;USTAINABILITY OF MARINE FISHERIES IN MALINDI-
JNGWANA BAY IN KENYA"

BY

ODHIAMBO JACOB OCHIEWO
REG.NO.: C/50/7121/2002

. ... .ITY OF NAIROBI
EAST AFRICANA COLLECTION

Research Paper submitted to the Department of Economics, University of Nairobi, in Partial Fulfilment of the Requirements for the Degree of Master of Arts in Economics.

JOMO KENYATTA MEMORIAL
LIBRARY

September 2004.

University of NAIROBI Library
0443319 9

DECLARATION

This Research Paper is my original work and has not been presented for a degree award in another University.

ODHIAMBO JACOB OCHIEWO

This Research Paper has been submitted for examination with our approval as University of Nairobi Supervisors.

DR. M. H. KHALIL

DR. T. KIRITI

ACKNOWLEDGEMENTS

I sincerely thank my employer (Kenya Marine and Fisheries Research Institute) for granting me study leave and provided the financial and logistical support that enabled me conduct the study.

I wish to express my gratitude to Dr. Mohammed H. Khalil and Dr. Tabithi Kiriti, who supervised my work and provided the assistance that I greatly needed. Their prompt comments provided direction and facilitated the completion of this dissertation. I also owe much to Dr. Johnson Kazungu and Dr. Rennison Ruwa, the Director and Deputy Director of KMFRI respectively, who were a source of inspiration and encouragement during the writing of the dissertation.

I thank AERC for sponsoring me to participate in the 2003 Joint Electives Facility (JFE) where I acquired valuable analytical skills and providing some financial support, which facilitated the completion of this dissertation.

I also wish to thank Richard Angwenyi, Suleiman Tora, Peter Chiteri and Maurine Musyoka, who assisted during the primary data collection. Mr. Stephen Mwangi provided a research vehicle at the right time and Dr. Johnson Kitheka facilitated the research in many ways. Irene Githaiga, Liston Mwanjila, and Munyoki provided valuable services in the production of this dissertation.

My wife, Carren, who performed the roles of mother and father to my two sons and daughter, provided encouragement and comfort that I really needed during my study and for this dissertation to be complete. Pastor Dan Otigo and his family provided valuable accommodation and encouragement during the period of study. My student colleagues, John M. Muiyuro, Clive Mutunga, Samwel Andati, and the academic staff of the Economics Department, who participated in the departmental seminar during my oral presentation of the research proposal, gave positive criticisms that have helped shape some of my ideas.

DEDICATION

To my wife Carren and children, Richard, Valarie and John, for what is so dear that I may not be able to explain nor pay.

TABLE OF CONTENTS Page No.

LIST OF TABLES

ABBREVIATIONS

AERC	African Economic Research Consortium
CPUE	Catch Per Unit Effort
E_{MSY}	Fishing effort that correspond to the maximum sustainable yield
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
ITQ(s)	Individual Transferable Quota(s)
KMFRI	Kenya Marine and Fisheries Research Institute
Ksh.	Kenya Shillings
Kg(s)	Kilogramme(s)
MSY	Maximum Sustainable Yield
OLS	Ordinary Least Squares
SPSS	Statistical Package for Social Sciences
US	United States of America
UNEP	United Nations Environment Programme
WCED	World Commission on Environment and Development

ABSTRACT

Sustainability is a fundamental issue in the exploitation and management of fisheries resources both in Kenya and the rest of the world. This study is motivated by the fact that thousands of households whose livelihood depend on the fisheries resources at the Malindi-Ungwana bay are faced with uncertainty over the sustainability of these resources due to increase in unsustainable fishing practices. Fisheries management will improve if a clear understanding of the factors that influence fish harvesting and sustainability is obtained. This study therefore investigates the factors that influence fish harvesting, the relationship between fish yield and fishing effort, the maximum sustainable yield of the shallow water prawn fishery and the plausible policy measures to enhance optimal utilization of the fishery.

The study has established that the type of fish caught is influenced by type of gear used and location of the fishing ground. The results also show that there is a statistically significant positive relationship between the rate of fish catch and particular fishing effort variables namely size of the fishing vessel (in terms of size of crew and type and size of fishing gears used), number of fishing hours per day, age of the head of a fishing unit, and level of education attained by the head of a fishing unit. In addition, the maximum sustainable yield for the shallow water prawn fishery has been estimated using the Schaefer's surplus production model to be 448 tonnes of prawns per year. Fishing effort at this maximum sustainable yield is estimated at 5 prawn trawlers fishing at a time. The study has concluded that fishing effort is the main determinant of the rate of fish harvest.

The study recommends that size of fishing vessels, time spent in harvesting fisheries resources, age of a fishing unit head and the level of education attained by the head of a fishing unit are important variables in the artisanal fishery that should be targeted by policy makers for manipulation in order to maximize benefits from the fisheries. The elasticities of fish yield with respect to each of these variables have been estimated and should be considered while taking fisheries management decisions. In the shallow water prawn fishery, a maximum of five trawlers should be licensed to operate in each year and they should land a maximum of 448 tonnes of prawns per year.

CHAPTER ONE

BACKGROUND AND INTRODUCTION

1.0 INTRODUCTION

This study investigates factors that influence fish harvesting and sustainability of the Kenyan Malindi-Ungwana bay fishery. The importance of marine fisheries resources cannot be over-stated. Marine fish provides livelihood to millions of people who live in coastal areas worldwide. In addition, fish has been viewed as a cheap source of animal protein in many developing countries. In Africa, it has been estimated that about 20% of the population obtain their animal protein from fish. However, it is estimated today that the exploitation levels of the world's marine fisheries is about 20% above sustainable levels (Myers, 1997). The sustainability of marine fisheries in Kenya is threatened by overexploitation. Some of the factors that cause overexploitation include excessive expansion in fishing effort due to open access characteristic of the fishery, poverty, rapid population growth, lack of alternative employment opportunities, breakdown of traditional fisheries management systems, ready market for fish especially pressure from middlemen, and destructive fishing practices. Destructive fishing practices include the use of fine mesh size nets, beach seines, traditional concoctions of poisons, dynamite, and the destruction of breeding and nursery grounds for fish. Capture fisheries also suffer from increasing degradation and pollution of the coastal environment (Ikiara, 1999).

The rapid increases in fishing effort in the artisanal fishery and activities of prawn trawlers have raised concern. The open access of the common property fishery resources and the lack of information on exploitation especially the maximum sustainable level for the fishery have emerged as major issues from the Malindi-Ungwana bay fishery. Local communities that reside along the coast especially those dwelling close to areas frequented by prawn trawlers have been complaining about the discarded by-catch that are washed ashore by the currents. They link the discards to their declining per capita catches and loss of welfare. In view of the concerns raised by the fisheries stakeholders in the Malindi-Ungwana bay complex, the study intends to analyse the production and yield functions and investigate the factors that influence the sustainability of the fishery.

From the study, it is expected that the relationship between fishing effort and yield is positive. If fishing effort increases beyond the maximum sustainable yield it results in overexploitation and threatens sustainability of the fishery. Excessive bycatch and discards in the trawl fishery also threatens sustainability. Similarly, there is a direct relationship between price and output, and there is a significant influence of seasonality on rate of fish harvest.

1.1 Statement of the problem

Over the years, per capita catch has been declining in the Malindi-Ungwana bay. Since declining per capita catch implies reduced incomes, the standard of living of the fishermen has been declining. Unlike other fishing grounds where only artisanal fishing activities take place, here both artisanal fishing and commercial prawn trawling are practiced side by side. The artisanal fishing in this area is labour-intensive providing employment and livelihood to many households. Currently, about 10,000 fishermen are directly engaged in artisanal fishing in the Kenyan coast with about 2000 registered fishermen operating in the Malindi-Ungwana bay (KMFRI, 2002). Since the fishery is a common property resource, fishing effort has increased with increase in the number of artisanal fishermen over the years. Commercial prawn trawling is carried out in the same locations where the artisanal fishermen operate. Currently, 4 prawn trawlers have been licensed to fish in this area. These prawn trawlers target paneaid prawns but the fishing technology that they use, bottom trawling, is destructive as it results in excessive bycatch and discards, and impacts adversely on the seabed. The bycatch comprise of fish that are not the target species for the prawn trawlers that in turn discard a big proportion back into the sea. There is fear that the large quantities of discarded bycatch are associated with juvenile wastage that may threaten the sustainability of the fishery. Consequently, there are conflicts in the fishery between the prawn trawlers and the artisanal fishermen as the artisanal fishermen continue experiencing declining per capita catch. Although the use of destructive fishing practices such as beach seines, fine-mesh size nets, traditional concoctions of poison are prohibited, their use has shown an increasing trend over the years. These destructive fishing technologies, like bottom prawn trawling, threaten sustainability of the Malindi-Ungwana bay fishery. This study therefore seeks to provide an understanding of why per capita catch in the artisanal fishery is declining, by examining the fish production functions and the maximum sustainable yield.

1.2 Objectives of the study

The study aims at investigating the factors that influence the sustainability of fish harvesting in the Kenyan Malindi-Ungwana bay. The study focuses on the following objectives:

1. investigate the factors that influence fish harvesting
2. establish the relationship between fish yield and fishing effort
3. estimate the maximum sustainable yield (MSY) of the shallow water prawn trawl fishery
4. suggest policy measures that would enhance optimal utilization of the fishery.

1.3 Significance of the study

Many households along the coast depend wholly on fisheries for their livelihood. These households are faced with uncertainty over the sustainability of these resources due to increase in unsustainable fishing practices. Obtaining a clear understanding of the relationship between effort and rate of harvest, factors that influence sustainability and their implications on sustainable exploitation of the fisheries resources and livelihoods of the fishing households, would improve the fisheries management. This study provides information that is useful in formulating fisheries management policies. Furthermore, the research is important because it provides information on what can be done to sustain fish harvesting in the Malindi-Ungwana bay for the benefit of both the present and future generations. Sustainability in the fishery would enhance food security, employment creation and high standards of living of the communities that are dependent on fishing. Fishing is a labour-intensive activity, requiring substantial manpower in harvesting, processing and distribution. Because of this characteristic, fishing has a direct effect on the social welfare of the rural coastal population. In addition, there is need for the country to be self sufficient in food production. This makes the improvement of fish production essential. In order to increase fish harvesting without compromising inter and intragenerational equity, there is need for a thorough understanding of the factors that influence and constraints that face fish harvesting.

In addition, the results of the study would facilitate conflict resolution in the fishery. Currently, there are conflicts between the artisanal fishermen and commercial prawn trawlers since the two groups operate in the same fishing ground yet the prawn trawlers use sophisticated effective fishing technology while the artisanal fishermen use simple traditional fishing technology.

Marine fisheries are an important sub-sector employing about 110,000 people both directly and indirectly (KMFRI, 2002). The contribution of fishing to Kenya's GDP has been increasing. Nationally, the sector accounted for an average of 2% of the GDP attributable to the non-monetary economy and 4.4% of the monetary sector's GDP in 1989/90. In 1995, fish trade earned fishermen Ksh. 5.2 billion while the retail value was estimated at Ksh. 19.5 billion. During the same year, fishing earned the country Ksh. 1.5 billion in foreign currency from exports (Ikiara, 1999).

1.4 Area of study

The study has been conducted at the Malindi-Ungwana bay in the northern Kenya coast (see figure 2). The Malindi-Ungwana bay lies between latitudes $3^0$30'S and $2^0$30'S and longitudes $40^0$00'N and $41^0$00'N. It has a wide continental shelf with simple trolling grounds. It is one of the most productive fishing grounds along the coast of Kenya. Other productive fishing grounds are the Lamu-Kiunga area in the northernmost part and the Majoreni-Vanga area in the southern part of the Kenya coast (Ruwa et. al., 2003). The Malindi-Ungwana bay is a large estuarine bay into which Rivers Athi and Tana discharge. The artisanal fishermen exploit the shallow water (inshore) stocks using mainly the traditional non-motorized boats and simple gear, and land about 90% of the entire yield from the marine fisheries. About 2000 fishermen have been registered at the Malindi-Ungwana bay by the Fisheries Department. However, this number does not accurately reflect the total number of artisanal fishermen who operate in this area since those who have not been registered are equally many. Besides the artisanal fishery, a number of prawn trawlers have also been licensed to fish in this area for the last 20 years.

The number of licensed trawlers has been fluctuating between 4 and 10 since the time prawn trawling began. Currently, 4 trawlers have been licensed to trawl for shallow water prawns in the year 2004. The prawn trawlers land about 10% of marine fish per year. Prawn trawling is associated with excessive by-catch. The ratio (by weight) of prawns caught in the trawl net to the weight of by-catch is 1:7 (KMFRI, 2002). The excessive by-catch is serious problem in the Malindi-Ungwana bay and is a major cause of conflicts since the bulk of the by-catch is being discarded back into the sea. In addition, prawn trawlers sometimes destroy the fishing nets that belong to artisanal fishermen thereby causing conflicts.

CHAPTER TWO

LITERATURE REVIEW

2.0 INTRODUCTION

Many studies have been conducted on the economics of marine fisheries in both developed and developing countries. Some of these studies have focused on the problems of open access and how this results in over-fishing. Other studies have looked at the use of economic instruments such as the use of transferable fishing quotas to achieve sustainability in the exploitation of open access fisheries in different parts of the world.

2.1 Theoretical literature

Fisheries are a renewable resource. By definition, renewable resources are those capable of self-reproduction (Hanley, *et al.*, 1997), or those for which the stock can be continually replenished (Tietenberg, 1996). A renewable resource can remain productive indefinitely, although it may be driven to extinction if it is overexploited. While addressing fisheries, the issue of market structure and potential for catelisation is insignificant. The main focus is upon the nature of the fishery production function and how fishing effort interacts with fish stock (Hanley, *et al.*, 1997). Equally important is the issue of open access nature of the resource stocks and policy measures employed to protect the resource from economic over-exploitation. Hanna (1996) has argued that fish populations have the potential to support the long-term economic and social benefit of the society but for this to happen, the fish populations must be managed in ways that maintain ecological health. In this case therefore, integrating the human and ecological systems over their biological, economic, social and cultural components is the main challenge of fisheries management. However, the study has also found that achieving management that could perform this integration and promote sustainability has been difficult. Since sustainability is a long-term effort, managing for sustainability requires the subjection of individual well being to the collective good.

Fisheries are a renewable resource but when rate of harvesting exceeds the rate of natural regeneration, then its sustainability is threatened. According to Conrad and Clark, (1994), a renewable resource is defined to mean a plant or animal population with the capacity for reproduction and growth or an inanimate mass or energy source subject to constant periodic flux. Sustainability on the other hand is a concept that has elicited a lot of debate. Some extreme ecologists are opposed to sustainable utilization of natural resources. They argue that it is wrong to conceive the environment as a collection of resources that should be used by human beings at all (Rolston, 1988). Sustainable development has however been one of the key concepts utilised in the environmental debate in deciding if economic activities are environmentally tolerable and can provide a resource base in the long-term (Ferguson, 2004). According to Turner (1995), sustainable development is future-oriented since it seeks to ensure that future generations are at least as well off, on a welfare basis, as current generations. In economic terms, it is a matter of intergenerational equity and not just efficiency. The basic idea of sustainability was outlined in the World Commission on Environment and Development (the Brundtland Commission, 1983-1987) as, development that meets the needs of the present without compromising the ability of the future generations to meet their own needs (WCED, 1987). In this case, the ethical argument is that future generations have the right to expect an inheritance sufficient to allow them the capacity to generate for themselves a level of welfare that is not less than that enjoyed by the current generation.

It has been observed that fish harvesting in many developing countries is suffering from the "Malthusian over-fishing" whereby fishermen are driven by desperation to indiscriminate use of destructive harvesting technology (Charles, *et al.*, 1994). In the Malindi-Ungwana bay, local fishermen are driven by desperation to use effective but destructive fishing techniques such as the use of beach seines, fine mesh-size nets and traditional concoctions of poisons, and the prawn trawlers use bottom trawl nets, so that they could maximize present gains from increased output with little regard to future production needs. The study by Charles, *et al.* (1994) however does not adequately provide solutions to the trend. It is too general as it looks at fisheries across the developing countries and this makes it lack detail that may be essential when formulating a fish production policy. This study is therefore meant to capture the site-specific detail. For example, there is over-exploitation of the artisanal fishery while the deep-sea resources have remained largely unexploited in Kenya. The reasons behind the existence of this situation should be clearly understood for appropriate policies to be formulated.

2.2 Empirical literature

Over-exploitation of the fisheries is mainly due to the common property problem. If a fishery resource is commercially valuable and is open to unrestricted exploitation, the resource will certainly be subject to excessive depletion from society's point of view. Since the resource is open to all and owned by none, no fishermen will have an incentive to conserve it. A fisherman who refrains from harvesting the resource is likely to find that he has not helped conserve the resource but has enhanced the harvest opportunities of his competitors (Munro and Scott, 1985). An open access resource is one whose exploitation is not controlled and anyone can harvest at his/her convenience.

Until the 1970s, most of the marine fisheries were largely unregulated, although several agreements had been negotiated (Clark, 1990). Even after the 1970s, the exploitation of Kenya's marine fisheries has not been restricted. Despite the enactment of the fisheries laws and regulations, fisheries have continued to be an open access resource where anyone can become a fisherman any time he feels like and can conduct his fishing operations anywhere with the exception of Marine Protected Areas. The lack of restrictions has partly been due to the nature and scale of fisheries. Poor fishermen who do it at near subsistence level for instance undertake the artisanal fish production and this is their main source of livelihood.

The fisheries laws and regulations are also inadequate and the institutional constraints make it even harder to implement and enforce them. Whereas other studies have looked at the inadequacies of the laws and regulations and the institutional capacity constraints, the plight of the fishermen has not been addressed in the crusade to restrict access into the open access fisheries. For example, it has been observed that the government departments that are charged with the responsibility of managing, regulating and monitoring the fisheries in Kenya are poorly funded and politically marginalized (O'Riordan, 1996). It is important to understand the reasons behind this scenario.

The common property problem leads to excessive harvesting capacity (Munro and Scott, 1985). They argue that if government regulation of fish harvesting is absent, excessive harvesting capacity arises, as the fishing fleet becomes sufficiently large to reduce the resource well below the optimal level. This could drive the resource to extinction and the fishery is destroyed, or the harvesting costs are raised as a consequence of the resource depletion to the point where the net economic benefits from the fishery is dissipated. They studied a more capital intensive production technology where fishing fleet is the main determinant of fishing effort. This study looks at a fishery that is dominated by the heavy harvesting of the shallow inshore stocks, which is more labour-intensive, and fishing effort is dependent on the number of fishermen and the number of hours spent fishing.

According to Anderson (1996), the main problem that fisheries management faces is the fact that fishing capacity is too large for the number of fish available. Consequently, stocks of fish are being pushed to levels where their abilities to sustain future harvests are curtailed. In some cases, fishing capacity surpasses the long-term productive ability of stocks and therefore operates inefficiently. This problem arises from competition for fish in open access and from the failure of the government to correct it. It is also noted that open access does not in and of itself cause over fishing, it creates pressures to over fish in ways that traditional management may not be able to control.

Hanley, *et al.* (1997) observed that in many fishing communities, the opportunity cost of labour and capital devoted to fishing effort are very low, since only few alternative employment opportunities exist for the labour and capital employed in fishing. Because of this, resources may be committed to fishing at high levels of effort, which is damaging to the sustainability of fish stocks.

In an attempt to provide solutions to the common property problem in the Canadian commercial fishery, Scott and Neher (1981) presented logical suggestions. They proposed the establishment of a limited entry Programme whereby the number of vessels and the fishermen could be restricted from entry into the fishery. They proposed particular actions such as stipulating that no vessels will be permitted to operate without a licence and then proceed to limit the number of licensees. In addition, no new vessel would join the fleet unless an existing member of the fleet was simultaneously removed. Their suggestions fit the developed industrial and semi-industrial fisheries where vessel monitoring and surveillance system has been put in place and the fishermen are actually industrialists who operate on large scale. The suggestions cannot apply fully to the Kenyan artisanal fishery that is a traditional source of livelihood to many coastal dwellers. Majority of the artisanal fishermen use very small crafts and operate from very small landing beaches, some of which are inaccessible to the managing authorities.

Considering the complexity of managing an open access fishery, collaborative management is perhaps the most appropriate approach. In this regard, consensus was reached during the long series of United Nations initiated conferences that sustainable development should be based on local-level solutions derived from community initiatives (Leach, *et al.* 1999). Collaborative management provides for securing rights of resource use, sustainable long-term production, better distribution of resources, local decision-making, and empowerment. Similarly, the 1992 Earth Summit, Agenda 21 strongly advocated the combination of government decentralization, devolution of responsibility for managing natural resources held as commons to local communities, and promotion of community participation at all levels of decision-making and implementation (Keating, 1993). The study by Smith (2004) found that these approaches argue for co-management, a concept that has been defined by Leach, *et al.* (1999) as an appropriate sharing of responsibilities for natural resource management between national and local governments, civic organizations and local communities. If a renewable resource such as forests (or fisheries) has been extensively depleted and degraded, a collaborative management approach that involves the government and society, and employs advanced technical knowledge and management systems is necessary for its restoration and continued provision of the livelihood and eco-services to the local communities (Smith, 2004).

A number of studies have been conducted on the use of suitable economic instruments to create incentives for sustainable fishing in open access fisheries. In this regard, transferable fishing quotas (management tools that allocate privileges or rights to harvest specified amounts of a quota to fishing units or firms) have been proposed as a possible mechanism to control fishing effort. Transferable quotas are a form of "rights based management" where a government has responsibility for setting and enforcing an annual quota, gear restrictions or seasonal openings on a fishery, while fishermen control shares that determine how much of the quota they can harvest or gear that they can use (McCay, 1996; McCay, et al. 1996; Palsson and Helgason, 1996; Ginter, 1996; Anderson, 1996). This calls for the need to improve the communication link between the fisheries regulatory agency and the local fishing community.

McCay, *et al.* (1996), in their analysis of the individual transferable quotas (ITQs) in the Canadian and the US fisheries found that ITQ system is very effective at reducing the numbers of vessels that are involved in the fishery thereby reducing overcapitalisation and fishing capacity. It also led to decline in labour and employment in the short run. However, the displaced workers generally tried to stay in fishing related work although they found this work to be very scarce.

Fishermen have a unique culture and are more adept at evading the input restrictions than the regulators are at devising and imposing them (Scott and Neher, 1981). Just as in the case of the Kenyan coast where we have many and different types of fishing gears, they admit that even in Canada, there are too many gears making it difficult for all to be controlled effectively. Opportunities for substitution are abundant. The experience of Canada can serve as an example and can be modified to suite our situation.

The level of production from the artisanal marine fishery is dictated by weather (rough sea that makes it risky to fish using small crafts) and culture of the fishermen (Ikiara, 1999). It is observed that fishermen do not go to fish when they have money in their pockets. While these factors are known to be significant, a detailed analysis of all the factors that determine the level of production from the marine fishery has not been done ıere in Kenya. This study will therefore provide an in-depth analysis of the level of sustainability in the fishery and the factors that influence artisanal fish production in the marine sector, paying specific attention to the conflict prone prawn trawling in the Malindi-Ungwana bay, Kenya.

Fish landing records for Kenya showed a decreasing trend in the period 1981-2000 (FAO 1996, 2000). Inshore catches by artisanal fishermen account for 90% of the total annual catches. Illegal and unlicensed fishing mainly by distant foreign fishing fleets is common in the offshore waters.

Available information shows that catches in inshore waters are declining (McClanahan, 1996 and Obura et. al., 2002). This is for example significant for catches of important commercial species such as lobsters and pelagic barracudas that have shown sharp decline (FAO, 1996; 2000). Although the catches for prawns have not declined, excessive by-catch are generated whereby the ratio by weight of prawn caught in the trawl net to the weight of by-catch is 1:7, that is, about 83% by-catch is generated per trawl, most of which (about 57%) is discarded. This by-catch problem is serious in the Malindi-Ungwana bay (FAO, 1996; 2000). Besides trawling other destructive fishing practices such as use of beach seines by artisanal fishermen in lagoons, which destroy seagrass, beds and benthic fauna; and use of poisons by artisanal fishermen which break up coral reefs and kill indiscriminately are common in the Malindi-Ungwana bay. The most notable endangered species frequently impacted by the destructive fishing techniques are sea turtles.

Ngugi (1998), observed that most fishermen from around the Mombasa Marine Park are household heads and their earnings from fishing are now low due to the reduced volume of fish catch experienced as a result of exclusion of the fishermen from their original productive fishing grounds within the park. The author introduced a new dimension into the analysis of artisanal fish production namely the economic impact of the Marine Protected Areas. The study found that most fishermen are self-employed, operating in small dugout canoes, and using gillnets, fishing lines, and fishing traps that are owned ndividually. The Marine Protected Areas limit the size of the fishing grounds. The catch per fisherman declines as more people are confined into a small fishing area and they divide among themselves a more or less constant resource base. The study was concerned with the economic impacts of the marine protected areas in the Mombasa inshore waters, and did not analyse the factors that determine artisanal fish production. This study will fill in the information gaps that exist.

CHAPTER THREE

METHODOLOGY

3.0 CONCEPTUAL FRAMEWORK

3.1 Factors Influencing Fish Harvest

In this study, the unit of analysis is the fishing unit. Fishing unit refers to the fishing vessel used, the fishing crew, fishing gear and the head of the team/owner. It aims at maximizing fish catch but it is faced with input and other constraints. The fishing effort by the fishing unit consists of capital particularly fishing vessels (fishing crafts) and fishing gears, level of technology, and labour. The other factors that are perhaps equally important in fish harvesting are the availability of fish stock, weather conditions, and the educational level of the unit leader.

Fishing activities are perhaps also influenced by the monsoon seasons. During the North-East Monsoon, each artisanal fishing unit goes to the sea daily for 6 days a week, but, during the South-East Monsoon, it goes 4 to 5 days a week because of the heavy rains and the rough sea. The artisanal fishing unit spends an average of 7 hours per day fishing during the North-East Monsoon. During the South-East Monsoon, it spends fewer hours in fishing per day. Artisanal fishing is conducted throughout the year with peak and slack production cycles according to the monsoon seasons. Catches are high during the North-East Monsoon (August – March) when the sea is calm and weather is favourable causing increased effort. During this season, the fishing unit tries to maximize its output by investing more of its time (fishing 6 days a week) and resources in fishing. On the other hand, during the South East Monsoon (April – July), the weather is normally harsh for the fishermen since, this season corresponds with the long rains between April and June and the sea is rough. When the sea is rough, it is normally risky for the artisanal fishermen to go fishing in their small non-motorized dugout canoes. During this period, the artisanal fishing unit expects minimum outcomes and so it minimizes its expenditures until the next season.

The number of fishermen in one artisanal fishing unit depends on the size of the fishing vessel and the type of fishing gears used. The number ranges from one fisherman in fishing units operated by the owner or captain (one person) alone to 16 fishermen in fishing units that have larger canoes and use larger nets such as ring nets, beach seines or long lines. Since the artisanal fishery is labour-intensive, labour is an extremely important factor with capital as a bounding constraint.

The artisanal fishery is an open access resource and a large number of fishermen compete for renewable stocks that are already threatened with depletion. Since the fishery is open to all and no single person claims ownership, there is no incentive for a fisherman to conserve it. If a fisherman refrains from harvesting it, his competitors would harvest it. Therefore, by refraining from harvesting the resource, he enhances the chances of his competitors harvesting more (Munro and Scott, 1985). Once over-fishing exhausts the fishery, the per capita catch falls implying that the unit cost of fish production rises. This continues until a point where further depletion of fish stock results in negative returns to the fisherman.

The lack of ownership rights means the resource rent accrues to the fishing unit who earns returns far in excess of its opportunity costs. As the artisanal fishery is competitive, increased numbers of fishermen, and fishing gears and crafts enter the fishery as long as supernormal returns continue to be earned in the fishery. Since there are no strict controls, the fishery expands beyond the socially optimal level. In this study, the fishing practices will be looked at in terms of a production and yield functions.

3.2 Model specification

3.2.1 The fish production and yield functions

The fish production function gives the relationship between the quantities of fish landed, fishing effort, and stock abundance. It is a mathematical equation showing the maximum quantity of output that can be obtained from a given set of inputs, holding stock abundance constant. Put another way, a fish production function is a mathematical equation that gives the minimum quantities of inputs that can be utilized to achieve a given level of output. It is the relationship between output and the quantities of inputs, the efficiency with which the resources are utilized as well as other non-input variables that influence output. The quantity of fish landed by the artisanal fishing units vary because of differences in fishing technology used, input combination, level of technical efficiency, abundance of the fishery resource, seasonality variations, and the educational level of the fishermen.

When a fishery is harvested, it is assumed that the rate of harvest (catch rate) is a function of the economic inputs devoted to harvesting and the available stock (Conrad and Clark, 1994). That is, the fish production function may be presented as

$Y(t) = H(E(t), X(t))$ ....(1)

Where:

$Y(t)$ = The catch rate

$E(t)$ = Effort, which is the aggregate measure of various fishing inputs. That is, it measures the capital, time and labour devoted to fishing during a particular time period (Hanley, *et al.*, 1997). The number of standardized boats used in a fishery, or the number of fishermen, or the length of time spent fishing in a particular day can be used to measure it.

$X(t)$ = Fish stock available. Quantity of fish caught generally depends on stock availability. If fish is more abundant, it is generally easier to locate and catch them.

3.2.2 The rate of growth of fish stock

When fish is harvested, the rate of growth of the fish stock must reflect:

(i) The fish stock, $F(X(t))$, and

(ii) The catch rate, $Y(t)$

Therefore, we have:

$\dot{X} = F(X(t)) - Y(t)$ ....(2)

Equation (2) states that the growth in the fish stock, $\dot{X}$, is a function of the fish stock, $F(X(t))$ less the catch rate, $Y(t)$.

3.2.3 Sustainable Yield Functions

Sustainable yield refers to a situation where fish stock (X), catch rate (Y), and fishing effort (E), all remain constant over time. Sustainable yield function is therefore an equilibrium concept that expresses sustainable yield as a function of effort (Conrad and Clark, 1994).

From equations (1) and (2), we obtain

$$\dot{X} = F(X) - Y = 0 \qquad \text{.......... (3)}$$

Since X, Y and E are constant, $\dot{X} = 0$

$$Y = H(E, X) \qquad \text{.......... (4)}$$

Eliminating X from (3) and (4) gives the sustainable yield function:

$$Y = Y(E) \qquad \text{.......... (5)}$$

From this sustainable yield function, fish yield is determined by how much effort is put in fishing. Fishing effort depends on the input combination by the fishing unit, other factors being equal.

Suppose we have the logistic function

$$\dot{X} = F(X(t)) = rX(t)(1 - X(t)X(t)/K) \qquad \text{.......... (6)}$$

and the following production commonly used in fisheries models:

$$Y(t) = q\,E(t)X(t) \qquad \text{.......... (7)}$$

Where q is constant; r is the intrinsic growth rate of the population; K is the carrying capacity of the environment

Equation (7) is based on the following two assumptions:

(i) The catch per unit of effort (Y/E) is directly related to the density of fish in the fishery, that is $Y(t)/E(t) = qX(t)$

(ii) The density of fish is directly proportional to the abundance of fish, X(t)

From equation (6) and equation (7) we obtain the rate of growth functions as:

$$\dot{X} = F(X(t)) - Y(t) = rX(t)(1 - X(t)/K) - Y(t) \qquad \text{.......... (8)}$$

Where $Y(t) = qE(t)X(t)$

The sustainable yield function is:

$X = F(X) - Y = 0;$

$= rX(1 - X/K) - Y = 0$

Therefore, $rX(1 - X/K) = Y$ ....(9)

But from equation (7), $Y = qEX$

Substituting this value of Y into (9), we get:

$rX(1-X/K) = qEX$

Solving for X we obtain:

$rX - rX^2/K = qEX$

$rX - rX^2/K - qEX = 0$

$X(r - rX/K - qE) = 0$

Therefore, $r - rX/K - qE = 0$

Simplifying this for X yields:

$X = K(1 - qE/r)$ ....(10)

Substituting (10) into (7), the sustainable yield function is:

$Y = qEX = qEK(1-qE/r)$ ....(11)

Equation (11) gives the sustainable yield or the yield-effort function for the Schaefer fisheries model. The Schaefer model is a surplus production model and is suitable for the analysis of an all species fishery such as the fishery of Malindi-Ungwana bay. This type of model is being applied in order to determine the optimum level of effort that can produce maximum yield without compromising long term productivity of the fish stock (FAO, 1992). In this model, equation 11, qE is the relative rate of growth of the fish stock. If $qE = r$, then $Y = 0$. This implies that if the relative rate of harvest, (qE), exceeds the rate of growth of the fish stock, r, then the population will be driven to extinction and the yield will become zero.

It is worth noting that although the fisheries are renewable resources, they can be depleted if the rate of harvest exceeds the rate of regeneration of the fish stock.

3.2.4 The Maximum Sustainable Yield (MSY)

The maximum sustainable yield refers to the highest possible yield without depleting the resource. Its estimation is important as it establishes the optimal level of effort that produces the maximum yield without compromising the long-term productivity of the fish stock. Mathematically, the maximum sustainable yield (MSY) is obtained by maximizing the sustained yield function in equation (11) to obtain

$\partial Y/\partial E = 0$; $\partial Y/\partial E = qK(1-2qE/r) = 0$

Solving for E, we get $E_{MSY} = r/2q$. This implies that if effort exceeds E_{MSY}, the equilibrium stock is reduced. Generally, if E exceeds E_{MSY} both the stock and catch decline.

3.3 Empirical Model

From equation (11) above, we have an estimable yield-effort relationship. Based on this relationship, a Cobb-Douglas specification will be chosen for this relationship because of its simplicity and convenience in the interpretation of results. The following model will therefore be estimated:

$Y = qE^{b1}X^{b2}$, $b_1+b_2=1$, $0<b_i<1$ ....(12)

Where as defined earlier, Y is the catch rate, E is a composite measure of fishing effort, X is the fish stock, and q is a constant. However, when cross-sectional data were collected from heads of fishing units in the month of June 2004 and repeated in July 2004 on the same respondents, it emerged that there were insignificant differences in observed landed catch during the two periods. Since the observed landed catches in the two periods are more or less the same, we can assume that fish stock is constant and therefore yield (catch rate) depends solely on fishing effort. With fish stock being held constant, the model is linearized as follows:

$LnY = q + b_1 lnE + u$.

Similarly, from equation (11), we have $Y = qEK(1 - \frac{qE}{r})$

$Y/E = \frac{qEK}{E}(1 - \frac{qE}{r})$; or, $Y/E = qK - \frac{q^2KE}{r} = a - bE$ ....(13)

$Y/E = a - bE$ ....(13i)

Where: $a = qK$; $b = \frac{q^2K}{r}$

Y(t) = annual fish catches (yield)

E(t) = aggregate measure of fishing effort in year t and includes labour (number of fishermen or size of crew in a fishing vessel) and capital (fishing vessels and fishing gears). In this case, fishing effort is considered the main determinant of fish catch. The intercept, a, and the coefficient (slope), b, are determined through a linear regression of fishing effort, E(t) on yield per unit effort, Y(t)/E(t). Yield per unit of effort in year t is obtained by dividing the yield in year t for the entire fishery by the corresponding effort in year t. The coefficient, b, is expected to be negative if catch per unit effort, Y/E, decreases for increasing effort. Since E is the aggregate measure of fishing effort, it will be represented by vessel size and time spent in artisanal fishing operations and number of fishing vessels/trawlers in the industrial prawn fishery. Once the values of the constant/intercept, a, and the coefficient, b, are estimated, MSY and E_{MSY} will be empirically computed by the Schaefer model formula given by FAO (1992) as

$MSY = -0.25 \times a^2/b$, and $E_{MSY} = -0.5 \times a/b$.

3.3.1 The Marginal Productivity of factor inputs

Taking capital and labour separately, the production function becomes:

$Y = f(K, L, T, X)$

Where:

Y = the catch rate,

K = the equipment used in fishing (such as fishing vessels (boats) and gears),

L = manpower (labour),

T = technology used in fishing and captures the various fishing techniques,

X = fish stock.

To maximize output, the artisanal fishing unit employs the factors according to their marginal productivity. The marginal product ($MP_{K,L}$) refers to additional output that can be produced by employing one more unit of input while holding all other inputs constant. However, differences in technology, T, are not captured in the analysis of results since the methods used in fishing are not so much different and the various fishing techniques are already captured by the type of equipment, K, used in fishing.

3.3.1.1 The Marginal Product of Capital (MP_K)

Marginal product of capital is given by the partial change in output due to change in capital. Thus, $MP_K = \partial Y/\partial K$ In this fishery, it is expected that $\partial Y/\partial K > 0$ and $\partial Y^2/\partial K^2 < 0$, implying that the marginal product of capital is increasing at a decreasing rate. Additional units of capital increase output in the short term when the fish resource is abundant. As more capital input is added, an optimal level of output is reached after which, any further increase in capital results in diminishing returns. Capital used in the artisanal fishery includes fishing vessels and fishing gears. Fishing vessels are basically traditional non-motorized dugout canoes, outrigger canoes and small-motorized boats. Over the years, there has been a gradual increase in the number of fishing vessels in the Malindi-Ungwana bay fishery. The fishing gears include fishing nets; traditional traps, fishing lines and spear-guns. As the number of fishermen has increased over time, the number and type of gears used have increased. The combined effect of the increase in fishing vessels and fishing gears has been a general increase in the quantity of fish landed, over-exploitation and declining catch per unit of effort.

3.3.1.2 The Marginal Product of Labour (MP_L)

The marginal product of labour is given by the partial change in output due to a change in units of labour employed, thus $MP_L = \partial Y/\partial L$ Therefore, in the fishery, it is expected that $\partial Y/\partial L > 0$ and $\partial Y^2/\partial L^2 < 0$, showing that the marginal product of labour is increasing at a decreasing rate. Additional units of labour increase fish catch/output in the short term when fish stocks have not started dwindling. However, since we are dealing with a fishery, which is renewable and suffers depletion, additional units of labour would improve output until the optimum output level is attained. After the optimum output level, any additional labour input results in a declining output. Labour refers to the number of fishermen as well as the number of hours spent fishing in a day. Number of hours spent fishing at sea is a very important choice variable that the fishing unit can manipulate in the short run. A fishing unit can choose to go fishing or not.

3.3.1.3 Effect of a change in stock abundance

Stock abundance is an important determinant of fish yield at any given time. Therefore, $\partial Y/\partial X > 0$ and $\partial Y^2/\partial X^2 < 0$ reflecting the fact that quantity of fish landed depends on the abundance of fish stocks. Fish stocks in the inshore fishery that is being considered are quite dispersed and output varies from location to location. It is therefore important to consider the resource abundance alongside capital, labour and technology.

3.3.1.4 Other factors

Other important factors include climatic variations and educational level of the fishermen. Climatic variations cover the two monsoon seasons, which considerably influence the output from the artisanal fishery in the study area. The monsoon seasons are the North East monsoon, which is more favorable to the fishermen, and the South East monsoon, which coincides with the rainy season, and makes the sea rough. Educational level of the fishermen determines how effective a fisherman is in terms of knowing the alternative opportunities around him and it also determines management ability/skills of an individual. A person who has some formal education is more likely to excel in the management of his fishing unit compared to another person who does not have any education.

3.4 Hypotheses

1. H_0: There is a significant positive relationship between fish yield and fishing effort.
   H_1: There is no relationship between fish yield and fishing effort.
2. H_0: There is no significant relationship between the age of a fishing unit head and the rate of fish harvest.
   H_1: There is a significant positive relationship between the age of a fishing unit head and the rate of fish harvest.
3. H_0: A significant positive relationship exists between level of education attained by the head of a fishing unit and quantity of fish landed.
   H_1: There is no significant relationship between the level of education attained by the head of a fishing unit and the quantity of fish landed.

3.5 Data

Secondary cross sectional data were obtained from a fisheries database at the Kenya Marine and Fisheries Research Institute, and annual fisheries statistics at the Department of Fisheries (Malindi District and Coast regional headquarters). This was basically data on fish catch (yield), fishing effort especially the registered number of fishing vessels (K), type and number of fishing gears used, and number of fishermen (L). Primary cross sectional data were obtained from a sample of 162 fishing units. The variables covered include fish catch (yield), number and size of fishing vessels, type and number of gears used, number of fishermen in each fishing vessel, number of hours spent fishing in each day, number of days spent in fishing per month, state of the fishing ground, and time spent to reach the fishing ground as a proxy for location of the fishing ground. The data were collected for two months (June and July 2004).

3.5.1 Primary data collection

Cross section primary data were collected at Malindi, Ngomeni, and Kipini where fishing is a main economic activity and there are major fish landing beaches. Malindi is an urban area while Ngomeni and Kipini are rural settlements. The sample respondents were randomly selected from heads of fishing units in these fish landing beaches. Heads of fishing units often arrived early at the fish landing beaches to ensure that the vessels and fishing gears were in order before going out to fish. After returning from their fishing trips and landing their catch, the heads of fishing units often went to their houses and later returned to the fish landing beaches to oversee the repair and maintenance of their fishing vessels and gears. This made it possible for us to interview about 60% of the heads of fishing units from the beaches where they repair and maintain fishing equipment. The remaining 40% were interviewed from their homes.

To collect primary data, a combination of techniques were used namely observation, key-informant interviews, semi-structured interviews, focus group discussions and surveys. Most of the time, observation and semi-structured interviews were used simultaneously.

Observation

Using this technique, the research team (scientist and field assistant) attentively watched and recorded the events from the surrounding. Direct observation described by Bunce, *et al.*, (2000), was used to explore key features of fishing. This method provided first hand information about the fishery. The information then formed a basis for detailed interviews with the fishermen. It was also useful in confirming some issues that came up during the semi-structured interviews and focus group discussions. During observation, questions were asked about issues that are relevant to the variables under investigation, for example, issues about the fishing grounds and the fishing technique used were probed. The questions concentrated heavily on issues that could not be observed. At the end of each day, the research team sat to review the quality of data and information collected.

Semi-structured Interviews

Interviewees were randomly selected at the fish landing beaches. In most cases, interviews were conducted on the spot while in some cases; appointments were booked for interviews to be conducted at a time that was convenient to the respondents. These appointments followed a thorough introduction of the project to them. Introduction was accompanied by a clear explanation of the objectives of the study. Semi-structured interviews were based on open-ended questions that helped to generate qualitative information. Using this method, it was possible to probe for answers, follow-up the original questions and pursue new lines of questions. It created room for two-way interaction and exchange of information between the interviewer and the respondent. During the interviews, notes were taken. At the end of each day, the research team sat together to review and harmonize the results.

Key-informant Interviews

This method was used to extract information from people who were considered to be the opinion leaders in their respective villages. These were people who held some special positions in the society and were more experienced and knowledgeable. The key informants included the fishermen's cooperative leaders, local beach management unit leaders, elderly fishermen with outstanding qualities, and were selected with the assistance of the local fisheries officers and the fishermen's associations' leadership. The key informants gave insight on many issues that needed further clarifications. They were helpful in the validation of information collected using the other research methods.

Focus Group Discussions

This technique was applied following the approach proposed by Bunce, et al. (2000). A set of open-ended questions was used to prompt participants into free discussions focusing on the issues under study. The focus group interviews were arranged in advance and the respondents decided on the venue. Using this method, it was possible to probe for answers, while still following up the original research questions. The method also encouraged interactions between the interviewees and the interviewers. It was applied towards the end of the data collection process.

Survey

A structured questionnaire was administered to a sample of 165 respondents to obtain quantitative data that could be statistically analysed. The respondents were selected randomly from among the captains/owners of the fishing units. Out of the 165 questionnaires administered, 162 were valid while 3 were spoilt. The questionnaire that was administered had two distinct sections. The first section elicited responses on the socio-economic background of the respondent. The second section addressed the determinants of fish catch (yield).

3.5.2 Problems encountered during primary data collection

The fieldwork took place during the long rains. The heavy rains that some times fell for a whole day during this season interrupted our fieldwork. In addition, some of the respondents were hostile to us as they suspected that we could be linked to the officers from the department of criminal investigations. Some of the respondents who had been given false promises by students in the previous years were also very hostile. We therefore had a very difficult time trying to explain to them the objectives of our study without giving false promises. Since the bulk of data collection took place in areas that are largely rural, some of the respondents mistook us to be affiliated to grant or credit giving organisations and thus wanted to provide information that would favour them in case we had come from such an organisation. This was however corrected when we did data validation through follow up visits.

A group of artisanal fishing unit owners who had lost some of their fishing gears to the prawn trawlers and had not been compensated felt neglected by the government and became hostile as they thought that we had been sent by the Government to investigate them. However, when we explained our mission, they eventually co-operated.

Some respondents provided conflicting information and this forced us to go back to them to validate the information. Travelling back to the field to validate the information was quite costly since we were operating on a limited budget.

3.5.3 Data Analysis

Qualitative data were coded and a descriptive analysis performed. Quantitative data were analysed using descriptive statistics, graphical techniques and regression analysis. Descriptive analysis has been undertaken with the help of SPSS. Trend graphs have been drawn using MS Excel while econometric software especially Stata has been used for the regression analysis. Data have been first tested for normality, heteroscedasticity and multicollinearity to establish the suitability of OLS as an estimation technique before regression results were obtained. The estimation procedure suggested by FAO (1992) has been used to estimate the maximum sustainable yield (MSY) in the prawn fishery. According to this procedure, Schaefer model's MSY = $-.25 \times a^2/b$. This approach assumes that fish stock is one big unit of biomass. Therefore, this study deals with the entire stock, the entire fishing effort and the total yield obtained from the stock, without entering into the biological details such as the growth and mortality parameters or the effect of the mesh size on age of fish capture.

3.6 Diagnostic Tests

3.6.1 Testing for normality

Descriptive statistics indicate that the dependent variable, observed catch, has a skewness of 3.93 and a kurtosis is 24.601. This implies that the sample is positively skewed. For a normal distribution, skewness should be '0' while kurtosis should be 3. When drawing a histogram to show the distribution of these observations to test normality, the same has been confirmed. However, when the data was transformed into logarithms, a histogram of the transformed data showed a normal distribution (fig. 3). A boxplot analysis (figure 4) has indicated that the dependent variable has some extreme observations. However when the observations were transformed into logs, a more normal distribution was obtained (figure 5). The same information is conveyed by the normal P-P plot of observed catch (figure 9). The tests have confirmed that observations on the rest of the variables are normally distributed (see figures 6, 7, 8, 10, 11, and 12).

3.6.2 Testing for multicollinearity

From the correlation coefficients (table 6), all the variables have values that are closer to 0 than 1. This implies that there is no strong correlation hence we retain all the variables in the model. From the signs of the correlation coefficients, we expect a positive relationship between fish catch and size of the fishing vessel, number of hours spent in fishing per day, the age of a fisherman, and the price of fish at the landing beach. We however expect an inverse relationship between fish catch and the number of days spent in fishing per week.

3.6.3 Testing for heteroscedasticity

Heteroscedasticity tests were performed on all the estimated models using the Cook-Weisberg test. The test indicates that in the transformed log-log model (results in table 7.1) the Chi2(1) is 0.20 and the P-value is 0.6511. In the semi-log model with logarithm of observed catch as dependent variable (results in table 7.2) the chi2 is 0.01 and P-value is 0.9294. The semi-log model with logarithm of value of catch as the dependent variable has chi2(1) of 0.11 and P-value of 0.7424. From these results, the chi2 is very small and the P-value is greater than 0.05. Since we also know from theory that if P-value is greater than or equal to 0.05, we cannot reject the null hypotheses of homoscedasticity, we therefore conclude that heteroscedasticity is not a problem in the estimated models.

3.7 Limitations of the Study

1. The primary data collection coincided with the long rains along the coast and this caused delays and inconveniences.
2. Due to time constraints, primary data were only collected for two months. Consequently, variables such as stock density, global climate change, changes in critical marine habitats, etc. that require long time monitoring, collaboration with experts from other natural science backgrounds as well as application of stock assessment techniques have been excluded in the estimation of the model.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 ANALYSIS OF DESCRIPTIVE STATISTICS

The descriptive statistics show that most fishermen use traditional non-motorized sailboats that carry approximately 4 fishermen at a time. The boats and fishing net owners engage the services of fishing crew (labour) who are paid at the end of each fishing trip. Their payment depends on how much they catch. Out of each day's catch, 50% goes to the boat and fishing gear owner while 50% is left to the crew to divide among themselves. In some cases, the crew have their own fishing gears. In this case, they only pay a 20% commission to the vessel owner and retain the rest of the catch. Each crewmember knows his fishing gear and the catch is separated while still on board a fishing vessel. If a crew member has fewer fishing gears than what he considers to be optimal for his fishing operation, he rents some of them from those who keep them for rental. In turn, they pay the gear owners a commission which is calculated as a percentage of the quantity of fish landed by the gear. The owners of fishing units often do not go fishing but in stead hire qualified captains to manage the crew. In some cases the captain is paid a fixed wage per day but in some cases he is paid according to the quantity and value of fish landed. His pay is always high and is meant to boost his morale and enhance his commitment to serving the unit. There are approximately 300 boats exploiting the inshore stocks.

4.1 Fishing gear and vessel

4.1.1 Fishing gear

The main fishing gears used at the Malindi-Ungwana bay are shark nets, gill nets/cast nets, basket traps, other nets, hand lines, long lines, lobster nets, beach seines, and diving equipment. From table 1 below, it is evident that gillnet and cast nets, shark nets, and hand lines account for about 75% of all the fishing gears used in the Malindi-Ungwana bay. This finding is consistent with the results of a study by Carrara and Coppola (1985) which established that the 3 gears constitute 62% of all the fishing gears used in the entire artisanal fishery of the Kenyan coast (table 2).

The type of fishing gear is an important determinant of fishing efficiency hence the popularity of some gears over others. In the artisanal fishery, the quantity of fish caught by a fishing unit is influenced by the type of fishing gear used. Some fishing gears such as shark nets, beach seines and long lines have higher efficiency than other gears. Although shark nets and long lines are assumed to be more efficient and are thus associated with higher catch rates (yields), only a few fishing units have them since most of the fishing units find them to be too expensive. One shark net costs approximately Ksh. 20,000 and a fishing unit requires between 5 and 15 of these shark nets in each day. This is too costly to most artisanal fishing units that rarely save due to declining average catches.

The species of fish caught by each gear and the proportion of vessels that use each gear is presented in the table 1 below. While shark nets and long lines are used in the deeper parts of the inshore waters, the other gears especially basket traps, cast nets and small gill nets, beach seines, and most hand lines are used in the shallow parts. Despite the fishery being a mixed species fishery, the type of fish caught is influenced by type of gear used and location of the fishing ground. Table 1 shows the type of fish caught by each gear and it is evident that particular gears such as basket traps, lobster nets, long lines and lobster pots (scuba diving) target particular species.

Table 1: Fishing gears used by artisanal fishing units in the Malindi-Ungwana Bay, Kenya (Source: own data from individual interviews with the fishing units)

Type of gear	Main species of fish caught	Percentage of vessels using the gear
Shark nets	Sharks, King fish, Snappers, Rabbit fish, Scavenger, Roc cod, sail fish, Rays	15.6
Gill nets & cast nets	All	45.3
Hand lines	Rabbit fish, Scavenger	14
Lobster nets	Lobster	11.7
Basket traps	Rabbit fish, Scavenger, Parrot fish, King fish, Roc cod	7.3
Long line	Snappers, King fish, Roc cod	2.2
Beach seines	All	1.1
Lobster pots/ Diving equipment	Lobster	2.8

JOMO KENYATTA MEMORIAL LIBRARY

NAIROBI
EAST AFRICANA COLLECTION

Table 2: Types of fishing gears used by Kenyan artisanal fishermen, catch per unit effort and relative harvest by gear (Source: Carrara & Coppola 1985).

Gear Type	Relative frequency (%)	Catch per unit effort (kg/boat/day)	Relative harvest by gear %
Cast net	12.4	27.1	12.5
Gillnet	21.0	33.3	27.3
Beach seine	4.6	108.2	18.4
Hand line	28.0	21.0	21.9
Lobster gear	7.5	4.6	18.5
Other gear	25.5	19.5	1.4

4.1.2 Fishing vessels

Fishing vessels used in the artisanal fishery of Malindi-Ungwana bay are mainly traditional dug out canoes and wooden sailboats. Most of them are either wind propelled or paddled. A very insignificant number (about 1%) are propelled by outboard engines. This has implications on the scale of fishing operations.

Table 3: Size of vessels used in the artisanal fishery of Malindi-Ungwana bay (Source: This study)

Vessel's size (no. of fishers that it carries)	No. of vessels	As a percentage of sample size
1	15	9.3
2	24	14.8
3	29	17.9
4	38	23.5
5	35	21.6
6	16	9.9
7	3	1.8
10	2	1.2
Total	162	100

From the table 3 above, about 78% of the sample vessels carry 2-5 fishermen at a time. The fishing vessels that carry 1-4 fishermen are considered to be small in size since most of them are traditional dugout canoes that cannot sail into the deeper waters. This means that 65% of the sample vessels are small in size. On the other hand, those fishing vessels which carry 5-10 fishermen are considered to be large in size. This implies that 34.5% of the sample vessels are large vessels that can sail over long distances.

4.1.3 Characteristics of the fishing units

Table 4 below shows the characteristics of the fishing units with simple descriptive statistics.

Table 4: Descriptive Statistics with observed catch (OBCATCH) as dependent variable.

Variable	Sample size	Minimum	Maximum	Mean	Standard deviation	Skewness	Kurtosis
OBCATCH	162	.50	170.00	15.14	19.7135	3.930	24.601
VESLSIZE	162	1.00	10.00	3.79	1.6548	.457	1.056
HRSPD	162	1.50	8.00	4.72	1.5801	-.153	-.904
DAYSPW	162	3.00	7.00	6.27	.8268	-1.546	3.502
AGEYRS	162	16.00	70.00	34.47	12.2673	.779	.097
PRICEPKG	162	30.00	90.00	50.68	14.0486	.926	-.361
Dnoeduc	162	0.00	1.00	0.34	0.48	0.68	-1.55
Dprimary	162	.00	1.00	0.56	0.5	-. 23	-1.98
Dsectert	162	.00	1.00	0.09	0.3	2.7	5.44

Definitions: VESLSIZE = vessel size, HRSPD = fishing hours per day, DAYSPW = fishing days per week, AGEYRS = age of the respondent in years, PRICEPKG = price of fish per kilogramme, Dnoeduc = dummy variable for no education, Dprimary = dummy variable for primary education, Dsectert = dummy variable for secondary and tertiary education.

The descriptive statistics, table 4, indicate that on average, most fishing units in the Malindi-Ungwana bay conduct their fishing operations for 6 days a week. This is explained by a mean value of 6.27 days. The heads of fishing units stated that more days are spent in fishing during the north-east monsoon season (September – March) compared to the south-east monsoon season. This implies that fishing effort is much higher during the north-east monsoon and consequently both catch in weight and value is higher during this season (see figures 13 and 14). Overall, fishing operations are conducted for 3 – 7 days a week. 95% of the fishermen fish for 6-7 days per week during the North East Monsoon while 89% fish for the same number of days during the South East Monsoon. Approximately 96 % of the heads of fishing units are full-time fishermen, fishing for 5-7 days in each week.

Similarly, the descriptive statistics show that the fishermen fish for an average of 5 hours a day. This is evident in a mean of 4.72 hours. Those who set their gears and leave them to stay over night in the sea and check their catch the following day spend a minimum of

1 hour 30 minutes fishing per day. On the other hand, a maximum of 8 hours are spent in actual fishing operations per day during the north east monsoon. This implies fishing pressure is higher during the north east monsoon compared to the south east monsoon with corresponding higher catch (see figures 13 and 14). The high fishing pressure during the north east monsoon is explained by the fact that during this season, both weather and sea conditions are favourable.

The study established that during the North East Monsoon the sea is calm and fishermen are able to travel further in search of better fishing grounds. During this season, most fishing units that use large sized vessels at Malindi and Ngomeni in the southern part of Malindi-Ungwana bay travel long distances to Kipini and Ziwayu in the north where they camp and fish for 1-3 weeks before sailing back to their homes. The south east monsoon on the other hand is characterized by rough sea and long rains. Fishing activities are therefore restricted to the sheltered shallow inshore waters within the reef and mangrove areas. The presence of the long rains also limits the fishing pressure by reducing the number of days fishing is done per week and hours that are spent in fishing per day.

From the survey results (table 4), fishermen are 16 to 70 years old with a mean of 34 years. In table 5 below, it is evident that most of the heads of fishing units are in the age 19-35 years. If we assume that the most productive working age is 19-55 years, we can conclude that 89% of the sample are in this productive age category. Further more, it has been observed that about 30% of the fishing units in the Malindi-Ungwana bay are headed by the fishing vessel and gear owners, while 70% are headed by hired captains.

Table 5: General age distribution of the sample heads of fishing units

Years	Number of heads of fishing units	As a percentage of the sample size
18 years and below	9	5.5
19 – 35 years	101	62
36 – 55 years	43	27
56 years and above	9	5.5
Total	162	100

Number of fishermen in a fishing unit depends on the size of fishing vessel, type of fishing gear used and type of fish targeted. This number ranges from 1 for fishing units operated by the owner/captain alone to 10 in fishing units that use beach seines. The average size of the crew (fishermen/ labour) in each fishing unit is 3.8 and the median is 4. The mode is 4 indicating that 4 fishermen operate most fishing units. Of the fishing units interviewed. 23.3% are operated by 4 fishermen, 21.5% are operated by 5 fishermen, 17.8% are operated by 3 fishermen, 14.7% are operated by 2 fishermen, 10.4% are operated by 6 fishermen, 9.3% are operated by 1 fisherman/captain only, while 1.8% and 1.2% are operated by 7 and 10 fishermen respectively. Since fishing is a labour intensive activity, the influence of labour in fish production is further analyzed in the next section where regression results are presented.

In the last section, it had been assumed that the level of education attained by the head of a fishing unit influences how he manages his fishing unit and therefore impacts on fish catch/yield. According to table 4, the dummy variable for no education has a mean of 0.3395. This means that about 34% of the fishermen have no education at all but have instead obtained some basic Islamic education ('*madrassa*'). According to table 4, the dummy variable for primary education has a mean of 0.5556 implying that about 56% of the heads of fishing units have acquired 2-8 years of primary education, while 10% have obtained 1-4 years of secondary education. None has received university and post secondary training.

About 90 % of those interviewed are household heads fending for their families and also support other dependents that are either staying with them in the same households or live elsewhere. The results of the interviews indicate that the average catch per fisherman is declining due to a number of factors ranging from increased trawling in shallow waters for the shallow water prawns to the widespread use of destructive fishing technology such as small mesh size nets, traditional concoctions of poison and beach seines, and general over-fishing. It has also been observed that catches vary according to seasons. The southeast monsoon season (April – August) is associated with low catches since this is a rainy and windy season and the sea is very rough. The fishermen are therefore forced to fish only within the sheltered creeks that are relatively calm but where the mature fish biomass is low compared to other distant fishing grounds. In addition, many fishermen pull their boats from the water to dock during this season while the rest are compelled to fish for fewer days in a week since they often do not go fishing on days when it is raining heavily.

In general, the study also established that most fishing units operate with very simple and inefficient traditional fishing technology. Some of the explanations for the use inefficient traditional fishing technology as given by the heads of fishing units include:

1. Declining catch per fishermen that translates into low income and economic difficulties.
2. Lack of cold storage facilities for fish that is a highly perishable commodity. This results into drastic fluctuations in the price of fish. During the north-east monsoon when catches are higher, there is glut in the market and fishermen are forced to sell their catch at throw-away prices or else, the fish get spoilt and are thrown away.
3. Lack of credit facilities to facilitate the acquisition of fishing inputs especially appropriate fishing vessels and gears.
4. There is unfair competition for fish from the semi-industrial prawn trawlers. The prawn trawlers are also blamed for destroying the fishing ground, as they are associated with excessive by-catch and discards.
5. Reliance on traditional fishing vessels and gears that cannot fish in the deeper waters limit the quantity of fish that cannot be landed at any one time.

4.2 ANALYSIS AND DISCUSSION OF CORRELATION AND REGRESSION RESULTS

4.2.1 Yield-Effort relationship

Correlation and regression analyses have been performed taking observed catch weight and the recorded catch weight as the dependent variables in the mixed species artisanal fishery and the prawn trawl fishery respectively. Regression analyses are first performed for a mixed species artisanal fishery where the fish catch is combined without separating them into species. Later estimation is performed for the prawn trawl fishery which is a specialised industrial fishery. The estimation results are presented in tables 7.1 to 9.2 below.

Table 6: Correlation matrix

	OBCATCH	VESLSIZE	HRSPD	DAYSPW	AGEYRS	PRICEPKG
OBCATCH	1.000					
VESLSIZE	.408	1.000				
HRSPD	.327	.351	1.000			
DAYSPW	-.104	-.153	.054	1.000		
AGEYRS	.212	.144	.189	-.180	1.000	
PRICEPKG	.041	-.078	.137	.150	.089	1.000

The correlation matrix (table 6) above shows that there is no strong correlation between the explanatory variables. If there were a strong correlation between the variables, we would have expected multicollinearity problem in the estimated model. This is because the existence of multicollinearity makes it difficult to separate the influence of each of the explanatory variables from the dependent variable. Since multicollinearity does not exist in our case, it means that regression can be run on this model without any problem.

4.2.2 The all species artisanal fishery

From table 6, the positive sign of the correlation coefficient for vessel size, and number of fishing hours implies that there is a direct relationship between fish yield and fishing effort. Regression analysis was conducted on both the original and transformed data. From the results (tables 7.1 – 7.4) below, number of observations refers to the number of people interviewed. When the model was estimated using data that had not been transformed into logs the results (table 7.4) show that there is a significant positive relationship between fishing effort and fish yield (catch rate). When the transformed data were used the results (tables 7.1 and 7.2) also indicate that a significant positive relationship exists between fish yield and fishing effort. Among the aspects of fishing effort that have emerged to be considerably important are vessel sizes, number of hours spent in fishing operations, and age of the captain. The normality tests had shown that the dependent variable is not normally distributed. The tests for heteroscedasticity have shown that the original model is heteroscedastic but the transformed model is homoscedastic. It has therefore been necessary to transform the data into logs so that the dependent variable approaches a normal distribution and the assumptions of OLS are satisfied. When estimation was done using the original data, the estimated coefficients and standard errors are much bigger than those obtained when the transformed data were estimated. The coefficients and standard errors of the transformed model are much smaller.

Since the dependent variable is not normally distributed and the original model is heteroscedastic, interpretation of results has been based on both the transformed log-log model and the semi-log model, which have satisfied the assumptions of OLS. Both observed catch and value (obtained by multiplying the observed catch and price of fish at the landing beach) have been used as dependent variables but the results (tables 7.1, 7.2, 7.3) show that there is no significant difference in the estimated coefficients and standard errors. Estimated coefficients in the log-log model (table 7.1) give elasticity. Some of the important explanatory variables such as hours of fishing per day, age of the head of the fishing unit and age square that are statistically insignificant in the original model (see table 7.4) are actually statistically significant in the transformed model (tables 7.1 and 7.2) at 1% level.

4.2.2.1 *Size of the fishing vessel*

Based on the regression results (tables 7.1, 7.2, 7.3, 7.4), it is evident that the size of the fishing vessel significantly determines the quantity of catch landed by an artisanal fishing unit. The vessel size influences the size of crew to be taken on board, type and number of fishing gears for example, the type and number of fishing nets to be used at a particular time. The shark nets and long lines for instance, require a relatively large and stable fishing vessel. In addition, richer fishing grounds are located far away from the areas where artisanal fishermen dwell. Those who have bigger fishing vessels often sail to these richer fishing grounds and are able to catch higher quantities and bigger sizes of fish compared to their counterparts who operate using small traditional dug out canoes. With a coefficient of 0.781 and a t-value of 4.77 at 1% level (table 7.1), a 1% increase in vessel size leads to 0.78% increase in daily fish catch. This has important policy implications. For sustainability to be achieved in the management of this fishery therefore, vessel size is a very important variable that policy makers may have to target. Vessel propulsion on the other hand was dropped as a variable since less than 1 % of the vessels used outboard engine. Over 99% of the fishing vessels are either sailed/wind propelled or paddled. Observations however revealed that the few vessels that use the outboard engines catch relatively higher quantities of fish during the south east monsoon since they are able to venture into the rich fishing grounds despite the harsh conditions in the sea. This situation however does not hold during the north east monsoon.

4.2.2.2 Number of fishing hours

The regression results (table 7.1) also indicate that the number of hours spent in actual fishing per day is a statistically significant determinant of fish catch at 1% level. Its estimated coefficient show that a 1% increase in the number of hours spent in fishing operations leads to a 0.78% increase in the quantity of fish landed per day. With a coefficient of 0.777 and a t-value of 3.49, number of fishing hours is an important aspect of fishing effort in the artisanal fishery of the Malindi-Ungwana bay.

Table 7.1: Regression results for the production function of the all species fishery of Malindi-Ungwana bay using logged dependent and explanatory variables

Variable	Dependent variable is log (observed catch)					
	Coefficient	Std. error	t - value	P>t	[95% Conf. Interval]	
Ln vessel size	0.781	0.164	4.77	0.000	0.457	1.105
Ln hours per day	0.777	0.222	3.49	0.001	0.338	1.217
Ln age in yrs	0.700	0.251	2.79	0.006	0.204	1.196
Primary education	0.430	0.186	2.31	0.022	0.0062	.798
Secondary and tertiary education	0325	0.291	1.12	0.265	-0.249	.899
Constant	2.733	0.919	2.97	0.003	4.55	.917
Number of observations, N	162					
R^2	0.306					
Adjusted R^2	0.284					

Table 7.2: Regression results for the production function of the all species fishery of Malindi-Ungwana bay using logged dependent variable, observed catch.

Variable	Dependent variable is log(observed catch)					
	Coefficient	Std. error	t-value	P>|t|	[95% Conf. Interval]	
Vessel size	0.259	0.050	5.15	0.000	0.160	0.359
Hours per day	0.177	0.053	3.35	0.001	0.073	0.282
Age in years	0.108	0.035	3.10	0.002	0.393	0.177
Age square	-0.001	0.0004	-2.75	0.007	-0.002	-0.0003
Primary	0.363	0.181	2.00	0.047	0.005	0.721
Secondary & tertiary education	0.218	0.281	0.77	0.440	-0.338	0.773
constant	2.094	0.659	3.18	0.002	3.395	0.792
Number of observations, N	162					
R^2	0.3573					
Adjusted R^2	0.3325					

Table 7.3: Regression results for the production function of the all species fishery of Malindi-Ungwana bay using logged dependent variable, *value of catch.

Variable	Dependent variable is log (value)					
	Coefficient	Std. error	t - value	P>t	95% conf. interval	
Vessel size	.238	.051	4.67	0.000	.137	.338
Hours per day	.207	.053	3.87	0.000	.101	.312
Age of captain/owner in yrs	.108	.035	3.08	0.002	.039	.177
Age Squared in yrs	-.001	.0004	-2.65	0.009	-.002	-.0003
Primary education	.454	.183	2.48	0.014	.092	.815
Secondary and tertiary education	.459	.284	1.62	0.108	-.101	1.020
Constant	1.621	.665	2.44	0.016	.308	2.934
Number of observations, N	162					
R^2	0.3624					
Adjusted R^2	0.3377					

*Definition: *Value of catch is obtained by multiplying the landed catch by price.*

4.2.2.3 Age of the head of a fishing unit

Age of the head of a fishing unit has been used in the analysis to capture the experience and quality of labour offered to the fishing unit. According to the results in tables 7.1, 7.2 and 7.3 above, age of the head of a fishing unit is a statistically significant determinant of quantity of fish landed. It is evident that when a captain acquires one more year's experience, his fishing unit would realize 0.1% increase in the quantity of fish caught per day. Experience comes with age and therefore the more elderly fishermen have vast knowledge of their fishing grounds. In turn they are able to land bigger catches than the less experienced younger fishermen. Age Square on the other hand has a negative coefficient indicating that fish catch increases with age at a declining rate. This is in line with economic theory that requires age square to have a negative sign if it is regressed with income as the dependent variable. Policy makers need to target the more elderly fishermen with the aim of involving them in fisheries management since they are custodians of valuable information.

4.2.2.4 Level of education

There is a significant positive relationship between level of education attained by the head of the fishing unit and fish catch (yield). The positive influence of primary education is significant at 1% level of significance while the influence of secondary and tertiary education is insignificant. This can be explained by the fact that most heads of fishing units have acquired primary education and very few of them have acquired secondary and tertiary education.

4.2.2.5 Constant

The regression results (table 7.1) indicate a constant of 2.733, which is statistically significant at 1% level. This constant captures a number of things, which make it possible for effort to be applied in the fishery. The things captured by the constant include the environmental conditions such as weather, condition of the fishing boat, health conditions of the workers, etc. Since the constant is positive, it shows that the environmental conditions are favourable and the workers are generally in good health.

4.2.2.6 R-Squared

From the regression results (table 7.1), the $R^2 = 0.306$. This implies that 30.6% of the variations in the catch rate (yield) is explained by the explanatory variables. However, when a semi-log model was estimated with log(observed catch) as dependent variable, (table 7.2). R^2 rose to 0.357 meaning that about 36% of the variations in yield are explained by the explanatory variables. The same R^2 of 0.36 is obtained when a semi-log model is estimated with log(value) as the dependent variable. Being a cross sectional data, R^2 of 0.36 is acceptable. This implies that other factors that are not included in our model account for 64% of the variations in the catch rate (yield). These other important factors may include stock density (abundance), global climate change, and changes in critical marine habitats, to mention a few, all which could not be included in the model.

4.2.3 Prawn fishery

In the prawn trawl fishery, trends in prawn catch between 1996 and 2001 (see table 8) indicate that an increase in fishing effort is associated with improved yield. However, if effort increases beyond a certain critical level then over-exploitation crops in and stocks are depleted. When the number of prawn trawlers increased from 5 to 6 between 1996 and 1998, prawn catch first increased from 307.4 tonnes and peaked at 664.7 tonnes. The catch per unit effort (CPUE) also increased from 61.5 to reach a peak of 110.8. However, as the 6 trawlers continued fishing in the same fishing grounds, the stocks were depleted and prawn catch declined to 355.2 tonnes while the CPUE declined to 59.2. The decline in both total prawn catch and CPUE prompted the trawler companies to remove two of their trawlers in a random attempt to obtain the optimal number of trawlers that can exploit the fishery in a sustainable manner. It is evident that after the number of trawlers was reduced from 6 in 1999 to 4 in the subsequent years, both total catch and the CPUE improved tremendously.

Table 8: Fishing effort in the prawn trawling of Malindi-Ungwana bay (Source: KMFRI, 2003)

Year	No. of trawlers	Prawn catch (metric tonnes)	CPUE (prawn catch/) no. of trawlers
1996	5	307.4	61.5
1997	6	398.6	66.4
1998	6	664.7	110.8
1999	6	355.2	59.2
2000	4	373.5	93.4
2001	4	506.6	126.7
TOTALS	**31**	**2606**	**517.9**
AVERAGE	**5.2**	**434.3**	**86.3**
Std. Deviation			12.5
Constant			161.2
Coefficient			-14.5
Confidence limits - t			95%

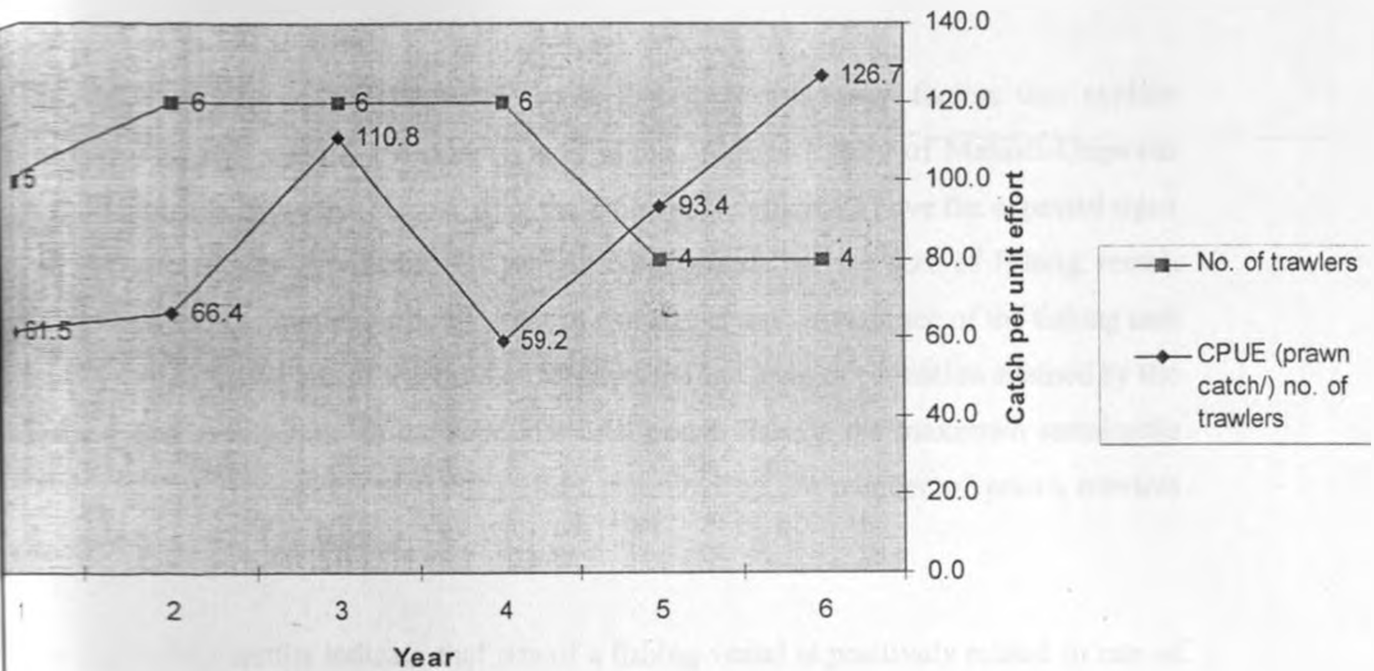
In table 9.1, the regression results for the prawn fishery of catch per unit effort, Y(i)/E(i), against effort, E(i) estimates the constant, a, to be 161.2 while the coefficient, b, is estimated to be -14.5. The constant of 161.2 is the catch per unit effort, Y/E, value which is obtained immediately after the first fishing vessel enters the virgin prawn fishery and fishes the prawn stock for the first time. As more fishing vessels join the fishery that is, as fishing effort increases, the catch per unit effort declines. Since the fish/prawn stock is a limited resource shared by the competing fishing vessels, each vessel receives a smaller share as more fishing vessels enter the fishery. This finding is consistent with what has been reported by FAO (1992) on the Gulf of Java fishery.

Although the data used is time series data since it represents six consecutive years, no unit root tests were performed since the sample size was seen to too small to show a reasonable degree of stationarity. When catch was regressed against CPUE and number of fishing vessels in each year, the influence of the number of fishing vessels and CPUE were found to be significant at 1% significance level, and they explain 97% of the variations in catch.

Applying the Schaefer model (FAO, 1992) and using data in table 8, the MSY for the prawn fishery in the Malindi-Ungwana bay is estimated to be 448 tonnes per year. This means that all factors being equal, the fishery regulatory authority should allow a maximum of 448 tonnes of prawns to be harvested per year. The E_{MSY} is estimated to be 5 trawlers. This implies that a maximum of 5 prawn trawlers using the same fishing capacity should be licensed in any given year. This estimates are close to an MSY of 433 tonnes per year and a maximum of 4.7 trawlers obtained by KMFRI (2002) using the same data but applying another surplus production model proposed by Sparre and Venema (1992).

In figure 1 below, the prawn catches were high in 1998 following the influence of the El Nino phenomena. Catches in all the other years ranged between 300 and 500 tonnes per year. It is however clear from the figure that the CPUE is dependent on how much effort is applied to the fishery.

Figure 1: Trends in prawn catch in Malindi-Ungwana bay 1996-2001



In this table, years 1, 2, 3,4, 5, and 6 represent 1996, 1997, 1998, 1999, 2000, and 2001 respectively.

CHAPTER FIVE

CONCLUSIONS AND POLICY IMPLICATIONS

5.0 CONCLUSIONS

The analyses of results (chapter 4) show that there are many factors that explain variations in fish yield (harvest/catch rate) in the artisanal fishery of Malindi-Ungwana bay. The results show that almost all of the estimated coefficients have the expected signs and are statistically significant. Of particular importance are the size of fishing vessel, time measured by number of hours spent in fishing per day, experience of the fishing unit leader, measured by age of the head of fishing unit, and level of education attained by the head of the fishing unit. In the semi-industrial prawn fishery, the maximum sustainable yield and the corresponding fishing effort measured by the number of prawn trawlers licensed have been computed.

The regression results indicate that size of a fishing vessel is positively related to rate of fish catch (harvest rate). It is statically significant at 1% level of significance. This is consistent with our expectations. This is because vessel size influences the size of crew that can be taken on board and the type and number of fishing gears that can be used at a particular time. In addition, big fishing vessels are able to sail to the distant rich fishing grounds and are therefore able to land higher fish catches compared to much smaller fishing vessels such as the traditional dug-out canoes. Vessel size is therefore a very important component of fishing effort. So far the agency responsible for the management of fisheries resources has taken steps to register vessels that fish in this area but it does not have a programme that targets the size of vessels as a measure of effort.

The number of hours that fishing units spend in fishing operations per day is another important determinant of the rate of fish catch (harvest rate). It is positively related to the rate of fish catch and it is statistically significant at 1% significance level.

The age of the captain/ head of a fishing unit is a statistically significant determinant of the rate of fish catch (harvest rate) at 95% confidence level. It is positively related to the rate of fish catch and by extension, to income earned by the fishing unit. We therefore reject the second null hypothesis and accept the alternative hypothesis that there is a significant positive relationship between the age of a fishing unit head and the rate of fish harvest. As expected, age has a statistically significant positive coefficient and age-square has a statistically significant negative coefficient. These indicate that as the age of the fishing unit head increases, fish catch increases but at a diminishing rate.

The level of education attained by the head of a fishing unit has a positive relationship with the rate of fish catch. This positive relationship is statistically significant with respect to primary level of education but insignificant with respect to secondary and tertiary level of education and is consistent with our expectations. It shows that as the head of a fishing unit acquires more years of primary education, he acquires organizational skills and his fishing unit is able to operate more efficiently and land higher catches *ceteris peribus*.

From the foregoing, it is evident that fishing effort is the main determinant of fish yield (catch rate). We therefore accept the null hypothesis and conclude that there is a significant positive relationship between fish yield and fishing effort.

A maximum sustainable yield (MSY) of 448 for the prawn fishery has been estimated using the Schaefer's surplus production model. The corresponding fishing effort (E_{MSY}) has been estimated to be 5 trawlers. For sustainability to be achieved, prawn trawlers should be restricted to land not more than 448 tonnes of prawns per year. It had also been established that prawn trawling is associated with excessive by-catch and discards, i.e. 1kg. of prawns comes with 7kgs. of by-catch, most of which is discarded. The excessive by-catch and discards are a big threat to the sustainability of the Malindi-Ungwana bay fishery. By limiting the prawn catch to the estimated MSY, by-catch production would be restricted.

About 36% of variations in the rate of fish (harvest) in the artisanal fishery are explained by size of fishing vessel, hours spent in fishing per day, age of the head of the fishing unit and level of education attained by the head of the fishing unit.

The problem of overfishing in the Malindi-Ungwana bay has been caused by increased fishing effort. Fishing effort has increased drastically as the size of fishing vessels, fishing time, experience, and educational levels have increased. Other factors that have also contributed to increased effort include rapid increase in population along the coast of Kenya, lack of alternative means of livelihood, free entry into the fishing industry, widespread poverty among the fishers, use of destructive fishing technology, expansion of the fish market in the coast province, and bottom prawn trawling with its excessive by-catch and discards.

5.1 POLICY RECOMMENDATIONS

While fishing vessels are being registered by the Government agency responsible for fisheries management in the country, time spent in harvesting the fisheries resources has never been considered to be an important dimension of effort that needs to be regulated. When there is need to increase the rate of fish harvest, conditions should be created that would enable fishermen to spend more hours fishing in the sea especially in the less exploited deep sea. If reducing fishing effort is the priority especially in the inshore areas where there is over-fishing, there is need to reduce the number of fishing hours.

Since both maximum sustainable yield (MSY) and the corresponding fishing effort (E_{MSY}) have been estimated, the information should be factored into the fisheries management decisions. For sustainability to be achieved only five prawn trawlers should be allowed in the fishery and output should be restricted to a maximum of 448 tones of prawns per year. This output restriction could be applied through the establishment of individual transferable quotas to the licensed trawlers. It had also been established that prawn trawling is associated with excessive by-catch and discards, i.e. 1kg. of prawns comes with 7kgs. of by-catch, most of which is discarded. By limiting the prawn catch to be estimated MSY, by-catch production would be restricted. In addition, a policy should be formulated to facilitate better use of by-catch and minimization of discards.

Size of the fishing vessel is a significant determinant of fish harvest rate. The agency responsible for fisheries management should establish a mechanism for controlling the size of fishing vessels especially in terms number of crew that go on board, and type and number of fishing gears in shallow areas that are already threatened with over-fishing. To maximize output from the artisanal fishery, the bigger size vessels should be encouraged to fish in the deeper waters that are currently less exploited.

Fishing time has emerged to be one of the most important determinants of the quantity of fish landed. It is important for the fisheries regulatory authorities to take this into account when formulating the fisheries management policies. For example, closed seasons should be introduced in order to control over-fishing in the shallow inshore waters. The closed season should be designed to coincide with the period when many species of fish breed. During this time, artisanal fishermen should be empowered so that they are able to fish in the deeper waters, which are currently less exploited. This should be implemented alongside strengthening of the surveillance system so that the closed season is fully observed.

Since the use of inappropriate/destructive fishing gears is another important aspect of increased fishing effort and is a cause of over-fishing and habitat modification, the production, sale and use of these destructive fishing gears should be regulated. Regulation of these gears may involve the introduction of an appropriate economic incentive that would promote the production and use of appropriate gears and practices. For example, the prices of appropriate gears particularly those that are used in the deeper waters such as shark nets should be subsidized by the government to make them affordable to the artisanal fishermen. On the other hand, the use of destructive fishing gears should be banned and high fines should be introduced on them to deter their illegal use. Enforcement and monitoring should also be strengthened to eliminate the production and use of destructive fishing practices. In addition, special micro-credit schemes should be established to facilitate the acquisition of appropriate fishing gears.

The lack of cold storage facilities should be addressed by strengthening the existing fishermen co-operative societies and beach management units by training their respective officials on how to manage community-based organisations. These organisations should then be empowered to market their members' catch and be given access to credit so that they could establish cold stores.

The estimated R^2 indicate that the explanatory variables in the model explain only 36% of the variations in the rate of fish harvest; there is need for further studies to establish the other factors that are not included in the model but account for the remaining 64% of the variations. The factors that have not been included in the estimation of the model are stock density, global climate change, changes in critical marine habitats, etc.

REFERENCES

Anderson, L. G. (1996), "A Commentary on the Views of Environmental Groups on Access Control in Fisheries". *Ocean and Coastal Management*, Vol. 28, Nos 1 – 3, pp. 165–188.

Bunce, L., P. Townsley, R. Pomeroy, R. Pollnac. (2000), *Socioeconomic Manual for Coral Reef Management*, Australian Institute of Marine Science: Melbourne.

Carrara, G. and R.S. Coppola. (1985), *Results of the first year of implementation of the Kenyan catch assessment survey*. RAF/79/065/WP/18/85/E) 85p.

Charles, A. T., T. R. Brainerd, B. M. Alicia, H. M. Montalvo and R. S. Pomeroy. (1994), *Fisheries Socioeconomics in the Developing World: Regional Assessments and an Annotated Bibliography*, IDRC: Ottawa.

Clark, C. W. (1990), *Mathematical Bioeconomics: The Optimal Management of Renewable Resources*, John Wiley & Sons, Inc.: New York.

Conrad, J. M. and C. W. Clark. (1994), *Natural Resource Economics: Notes and Problems*, Cambridge University Press: Cambridge.

Emerton, L. and Y. Tessema. (2000), *Economic Constraints to the Management of Marine Protected Areas: The case of Kisite Marine National Park and Mpunguti Marine National Reserve, Kenya*. IUCN – The World Conservation Union, Eastern Africa Regional Office: Nairobi.

FAO. (1992), "Introduction to Tropical Fish Stock Assessment: Part I – Manual". *FAO Fisheries Technical Paper 306/1 – Rev.1*, DANIDA, Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO. (1996), Report of the Government of Kenya on Fisheries Development Possibilities. Based on work of D. H. Rhodes, FAO/TA Fisheries Development Adviser. Rep. FAO/TA, (2144): 77p.

FAO. (2000), "Fishery Statistics – Capture Production". *FAO Yearbook*, Vol. 90/1, FAO, Rome.

Ferguson, R. J. (2004), Environmental Sustainability in India and China – Prospects and Risks, In: K. C. Roy (ed) *Twentieth Century Development: Some Relevant Issues*, Nova Science Publishers: New York.

Francis, J., A. Nilsson, D. Waruinge. (2002), "Marine Protected Areas in the Eastern African Region: How Successful Are They?". *AMBIO – A Journal of the Human Environment*, Vol. 31, No. 7-8, pp. 503-511.

Ginter, J. J. C. (1996), "The Alaska Community Development Quota Fisheries Management Program". *Ocean and Coastal Management*, Vol. 28, No. 1-3 pp.147-163.

Hanley, N., J. F. Shogren., B. White. (1997), *Environmental Economics in Theory and Practice*. Oxford University Press: New York.

Hanna, S. S. (1996), "User participation and fishery management performance within the Pacific Fishery Management Council". *Ocean and Coastal Management*, Vol. 28, Nos 1 – 3, pp. 23 – 44.

Hardin, G. (1968), "The tragedy of the commons", *Science*, Vol. 162, pp. 1243 –1248.

Ikiara, M. M. (1999), Sustainability, Livelihoods, Production and Effort Supply in a Developing Fishery: the case of Kenya's Lake Victoria fisheries, PhD Dissertation, University of Amsterdam.

Kenya Marine and Fisheries Research Institute (KMFRI). (2002), "Current Status of Trawl Fishery of Malindi-Ungwana Bay". Unpublished Manuscript, Kenya Marine and Fisheries Research Institute.

Keating. M. (1993), *The Earth Summit's Agenda for Change – A Plain Language Version of Agenda 21 and Other Rio Agreements*. Centre for Our Common Future, Geneva, Switzerland. pp. 35.

Leach. M., R. Mearns and I. Scoones. (1999), "Environmental Entitlements: Dynamics and Institutions in Community-Based Natural Resource Management", *World Development*, Vol. 27 No. 2, pp. 225-247.

Myers. N. (1997), "Marine Fisheries: Two Macro-constraints". *Environment and Development Economics,* Vol. 2, pp. 88 - 93

McCay. B. J. (1996), "Social and Ecological Implications of ITQs: An Overview". *Ocean and Coastal Management*, Vol. 28, No.1-3, pp. 3-22.

McCay, B. J., C. F. Creed, A.C. Finlayson, R. Apostle, and K. Mikalsen. (1996), "Individual Transferable Quotas (ITQs) in Canadian and US Fisheries". *Ocean and Coastal Management*, Vol. 28, Nos 1 – 3, pp. 85 – 115.

McClanahan. T. R. 1996. Oceanic Ecosystems and Pelagic Fisheries. In: McClanahan, T. R. and T: P. Young (eds). *East African Ecosystems and their Conservation.* Oxford University Press: New York, Oxford.

Munro, G. R, A. D. Scott. (1985), The Economics of Fisheries Management. In: Kneese V A, Sweeney L J. (eds) *Handbook of natural resource and energy economics* Vol. II, pp. 623 – 673.

Ngugi, I. (1998), Economic Impacts of Marine Protected Areas: A Case Study of the Mombasa Marine Park. M.A. Dissertation, Department of Economics, University of Nairobi.

O'Riordan, B. (1996). An Assessment of the Current Status of Kenya's Lake Victoria Fisheries. A Report for the Intermediate Technology Development Group, IT Kenya.

Obura, D. O., N. A. Muthiga and J. M. Mwaura. (2002), Participatory Monitoring of Artisanal Fishery in Kenya. In: Linden, O., D. Souter, D. Wilhemsson and D. Obura (eds). *Coral reef degradation in the Indian Ocean – Status Report 2002.* Kalmer, Sweden.

Palsson, G. and A. Helgason. (1996). "Figuring Fish and Measuring Men: the ITQ System in the Icelandic Cod Fishery". *Ocean and Coastal Management*, Vol. 28, No. 1-3 pp. 117-146.

Republic of Kenya. (1997). *Kwale District Development Plan 1997 – 2001.* Government Printers: Nairobi.

Republic of Kenya. (2003), *Geographic Dimensions of Well-being in Kenya: Where are the Poor? Vol.1*, Central Bureau of Statistics: Nairobi.

Rolston, I. H. (1988), *Environmental Ethics.* Temple University Press: Philadelphia.

Ruwa, R. K., G. Habib, M. Mukira, G. Okoth and G. Mwatha. (2003), Profile of Kenya Marine and Fisheries – Country Working Resource Document. GEF-South-West Indian Ocean Fisheries Project (SWIOFP) in Kenya. Publication No. 1 (2003), 71p.

Scott, A.D. and P.A. Neher. (1981), *The Public Regulation of Commercial Fisheries in Canada.* Economic Council of Canada: Ottawa.

Smith, L. R. (2004), The Resurgence of Community in Sustainable Natural Resource Management: A Case Study of the Solomon Islands. In: K. C. Roy (ed) *Twentieth Century Development: Some Relevant Issues*, Nova Science Publishers: New York.

Tietenberg, T. (1996), *Environmental and Natural Resource Economics*. Harper Collins College Publishers: New York.

Turner, R. K. (1995), Sustainability: Principles and Practice. In: R.K. Turner (ed) *Sustainable Environmental Economics and Management – Principles and Practice*, John Wiley & Sons: Chichester.

UNEP. (1992), *Our Planet*, Vol. 4, Number 6.

World Commission on Environment and Development, (1987), *Our Common Future*. Oxford University Press: Oxford.

APPENDICES

APPENDIX I - Table 7.4: Regression results for the production function of the all species fishery of Malindi-Ungwana bay using observed catch as dependent variable.

Variable	Dependent variable is observed catch					
	Coefficient	Std. error	t - value	P>t	95% conf. interval	
Vessel size	5.198	0.843	6.17	0.000	3.532	6.862
Hours per day	1.616	0.885	1.83	0.070	-0.132	3.363
Age of captain/owner in yrs	0.990	0.582	1.70	0.091	-0.159	2.139
Age Squared in yrs	-0.008	.007	-1.14	0.255	-.022	0.006
Primary education	9.400	3.031	3.10	0.002	3.412	15.388
Secondary and tertiary education	5.806	4.704	1.23	0.219	-3.486	15.098
Constant	-41.056	11.017	-3.73	0.000	-62.818	-19.294
Number of observations, N	162					
R^2	0.344					
Adjusted R^2	0.319					

Cook-Weisberg test for heteroskedasticity using fitted values of obcatch
Ho: Constant variance.
chi2(1) = 184.81
Prob > chi2 = 0.0000

APPENDIX II - Table 9.1: Regression results of catch per unit effort (CPUE) and vessel size for the prawn fishery

Variable	Dependent variable is CPUE					
	Coefficient	Standard error	t-value	P>t	95% Conf.	Interval
Vessel	-14.48965	12.48485	-1.16	0.310	-49.153	20.17384
cons	161.195	65.4711	2.46	0.070	-20.580	342.9735
R-squared	0.2519					
Adj R-squared	0.0649					

APPENDIX III - Table 9.2: Regression results of annual catch, catch per unit effort (CPUE) and vessel size for the prawn fishery

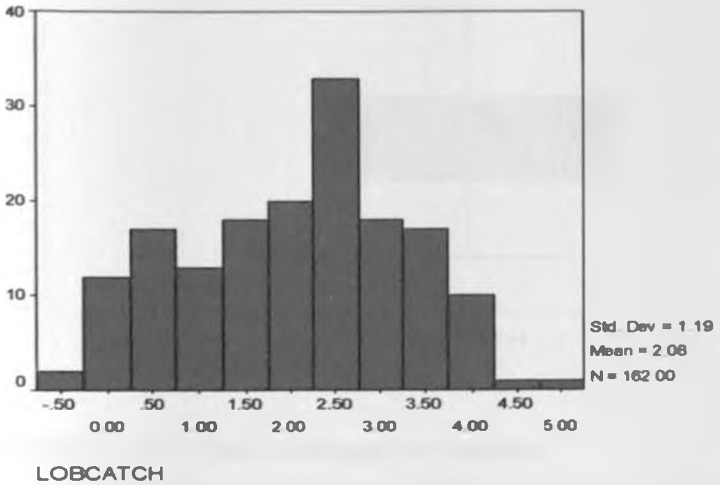
Variable	Dependent variable is Catch					
	Coefficient	Standard error	t-value	P>t	95% Conf.	Interval
Vessel	96.747	14.240	6.79	0.007	51.430	142.063
CPUE	5.191	.493	10.52	0.002	3.622	6.761
cons	-513.678	102.435	-5.01	0.015	-839.67	-187.683
N	6					
R-squared	0.974					
Adj R-squared	0.957					

APPENDIX IV -**Table 10: Annual catches from the semi-industrial shrimp fishery in Kenya**

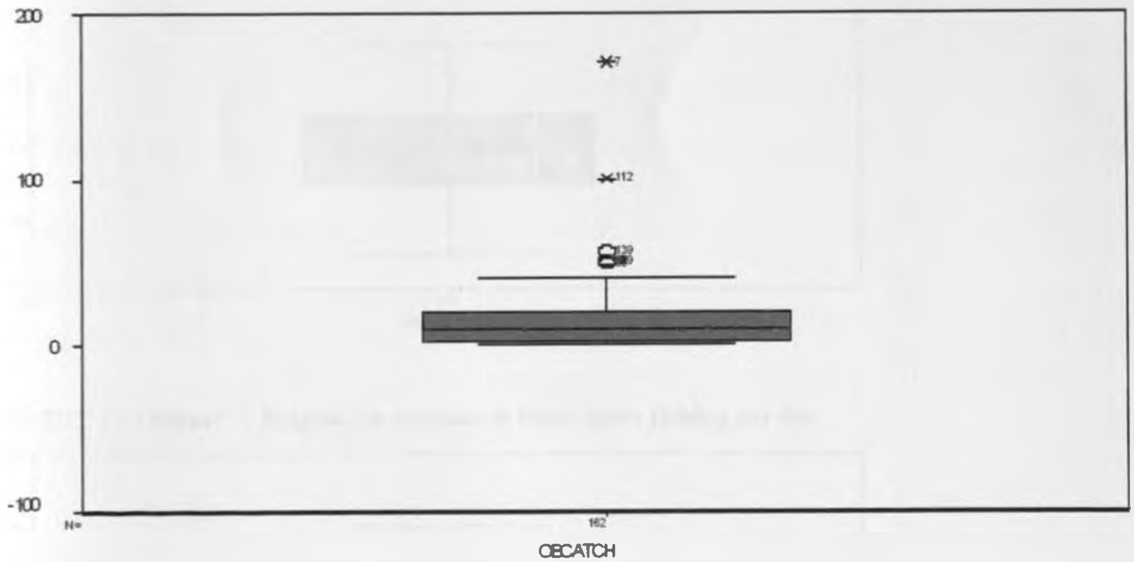
YEAR	TOTAL CATCH (Tonnes)	PRAWNS (Tonnes)	VALUABLE FISH (Tonnes)	PERCENT VALUABLE FISH
2002	1049.6	495.3	554.3	52.8
2001	950.9	454.1	496.8	52.2
2000	712.4	399.7	312.6	43.9
1999	736.6	429.3	307.3	41.7
1998	858.3	587.4	270.9	31.6

FIG. 2.: LOCATION OF THE MALINDI-UNGWANA BAY IN THE KENYA COAST

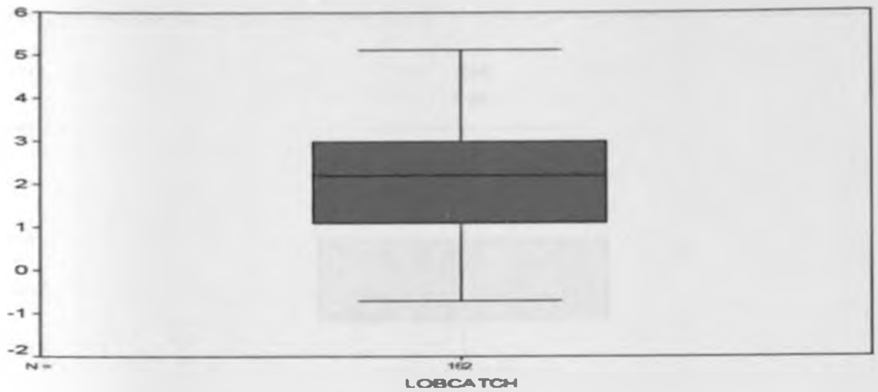
APPENDIX V - **Figure 3: Distribution of natural logarithm of observed catch**



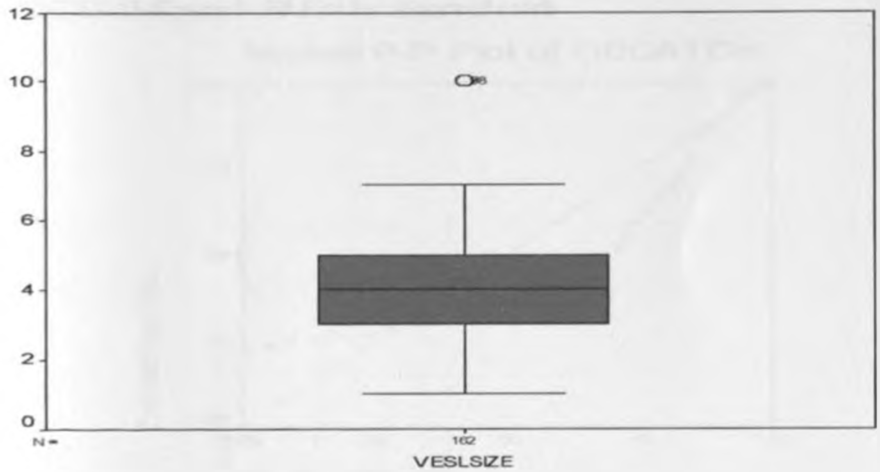
APPENDIX VI - **Figure 4: Boxplot for observed catch**



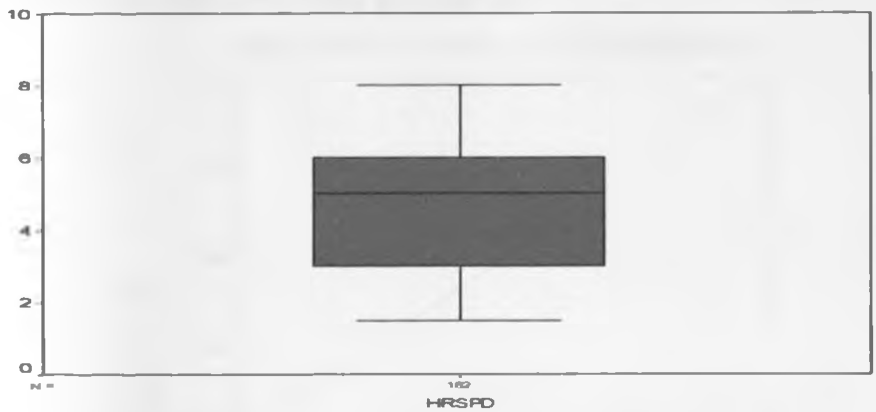
APPENDIX VII - **Figure 5: Boxplot for log of observed catch**



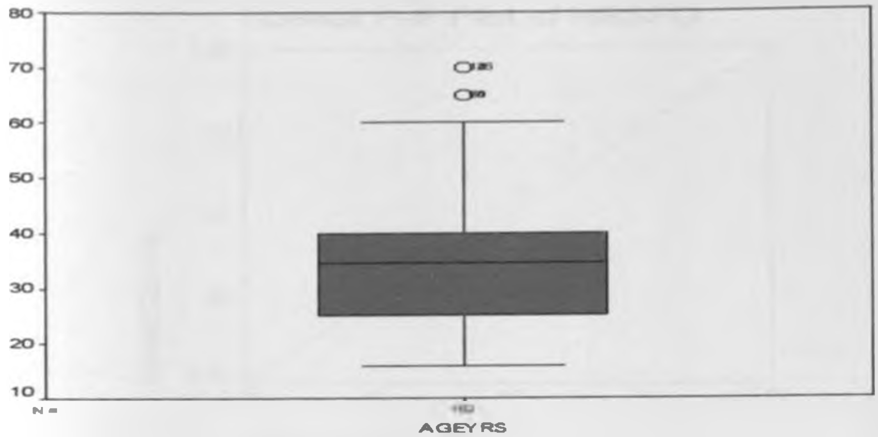
APPENDIX VIII - **Figure 6: Boxplot for vessel size**



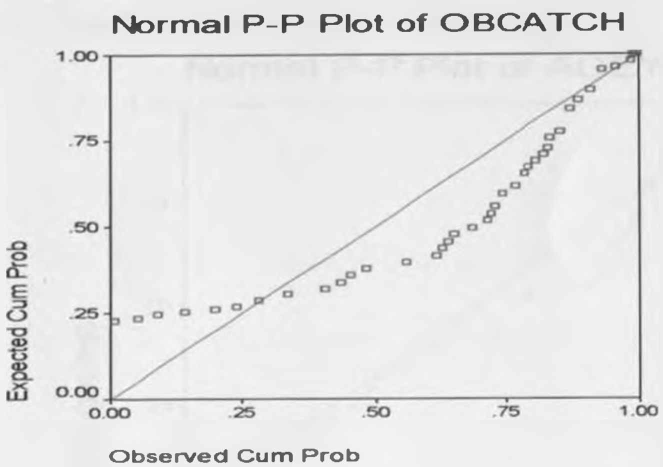
APPENDIX IX - **Figure 7: Boxplot for number of hours spent fishing per day**



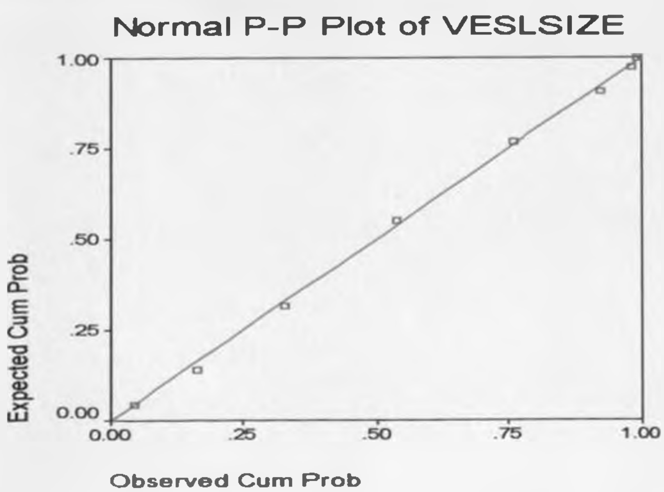
APPENDIX X - **Figure 8: Boxplot for age**



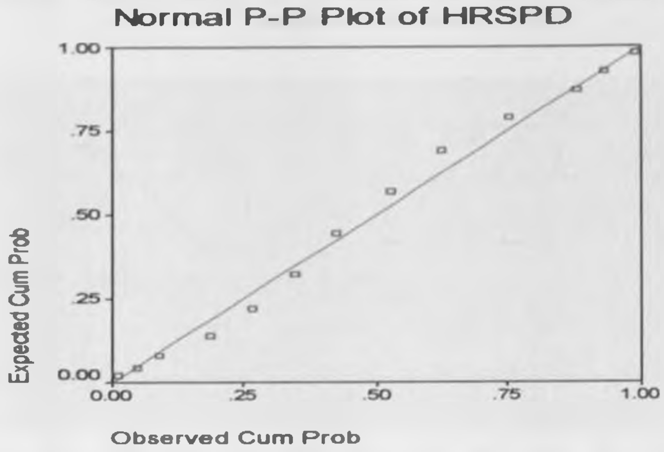
APPENDIX XI-**Figure 9: PP Plot for observed catch**



APPENDIX XII-**Figure 10: P-P Plot for vessel size**



APPENDIX XIII - **Figure 11: P-P Plot for number of fishing hours per day**



APPENDIX XIV - **Figure 12: P-P Plot for age of the fisherman**

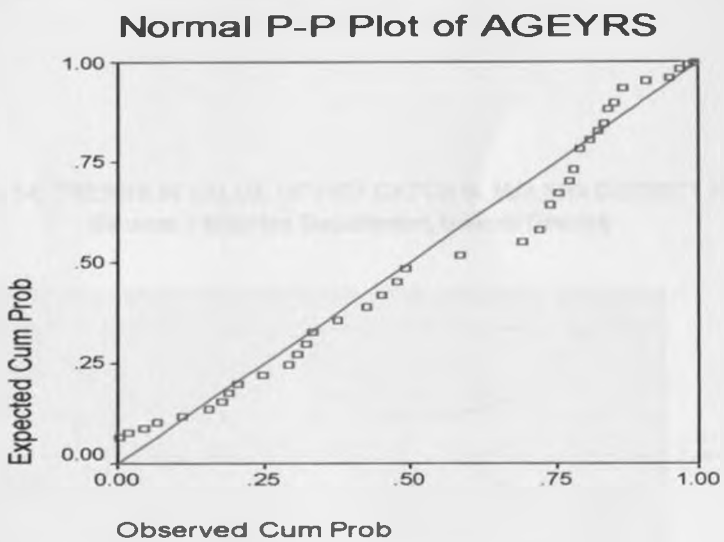


Figure 13: TREND IN MONTHLY CATCH FROM MALINDI DISTRICT IN WEIGHT (Source: Fisheries Department, Malindi District, 2004)

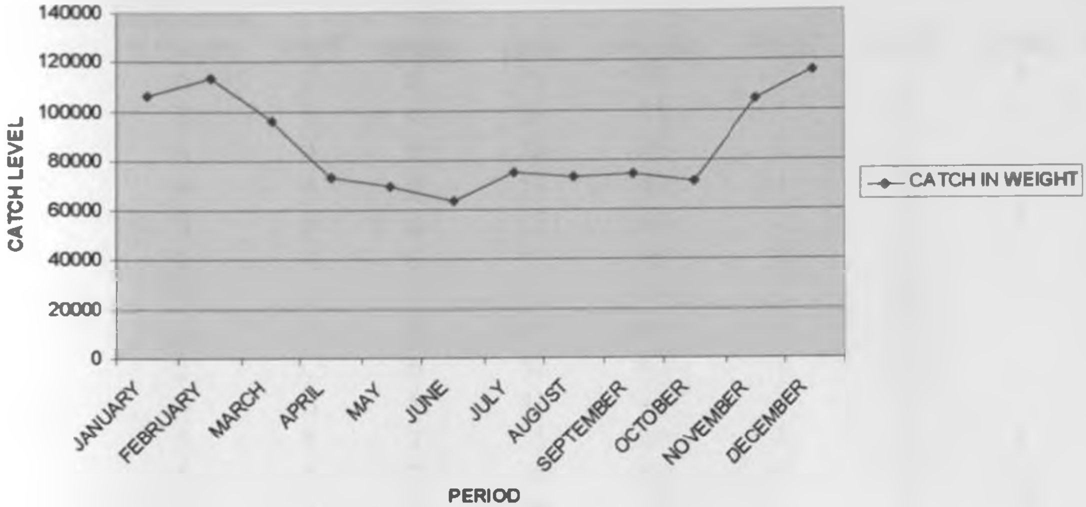
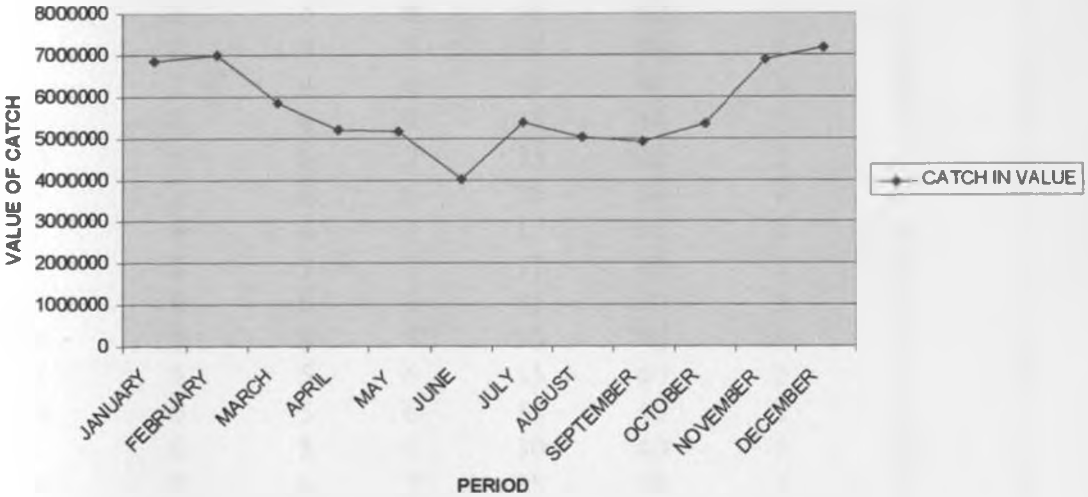


Figure 14: TRENDS IN VALUE OF FISH CATCH IN MALINDI DISTRICT 2003 (Source: Fisheries Department, Malindi District)



APPENDIX XV – CATCH EFFORT DATA FROM THE ARTISANAL FISHERY OF MALINDI-UNGWANA BAY(Source: Own data from field survey in June-July 2004)

Obcatch (in Kgs)	Veslsize (no of fishers)	hrspd	dayspw	ageyrs	pricepkg	educlevl	noeduc	primary	sectert
10	4	3	6	35	40	1	1	0	0
6	2	6	6	36	50	1	1	0	0
6	3	4	5	30	40	1	1	0	0
10	4	4	6	35	40	2	0	1	0
25	4	6	6	25	40	2	0	1	0
3	1	4	6	20	40	3	0	0	1
170	10	6	6	55	40	2	0	1	0
35	6	6	6	40	90	2	0	1	0
21	2	5.5	6	50	40	1	1	0	0
10	5	6	5	35	40	1	1	0	0
30	5	5	7	35	40	2	0	1	0
15	5	5	7	19	50	2	0	1	0
25	5	5	6	36	50	1	1	0	0
30	6	4	3	35	30	2	0	1	0
20	4	5	3	55	40	1	1	0	0
40	5	5	6	40	40	2	0	1	0
5	5	6	7	55	40	1	1	0	0
18	4	6	7	35	40	2	0	1	0
23	3	6	7	35	40	1	1	0	0
15	4	5	7	19	40	1	1	0	0
25	5	5	6	35	40	1	1	0	0
9	2	4	7	17	40	2	0	1	0
3	1	4	6	55	40	3	0	0	1
20	5	6	7	35	40	2	0	1	0
50	6	6	7	35	40	2	0	1	0
6	2	6	6	35	50	1	1	0	0
2	4	4	7	17	35	2	0	1	0
3	3	3	7	17	40	3	0	0	1
50	6	6	6	55	40	2	0	1	0
40	5	5	5	36	40	1	1	0	0
15	5	5	6	35	40	2	0	1	0
13	6	5	6	55	40	2	0	1	0
3	6	5	5	30	40	1	1	0	0
25	2	6	7	35	40	1	1	0	0
17	4	6	7	35	40	2	0	1	0
7	3	5	7	20	40	1	1	0	0
21	6	7	6	55	60	1	1	0	0
21	5	6	6	20	40	2	0	1	0
14	4	5	6	20	40	2	0	1	0
15	5	6	7	35	40	2	0	1	0
50	6	6	5	33	60	2	0	1	0
37	2	7	6	25	40	2	0	1	0

27	2	7	6	55	40	1	1	0	0
11	4	5	7	20	40	2	0	1	0
6	5	5	7	25	40	2	0	1	0
7	1	5	6	35	40	2	0	1	0
26	2	6	6	35	40	2	0	1	0
29	6	7	6	55	60	1	1	0	0
6	1	4	6	25	40	2	0	1	0
9	1	5	6	25	40	2	0	1	0
7	2	4	6	35	40	2	0	1	0
11	5	6	7	25	40	2	0	1	0
0.5	4	5	6	33	40	1	1	0	0
18	5	7	7	35	60	1	1	0	0
14	5	5	6	35	40	1	1	0	0
9	3	6	7	30	45	2	0	1	0
40	4	5	7	30	50	2	0	1	0
8	4	8	6	25	70	2	0	1	0
50	5	6	5	55	70	1	1	0	0
12	3	5	6	65	70	2	0	1	0
40	3	6.5	6	60	60	2	0	1	0
5	3	3	6	35	50	2	0	1	0
5	5	4	6	25	50	2	0	1	0
2	4	4.5	6	35	60	2	0	1	0
50	4	4	6	25	70	2	0	1	0
49	4	6	6	32	70	2	0	1	0
50	4	3	7	40	50	2	0	1	0
50	5	3	6	41	60	1	1	0	0
3	5	2.5	7	30	50	1	1	0	0
10	5	3	6	30	40	2	0	1	0
5	3	5	6	35	50	2	0	1	0
3	3	6	7	23	50	2	0	1	0
30	4	4	7	45	50	1	1	0	0
5	4	2	6	65	40	1	1	0	0
2	5	3	5	30	50	2	0	1	0
2.5	2	3.5	4	55	40	1	1	0	0
5	2	3	5	56	40	1	1	0	0
10	4	4	7	30	60	2	0	1	0
10	5	6	7	50	40	1	1	0	0
5	2	4	3	20	45	3	0	0	1
6	6	4	6	35	50	2	0	1	0
5	4	1.5	6	30	45	2	0	1	0
2	5	5	6	30	50	2	0	1	0
8	4	3	4	25	40	2	0	1	0
20	5	1.5	6	37	40	1	1	0	0
3	5	2.5	6	20	40	1	1	0	0
10	6	3	7	21	40	1	1	0	0
5	5	6	7	39	50	3	0	0	1

40	5	6	7	41	90	2	0	1	0
9	4	5	6	30	40	2	0	1	0
1	4	2	7	37	50	1	1	0	0
3	3	5	7	47	40	1	1	0	0
1	3	5	7	33	40	2	0	1	0
9	5	6	6	20	40	2	0	1	0
10	5	6	6	20	40	2	0	1	0
10	5	6	6	26	40	1	1	0	0
10	6	4	6	47	40	1	1	0	0
40	10	8	6	24	40	2	0	1	0
24	6	4	6	35	40	1	1	0	0
4	5	3	4	40	40	1	1	0	0
10	4	6	7	44	40	1	1	0	0
15	5	5	6	53	40	1	1	0	0
2	4	6	6	26	50	1	1	0	0
10	3	3.5	7	18	40	1	1	0	0
2	3	3	7	24	40	2	0	1	0
2	3	2.5	7	22	40	2	0	1	0
2	3	2.5	7	20	40	2	0	1	0
2	1	2	7	49	40	2	0	1	0
1	1	2.5	7	21	40	2	0	1	0
1	1	2.5	7	19	40	2	0	1	0
2	2	5	7	18	40	2	0	1	0
100	6	7	7	34	45	2	0	1	0
1.5	4	2	7	23	40	2	0	1	0
9	2	2	5	25	40	2	0	1	0
15	3	4	7	31	40	3	0	0	1
3	3	4	6	36	40	2	0	1	0
5	2	2	6	18	45	2	0	1	0
1	2	3	7	30	40	2	0	1	0
50	4	8	6	28	70	2	0	1	0
2.5	3	3	7	46	70	3	0	0	1
3	1	1.5	6	44	60	1	1	0	0
3	4	3	7	21	70	2	0	1	0
2	4	3	6	20	70	2	0	1	0
9	2	7	6	32	70	2	0	1	0
5	3	6	6	60	70	1	1	0	0
1	2	6	7	70	70	1	1	0	0
21	3	6	7	35	70	2	0	1	0
21	3	6	7	32	70	2	0	1	0
5	4	6	7	30	70	1	1	0	0
4	4	6	6	28	70	2	0	1	0
1	2	3	7	17	70	2	0	1	0
1	2	3	7	21	70	2	0	1	0
2	3	4	6	21	40	1	1	0	0
4	2	2	7	34	70	3	0	0	1

2	2	2	7	32	70	3	0	0	1
10	2	6	7	37	70	2	0	1	0
5	1	4	7	37	70	3	0	0	1
0.5	2	5	7	60	70	1	1	0	0
56	4	3	5	31	70	3	0	0	1
14	4	3	5	31	70	3	0	0	1
2	3	5	5	31	70	3	0	0	1
10	3	6	7	29	70	2	0	1	0
16	4	3	7	32	70	2	0	1	0
10	3	3.5	6	35	70	2	0	1	0
5	1	3	7	18	70	2	0	1	0
2	3	3	6	70	70	1	1	0	0
1	4	5	7	22	70	1	1	0	0
1	3	7	7	27	70	1	1	0	0
1	4	7	7	37	70	2	0	1	0
1	4	7	7	25	70	2	0	1	0
6	2	7	7	27	70	2	0	1	0
12	3	4	7	16	70	2	0	1	0
4	1	3	6	42	40	22	0	0	0
9	1	4	7	27	70	2	0	1	0
2	1	2	7	35	60	2	0	1	0
30	6	7	7	50	40	1	1	0	0
35	7	7	6	45	90	3	0	0	1
35	7	7	6	45	90	3	0	0	1
10	5	6	6	55	40	3	0	0	1
15	6	7	6	56	40	1	1	0	0
15	6	7	6	45	40	1	1	0	0
10	5	5	6	35	40	2	0	1	0

***Definitions**: Obcatch = observed catch in kilogrammes, veslsize = size of fishing vessel (number of fishermen that go on board), hrspd = fishing hours per day, dayspw = fishing days per week, ageyrs = age of the fishing unit head, pricepkg = price of fish per kilogramme, educlevl = level of education acquired by the head of fishing unit, noeduc = no education at all, primary = primary level of education, sectert = secondary and tertiary level of education.*

APPENDIX XVII – QUESTIONNAIRE

A. BACKGROUND

Name of respondent: ....

1. Location: .... 2. Sex of respondent: Male (......) Female (.....)

3. Age of respondent:

Below 18 years	19 – 35 years	36 – 55 years	56 years and above

4. Where is the location of residence from the beach:

Less than 1 km	1 – 3 km	3 – 5 km	5 – 7 km	7 – 9 km	9 – 11 km

5. Marital status:

Single	Married	Divorced	Separated	Other

6. (a) Household size: Total: ....

Adults: No. of spouses .... No. of children below 18 years........... No. of children aged 19 years and above ....

(b) Any other relatives supported by respondent? ....

....

7. What is the role of the respondent in the household?

Household head	Other (specify)

8. Main occupation: ....

9. Other sources of income: ....

10. (a) Income from the main occupation in Kshs.

1–3,000	3,001–10,000	10,001–20,000	20,001–30,000	30,001 and above

(b) Income from other sources in Kshs.

1–3,000	3,001–10,000	10,001–20,000	20,001–30,000	30,001 and above

(c) Income earned by other members of the household in Kshs.

1–3,000	3,001–10,000	10,001–20,000	20,001–30,000	30,001 and above

11. What is the respondent's educational level?

Never gone to school	Primary	Secondary	University	Other (specify)

B. IF FISHERMAN

1. Where is the fishing ground? ……………………………………………………
2. How long does it take to reach the fishing ground? ……………………………..
3. (a) What fishing vessel is used? …………………………………………………

   (b) Who owns the vessel? …………………………………………………………

   (c) Size of the fishing vessel i.e.

   (i) How many fishermen does it carry? …………………………………

   (ii) Does it have an engine? Yes (……..……..) No (……………..)

   (iii) If yes, what is the size of the engine? ……………….. horse power.

   (iv) Name of the vessel: ………………………………………………
4. (a) Which fishing gears are used? ………………………………………………

   (b) If gill nets/shark nets/basket traps, how many are set per day?……………..

   (c) If long lines, how many hooks does each have? ……………………………

   (d) Who owns the gears? …………………………………………………………
5. (a) How much fish has been landed by the vessel today? ………………… kgs.

   (b) How much is the average daily catch per head? …………………… ….kgs.
6. (a) How many hours did the respondent spend fishing? …………………..hours.

   (b) For how many days is fishing done per week? ……………………… ..days.

   (c) Do the number of days spent in fishing vary according to season?

   Yes (…..) No (……..)

(d) If yes, how many days is fishing done per week during N.E. monsoon? …days

(e) For how many days is fishing done per week during S.E. monsoon? … …days

7. What fish species have been caught?……………………………………………

………………………………………………………………………………………

8. What fish species are generally caught?………………………………………

………………………………………………………………………………………

9. (a) How has the catch trend been in the last ten years?

Increasing (…………) Decreasing (………………)

(b) What causes the trend? ……………………………………………………..

10. How is the fish sold? …………………………………………………………

11. Who buys the fish? ……………………………………………………………..

12. What is the current price of fish? ……………………/kg

13. What is the price of fish during the N.E. monsoon? Kshs……………

14. What is the price of fish during the S.E. monsoon? Kshs……………

UNIVERSITY OF NAIROBI
EAST AFRICANA COLLECTION

JOMO KENYATTA MEMORIAL
LIBRARY