed by 5 inches (~15 cm) with 491, 4 inches (~12 cm) with 425 and <3 inches (~9 cm) with 415 gillnets. Up to 2008 when the last FS was conducted, the total number of gill nets had reduced from 7,431 in 2004 to 5,916 in 2006 and a further reduction to 3,956 in 2008 (DoF, 2008). Although, Malindi district had the highest concentration of gill nets (1,599) a scenario that confirms results of this study (Fig. 3.3) where similar high numbers were observed within the Malindi-Ungwana bay which falls within the same area. Surprisingly, the same report vaguely concluded that from the 3,956 gillnets enumerated in 2008, mesh size ranged from < 2 ½ inches to > 10 inches (DoF, 2008). This means gill nets of small mesh sizes (as small as <2 inches) operate within this fishery; this being more than 2 cm below the recommended legal minimum mesh size of 6.35 cm (Hicks and McClanahan, 2012). Since no frame survey was conducted in 2010, this study provides a stern warning on the steady increase of gill nets especially within the Malindi-Ungwana bay in Malindi district. Although this gear is selective when used appropriately, small mesh sizes can be extremely effective in removing even the smallest of juvenile fishes. More studies need to be done to verify the actual mesh sizes used in this fishery and the impact of this gear type. In addition McCLanahan and Mangi (2004), reported that gillnets and traps capture similar species and hence further evaluation is needed so

as to distinguish their respective detriments and benefits. Since managing tropical fisheries by species, effort and size is complicated especially where both fishers as well as management institutions undermine effective monitoring and enforcement of fisheries regulations, gear based management should be considered as gears are easily identified and monitored (Ruddle, 1996).

3.4.3.4. Beach seines

Beach seines in Kenya operate below the recommended legal minimum mesh size of 6.35 cm and as a result juveniles form a substantial proportion of catch from this gear (Hicks and McClanahan, 2012). They are also known to target slow growing species; a scenario that prompted the government through the Kenya Gazette Notice No. 7565 Vol.CIII. No. 69 of the 9th November 2001 to restrict beach seines. This ban includes about three types of marine seine nets (beach seines, prawn seines and reef seines) although all are commonly referred to as 'beach seines'. While prawn nets are usually used by fishers targeting prawns during *Kasi kazi* (NEM) season when the conditions are conducive for fishing in estuaries (river moths), reef seines are usually operated throughout the year (DoF, 2008). Despite this ban, beach seining is still rampant (Fig. 3.1; Fig. 3.2; Fig. 3.3) as they were found in all the coastal regions over the 9-year period. In different instances, over 40% of beach seiners were recorded in Mombasa area both in this study (Fig. 3.2b), by the fisheries department (DoF, 2008) and in previous surveys conducted by the Wildlife Conservation Society (WCS). The shallow and long continental shelf along the Mombasa-Kilifi area where this gear dominates is believed to be the main geological factor that favours beach seining as opposed to the other regions whose shelf is narrow. These results however differ slightly with those of the fisheries department in terms of spatial distribution; in that no beach seine was reported in Malindi district (DoF, 2008) yet Fig. 3.2b, shows about 10% of the fishers within the same region use beach seines. Even recent socio-economic studies

revealed that at least 2% of fishers from this region use beach seines (see chapter 4). Despite their existence, this study observed a substantial reduction of beach seines since 2003 (Fig 3.3d). A similar trend was observed by the fisheries department where beach seines reduced to about 139 in 2008 from 560 beach seines recorded in 2006 (DoF, 2008). These sharp declines could be attributed to efforts of co-management and sensitization of fishers on damages caused by this illegal gear. Previous studies by McClanahan et al., (1997) indicate that CPUE for various gears in areas fished by beach seines are significantly lower compared to CPUE values for gears in areas where beach seines are restricted. Since beach seines are known to capture species below age at first maturity and with low mean trophic level thereby threatening sustainability. Although restrictions have been proposed as part of the concerted efforts to come up with an optimal mesh size for a fishery around the world (MacLennan, 1992), there might be need for increased enforcement efforts in terms of gear-based restrictions for this gear to be completely eradicated in the Kenyan coast.

3.4.3.5. Spear gun

This gear mainly targets dermersal species in the intertidal areas mostly on the reef and can be very destructive to the corals reef structure which offers the best habitat for spawning, breeding and feeding (Mardle et al., 2002). Like beach seines, this gear is also known to target slower growing species that are likely to be less resilient to the high fishing pressures (Hicks and McClanahan, 2012) and is therefore illegal as per the fisheries regulations. However, despite being illegal, spearguns have continued to increase in numbers particularly in the Diani-Chale area (Fig. 3.2b). This again may either be due to weak monitoring control and surveillance systems (MCSS) or its ease of acquisition at low cost, ease of portability or even the danger it poses if used against fisheries law enforcers themselves. Indeed during the 2008 frame survey by

the fisheries department, the number of spearguns increased tremendously by 61 % from 624 in 2006 to 1,007 with most records obtained from the southern part of the Kenya coast (DoF, 2008) where this gear is believed to be more popular among young fishers entering the fishery who usually dive for fish in the coral reef. The elderly fishers who happen to be more conscious about the destruction caused by this method to the fishing environment have in fact raised their concern (McCLanahan and Mangi, 2004). Though its popularity is gradually decreasing, enforcement efforts are still crucial (Fig. 3.3e).

3.4.3.6. Other gears

Apart from the five main gears, a number of 'other' gears were found within this artisanal fishery (Fig. 3.3f). These include trolling, scoop nets, harpoons, ring nets, longlines, cast nets, fence traps, cages, trammel nets, monofilament nets, handpicking among others. Although the general trend shows a massive decline, it's worth noting that some gears within this group may have reduced, some increased and others may have remained stable. For example, Munga et al. (2010) reported an increase in ring nets within the Funzi-Shirazi bay area due to its proximity to the neighboring country Tanzania where this gear is believed to have originated from. Although this gear is expensive and targets a variety of pelagic species especially those which move in schools, ring nets can be very destructive when used in shallow waters especially in the coral reef lagoons (Munga et al., 2010). To date this gear has not been fully endorsed by the fisheries agencies although the process to develop a ring net management plan is at an advanced stage (Maina, 2012). Apart from ring nets, longline was another gear that was found in use especially in the Funzi-Shirazi bay (Fig.3.2). According to the FS data, these hooks are of different sizes (size <4, size 4-7, size 8-10 and size >10) and target various pelagic species with hooks of sizes 4-7 being the most common followed by size 8-10. This increase in numbers of gears targeting pelagic

species in the recent past could be exacerbated by the decline in productivity of the near-shore fishery (Obura, 2001a). This includes trolling lines, which also increased marginally from 2006 (DoF, 2008) with the majority being recorded in the Mombasa-Kilifi region (DoF, 2008). While this scenario is plausible as it shows some efforts by the local fishers to exploit the pelagic fishes, the minimal increase in these two gears is too inconsequential to cause any significant change in the general trend of gears in this category (Fig. 3.3f). This is so because other gears like the monofilament nets are in fact illegal as per the fisheries regulations hence the reduction due to the fear of being arrested by law authorities. Trawl nets are also unpopular since they are only used to target prawns in very limited areas along the coast and sometimes are regarded as illegal-small beach seine nets. Cast nets on the other hand have simply been overtaken by the influx of cheap and effective gillnets. Scoop nets and hand picking have basically become unreliable methods of fishing while due to the reduction of near-shore fish stocks. Fence traps and cages on the other hand are simply not appealing gears to the local fishers due to their use limitations and therefore could only be found in a single site.

3.4.4. Catch and effort trends

Due to the minimal requirements (as stipulated in the Fisheries Act Cap 376) needed to acquire a fishing license, the fisheries sub-sector has recently attracted a high number of new entrants ranging from young to old, local to migratory fishers (Munga et al., 2010). Based on the official annual fisheries statistical bulletins, the number of artisanal fishers increased progressively from 7,500 in1990 to 12,077 in October 2008 (DoF, 2008). Consequently, fishing effort must have increased tremendously. In principle, this typical Open Access Equilibrium (OEQ) scenario created by the insurgent of high numbers of fishers exploiting various ways of enhancing their catch while also advancing fisheries management and conservation efforts should explain the

spatial and temporal varying trends of CPUE within this fishery (Fig. 3.14; Fig. 3.15; Fig. 3.16; Fig. 3.17). Translating the Table 3.7 CPUE figures economically for instance indicates that a basket trap fisher takes on average 6.3±1.1 kg (about KShs.700) per day; a hook and line fisher takes on average 6.9±0.1 kg (about KShs.800) per day; a gill net fisher takes on average 9.3±1.2 kg (about KShs.1000) per day; while a beach seine fisher takes 4.2±0.3 kg (about KShs.500) per day (Table 3.4). Even before wondering what these statistics mean, Obura (2001b), commented that they demonstrate low incomes and living standards experienced in these areas where people not only depend on fish economically but also for food. Thus, from this economic viewpoint alone, the reef fishery seems to be unsustainable (Pauly et al., 1989; McClanahan and Mangi, 2004). Additionally, from the increased competition by fishers on the limited fishery resources, the effect of time spent fishing on the landed catch was hardly noted or perhaps also explaining the in-effectiveness of most of the fishing gears (Alidina, 2004). Johnson (2010) reported a maximun of 4.2±0.3 kg/fisher/day among the basket trap fishers in the Caribbean, Manach et al. 2012 reported 2.1 kg/fisher/day as the most recent CPUE values from dominant artisanal fishery in Madagascar, Moreover, the negative correlation observed between catch landed (CPUE per gear) and gears preferred by the local fishers perhaps also shows how economic constraints affect gear preferences. For example, gillnets had the highest CPUE values, although the same gear was not necessarily the most preferred by the artisanal fishers (Fig. 3.1, Table 3.4). Consistently, other studies done by Obura (2001b), McCLanahan and Mangi (2004) in the Kenyan coast revealed that longliners who represented only 15% of the overall number of fishers landed an average minimum of 4.4±0.86 kg per fisher while fish traps (basket traps) fishers with 56% representation yielded only a maximum of 3.1±0.86 kg per fisher.

Vessels used for fishing could also have some stake in the low CPUE values recorded. This is because the fishery is dominated by non-motored vessels (Table 3.3; Table 3.5) limiting the local fishers from accessing the deeper waters, which are believed to be richer in fish stocks (Ruwa, 2010). This could explain why there are deliberate efforts towards increased use of motorized boats as the percentage composition of motorized boats increased (Table 3.5) compared to those reported by Pauly et al. (1989), Obura (2001b), McCLanahan and Mangi (2004) where only 1.6% and 2.1% were reported to use engine boats. This slight shift in fishing technology reflects the attempts being made by local fishers to fish in the deeper, unexploited waters since the use of motorized boats is associated with the more effective gears such as longlines. This paradigm shift to offshore fishing will certainly reduce pressure on the nearshore reef fishery.

3.4.5. Species composition

The high diversity of species caught highlights the multi-species nature of the Kenyan artisanal fishery is clear (Table 3.4). Most species that emanate from this artisanal fishery were included because of the long periods of fishing and sampling at many landing over the 9-year period (McClanahan et al., 1994). Moreover, as explained by Obura (2001a), this was so because fishers take any fish caught in the gear discarding just a few as inedible and therefore sampling was done for all species whether marketable or not to avoid actual catch bias and reduction of the number of species. Consequently, these results include even the less marketable species that were usually kept for home consumption (Glaesel, 1997). This however does not mean that fishers have no preferences for certain fish. For example, it is known that rabbit fishes and snappers are a prime target for basket trap fishers (Johnson, 2010).

Despite this high diversity of the species caught, most of the catch was dominated by a few species (Table 3.4) this being a common scenario along the tropical African coastline (Gell and Whitington, 2002). For example, three out of the top five species in Kenya were among five species that comprise 60% of the catch in Mozambique (Gell and Whittington, 2002). Most recently, Hicks and McClanahan (2012), using a dataset from the annual fish catch monitoring programs conducted by WCS reported that 63% of the catches from Kenya's seagrass and coral reef fisheries are dominated three species (*Leptoscarus vaigiensis, Siganus sutor* and *Lethrinus lentjan*). Globally, these species are also known to dominate catches from basket traps set in reef lagoons (Johnson, 2010); basket traps being the main gear along the Kenyan coast. Being demersal coral reef and seagrass-associated species (McClanahan and Mangi, 2004, Table 3.4) this clearly reflects where the fishing effort is focused. Although this study focused on 5-main species, there is a possibility of differences in gear selectivity with regards to species targeted (McCLanahan and Mangi, 2004).

Although there have been some declines in total landings in the fishery over the years, these five species consistently dominated catches over the 9-year period both in weight and number. This is thought to be as a result of ontogenetic migrations of adult stocks from a possibly natural refuge in deeper reef habitats where spawning aggregations occur and no major fishing effort takes place (Kimirei et al., 2011). Juveniles and small adults from these species dominate in seagrass beds, mangroves and sandy areas whilst adults are solitary and found spawning in deeper water (Kimirei et al., 2011). This cross ecosystem separation of the adult and juvenile stages could be a strategy that minimizes mortality and maximize growth for these species (Adams et al., 2006, Grol et al., 2011). The presence of mangrove and seagrass habitats in proximity to deeper reefs also affects reef assemblages of these species (Dorenbosch et al., 2005) as this scenario enables

resettlement of the pelagic larval stage onto suitable habitats (Armsworth, 2002). The natural protection provided to these deeper habitats may therefore be critical for replenishing the lagoon fishery (Armsworth, 2002). To bring the status of this fishery within optimally exploited status, mesh size and gear exclusion laws must be enforced particularly for the very fast-growing species like *S. sutor* (Hicks and McClanahan, 2012).

4.1. Introduction

Because of the peoples social, economic and cultural factors that influence how individuals and communities exploit fisheries resources (McManus, 1997), it is always important to understand the people involved in the fishery as much as it is critical to understand the fishery itself (Pauly, 1995). Creating partnerships with resource users when addressing the needs and concerns of the stakeholders also increases the effectiveness of fisheries management actions (McClanahan et al., 2005; Castilla and Defeo, 2005). For example, fishers may not adopt new fishing methods like FADs if they do not understand the connectivity of this particular fishing technique to their economic wellbeing (Stewart et al., 2006). Likewise, compliancy and sustainability may be a toll order if implementation strategies are designed in ways that are insensitive to the needs of those dependent on the resource (Wilen, 2004). Therefore, it is essential to understand these human attitudes in attempts to involve local people when introducing new fishing techniques, as successful fisheries projects may need to direct outcomes at local values (Brandt, 2007).

Therefore as we move into a new era of working with resource users to develop partnerships, the need to integrate this social science in fisheries management is apparent (Stewart et al., 2006). This can help to adapt and refine new fishing strategies to reflect the needs and desires of the stakeholders, select strategies that are appropriate for the local conditions, and utilize scarce resources more wisely by targeting specific initiatives to communities where these segments are most needed (Holland, 2002). Understanding the conditions that make fishers choose a particular option of fishing is crucial to developing management policies with high compliance and success (Bjorndal and Conrad, 1987). Early work on decision making among fishers assumed that in open-access systems fishers respond to profitability, acceptance or rejection of a particular

fishing technique in response to the balance of revenue and costs, including the opportunity costs emanating from other economic activities including fishing (Wilen, 2004). This led to the understanding of fishing effort in terms of bioeconomic equilibrium, where fishers reject a fishery when there is a possibility that their yields may drop below a cost-effective threshold (Beddington et al., 2007).

Additionally, in developing countries, the low opportunity cost experienced by fishers in the context of an excess labour force and the limited costs of entering an introduced fishery is assumed to lead to a bioeconomic equilibrium in which the fishery is heavily overexploited (McManus, 1997). These analyses usually ignore the complexity and diversity that characterizes fishers' behavior (Wilen, 2004). Recently researchers have attempted to incorporate this diversity by modeling individual, vessel, and firm-level responses to different conditions to identify individuals that may be displaced by new fishing technology interventions and how they may reallocate their effort (Holland, 2002; Brandt, 2007). To date, knowledge of how fishers decide to enter or reject a fishery has been derived almost entirely from commercial fisheries in developed countries (Pradhan and Leung, 2004; Brandt 2007). Few researchers have explored these issues in artisanal fisheries which apparently forms an important sector especially in coastal developing countries (Castilla and Defeo, 2005; Sievanen et al., 2005). However, the limited work of integrating quality social science in fisheries studies done elsewhere, to date, has already produced important results and helped to guide sustainability policies (Wilen, 2004). In Maldives, for instance, interdisciplinary social and biological work has shed light on how traditional practices can be integrated into the FAD fishery programs (Dagorn, 2009, pers comm). As part of this study, a socioeconomic assessment was conducted along the coast

between January and March 2011. Fishers along the Kenyan coast were interviewed to explore their socioeconomic characteristics and their willingness to enter the FAD fishery prior to the deployment of FADs along the Kenyan coast.

4.2. Materials and Methods

4.2.1. Survey design

Four coastal sites along the Kenyan coast between Kilifi and Kipini were studied: Kilifi Central BMU, Watamu, Malindi, and Kipini. These sites represent the few areas where large pelagic fishes are still abundant. Most of the sport fishers engaged in tag and release expeditions of billfish, marlins, kingfish, tunas and swordfish operate within this region. The sites also fulfill all the morphological, geological and ecological requirements for FAD deployment.

Figure 4.1. Field interviews conducted in Kipini.

Information was gathered using a combination of systematic surveys with key informants (artisanal fishers, recreational fishers and hotel agents); semi structured interviews, participant observations and analyses of secondary sources such as population censuses and fisheries records. About 30–40 surveys were conducted per site depending largely on the population of the selected fishing site. Fishers were randomly selected from lists of active fishers provided by local fisheries representatives. Sampling of fishers within landing sites was based on a systematic sample design, where a sampling fraction of every ^{i}th fisher (e.g. 2nd, 3rd, 4th) was determined by dividing the total fisher's population per site by the sample size (Henry, 1990; De Vaus, 1991).

4.2.2. Socio-economic indicators

Five main socioeconomic indicators that were hypothesized to be related to decisions by fishers to accept (join fishery) or reject the FAD fishery were examined: how far fishers would be ready to go from land, whether they knew the species that might be caught at FADs: (tunas, dolphinfishes, wahoos), if they knew the fishing techniques at FADs (hook and line, longline and trolling), whether hotels, restaurants, fish traders, markets, would be willing buy FAD species (tunas, dolphinfishes, wahoos, etc.), whether there was ready market for the FADs species as well as other major socioeconomic factors that affect the condition of the offshore fishers. The relationship between the probability of fishers remaining in the fishery and their socioeconomic characteristics was also examined. This survey also sought to examine fishers demographics at these sites, material style of life; daily expenditure per fisher; whether expensive equipment (e.g. a net or boat) was owned; age; years of education; proportion of catch bartered or sold; catch rate; occupational diversity; and whether fishing was the household's primary occupation. Interviewees also estimated fisher's total daily expenditure, to provide a further indication of

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wealth that accounted for a household. The occupational portfolio of fishers was examined by asking respondents to describe all activities that brought food or money into the household. These occupational portfolios were ranked in order of importance to determine whether or not fishing was a primary occupation. Occupational diversity was defined as the number of different types of occupations (e.g. fishing, agriculture, informal economy sectors). The number and types of occupations in which fishers participate was examined by asking respondents to describe the work that they do that can bring food or money into their house. Fishers were asked about the type of gear they owned and the proportion of their catch they sold. Fishers were also asked to report their catch on a good, bad, and normal day/season. The normal-day/season figure was used to construct hypothetical scenarios involving a reduction of catch. Dependence on fishing was determined by having respondents suggest all the occupations the fishers engaged in for food or money besides fishing. Respondents were then asked to confirm whether fishing was the main source of income and if possible estimated the percentage of their fish catch sold. To determine the origin of fishers, respondents were asked where they were from and were considered immigrants if they came from another landing site or country. Information was collected on how many respondents immigrated and their reasons for doing so, and although reasons for migration were not analyzed further, this information was a useful indicator of the confidence that people have in the local resources. To determine the intensity of fishing effort in the communities, respondents were asked to estimate the average distance or how far they go fishing from the shore in terms of kilometers, as well as their willingness to go further than their current distance. Community resilience in relation to changes in fish catch was explored by asking respondents to describe what they would do under one hypothetical scenario: a reduction in catch. Participants were given three possible choices for each scenario: 1) willingness to exit

fishery (agree to exit), 2) change to an alternative fishing gear and continue fishing (moderate), and 3) continue fishing as now without any alteration in the current fishing method (disagree to exit). Respondents were assigned 1 point for answers in agreement with the choice and 0 for answers against (irrespective of the scenario). From this, a resilience scale was created ranging from 0-1. Participants were also asked what they would do in response to a sustained decline in their normal catch. Responses were recorded as either to continue fishing as now, adapt in some way (moving location, changing gear, or increasing effort), or to stop fishing.

4.2.3. Data analysis

Although analyses were completed for all respondent groups together, it's worth noting that all results presented for Watamu refers specifically to the sport fishers (emphasis added). Before performing any statistics, the Mahalanobis distance method was used to test for outliers (especially in the income and expenditure data) and although identified, these outliers did not significantly change the results and therefore results include these outliers (Sall et al., 2001). All count data was examined by visually comparing plots of the proportion from each location. Data on the fishing gears and vessels used by the local fishers was in the form of counts, thus contingency tables were used to classify the frequency data with respect to two factors, namely landing site and the fishing method. Optimal fits to the data and the explanatory variables to understand the socio-economic aspects of the fishers and predict the perceptions of fishers towards the FAD fishery (as suggested) on the basis of a number of hypothetical scenarios e.g. the distance they are willing to travel, among others were performed. The Likert-scale data collected for measures of perceptions were treated as continuous data. All the statistics were performed with JMP statistical software (Sall et al., 2001). In terms of resilience to change their fishing techniques, fishers were given three possible choices for each scenario as explained

above and assigned 1 point for answers in agreement with the choice and 0 for answers against (irrespective of the scenario). From this, a resilience scale was created ranging from 0-1. Results for each community from the respondents were presented in form of percentage resilience. Following the selection procedure, nested F tests were used to remove a single remaining term, which was still insignificant. Therefore, the selected variables had no missing values, so all the final plots were fitted to the full sample of 100.

4.3. Results

4.3.1. Demographics

During the 2 month fishery survey, which included 22 survey days, a total of 100 fishers were interviewed, of which 12 (12%) were from the recreational sector, and 88 (88%) from the subsistence sector (Table 4.1). The 12 from the recreational sector were mostly foreigners enjoying recreational fishing and dealt primarily on offshore tag and release big game fishing for Tunas, Dorados, King fishes, Marlins, Sailfishes etc.

Table 4.1. Number of surveys conducted and demographic characteristics of respondents, including mean age, migration, mean number of years of fishing.

Community /landing site	Number of surveys	Fisher surveys (n)	Fishers (% proportion)	Immigrants (% proportion)	Age (years)	Fishing (years)
Kilifi	53	29	54.7	27.6	37.9±2.1	18.1±1.9
Watamu*	34	12	35.3	0.0	37.7±1.8	15.6±2.9
Malindi	41	20	48.8	10.0	35.7±2.6	16.6±1.8
Kipini	68	39	57.3	15.5	36.3±3.3	9.2±1.7
All sites*e	196	100	51.0	17.7	36.6±2.7	14.6±1.8

*denotes 'recreational fishers'; *e-excluding recreational fishers

The mean age of all respondents was 36.6±2.7 years, although this varied slightly from a mean of 36.3±3.3 years to 37.9±2.1 years (Table 4.1). In all the landing sites, all respondents were males. Approximately 18% of all respondents had immigrated, however, only 4% of these were from other far areas along the Kenyan coast (Table 4.1). Kilifi, which is a temporary settlement, had the highest rate of immigration (27.6%), and Watamu where the recreational fishers were based had no immigrant fisher. The mean number of years of formal education of all respondents was 7.0±0.9 years, and this ranged from 6.1±0.7 to 8.0±1.2 (Table 4.2). Although there was a slight variability in both total fishers population size per landing site examined (Table 4.1), among them, there was a mean of 3.4±0.5 dependants per household in all the sites, though this ranged from 2.3±0.4 in to 3.7±0.7 (Table 4.2).

Table 4.2. Demographic characteristics of respondents, mean±SE number of years of formal education, mean±SE number of dependants and marital status.

Community /landing site	Education (years)	Dependants (mean±SE)	More dependants	% representation of marital status			
				D	M	S	W
Kilifi	6.1±0.7	3.1±0.5	2.0±0.4	0	75.9	24.1	0
Watamu*	6.4±0.6	2.3±0.4	1.4±0.4	0	83.3	16.7	0
Malindi	6.8±0.9	3.3±0.4	1.6±0.4	0	80	15	5
Kipini	8.0±1.2	3.7±0.7	2.5±0.3	7.7	79.5	10.3	0
All sites*[e]	7.0±0.9	3.4±0.5	2.0±0.4	2.6	78.5	16.5	1.7

NB: D-divorced; M-married; S-single; W-widower; *[e]- excluding recreational fishers

In some sites like Kipini and Kilifi, majority of the respondents had their own canoes while those who did not, joined the fishing crew as captains (Fig. 4.1). A good number of fishers comply with the government regulation of landing their catch in the designated landing sites although only a handful of fishers from Malindi do so. The same was true for BMU membership where majority of the fishers from Watamu and Malindi were not fully registered members (Fig. 4.1).

In terms of FAD knowledge, about 25% in every location were not even aware of the FAD fishery (Fig. 4.1). Most of them argued that they had maintained the same fishing techniques inherited from their parents and as a result had neither attended any training with regard to fishing nor been educated on any kind of offshore fishing (Fig. 4.1). However some fishers in Kilifi reiterated that an Italian NGO, CAST was planning to train them on the use of ringnets which are slowly being introduced into the local fishery. Finally, from the overall list of names, Islam was the dominant religion for all sites, but a majority of respondents in some sites like Watamu and Kilifi were Christian.
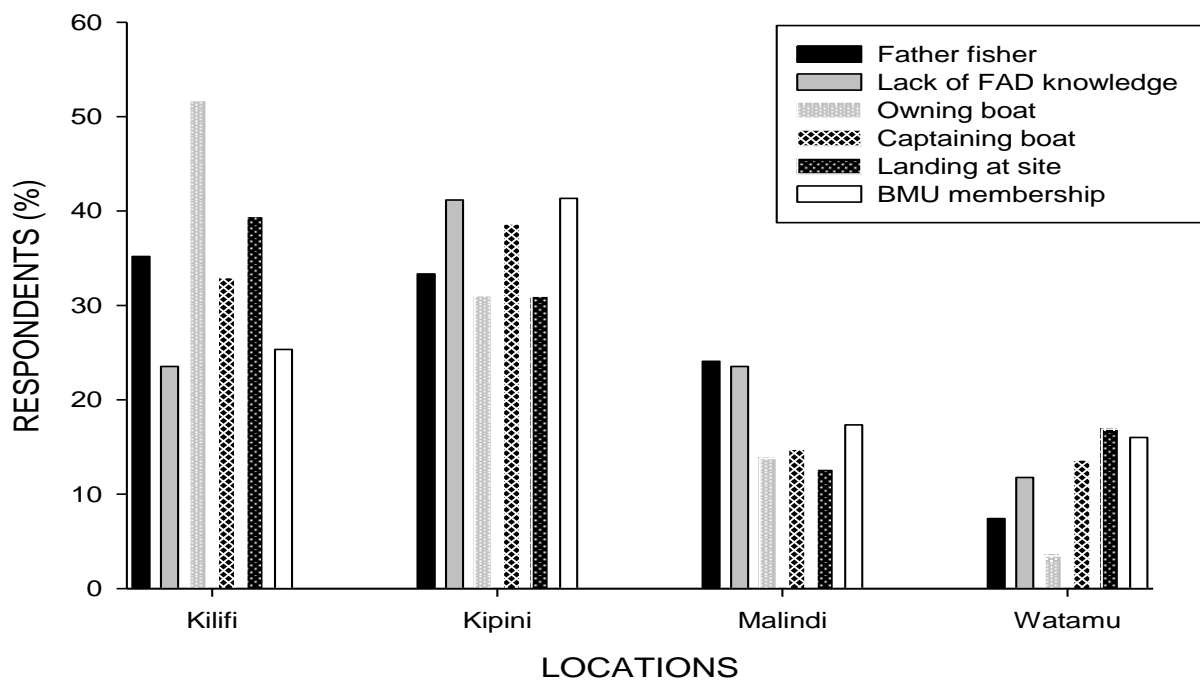
Figure 4.1. Percentage proportions of fishers in relation to various indicators.

4.3.2. Fishing patterns and individuals expenditures

Foremost, a good number (83.6%) relied on fishing as the main source of income (Table 4.3). This includes about 67.6% who primarily fished within the shallow lagoons fishers and about of

61.2% who fished both in the lagoons as well as in the offshore open waters. Other than finfish, about 40.8% of the respondents engaged in seasonal shrimp fishing in addition to fin-fish (Table 4.3). The mean crew size for the artisanal fishers ranged from 3.9±0.2 to 6.8±0.7 with a mean income of $26.6±0.1 per day; recreational fishers on the other hand had a mean crew size of 5.3±0.1 with an average income of $89.4±0.0 in a normal fishing day. Table 4.4 below presents typical species caught by sport fishers over the last 9-years.

Table 4.3. Fishing behavior in relation to fishery sustainability (NB. Figures on catch value are reported per boat)

Community/ landing site	Fishing reliance (%)	Fin-fish (%)	Shrimps (%)	Lagoon (%)	Offshore (%)	Crew size (mean±SE)	Catch value ($)
Kilifi	93.4	82.8	31.0	75.9	62.1	3.9±0.2	13.6±0.1
Watamu*	100	100	0.0	0.0	100	5.3±0.1	89.4±0.0
Malindi	83.0	85.0	35.0	50.0	60.0	4.1±0.2	47.4±0.2
Kipini	74.5	64.1	56.4	76.9	61.5	6.8±0.7	18.8±0.1
All sites*[e]	83.6	77.3	40.8	67.6	61.2	4.9±0.4	26.6±0.1

*[e]- excluding recreational fishers

Table 4.4. Species caught by recreational fishers over the last 9-years.

Fish species	Common name	Funzi-Shirazi bay %-proportion (mt)	Malindi-Ungwana bay %-proportion (mt)	Mombasa-Kilifi North coast area %-proportion (mt)	All coastal regions %-proportion (mt)
		Locations			
Acanthocybium solandri	Nguru mtwana	5.4(4.50)	6.8(39.6)	8.4(60.81)	7.5(104.91)
Caranx ignobilis	Kolekole	1.4(0.82)	2.7(28.71)	3.3(37.99)	2.9(67.52)
Carcharhinus melanopterus	Papa	0.04(0.04)	0.9(18.65)	0.7(24.29)	0.7(42.98)
Coryphaena hippurus	Fulusi	36.7(19.29)	9.3(23.61)	13.3(52.52)	12.9(95.42)
Galeocerdo cuvier	Papa	0.0(0.00)	0.4(47.99)	0.3(55.36)	0.3(103.35)
Istiophorus platypterus	Sulisuli makuti	12.0(40.41)	22.6(272.68)	17.7(227.88)	19.6(520.97)
Isurus oxyrinchus	Papa meu	0.04(0.22)	0.02(0.86)	0.01(0.46)	0.01(1.55)
Makaira indica	Sulusuli mweupe	0.7(4.29)	1.1(36.18)	1.2(60.74)	1.1(101.21)
Makaira nigricans	Sulisuli buluu	0.4(2.16)	0.09(3.76)	0.2(10.62)	0.2(16.55)
Rachycentron canadum	Songoro	0.08(0.08)	0.2(1.4)	0.08(0.8)	0.1(2.27)
Scomberomorus commerson	Nguru	2.6(1.14)	12.0(43.57)	6.9(37.93)	8.9(82.64)
Sphyraena barracuda	Kisumba	1.8(0.74)	4.4(13.97)	2.5(10.6)	3.4(25.31)
Sphyrna zygaena	Kisumba	0.03(0.21)	0.06(1.31)	0.05(1.48)	0.05(2.99)
Tetrapturus audax	Sulusuli mweupe	11.2(33.6)	0.5(13.65)	0.9(26.53)	1.3(73.78)
Thunnus albacares	Jodari	27.1(16.12)	38.7(211.28)	43.8(198.0)	40.5(425.39)
Xiphias gladius	Sulusuli mduwaro	0.5(1.19)	0.4(7.31)	0.7(8.18)	0.5(16.68)

In terms of boats, only 17.9% of fishers owned fishing gear that required a considerable capital investment, such as an engine boat (Table 4.5). To determine the intensity of fishing effort in the communities, results showed in all sites that fishers were willing to move as far as 10km offshore (Table 4.5), although this ranged slightly from 9.6±0.4 in Malindi to 13.0±0.0 in Watamu (where the recreational fishers were based). Fig. 4.2 clearly shows that most fishers joined the fishery having worked in the informal sector. Although reasons for quitting the informal sector were not included in this study, most of them argued that poor remunerations, job insecurity and freedom were among the main reasons that led them shift to fishing. In addition, fishers displayed two major forms of sharing their daily revenue. Most of them had opted to either sell the entire catch and share the money or share the raw catch for each one to approach the market independently.
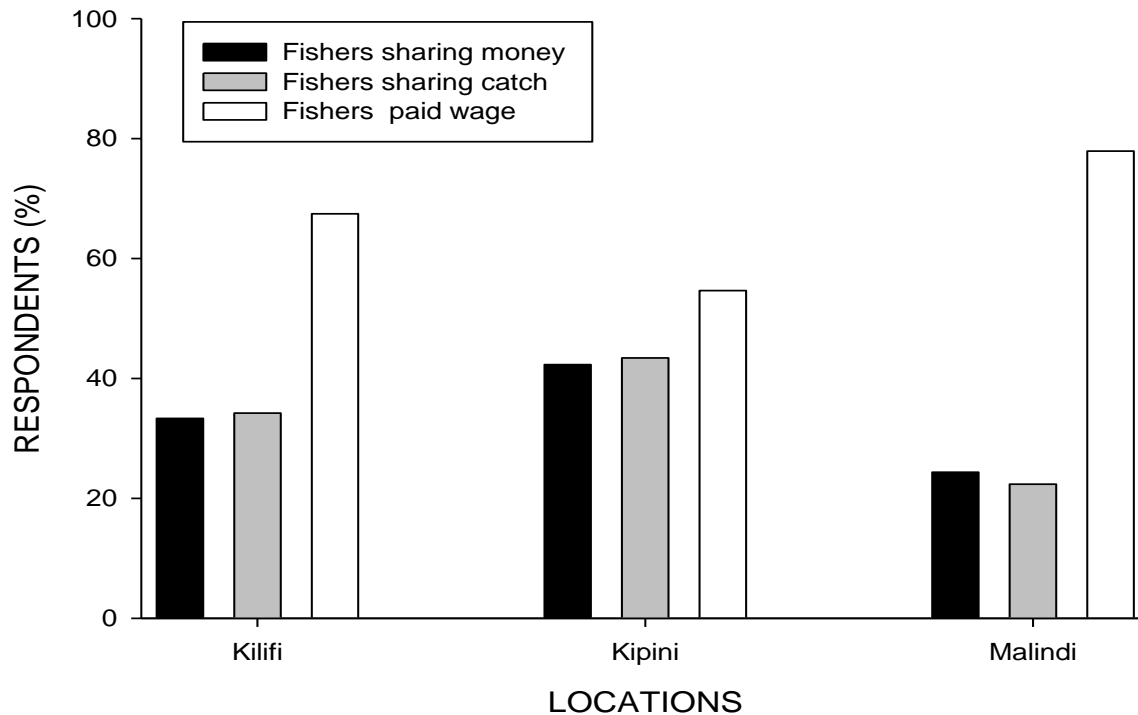
Figure 4.2. Different modes of revenue sharing adopted by artisanal fishers; proportion of fishers who joined the fishery from the informal sector.

Table 4.5. Mean±SE crew size, proportions of propulsion mode and mean distances fishers are willing to move.

Type of boat	Mean crew size				
	Kilifi	Kipini	Malindi	Watamu*	All sites*e
Un-motorized boats	3.6±0.4	0.8±0.0	2.0±0.1	0.0±0.0	2.1±1.7
Motorized boats	5.3±1.8	2.7±0.2	5.0±0.0	9.1±4.3	4.3±0.7
Propulsion mode	% proportions				
Inboard/outboard	20.7	23.1	10.0	100	17.9
Paddle/sail	58.6	56.4	15.0	0.0	43.3
Willingness to move	Mean distance (km)				
Offshore distance	11.1±0.2	10.7±0.2	9.6±0.4	13.0±0.0	10.5±0.3

*e- excluding recreational fishers

The total fishing effort across the four communities indicated that Kipini (with a higher variety of gears) exhibited the highest overall fishing pressure, and Watamu exhibited the lowest (Table 4.6). Gill nets were the most frequently used gear (80.5%), followed by hook and lines (29.1%), beach seines (including small trawl nets 11.3%), while ringnets (2.6%) were the least (Table 4.6).

Table 4.6. Percentage proportions of gear use among repondents.

Community/landing site	Gillnets	Hook & line	Traps	Longline	Ring nets	Beach seine
Kilifi	79.3	24.1	6.9	6.9	0.0	17.2
Watamu*	0.0	100	0.0	0.0	0.0	0.0
Malindi	70.0	35.0	0.0	15.0	0.0	15.0
Kipini	92.3	28.2	2.6	10.3	7.7	12.9
All gears*e	80.5	29.1	3.2	10.7	2.6	15.0

*e- excluding recreational fishers

Although most respondents were familiar with the FAD associated species (Table 4.7), almost all respondents confirmed their willingness to be trained on the fishing techniques around FADs. To some extent, all the preferred FAD fishing techniques existed in all the areas surveyed although

in varied proportions. For instance, Watamu had the highest percent proportions in terms of use of FAD fishing techniques as well as familiarity of FAD associated species (Table 4.7).

Table 4.7. Percentage proportion of fishers using FAD associated fishing techniques and familiarity of FAD associated species.

Community/ landing site	%-Use of FAD fishing techniques			%-Familiarity of FAD associated species		
	Trolling lures	Hook & line	Longlines	Tuna	Dorado	Wahoo
Kilifi	6.9	75.9	44.8	100	93.1	82.8
Watamu*	50.0	100	75.0	100	100	100
Malindi	10.0	90.0	60.0	90.0	100	85.0
Kipini	20.5	82.1	66.7	94.9	92.3	61.5
All sites*e	12.5	82.7	57.2	95.0	95.1	76.4

*e- excluding recreational fishers

Turning to individual's expenditure, a considerable variation was observed, but as expected, fishing accessories like boat buying and repair that required heavy investments were associated with the higher expenditures (Table 4.8). Due care was taken to present these figures, considering the varying frequency at which these costs might be incurred. For example, expenditure on boat buying could be incurred once in five years while boat repairs or transport may be weekly or daily expenditures respectively. A negative correlation was observed between mean years of education and expenditure (Table 4.2; 4.8) in that some locations like Kipini had the lowest mean expenditures but the highest mean education; Malindi on the other hand had the highest mean expenditures but not the highest mean education. However, this relationship between education and expenditure was not statistically significant (Spearman's rho = -0.04, p=0.75, n=4). As expected, communities' proximate to urban areas (i.e. Malindi, and Kilifi) had the highest expenditures and the rural areas (Kipini) had the lowest (Table 4.4). Again, given the small sample of communities used, this relationship was not statistically significant at the 0.05

level (H= 4.95, df= 3, p= 0.18). Results for the monthly, weekly and daily expenditures of each fisher examined are presented in Table 4.8. Results for Watamu were not included so as to avoid biasness in the figures given that Watamu was only comprised of foreigners engaged in very expensive big game fishing with huge investments in terms of boats, fuel and accommodation. In which case this would skew the overall results.

Table 4.8. Mean cost incurred by respondents with varying frequency.

Community /location	Mean cost incurred (US$)					
	Transport *(per day)*	Fuel cost *(per day)*	Net repairs *(per week)*	Boat repairs *(per month)*	Accommodation *(per day)*	Boat buying *(per year)*
Kilifi	0.5±0.3	3.6±1.8	3.7±1.1	7.1±3.3	0.1±0.1	206.0±130.4
Watamu*	-.-±-.-	-.-±-.-	-.-±-.-	-.-±-.-	-.-±-.-	-.-±-.-
Malindi	0.8±0.8	5.7±3.2	5.7±3.2	31.6±25	5.2±2.0	346.3±194.7
Kipini	2.4±1.2	0.8±0.8	1.6±0.7	5.7±2.7	6.2±1.6	18.1±8.0
All sites*[e]	1.2±0.8	3.4±1.9	3.7±1.7	14.8±10.3	3.8±1.2	190.1±111.0

*[e]- excluding recreational fishers

4.3.3. Market influences and resilience to change

At the sites examined, fish marketing was done primarily by small and medium-scale traders. However, medium-scale traders and large-scale traders that export fish by the ton (tuna traders) interested in large catches were believed to be in abundance.
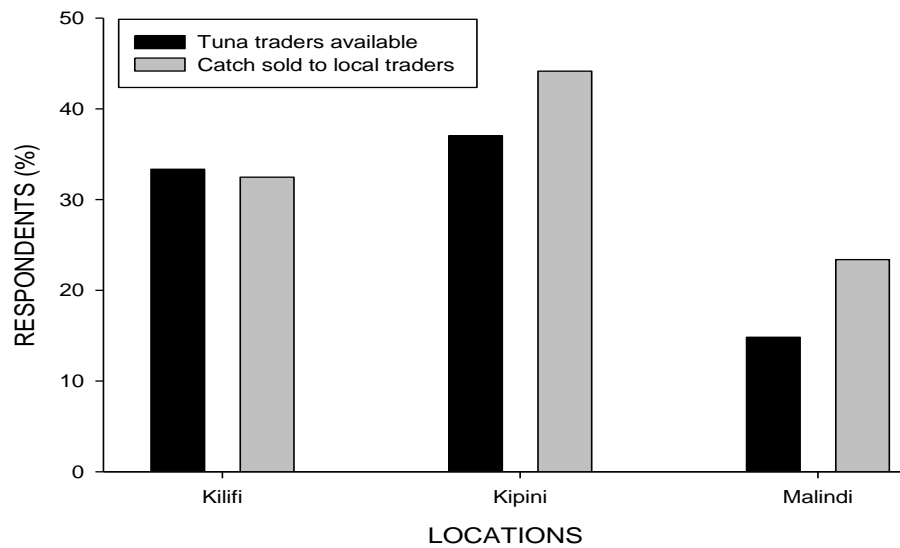
Figure 4.4. Respondents proportions from fishers on various indicators related to market influeces and catch sharing.

Under the hypothetical scenario of a reduction in catch with the three possible choices for each scenario, results of the mean percentage resilience scores for each community were almost similar (0.21% - Malindi and Kilifi; 0.23% - Kipini and Watamu) and generally low (0.22% - overall). Most artisanal fishers (over 50%) warned that they were ready to exit the declining fishery and join other ventures should their daily average catch continue to decline (Fig. 4.5a) although this was not the case for the recreational fishers with only a handful ~15% willing to do so. Almost all respondents agreed that FADs may have the potential to increase their catch (Fig. 4.5b) with majority still in believe that the Kenyan coastal fishery is still within the sustainable limits (Fig. 4.5c). In light of this, most of the respondents endorsed the idea of having FADs deployed in the entire Kenyan cost (Fig. 4.5d).
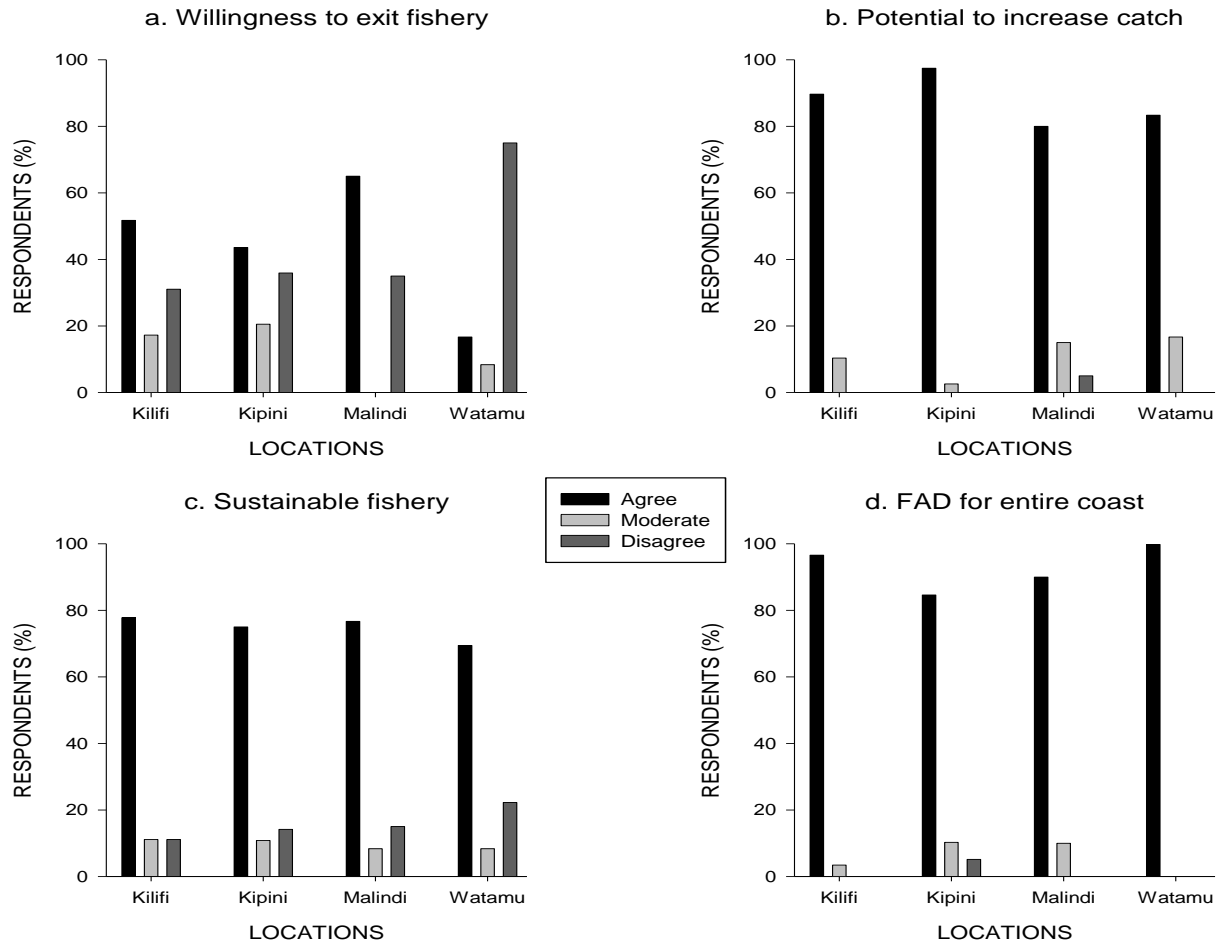
Figure 4.5. Fishers' responses in four locations based on various hypothetical scenarios: whether fishers are ready to abandon fishing should catch rates continue to decline (a), whether FAD fishing has the potential to increase fishers catch rates (b), whether fishery is still sustainable (c), and whether FADs programs should be extended to all areas along the coast (d).

4.4. Discussion

Other than the convincing reasons already in existence in support of FAD fishery, fisheries experts noted that for any fishing program to achieve sustainability, perceptions of resource users must be relied upon (McClanahan et al., 2005). Here, preferences to FADs had to be based on real or perceived costs, fishing culture, education, occupations, past history of interactions around resources, and be informed by scientific or qualitative investigations about their efficacy (Richardson et al., 2005). To place this new fishery further in context, heterogeneous perceptions and behaviour from various groups (both recreational and artisanal fishers) were relied upon. Since results on fisher demographics obtained in chapter three of this study did not differ from a far from those in this chapter, all discussion points on fisher demographics adopted in the previous chapter (see chapter 3) are endorsed herein - in their entirety.

4.4.1. Fishing patterns and individuals expenditures

a) Livelihood options and FADs

Fishing is highly regarded as the primary source of income in these communities. The only other occupational categories that dominated feedback (apart from fishing) included, selling marine products, agriculture, tourism, and the informal sector. Interestingly, only rural and remote communities suggested the highest number (maximum 3) of occupations while those in urban areas (mostly recreational fishers) had the lowest (maximum 1). Nonetheless, this occupational multiplicity and occupational diversity is relatively low (mean=2) compared to studies conducted in other countries. For example, in 21 communities investigated in Indonesia, the number of occupations per household ranged from a low of 2 to a high of 4 (mean=3) (Cinner et al., 2009). With this low diversity of livelihood options to draw upon and the high dependence on fishing

observed, it is quite obvious that FADs- if introduced - may have a direct impact on peoples livelihoods. Increase in fishers overall income could be a possibility given that most of the FAD associated species are of high value (Dagorn et al., 2007).

b) Income and FADs

A better way to decipher incomes in this artisanal fishery is by translating it to the amount of kilos a fisher takes home or sells or both at the end of each fishing day. Other than the recreational fishers (mean crew size 5.3±0.1) who take home an average minimum of about us$90 per day, artisanal fishers (mean crew size 3.9±0.2 to 6.8±0.7) here take home an average range of between US$14 to a maximum of about US$ 50 per day (Table 4.3). Again these statistics imply low incomes and living standards experienced in these areas making the fishery appear unsustainable (Obura, 2001a). Comparing these two groups, it's almost clear that the mode of exploitation has a significant bearing on the overall catch and income. Therefore it is not a question of whether a change is needed in the exploitation of fisheries resources but rather one of the most appropriate exploitation approaches. Consequently, the fact that the recreational fishers who apparently specialize in offshore pelagic fishing obtain higher revenues could simply explain why majority of the artisanal respondents believed that the offshore fishery is rich in fish stocks (Fig. 4.5c); and that their catches could be increased substantially if efforts are focused towards venturing into offshore fishing. Despite this knowledge, only a few had access to powerful fishing vessels that could maneuver the open waters. Most of them complained of the high costs associated to boat buying and maintenance as the major impediments hindering them from acquiring motorized boats. Majority could only afford to hire motorized fishing boats on a need basis in order to access the deeper waters or sometimes captaining boats only. In some areas, it was pointed out that many entrepreneurs had entered the fishery with a profit

maximization motive by investing in canoes for rental. A few individuals own more than 10 canoes each, which they rent out to fishers on a daily basis. Many fish dealers and middlemen have also entered into informal agreements with fishers to whom they give credit and/or lend fishing canoes on condition that the fishers sell to them all their catch. Consequently, fishers are bound by these agreements to sell their catch at low prices to these dealers in order to continue obtaining loans. The informal agreements have reduced the sovereignty of the fishers at some of the beaches, as fishers no longer have the freedom to fish and sell their catch to a buyer who offers the highest price.

c) Fishing gears and FADs

Given that most locations were dominated by gillnets (Table 4.6), whose mesh size is below the recommended size (DoF, 2008; Hicks and McClanahan, 2012), a decision has to be made on appropriate gear use at FADs. This is because majority claimed to use this illegal (due to illegal mesh size) gear out of need, rather than want. For example, one fisher pointed out that his net was so old and so often repaired that it was comprised of less than 10% of its original material. He suggested that he could not buy new gear and could only afford to continually repair this illegal net. A group of fishers also claimed to be very willing to do a gear exchange project to trade in their illegal gear for less destructive legal gears or even the preferred gears to fish at FADs. Therefore, it is not clear whether banning the use of these gears at FADs will be an easy option. But, since hooks and lines are the best gears for fishing at FADs, it could be a good idea either to put in place a proper sensitization plan particularly on the mode of fishing at FADs if not banning the use of gill nets and/or other inappropriate gears at FADs. Furthermore, all the preferred FAD fishing techniques (although in varying proportions) existed in all the areas surveyed meaning that little adjustments will be felt once FADs are in place particularly in

Watamu. Complementarily, it was the same area (where the recreational fishers were based) that had the highest use of gears that target pelagics besides the highest proportion of fishers familiar with the FAD associated species probably making the area appropriate for FAD deployment. Additionally, success of FADs in selected pilot areas could help decision makers obtain better comparative information before any possible expansion of FAD programs along the entire Kenyan coast. Since local fishers still have no clear ideas of what FADs are and how FADs may connect to their income and overall well being, it is critical that only cheap artisanal FADs fabricated from locally available materials such as bamboo rafts and coconut fronds are deployed. Typically they can be bamboo rafts, strings of fishing floats or metal cylinders, all with appendages (branches, ropes, or disused netting) suspended beneath to provide shelter for small fish. It is also understood that FADs vary in shape and sizes and can either be drifting or anchored (Franco et al., 2009). Anchored FADs are usually set in position by use of an anchor and a mooring line, whereas drifting FADs are deployed without mooring lines (Franco et al., 2009). It should be recommended that anchored FADs be prioritized as opposed to the expensive drifting FADs since it has been proposed that anchored fish aggregating devices (AFADs) can more easily attract pelagic fishes because of the sounds produced by their anchoring chains or the influence of current on the mooring ropes (Freon and Dagorn, 2000). Additionally, starting with artisanal FADs would allow fishers and communities to conceptualize and understand the rationale of FADs programs and win their support before investing on the expensive industrial FADs.

c) Recreational and artisanal fisher's FAD conflict

At this stage, it can only be hypothesized that conflicts may or may not arise between the artisanal and the recreational fishers. But even if conflicts are to occur between these two groups, these hypothetical conflicts are too inconsequential to neither defeat the rationale for introducing

FAD programs nor form the basis to reject this fishery. Furthermore FAD programs have succeeded in all regions implemented including remote islands states (Anderson and Gates, 1997). While care must be taken to avoid any possible conflicts between these two groups, rejecting the new FAD fishery over these speculative conflicts would clearly create a scenario whereby a project is rejected out of nothing. This is because, there are no other inclusive FAD fishery programs in existence within Kenya and as a result no baseline information or blue print exists for the present project to follow. Additionally, with no predictable criteria in existence on the implementation of FAD programs which need to be exhaustively fulfilled, this tentative framework (provided herein) is a classic case of a finder of fact (at its very least) where a subsequent post-analysis of views could be conducted after the introduction of FADs and results compared expeditiously. In any case, there is a possibility that incomes from the recreational fishers might increase as FADs are known to be recreational hotspots elsewhere around the world (Benivary, 2009).

4.4.2. Fisher's safety and training

For this fishery to realize its full potential, a training on FAD fishing techniques has to be done since most respondents, although familiar with most the FAD fising techniques (Table 4.7), confirmed their willingness to be trained on the appropriate fishing techniques around FADs. Secondly, education seemed to play a major role in fisher's expenditure (Table 4.2). Although no significant correlation was observed between education and expenditure (probably due to small sample size), it was clear that fishers with low (or minimal) education had high expenditures. This shows how education helps others to manage, budget and direct their incomes to either savings or better expenditures. Therefore, other than training fishers on FAD fishing techniques, it would be prudent to include training on financial management (either formal or informal)

using the BMU framework. This training will not only enable fishers become good financial managers, but will also boost the management of the natural resources which are directly linked to their incomes. In addition, most of the fishers who did not own boats suggested that (if possible) training boats and gears could be provided for the start (Table 4.5), since their traditional canoes had poor maneuverability and simply unsafe when the sea is rough. However, should this be a challenge to the fisheries agencies, this study suggests that near shore FADs could be deployed alongside the offshore FADs so that both fishers with or without motorized boats could benefit.

4.4.3. Type of FADs to be deployed

Although majority of the respondents (with or without motorized boats) were willing to engage in the offshore pelagic FAD fishery (Table 4.5), the gear and vessel types relied upon by most of these artisanal fishers remain a great concern. Most fishers argued that if the sea is calm and they are guaranteed of good catches at FADs, they could go as far as 10 kilometers offshore with their un-motorized vessels to access the FADs. While on one hand this could be a good sign of motivation by these fishers to exploit the FAD resources, this could also be interpreted as a sign of desperation and [it] must be said that this eventuality could undermine their safety at sea. Confronted by this truth, most of the respondents accused the government of ignoring them by not implementing the rescue mechanisms as articulated in the BMU laws. They cited the lack of functional rescue units in most of the landing sites as the main reason undermining their safety at sea. This clearly shows that the issue of sea safety has to be taken into consideration when planning to introduce the FAD program. Surprisingly, there was no mention of this problem by the recreational fishers probably because their boats are known to be equipped with all the safety paraphernalia. On this basis again, it remains to be seen whether the offshore FADs programs

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would be more beneficial to the recreational fishers as opposed to the targeted artisanal fishers. Yet again, near shore FADs (placed away from the coral reefs) and easily accessible by the commonly used un-motorized canoes could be of benefit to these communities.

4.4.4. Market influences

Market for the FAD associated species seemed to be a non-issue at these areas (Fig. 4.4). There were numerous small and medium-scale traders and middlemen that generally bought fish at landing sites. These fish mongers generally buy fish at landing sites, do some processing (scaling, gutting, and possibly cooking), and either sell their fish in local open air markets or transport fish to urban centers either in Mombasa or Malindi for sale in retail fish shops. Even the ring netters for example, who occasionally land up to fifty tons of fish, had never lacked market and always relied on this readily available market to sell their fish (Munga et al., 2010). However, in some areas like Kipini and Malindi, fish was sold mostly to small-scale marketers on the beach. These small-scale traders typically lack private motorized transport and were limited by what they could carry on a bicycle, their head, or as "carry-on" luggage on public transport including motorbikes. Medium-scale traders include traders with refrigerated storage capacity who purchase fish directly from fishers and later sell their fish to consumers in Mombasa or Nairobi and hotels in Malindi and Mombasa. Most medium scale Medium-scale traders were present in Malindi, Watamu, and Kilifi. In Malindi, the one site with a medium-scale trader, the trader owned a variety of vessels and gears and hired people to utilize his gear to capture fish. Large-scale traders that export fish by the ton were encountered in Watamu and Malindi. The shortest distance to proximate market was in Malindi where traders sold fish at a medium-scale trader's shop approximately 50-100 meters from the landing site. In Kilifi, the distance to the nearest fish market was only 500 meters, but fishers themselves did not sell

directly to the shops, but rather allowed middlemen to purchase their fish. This may be, in part due to the small size and resultant low demand for their particular fish, which would not likely have sold in a fish shop. The longest distance to market was Kipini. Exact figures are not available, but it is an estimated 5 km from Kipini BMU (which is approximately 35 km from the larger Witu market). Given the large sized and high valued species expected to be caught at FADs, the marketing strategy is expected to change substantially as fishers may opt to sell their catch direct to the shops rather than through middlemen.

4.4.5. Social resilience

Resilience is the ability of a system to absorb change before shifting to an alternate state (Cinner et al., 2011). In the social context, this can be interpreted as the ability of an individual, group, or organization to withstand social, economic, and natural disturbances without fundamentally altering what they do (McClanahan et al., 2005). More resilient people will be able to absorb higher levels of disturbance, adapt to change, and have the capacity to re-organize after a disturbance. For less resilient people, even low levels of changes will alter their lifestyles (McClanahan et al., 2005). In a natural resource management context social resilience is an important component of how stakeholders respond to and are affected by policy decisions, natural disasters such as hurricanes, bleaching events, and tsunamis, new fishery programs (e.g. the introduction of FADs in this case), and significant declines in resources abundance. The indicator for resilience explored within the coastal communities along the Kenyan coast was similarly low in many of the sites. This proves that fishers were willing to alter their fishing behavior to adopt other fishing techniques thereby putting the FAD fishery in context. However this willingness to change, coupled with the agreement that FADs should be introduced along the

entire coastal region should be attributed to the fact that fishers believed - beyond any reasonable

doubt - that FADs exhibit the potential to increase their catch and overall income (Fig. 4.5c).

CHAPTER 5 - GENERAL DISCUSSION AND MANAGEMENT RECOMMENDATIONS

5.1. Fishing Gears and Catch

Development of the Kenyan coastal fishery seems to be largely dependent on the fishing methods used, however several other aspects could be used to explain the dynamics of this fishery (Glaesel, 1997). Along the Kenyan coast, majority of the fishers are predominantly artisanal and engage in subsistence fishing as opposed to commercial fishing operations (McClanahan and Mangi, 2001). Some of the possible reasons overriding fishers from developing their fishing ventures from subsistence nature to commercial endeavors include the type of equipment used in harvesting the fishery resources, technological development and insufficient investment capital funds (Glaesel, 1997; McClanahan and Mangi, 2001). Traditional believes, time and energy factors partly explains the consistent dominance of these five rudimentary fishing gears which include the basket traps, hook and lines, spearguns, beach seines and gillnets. Fishing with gears like basket traps dates back to the 60's and to date most fishers seem to maintain the same fishing behavior inherited from their parents although with slight modifications (Cinner and McClanahan, 2009). Currently, several gear management restrictions have been put in place already including a ban in spearguns, beach seines and monofilaments gillnets as well as mesh size regulations. Although this is a commendable effort towards management of the fishery, studies by Hicks and McClanahan (2012) suggested that for these gear-based fisheries management actions to yield higher CPUE's, these restrictions should be based on life history and body sizes of the species targeted.

With regards to fisheries productivity, the small varying trends in terms of CPUE over the 9-year period clearly confirms that the artisanal fishers might have maximized output from the near

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shore coral reef areas that they can access with their traditional fishing technology (Obura, 2001a). This may have depleted the near shore stocks, thereby threatening sustainability (Fondo, 2004). As a matter of fact, minor changes have occurred in terms of CPUE since Muthiga and McClanahan (1987) reported that, the fishery had suffered declining productivity due to the use of destructive and illegal fishing gears yet fishers are fully aware of the gear that the government discourages but they have adapted to only some of the new legislation in only a few areas suggesting the need for better enforcement (McClanahan, 2010). This was confirmed by the very low CPUE values which were less than 2 kg/fisher/hour, with a fisher population of 5 to 13 per km^2 (Obura and Wanyonyi, 2001). Therefore, should this be attributed to the increase in the number of fishers (population) over the last two decades (DoF, 2008), then there is need to regulate the influx of fishers especially foreign fishers from neighboring Tanzania who are known to use destructive gears including the controversial ring nets (Munga et al., 2010).

5.2. FAD Fishery

As it is the first time that FADs are introduced in Kenya, fishers are not prepared yet to fish on these devices. As no training has been provided, they might end up using their ring nets instead of proper lines, ruining the site all at once. In this regard it is recommended that training be conducted as soon as possible in order to provide fishers with proper tools and techniques for fishing around FADs (Mauritius Institute of fishing technologies can help on this). Subsequently, since hooks and lines are the best gears for fishing at FADs, it could be a good idea either to consider banning the use of gill nets, ring nets at FADs or if this is not possible at the moment due to other known or unknown reasons, then a proper sensitization plan must be in place particularly on the mode of fishing at FADs. In the same line of thought, management rules have to be implemented to define gear use on FADs. Kenya fishers are quite mobile and migrate along

the coast depending of the fishing season. Their migration presents a potential risk of conflicts around FADs with local communities. Even short distance migration (fishing time of 3-4 days at sea, which is common) can create conflicts. Therefore, all coastal fishers must be sensitized with some basic knowledge on FAD and their use through a prioritized campaign of information. Management measures have to be set up in order to define fishing rights on FADs. The new 6-years project entitled Kenya Coastal Development Program (KCDP) that was launched at the end of 2011 has planned to deploy about 10 FADs on coastal fishing areas. This is a great opportunity for the local scientists to extend FADs activities and continue monitoring the socio-economic impacts of FADs on fishing communities.

This notwithstanding, adding to the need of FAD programs to boost artisanal catches is the fact that a normal day catch for an artisanal fisher is approximately 6 kg while that of a recreational pelagic fisher (if retained) is about 20kg. Based on this, it's highly expected that shifting from nearshore fisheries into the offshore pelagic fishery; fishers would increase their catch to as high as 20kg per fisher in a normal fishing day. This is because recreational fishers sometimes releases tagged fish a situation which may not arise for the artisanal fishers. As stated earlier, it is still unclear whether conflicts between the artisanal and recreational fishers will arise as no study has been seen to support this hypothetical scenario. But, in so far as there could be need to assess whether or not conflicts may arise, assertions in proposition of FADs from this study (though taken as speculative conclusions) could be considered as a classic example of a finder of fact that critically evaluated the perceptions from the very resource users to determine their position on this new fishery while also considering experiences from other countries on the same topic. Either way, this study gives a framework within which to work, based on, and in compliance

with, the needs of the local fishers since no study has been done to support the purported conflicts between these two groups. Accordingly, this study did not focus on the issues surrounding possibilities of conflicts between any competing groups within the fishery and therefore no assertive conclusions could be made other than recommending a comprehensive study to be conducted on the same.

5.2.1. Current data collection system

The collection of reliable data from the marine artisanal fisheries is rather complicated due to the complex nature of these fisheries (Jennings and Revill, 2007). In Kenya for instance, data is collected from the artisanal fishery from various parts of the coast archived by various institutions with different objectives and motivation. The Kenya Marine and Fisheries Institute (KMFRI) has the legal mandate to conduct research along the entire Kenyan coast, territorial waters and Exclusive Economic Zone. However, the institute still has not conducted a comprehensive assessment of marine fisheries. The current catch statistic system which relies on the data collected under the Beach Management Units (BMU) framework sometimes lack consistency and continuity. In some areas, this responsibility is even undertaken by NGOs with different protocols. For instance, within the region of Kilifi, an Italian NGO (CAST) started collecting data using their own protocol. It compiles the data and reports to the district fishery officer who, in turn, reports to the regional office in Mombasa. Although this could be a good effort, the lack of scientific objectives in the way CAST is handling data collection may make it impossible for the data to yield or indicate good fishing trends. Although KMFRI has an efficient data collection system, this data does not seem to be used as no major reports are based on them. At national level, within the RECOMAP project, the country fishery statistic system has been reshaped. A web database has been developed for the facilitation of data recording at local level

(it works currently only on Intranet but will be accessible through the Internet soon. The new computation system will be operational after the completion this year of a new frame survey (the last one was carried on in 2008). A new data sheet collection is already available (see appendix 2). In this regard, the deployment of FADs in Kenya has to be accompanied by the implementation of a proper data collection system. Data collection frames under the major World Bank funded project (SWIOFP) framework were provided (see appendix 2,3). They cover the whole set of indicators for the measurement of the socio-economic impacts of FADs. A generic database based on various socio-economic indicators has also been developed. Overall, 4 new data sheets have been developed. The first one is about catches and time spend around FAD, the second one local market data, the third one the well-being of fishers and fishing communities and the fourth one the management of FAD.

5.3. Perspectives for a Sustainable Fishery Management Program

Several issues affect the management as well as fish production in Kenya (McClanahan and Mangi, 2004). The types of fishing vessels and gears, the monsoon weather patterns, social and economic factors affect fish landings. Religious fastings, holidays, festivities (no fishing) and diversion of fishing boats into more lucrative tourist transportation and mangrove pole cutting, transport, among other factors affect fish production (Muthiga and McClanahan, 1987). In this regard, fisheries' management may require varies aspects including area, time, size, species and effort restrictions (McManus 1996; Morison, 2004). Some of the factors determining the acceptance of these restrictions vary based on government agencies, economic, cultural and technological reasons. In ethnically diverse nations like Kenya, management of multi-species, multi-gear and different levels of governance can be complicated with the mixed traditional and modern scientific knowledge (White et al., 1994). To avoid confusion and conflict among

resource users leading to poor enforcement of regulations, efforts to understand and rationalize the multiple types of possible management must be emphasized (White et al., 1994; Glaesel, 1997; Glaesel, 2000). For example, Muthiga and McClanahan (1987), Obura and Wanyonyi (2001) and Obura (2001a), highlighted the failure to enforce the few management measures (e.g. the 1994 gazzeted Diani MPA) as one of the major reasons undermining the management of the Kenyan near-shore fishery.

Turning to the issue illegal gears (i.e. beach seine and spears), these gears were still commonly used, with almost half of the fish landings attributable to beach seine catches. This is not withstanding that the estimates of the mesh size in use in the fishery are more than two centimeter below legal minimum. Recently, fisheries management in Kenya has had various success stories (McClanahan and Hicks, 2011). However this can be improved if the government is focused in improving compliance with current gear restrictions and implementing programs that help protect critical habitats e.g. spawning aggregation sites. By imposing appropriate penalties on law breakers, increasing monitoring and proper conflicts resolution, compliance may be improved (McClanahan et al., 2011). Other approaches that could enhance compliance include provision of alternative livelihoods, education and awareness geared towards improved management. For example, lessons learned from beach seine excluded sites could be promoted other locations along the Kenyan coast to increase compliance (McClanahan, 2010). Although the decentralized BMU approach was believed to usher in a new dawn in fisheries management there is a need for government agencies to promote greater education on this approach so as to foster local responsibility (Ault et al., 2008). Fostering these relationships encourages the adaptive and flexible approach required to balance multiple objectives in an environment that, by

necessity, will continue to be heavily modified by human use but could produce more income for impoverished fishers if managed more effectively. Enforcing the current mesh limits would allow immature individuals to mature. This would in turn increase the reproductive potential, thus increasing yield over time. In order to provide immature individuals similar levels of protection a minimum mesh size of 8.8 cm and 9.2 cm would be necessary (an increase of 2.45 cm and 2.85 cm from the current legal limit, and over 3 cm from that in use); a challenging target in the local socio-economic context. Consequently, current approaches to management are unlikely to maintain the resilience of the whole system or optimize incomes (McClanahan et al., 2011). Alternate, complementary approaches are therefore necessary to maintain key life stages including juveniles; key habitats such as seagrass or mangrove nursery grounds; functional groups (Graham et al., 2011); and species not protected within current gear restrictions (Cinner and McClanahan, 2009). The current system of marine parks along the Kenyan coastline goes some way to achieving these goals (McClanahan et al., 2011). The role deeper unexploited areas play in the potential ontogenic migration could provide further strategic areas for protection. Ontogenetic migration in this case refers to the population movement of juveniles and small adults principally found in seagrass beds, mangroves and sandy areas to the deeper waters as a way of minimizing mortality and maximizing growth (Kimirei et al., 2011).

Gear management and modifications present one of the most realistic steps to rescue the local fishery (Munro et al., 2003). In order to move the fishery in a positive direction and increase fishery yields, the Kenya's current legal gear restrictions must be enforced (McClanahan et al., 2008). This will help break the vicious cycle of poverty (Cinner and McClanahan, 2009) which has remained a social ecological poverty trap (Munro et al., 2003). For this to achieve its full

potential there is need to incorporate these changes into the current education and local institutional structures (Cinner and McClanahan, 2009). The local decision-making processes also need to consider the scientific basis for management decisions besides having a refugia system that protects the key habitats and species exploited by the fishery (McClanahan, 2010). This being the only way to ensure a diversity of tools to a portfolio of needs which is a toolbox approach to fisheries management (Jennings and Revill, 2007).

5.4. Fishery Management Recommendations

Because of the limited fisheries resources, fishing pressure needs to be controlled so as to avoid stocks from collapsing (FAO, 1995). This is why conservation of fish stocks is at the core of the FAO Code of Conduct (FAO Code of Conduct, Articles 6.2, 6.3, 7.1.1 and particularly 7.2.1). Consequently, good management involves preventing fisheries and ecosystem structure from collapsing and helping fisheries recover from bad situations and successful management requires attention to all these aspects (Pope, 1983). For the purpose of this chapter, these aspects are summarized in three headings.

- Appropriate governance structures

Foremost, there is need to put in place an appropriate economic, institutional and social basis for management by ensuring that appropriate governance structures exist. Additionally, fishers must have the right economic incentives so that they feel included in the decision-making process and that all legitimate concerns such as protection of the wider environment are openly discussed and given appropriate weight in formulating the management process (Hilborn, 2007). With these in place, more detailed prevention of the disease of overfishing can be addressed effectively.

- Technical management measures

Secondly, technical management e.g. gears restrictions and closed areas and seasons are needed to avoid wasteful harvest such as catching juveniles or non-target species. Basket traps for instance which are predominantly used in Kenya typically target high value fish such as groupers and snappers (Stewart, 2007; Johnson, 2010), but these traps are weakly selective and usually retain most fish that enter, resulting in the capture and mortality of many species (Munro, 1983). Consequently, high bycatch of juvenile fish and non-target species can reach >50% of the catch, even with relatively low fishing effort (Hardt, 2008). To date, bycatch in trap fisheries in Kenya still remains a common impact of this gear and reducing bycatch would be a key aspect of increasing fishery sustainability and ecosystem-based management (Johnson, 2010).

- Input - output controls

Lastly, inputs and outputs controls are also required in order to limit the total effort of use of the various fishing gear or limit the amount of fish caught i.e. fishing effort management.

Collectively these measures, like technical conservation measures, are designed to conserve fish and achieve sustainability (Redemeyer et al., 2007). Their main concern here is to limit the proportion of fish caught by fishing, besides limiting the sizes, areas and times at which fish are captured. The list of conservation tools needed for any fishery usually depends on the goals intended to be met by the primary objective of the management or the scalability of the management regime (national or multinational) in terms of either good or bad compliance/ enforcement or whether the fishery is conducted by a small centralized fleet of large vessels or by a large fleet of small vessels with many landing points or whether the fishery is based upon one or many species among others tools.

Figure 5.0 (see page 127) describes the factors that might influence the output and input controls as well as technical measures. The final judgment can be based on where the fishery lays with respect to the various factors and the relative importance given to each factor. For example, an international fishery might decide to enforce catch controls even if compliance was weak but backing this up with other measures. Just like other fisheries, the Kenyan coastal fishery is most suitable to adopt some form of effort restriction with several technical measures being part of the management plan. As described by Alverson et al. (2007), catch restrictions would be both ineffective and inappropriate if applied in the Kenya fishery which is multispecies with small boats landing fish in many small harbours. As explained by Heddon (2006), in countries where management systems are weak, there is need for management to rely on robust technical measures such as closed areas or seasons rather than upon detailed input or output controls. Kenya fishery is very complex as it combines both underexploited offshore fishery and overexploited but undeveloped nearshore fishery and as result fisheries managers are faced with both the discouraging task of repairing the damage caused by past overexploitation as well as trying to manage a fishery that is undeveloped. This requires fisheries managers to be aware of the problems that result from the natural tendency of exploitation in order to put measures in place well before the problems become acute especially for the underexploited stocks. In this regard, fisheries managers in Kenya should learn from the mistakes of others from the overexploited fisheries from developed nations and avoid complacency about the state of the management of the Kenya fishery besides listening closely and carefully to all opinions and complaints about the fishery are helpful to any fisheries manager (FAO, 1995).

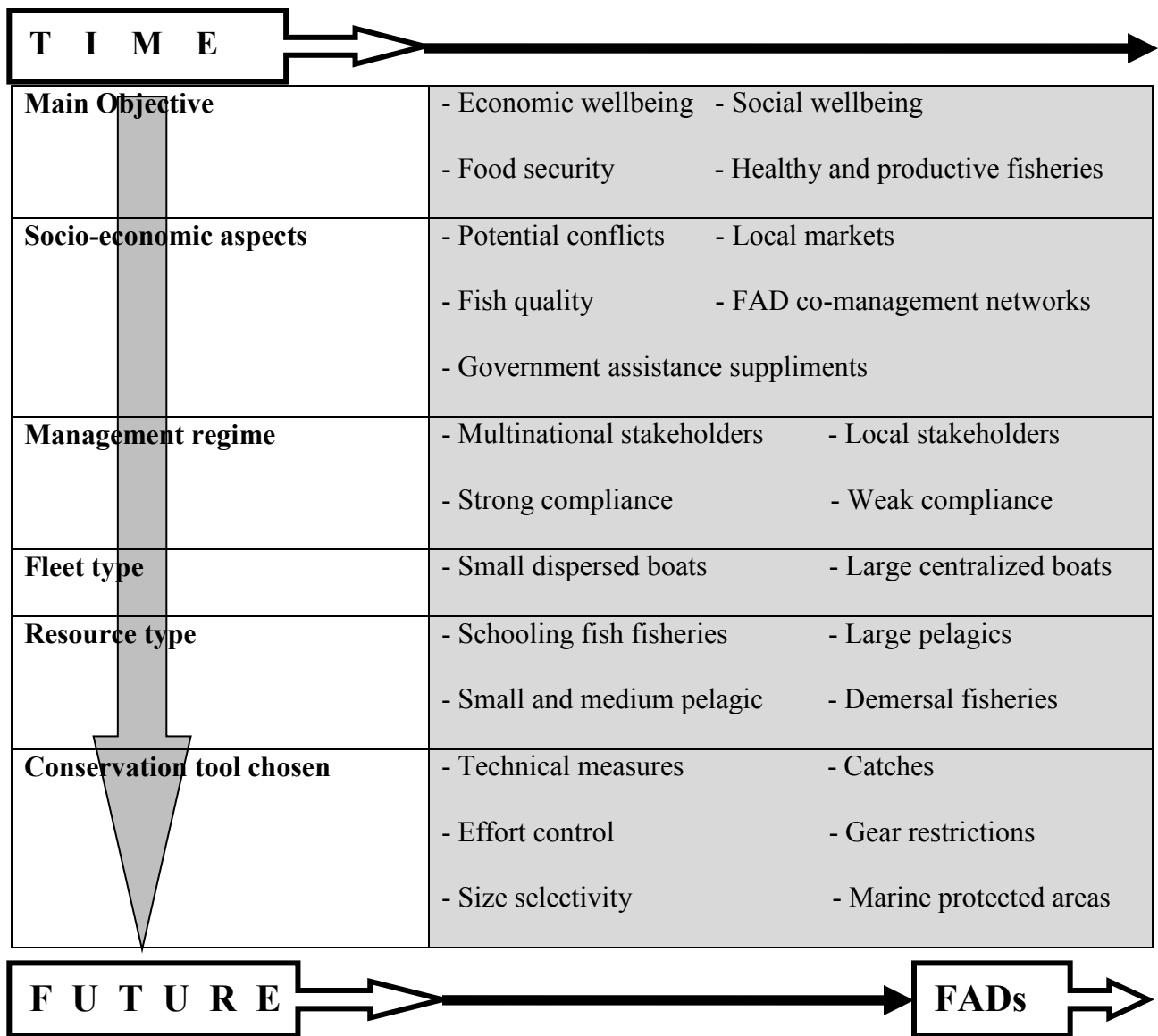| T I M E	
Main Objective	- Economic wellbeing - Social wellbeing - Food security - Healthy and productive fisheries
Socio-economic aspects	- Potential conflicts - Local markets - Fish quality - FAD co-management networks - Government assistance suppliments
Management regime	- Multinational stakeholders - Local stakeholders - Strong compliance - Weak compliance
Fleet type	- Small dispersed boats - Large centralized boats
Resource type	- Schooling fish fisheries - Large pelagics - Small and medium pelagic - Demersal fisheries
Conservation tool chosen	- Technical measures - Catches - Effort control - Gear restrictions - Size selectivity - Marine protected areas

F U T U R E → → FADs →

Figure 5.0. Factors which might influence the mixture of conservation tools chosen for the Kenya fishery.

5.4.1. FADs and MPA connectivity

Most of the Kenyan coastal coral reef areas are protected through community conserved marine areas (CCAs) also known as "tengefu". However, this noble idea still lack full compliance as fishers argue that it leads to a size reduction of their fishing grounds. An introduction of near shore FADs placed away from coral reefs will offer alternative fishing grounds to fishers diverted from these marine protected areas (MPAs). Besides increasing community compliance to the MPA management approach, FADs will help fishers reduce fishing pressure on local reef ecosystems whilst enhancing their fish catches and income.

However, before any FAD is deployed in any location along the coast, reconnaissance site surveys should be undertaken to confirm the site requirements for FADs location. Guidelines contained in the South Pacific Commission (SPC) Manual Vol. 1: Planning FAD Programmes (Anderson and Gates, 1997) could be followed in site selection. More importantly, perceptions of local fishers to these devices should also be considered before FADs are set up. Pre-selection surveys must include discussions and site visits with the local fishers. Information should be obtained on; influence of wind and currents, tuna fisheries, customary fishing grounds, offshore shipping and industrial fishing activities, local oceanographic and navigational charts should be examined. Agreement, support and authorization from national authorities must also be factored in. An attempt to understand the perceptions of the fishing communities towards these devices before and after deployment would be necessary. This will assist in setting up a large scale infrastructure where exchange in knowledge and experiences by different groups could be enhanced.

5.4.2. FADs design and FADs research

As explained in chapter 4, it is emphasized that artisanal FADs (FADs made from local available materials) be introduced during the initial start of this fishery. This would allow the local fishers to understand appreciate the importance of this fishery before huge investments on industrial FADs is considered. Since the Kenyan coastal fishery is predominantly artisanal and small scale, the proposed FADs are low-tech, low-cost, and fishing at FADs is done in exactly the same manner with hook and line. No training is required because fishermen do not need to alter their fishing methods. Because FAD materials are fabricated at a low cost, fishery departments or non-profits organizations would be able to supply them to fishermen for a subsidized cost or no cost at all. By involving local fishers during gathering of FAD materials, construction of FADs, deployment and maintenance, it is expected that the innovation would spin off directly to the fishers.

Before any possible extension of this idea to the entire Kenyan coast, it is critical to gain a better understanding of the dynamics of the aggregation in terms of species composition, interactions and information on the biomass at FADs. To investigate this phenomenon, the dynamics of FAD colonization and fish biodiversity at FADs could be assessed immediately after deployment. FAD colonization studies would provide information as to how long fish will take to fully colonize a FAD. Biodiversity studies would provide an inventory of species that are attracted to FADs, as an indicator of its viability and potential. Both studies usually include continuous diving at FADs where the entire upper section of the FAD is inspected by divers for any aggregating fish. The protocol set by Taquet et al. (2007) for underwater visual census (UVC) at FADs would be followed for these studies.

Although the degree of success is phasing out destructive gears through gear management programs has been variable, it should be maintained that the approach remains a viable way of illegal and destructive fishing gears. Concerted efforts by all stakeholders in the implementation, enforcement, enforcement monitoring and awareness on gear impacts will ensure a significant reduction in the use of illegal and destructive fishing gears and resource use conflicts associated with them. Even for the FAD fishery to succeed, it is paramount for the private and public fisheries agencies to ensure stronger fisher organizations, sustain enforcement of fisheries regulations, sustain effective monitoring and evaluation initiatives, support alternative income generating activities other than fisheries and more importantly enhance stakeholders participations in the management of the fishery.

5.5. Summary of Recommendations for Implementation and Sustainability

In the context of the preceding general recommendations, identifying investors and donors is key. Investment will help establish an international market, expand the industry and allow local fishers to sell their fish despite failing infrastructure, lack of cold storage and the difficulties transporting fish to national markets. Simultaneously, modern gears—nets and motors—must be introduced either through loan or credit schemes. In order to respond to an increased market potential, fishers must be given the opportunity to utilize offshore resources, capitalizing on their knowledge and skill. This will also decrease the use of destructive and illegal gears, which will ultimately increase fish productivity. Fishers must own their own equipment to facilitate the successful accumulation of capital, accountability for the gears and a motivation to continue to invest in the industry. The most effective way to establish loans schemes are through the developing cooperative societies. This will not only provide loans to local fishers, but will serve to strengthen organizational, marketing and regulatory bodies within the industry.

Likewise, while expanding the industry's potential, large-scale strengthening of organizational and educational units is strongly advised. Donors must be identified to invest in the unification of cooperatives and BMUs, which currently possess the legal capacity to effectively govern landing beaches. These entities must eventually become self-sustaining and must seek to educate fishers, not only on marketing and business strategies, but on conservation and preservation strategies, which now are largely being neglected due to the cyclical nature of poverty along the coast. From these units, eventually a coastal fishery educational institute should be established, giving fishers further opportunities to learn new fishing techniques like FAD fishing as well as how to effectively manage their own resources.

Further, for the future sustainability of the industry and its ability to compete on a global market, aquaculture and alternative preservation strategies must simultaneously be explored following the economic stimulus package that was provided by the government to support communities at the grassroots level. In many ways, investment in these activities will revitalize the industry allowing local fishing units to bypass some of the impediments currently inhibiting the industry. Women should be given key roles in the development of alternative preservation strategies, as they already possess the skills in these methods. In all ways, a unified approach is recommended, supporting the industry from the community level, through the Kenyan national government and through international investors. All initiatives must be community driven, propelled by community empowerment and ownership in resources and the entire fisheries sector. By recognizing and cultivating the extreme potential of artisanal fishers and the structures that currently govern their lives, a sustainable fishery can be established; one that facilitates poverty alleviation and empowers local coastal communities.

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Appendix

Appendix 1. Current KMFRI datasheet recording forms

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE
P.O BOX 81651, MOMBASA
<u>CATCH DATA: FORM A</u>

Name of Recorder... Station...

Date & (Tot No. Of Boats)	Area Fished	Boat Type	No. Of Crew	Gear Used	Mesh Size	Time In	Time out	Total Landing (Kg)	*CATCH ID#

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE
P.O BOX 81651, MOMBASA
<u>FISHERIES CATCH DATA: FORM B</u>

Name of Recorder... Station...

Date	Catch ID#	Weight of the sub-sample	Total number of fish in sub-sample	Species composition of subsample	Weight and total length (cm) of each individual of the species in the subsample		Sex	Total lengths and sex of 5 to 10 individuals of the same species from the catch (cm)
					Length (cm)	Weight (kg)		

Appendix 2. Proposed FAD catches datasheet

Catches datasheet

Frequency: daily
Sample: about 20% of the landing site boats

Site: Date:
Identifying (boat):   Data collector name:

	Total of all fishing practices	FAD	Fishing practice 1	Fishing practice 2	Fishing practice 3
			Name: (code)	Name: (code)	Name: (code)
Catches					
Species (to be coded)	Total catch volume of all fishing practices (kg)	Catch Volume FADs (kg)	Volume fishing practice 1 (kg)	Volume practice 2 (kg)	Volume practice 3 (kg)
Species 1 Name:					
Species 2 Name :					
Species 3 Name:					
Species 4 Name:					
Species 5 Name:					
Time					
	Total time at sea	FAD fishing time	Fishing practice 1 time	Fishing practice 2 time	Fishing practice 3 time
No. of hours (incl. Travelling time)					

*: 1 the weakest and 5 the strongest.

Appendix 3. Proposed market datasheet

Market datasheet

Frequency: monthly (at the end of each month)
Sample: between 5 to 10 fish retailers, the most important and the same ones from one sampling to another one
(data collection can be made over the phone once on two times)

Site: Date:
Name of fish retailer: Data collector name:

1-Have you observed an increase of pelagic fishes supply (big pelagics) this last month?   Yes ☐   No ☐

1.a If yes, what are the species to which quantities have increased and in which proportions?
- Albacore :   ☐   increase proportion: %
- Dolphin fish :   ☐   increase proportion: %
- Marlin: ☐   increase proportion: %
- Swordfish :   ☐   increase proportion: %
- Big eye: ☐   increase proportion: %
- Bonito: ☐   increase proportion: %
- Yellow fin tuna: ☐   increase proportion: %
- Skipjack   ☐   increase proportion: %
- Other Species 1 (to be coded) ☐   increase proportion: %
- Other Species 2 :   ☐   increase proportion: %
- Other Species 3 :   ☐   increase proportion: %

1.b If yes, did that affect the selling price of other species (Trevally fishes, kingfish, reef fishes, etc.) and in which proportion?

- Trevally fish :   ☐   decrease proportion: %
- Kingfish: ☐   decrease proportion: %
- Macquerel: ☐   decrease proportion: %
- Reef fishes: ☐   decrease proportion: %
- Other Species 1 (to be coded) ☐   decrease proportion: %
- Other Species 2 :   ☐   decrease proportion: %
- Other Species 3 :   ☐   decrease proportion: %

2- Does the price of some fishes change over the day time (morning, mid-day and end of the afternoon) depending on landings: Yes ☐   No ☐

2.a If yes, what are the reasons of change:
- Reason 1 (to be coded later):
- Reason 2 :
- Reason 3 :

2.b And what are the species that the price change:

	Morning	Mid-day	End of the afternoon
- Species 1 (to be coded later):	%	%	%
- Species 2:	%	%	%
- Species 3:	%	%	%

Appendix 4. Proposed FAD well-being and FAD management datasheet

Well-being and FAD management datasheet

Frequency: every 2 months
Sample: 5 to 10 FAD fishermen per site

Site:	Date:
Name of fishermen or boat:	Data collector name:

1-Do job conditions improved with FADs?

        Yes ☐ No ☐

1.a If yes, for what reasons:	1.b If no, for what reasons:
- Reason 1a (to be coded) :	- Reason 1b (to be recoded):
- Reason 2a:	- Reason 2b:
- Reason 3a:	- Reason 3b:
- Reason 4a:	- Reason 4b:

2-What are the conflicts occurring for the FAD fishery and what is the variation of their intensity (increase or decrease)?

- Among fishermen of the same fishing community using the same gears: ☐
- Between fishermen of different communities using same gears: ☐
- Among fishermen of same community using various gears: ☐
- Between fishermen of different fishing communities using different types of gears: ☐
- Between fishermen and sport fishermen: ☐
- Other explanation 1 (to be coded if recurrence) : ☐
- Other explanation 2 : ☐

3-What are the management rules that have been implemented by fishermen?

- Rule 3.1 (to be coded) :
- Rule 3.2 :
- Rule 3.3 :
- Rule 3.4 :

4-What are the State management measures implemented?

- Rule 4.1 (à coder) :
- Rule 4.2 :
- Rule 4.3 :
- Rule 4.4 :

5-What are the procedures implemented for the maintenance and the renewal of FADs?

- Visit patrol Protocol (diagnostic and repairing): ☐
- Intervention after information gathered from fishermen: ☐
- Other (to be mentioned) : ☐

5.a Frequency of maintenance visits : Monthly ☐ ; Bi-monthly ☐ ; Other (to be mentioned) ☐

5.b Time run between the loss of FAD and its replacement (number of days):