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ASSESSMENT OF THE MARINE ARTISANAL FISHERIES IN TANZANIA MAINLAND

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ABSTRACT

This study utilized available data sets from frame and catch assessment surveys from 1984-2011 to describe the marine artisanal fishery in mainland Tanzania. Results showed that catches have been fairly stable while fishing effort has been increasing, leading to a decline in catch per unit effort (CPUE). This could be attributed to population growth, poor fishing technology, use of non-motorized small vessels, and competition. Ring nets dominated the fishery in terms of catch landed per gear, and have been becoming more important to fishermen. Beach seines, and spears, which are declared illegal, have been increasing overtime. A linear regression analysis showed that fishers, vessels, gears, and catch value were significant variables in explaining the variations in landed catch over the time period ($r^2 = 0.7833$). Dar es Salaam recorded the highest catch ($p = 2.6E-06$) because of better markets and facilities while the lowest was observed in Mtwara ($p = 0.01126$). The coast region recorded more vessels and gear types. The catch was also significantly different ($p = 2.2E-06$) across the districts within the five regions, with the Ilala district recording the highest. Average income was significantly high in Dar es Salaam ($p = 0.008469$) because of urbanization and concentration of economic activities. Two clusters of regions that were similar according to the species landed were observed. Coast, Tanga, Lindi and Dar es Salaam were similar in species composition whereas Mtwara was different with fewer number of species observed. Data collection, entry and analysis need to be done in a more consistent manner. Proper data collection, management, and analysis could also lead to the fisheries sector being more representative towards the GDP of the country.

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1 INTRODUCTION

1.1 Overview of Fisheries in Tanzania

Tanzania is well endowed with water resources, sharing three of the largest inland lakes in Africa, namely Lake Victoria, Lake Tanganyika and Lake Nyasa, diverse river systems, numerous wetlands, and the Indian Ocean. The country is reasonably rich in marine and inland fishery resources making the fisheries sector important in the economy (Sobo 2012).

Tanzanian fisheries are categorized into artisanal and commercial fisheries. The artisanal fishery exploits the freshwater bodies and the demarcated territorial waters in the Indian Ocean. The catch comprises a variety of finfish and invertebrates. The commercial fishery is mainly comprised of prawns, octopuses, lobsters, and to a small extent sea cucumber fisheries in the territorial sea, while the Exclusive Economic Zone (EEZ) is exclusively exploited by foreign fishing vessels (Mngulwi 2003). Common fish species in the EEZ include tunas, marlins, sword fish, mackerels and sardines. Sharks are also caught mainly as by-catch. Fishing gears commonly used include gill nets, hook and line, trawling for prawns, and purse seining for sardines.

Tanzania is among the poorest countries of the world. The economy is heavily dependent on agriculture, which accounts for half of the GDP, provides 85% of exports, and employs 80% of the work force. The fisheries sector falls within the agricultural sector (Francis *et al*., 2007). Fisheries provide substantial employment, income, livelihood, recreation, foreign earnings and revenue to the country. The industry employs more than 177,000 small scale full time fishers and about 4,000,000 people are engaged in other related fisheries activities like net mending, boat construction, fish vending and processing (MLFD 2010).
The contribution of fishing in agricultural activities has remained fairly constant over the last decade ranging between 4.4% and 5.7% per annum and a period average of 4.6%. Starting from a low 2.9% annual growth in 2000, the sector's growth rate increased to around 6% between 2002 and 2005, and has since steadily dropped to 1.5% in 2010. The decrease in growth between 2009 and 2010 has been attributed to illegal fishing, and destruction of nursery grounds. Currently, the sector accounts for about 10% of the national exports (Planning Commission, 2012).

1.2 Artisanal Fisheries

The artisanal fishery in Tanzania comprises catch from both inland and marine waters. It is considered to be the most important fishery as it lands most of the inland and the marine catches, contributing about 98% to the total landings. Historically, artisanal fisheries have provided the economic base for the considerable number of people in Tanzania (Mapunda, 1983).
Fishing is one of the major economic activities, which provide highly needed food source and income for majority of coastal communities. Fish contributes more than 30% to the total animal protein consumed in Tanzania (Ministry of Livestock and Fisheries Development, 2011).
In many countries small-scale/artisanal fisheries are still developing rapidly (e.g. through export markets) and adopting new technologies such as monofilament nets, echo sounders, satellite positioning systems. In many others, however, artisanal fisheries are experiencing difficulties and suffer because of a lack of data and understanding on real trends and socio-economic impact (Humber et al. 2011).

Most of the artisanal catch in Tanzania is consumed locally, either as processed or fresh, while catches of nile perch, shrimps, lobsters, and octopuses are also exported. There is no effective central marketing agency in the villages. The fish traders visit different fish landing sites daily to buy fish and transport to markets in major towns. Price is set depending on the demand for fish and distances of villages from the major coastal towns. Hence, price of fish is influenced by the variable costs of transportation. Prices tend to be lower farther away from the major urban centers (Sobo, 2012).

1.3 Marine Artisanal Fisheries

This project focuses on data from the marine artisanal fisheries from Tanzania mainland (territorial sea). Marine water bodies are one of the major economic assets and the fisheries are a major economic resource being exploited, developed, conserved and managed. The sector is of profound economic and social significance to the country. It is the main source of protein to nearly 9 million people living along the coast, and provides source of employment and livelihood to a substantial number of people. Around 36,000 artisanal fishermen are employed as full time fishermen in the fishery and more than 500,000 coastal inhabitants, constituting majority of the coastal communities, derive their economic livelihood from the sector (Ministry of Livestock and Fisheries Development, 2010a). The marine artisanal fishery is the most considerable component of the fisheries in marine waters and contributes about 95% to the country's total catch from marine waters, while the remaining 5% is contributed by the industrial catches from the EEZ (Ministry of Livestock and Fisheries Development, 2010a).

By definition, artisanal fisheries are "traditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips close to shore, mainly for local consumption. Definition varies between countries, e.g. from gleaning or a one-man canoe in poor developing countries, such as Tanzania, to more than 20/m long trawlers, seiners, or long-liners in developed countries. In Tanzania artisanal fisheries can be of subsistence or commercial nature, providing for local consumption or export. They are sometimes also referred to as small-scale fisheries" (Sobo, 2004)

The marine internal and territorial waters constitute an area of approximately 64,000 km^2. The Exclusive Economic Zone (EEZ) area is estimated at 223,000 km^2. The marine fishery of Tanzania is concentrated in inshore waters whereby fishing activities are conducted within inner sea or internal waters within the 12 nautical miles (Julius 2005)

In countries with developed fisheries, the management of the artisanal fishery has relied on conventional methods where human activities are managed in a way that maximizes fisheries production, economic benefits, employment and national revenues. The conventional approaches do not adequately take into consideration the broader effects of fishing activities on the environment, the effect of other non-fisheries related human activities, the ecosystem approach, and rights-based management (Whitney *et al*., 2003). However, in Tanzania, entry into the marine artisanal fishery is open access in nature, leading to increased fishing effort which is subject to inefficient management control thus, leading to potential problems of over exploitation (Abdallah, 2004).

The demand for fish in Tanzania is progressively increasing, particularly with the greater number of people living along the coast and with the expansion of tourism activities. This increased demand for fish products has raised the prices substantially, which has increased the income of some people in the fisheries trade. However, the marine fisheries sector is still 95% artisanal as the majority of the local fishermen still use traditional fishing methods. Most of the fishermen are poor thus, despite profit opportunities, they have not been able to adjust to the increased demand (Harrison, 2010).

1.4 Literature Review

1.4.1 Background information

Tanzania is a coastal state, bordering the Western Indian Ocean (WIO) region. It has a total land area of 945,000 km^2 out of which 881,000 km^2 is in the mainland and 2000 km^2 is in Zanzibar. The total inland water area is 62,000 km^2, the distribution of which is as follows, 35088 km^2 Lake Victoria, 13,489 km^2 Lake Tanganyika, 5,760 km^2 Lake Nyasa, 3,000 km^2 Lake Rukwa, 1000 km^2 Lake Eyasi, and 1000 km^2 other small water bodies. Most of these water bodies have substantial fisheries resources. On the marine side the country has a territorial sea area of about 64,000km^2 and coastal line of 1,424 km. The EEZ is up to 200 nautical miles covering an area of 223,000 km^2 providing the country with additional marine area and fisheries resources (MLFD, 2011)

The continental shelf extends 4 km offshore, with exception of the Zanzibar and Mafia channels where the shelf extends to 60 km. The area of the shelf within the 200 m depth contour for both mainland Tanzania and Zanzibar combined is about 30,000 km^2. The islands within the continental shelf include Unguja, Pemba and Mafia as well as numerous small islands, islets and sand dunes surrounded by reefs such as Latham, Tutia, Songosongo and Mbudya. Important ecosystems include mangrove forests, estuaries, coral reefs, sea grass beds, and inter-tidal flats, muddy and sandy beaches (Julius, 2005).

In Tanzania the artisanal fishery is practiced throughout the near shore waters of the country. The fishery is almost 100% in the informal sector of the economy, particularly practiced by the small-scale fishers, who form more than 90% of the total workforce. Artisanal fisheries in marine waters is operated in shallow waters within the continental shelf which extend to about 4 km offshore using small sized vessels and gears including small boats, dhows, outrigger-canoes, canoes and dinghies (Jiddawi *et al*., 2002). Most of inshore fishing takes place on the continental shelf where productive areas such as coral reefs, reef flats, sea grass beds, mangroves and estuaries are located. These habitats have been reported to be subjected to heavy fishing pressures from artisanal fishermen (Guard *et al*., 2000).

Fish is highly nutritious, so even small quantities can improve people’s diets. It can provide vital nutrients absent in typical starchy staples, which dominate poor people’s diets. Fisheries can also contribute indirectly to food security by providing revenue for food-deficient countries (Tim *et al.*, 2009).

Almost all people in coastal communities are involved in fishing activities in one form or another. The average individual consumption of seafood in the country is 13 kg/year in Tanzania mainland. Exports of marine products include shrimp, sea cucumber, shells, lobsters, crabs, squid, octopus and sardines. However, the majority of export revenue comes from the harvest of shrimp or prawns (Richmond *et al.*, 2002).

The effects of artisanal fishing on marine communities have been studied extensively in a variety of tropical reef ecosystems. The most obvious approach to studying such small-scale multi-species environment is to focus on target species. These are usually defined as species sought and caught by fishers mainly due to economic importance. Decreases in abundance and biomass of target species have been detected in a number of different areas throughout the tropics. One of the indicators of the status of a fishery is the change in species composition and/or change in size of the fish. These are important components in evaluating trends in fisheries (Lowe-McConnell, 1987).

The role of women in fishing sector is unnoticeable in Tanzania marine artisanal fisheries however, they play a very significance role in other fishing activities; traditionally, men have fished offshore while women have concentrated on inshore activities through the collecting or gleaning of different species from the reef and other inshore areas. They are usually restricted to intertidal areas for some hours. They concentrate much on the collection of octopuses and seashells, usually during spring tides using hands and long wooden sticks or metal rods. Also they play a very great role in fish processing and trading within their locality. The nature of fishing areas and their development has played a crucial role in promoting gender disparities (Medard *et al*., 2002).

Apart from other important economic activities of farming and livestock keeping, artisanal fishing is a pillar to most coastal livelihood households thus calling for proper resource management (Wagner and Tobey, 1998) Management of fisheries cannot be operative in absence of reliable fisheries statistics. Fisheries information is the primary tool needed to monitor the social, economic, biological and environmental performance of the fishery (Dissanayake, 2005). In many parts of the world, the main supply of such information is done through monitoring of fisheries input (fishing effort) and output (catch), fishery-independent monitoring through experimental surveys is difficult to maintain by developing nations, as they are expensive and often they cannot generate the amount of data needed for the purpose of evaluating the status of the resources (Sobo, 2004). Fisheries statistics are the primary means to measure the social, economic, biological and environmental performance of the fishery (FAO, 2002) .

A sound fisheries management requires a good deal of reliable data on catch, fleet, fishing effort, fishery costs and earnings together with sound biological information on the fish populations. Coastal fishery is a complex system due to its diverse fishing systems and community organizations, exploiting a large number of species (Singh *et al.*, 2005) making data collection a challenge.

Cowx *et al*. (2003) studied artisanal data collection system in fisheries operating in Lake Victoria and suggested improvement measures. In his study he found that the fishery is well monitored, and adequate catch statistics are available. However he found numerous weaknesses with the output that was the lack of statistical data for Uganda and Tanzania that comprise 94% of the lake surface area. On the other hand, he found that in Kenya was slightly different because all landing beaches were monitored by the Department of Fisheries and the Kenya Marine & Fisheries Research Institute (KMFRI) and artisanal data were available.

1.4.2 Marine environment degradation

Natural calamities such as storms and strong waves are known to damage coral reefs and affect fish populations. Other impacts could be caused by river runoff, which could cause siltation especially around river mouths. In 1998, coral bleaching was caused by the increase in sea temperatures. This is believed to have impacted coral reefs in several parts of Tanzania with one of the effects being a change in fish species composition (Francis and Bryceson, 2007).

Increased fishing and the use of destructive fishing methods increases much of the pressure on fisheries and degradation of reef ecosystems. By far the most destructive type of fishing is the use of dynamite. Dynamite fishing was once widespread, but its use has been reduced drastically throughout the country. It has been practiced in Tanzania for over 40 years. Each blast of dynamite instantly kills all fish and most other living organisms within a 15-20 m radius and completely destroys the reef habitat itself within a radius of several meters. With numerous blasts occurring daily on reefs all over the country, over a period of many years, the cumulative effect has been overwhelming. Before 1995, Mafia Bay was reported to be like a war zone with blasts going off every hour (Wagner and Tobey, 1998).

Use of small mesh seine nets to capture fish on the bottom and around reefs is as destructive as the use of dynamite. The nets are weighted and dragged through the reef flat, dragging them over the reef flat damages coral and other marine life. Beating and smashing coral

colonies with poles to frighten fish into the net results in the capture of many juveniles. Capture of juvenile fish, when conducted intensively in nursery areas, results in depletion of fish stocks, alteration of species composition, loss of species diversity, and disruption of food webs (TCMP, 2001).
In the early 1980s, Mapunda (1983) already found out that while the marine fishery has not been able to fully exploit its annual potential, there were ample signs of overfishing in the coastal waters of Tanzania. Also, a decline in catches of certain commercial species, mainly reef fish, has been reported by Jiddawi *et al*. (2002). This suggests that the better fishery management needs to be imposed in order to maintain productivity of the fishery resource on a sustainable basis. Moreover, constant pressure is also applied from continued population growth and development of industrial fishing and migration from the hinterland. The degradation of coastal areas, population growth in fishing communities, and inappropriate property right regimes in fisheries are fundamentally responsible for the declining state of the fishery according to Tobey and Torell (2006).

1.5 Problem statement

Fish and fisheries are of immense importance worldwide and most of coastal people in developed countries depend on it for their livelihood. Historically artisanal fisheries have provided the economic foundation for most countries of the Southwest Indian Ocean region (Mapunda, 1983). Artisanal fisheries make an important contribution to nutrition, food security, sustainable livelihoods and poverty alleviation especially in developing countries like Tanzania.
The importance of fishery resources to the economy of Tanzania cannot be understated. These resources make a significant contribution to the Gross Domestic Product (GDP), foreign exchange earnings, provide both direct and indirect employment and supply relatively cheap protein to the coastal communities' population (Berachi 2003).
"Tanzania's fishery resources are believed to have reached the upper level of exploitation. This is believed to be so because fishermen have been fishing in the same areas since time immemorial" (Jiddawi and Ohman, 2002). However, at the same time fishermen lack suitable vessels and gear to fish offshore, hence they are forced to overexploit the inshore waters. Interviews with fishermen show that they perceive that catches are declining and an increase in fishing effort will not result in increased catches. Fishermen are also concerned about the increasing resource competition due to a rising number of both local and visiting fishers (Tobey and Torell, 2006). Fisheries resources are renewable; however, capture fisheries are subject to depletion if not sustainably exploited. High fishing pressure and illegal fishing practices contribute to resource depletion.
Management of fisheries cannot be effective without the availability of reliable fisheries statistics (Jacquet *et al.*, 2010; Dissanayake, 2005). There is a need for instituting effective resources management and control mechanisms. Currently, the management tools used include monitoring, control and surveillance, information gathering and processing, data analysis and dissemination, and collaborative resource management through stakeholder participation and empowerment. Despite ongoing fisheries resources management efforts, there has been a decline in fish stocks and degradation of the environmental (Harrison, 2010).
A lot of work has been conducted in Tanzania on monitoring the artisanal fisheries resources. Most of the data collected are from short-term projects with specific goals. Government sponsored projects cover a range of subjects but due to resource constraints the information in most cases is not synthesized.

1.6 Significance of the study

This study utilized the available data sets from the frame surveys (surveys on fishing effort) and catch assessment surveys to describe the marine artisanal fishery in Tanzania mainland. This baseline study attempted to bridge the information gap by collating and synthesizing the available data. The main aim of the study was to assess the marine artisanal fisheries in Tanzania mainland, mainly through descriptive analysis and exploring associations in the available data, and to use the findings to provide some useful guidelines for improving the data collection and storage system, which in turn will provide a basis for improving the fisheries management system. The specific objectives of this study were to;

i. Analyze the time trend of catch and the fishing effort data (fishers, vessels and gears)
ii. Relate the observed patterns to potential socio-economic factors such as average income of people and environment factors.
iii. Analyze temporal and spatial differences in catch and effort data in recent years.
iv. Analyze catch compositions across regions.
v. Review the data collection and storage system and propose potential improvements based on the assessments.

2 DATA COLLECTION PROGRAMS

The Fisheries Development Division, apart from dealing with all matters related to fisheries sector, is also the custodian of fisheries statistics and has obligation to collect, analyze, manage, and disseminate fisheries statistics to various stakeholders. The fishery resources of Tanzania have been monitored since before 1960 and the estimated yearly fish productions have been used in planning and management of fishery resources (Sobo and Mgaya, 2005). The artisanal fishery in Tanzania is mainly monitored through two main types of surveys namely the frame survey, which monitors the fishing effort, and the catch assessment survey, for monitoring catch landings.

2.1 Frame Survey

Frame survey is an inventory of fish producing factors such as number of landing sites, number of fishermen, number of fishing vessels and gears by type and size. It is also a description of fishing and landing activity patterns, processing and marketing patterns, as well as describing supply centers for goods and services. The frame survey is also referred to as fisheries census, which means the fishing effort is obtained by complete total enumeration (Cowx *et al.*, 2003).

For responsible fisheries management, evaluation of fishing capacity and analysis of fisheries information must be known and monitored. Therefore fisheries frame surveys are used to generate important information required both for management planning purposes and for helping design catch assessment surveys by providing the sampling frame. Frame survey data can also be used to study fishing and gear use patterns, which could potentially be used to study the socio-economics of a community (FAO, 2002).

In Tanzanian mainland, from 1967 to 1991 fisheries frame surveys were conducted on an annual basis. From 1992 the surveys were conducted every two years. However, surveys were not conducted in 1994 instead was postponed to 1995 due to financial constraints. The following frame survey planned for 1997 was also postponed to 1998 due to delay of funds. After 1998, surveys were conducted in 2001 and 2005. Two recent frame surveys have been conducted in 2007 and 2009 and were facilitated by a donor-funded project Marine and Coastal Environmental Management Project (MACEMP) funded by the World Bank. The next frame survey was supposed to be conducted in 2011, but it has not yet to be carried out due to financial constraints.

2.2 Catch Assessment Survey (CAS)

These are surveys of catch landings, which are conducted at selected landing sites. The collected information includes data on catch, species composition, associated effort, and other secondary data such as prices, weight of fish and number of fish caught for bigger fish.

FAO (2002) underlined that, “in small scale fisheries, the amount of information regarding, total landings, species composition and prices is so large that the use of census approach is impractical and sampling techniques are employed.” Therefore the most cost effective way to collect artisanal fisheries data is through sampling (Sobo, 2004).

The main objectives of the catch assessment survey data, in combination with the frame survey data are to:

i. Estimate total fish production (by all species, all boats and all gears) by weight and value per district, region, and water body for the whole country

ii. Estimate Catch Per Unit Effort (CPUE) i.e. average catch per fishing boat / fishing gear and average per fishing hours

iii. Conduct stock assessment based on available production and biological data.

In Tanzania catch and effort data are collected on sampling basis. The primary sampling unit is the landing site of which few landing sites are randomly selected from a frame survey list. In marine waters, there are 22 landing sites where CAS data collected on a daily basis out of 259 landing sites that were recorded during the 2005 frame survey. The secondary sampling unit is the day, which are also selected randomly. The data are collected for 10 days per month.

Catch landings data have been collected in marine waters since 1965 just after the establishment of the Fisheries Department. Fisheries field officers collected data in all identified landing sites. In subsequent years difficulties were experienced following decentralization, when regional/district fisheries officers were no longer reporting to central government (Fisheries Division). The inefficient transfer of management responsibilities from central to local government (decentralization) from the late 1990 ceased the collection of fisheries data and made it difficult to maintain responsible fisheries management.

In response of this situation, the fisheries division initiated fishery-dependent monitoring of fisheries statistics whereby fishing communities represented by Beach Management Units (BMUs) are now involved in data collection at their respective landing sites. This is to ensure timely, complete and reliable statistics on catch and fishing effort (Sobo, 2012).

2.3 Catch Assessment Survey Database

CAS Database like others is used to store fisheries information and organize it into a practical form and software applications giving the user great flexibility with the data. Data on both frame survey and catch assessment survey are entered into the database. The database interface provides users with features to organize their information simply and specifically and gives the ability to modify templates to personalize them for specific purposes.

CAS database software includes the option of creating user-friendly forms to make the task of entering data easier on the operator's eyes and it includes report creation functions. Reports allow users to manipulate data in numerous ways. Users can insert functions into reports to help in analyzing the fisheries data.

The collected catch data and frame survey are used to estimate the total fish production obtained from artisanal fishing. Previously, the data were analyzed at Fisheries Division through database II program called Tanzania Fishery Information Systems (TANFIS) which was introduced by FAO during the implementation of UNDP/FAO funded project “Strengthening Fisheries Statistical Unit” (URT/016/89). The CAS database was developed in 2000 exchanging the TANFIS program that was designed by FAO when Regional Fisheries Information System (RFIS) under the Southern Africa Development Community (SADC) project, was established. The project was intended to provide timely, relevant, accessible, useable and cost effective information to improve the management of marine fisheries resources in the Southern African region. Fisheries data on the catch assessment surveys and frame surveys were entered into the database. Later on, the database was modified and strengthened by consultants from UNU-FTP. The New CAS system introduced in 2007 has been simplified. The database is kept at the Fisheries Division where the data are analyzed centrally, backed up for easy storage, recovery, and data security (Sobo, 2004).

The data collected are entered in the installed database in 5 coastal districts, which belong to 5 administrative regions. This is to reduce heavy workload for Fisheries Division headquarters. The districts have an option to validate the data locally monthly, and there is also flexibility for districts analysis to provide for their needs as far as fisheries statistics is concerned.

3 MATERIAL AND METHODS

3.1 Study area

This study focused on marine artisanal fishery off Tanzania mainland. It includes all the coastal districts of Tanzania along the entire coastline of 1,424 km (TCMP, 1998) i.e. from latitude 4º 49'S at Jasini landing site (border with Kenya) to latitude 10º28'S at Bahasha landing site (border with Mozambique) (Fig. 1). This area includes sixteen coastal districts, which are Mkinga, Muheza, Tanga, Pangani, Bagamoyo, Kinondoni, Ilala, Temeke, Mkuranga, Rufiji, Kilwa, Mafia, Lindi Rural, Lindi Urban, Mtwara Urban, and Mtwara Mikindani. These districts fall within 5 main regions namely; Tanga, Coast, Dar es Salaam, Lindi and Mtwara.

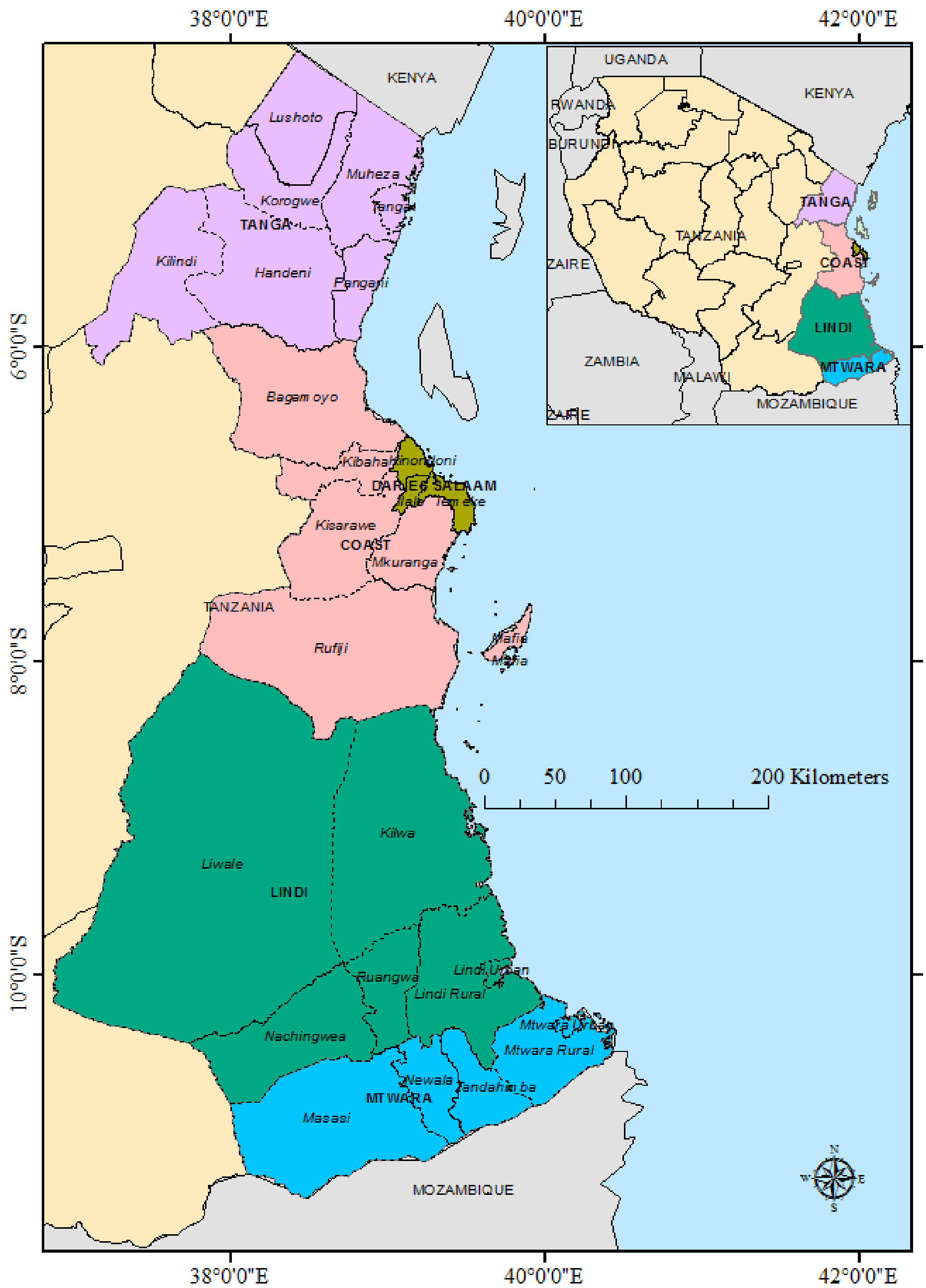

Figure 1: Map of the coastal districts of Indian Ocean within Tanzania Mainland. The five main regions include Mtwara (blue), Lindi (green) Coast (pink), Dar es Salaam (gold) and Tanga (purple)

3.2 Available data

The raw data available on marine artisanal fishery from Tanzania mainland are delineated in Table 1 below. Frame survey data, for all regions combined, constituted total effort i.e. number of fishers, number of vessels, and number of gears by gear type from 1984 – 1992. From thereon frame surveys were conducted every 2nd or 3rd year in 1995, 1998, 2001, 2005, 2007, and 2009. Frame survey data were also compiled by regions for years 2001, 2005, 2007 and 2009. Catch data included total raised estimated landed catch (weight in metric tons) from 1984 – 2011, and catch value, in Tanzanian shilling (Tshs), from 1993 – 2011 for all regions combined. Estimated landed catch by year, month, region, and district were available from 2007 – 2011, with available catch compositions for 2010 and 2011. Per capita income data (Tshs) from 1984 to 2010 were compiled with some missing data for 1995-1999. Data on per-capita income by regions were available for years 2001, 2005, 2007 and 2009 (National Bureau of Statistics, 2011). To take some environmental effects into account, air temperature data from Dar es Salam station was extracted from (Gray *et al.*, 2011) for years 1986 – 2011 with missing data on 2005 and 2006. Air temperature was considered to be an indicator for sea temperature. Further, data on population from the five regions were compiled from the two census surveys conducted in 1988 and 2002 (Ministry of Industries, 2010).

Table 1: Available data from the Tanzania marine artisanal fisheries

Type of data	Year	Source
Frame survey data (fishers, vessels, and gears by gear type) for all regions combined.	1984 - 2011	MLFD
Frame survey data by regions	2001 - 2009	MLFD
Catch Assessment Survey data (catch and value) for all regions combined.	1984 - 2011	MLFD
Catch Assessment Survey data (by regions, districts and months).	2007 - 2011	MLFD
Species composition of catch (by regions and districts).	2010 - 2011	MLFD
Average Income (per-capita income)	1984 - 2010	(National Bureau of Statistics 2007)
Average income (per-capita income) (by regions)	2001 - 2009	(National Bureau of Statistics 2011)
Air Temperature (Dar es Salaam station)	1986 - 2010	(Gray *et al.* 2011)
Population data by regions (two census surveys)	1988, 2002	(Ministry of Industries 2010)

3.3 Analysis

3.3.1 Catch and effort trends

Descriptive statistics were used to analyze the trends in catch, effort, average income and market value of catch. The trends and patterns in data were examined visually using graphs. The market value of catch and average income were adjusted for inflation based on the consumer price index (CPI). The adjusted value was calculated by dividing the estimated value by a scaled CPI index. The scaled CPI is obtained by dividing the CPI indices for each year by the base CPI index, for year 1.

Catch per unit effort was calculated based on the available data. A prominent measure of effort for this fishery is the type of gear used. Therefore catch per gear was calculated based on the analysis presented in Berachi (2003) but for a larger dataset, 1984 – 2011. The three main gear types that landed the highest catch in the fishery were ringnets, gillnets, and longlines according to Berachi (2003). Based on the current knowledge through communication with fisheries officers and fishermen (Ibrahim Mohamed, pers. comm), it is known that these three gear types still dominate the fishery. Since further information on catch by gear type was not available the same assumptions were used for this study. To obtain a standardized CPUE (E_s) the number of gear (g_i) was multiplied with a weighting factor (w_i) and summed up over all gear types $E_s = \sum_{i=1}^{I} g_i w_i$. The three most prominent gears were given weighting factors, which were taken from (Berachi, 2003), Table 4.3; Ringnets = 2.661305, Gillnets = 0.057321, Longlines = 0.061969. The standardized CPUE is obtained by dividing the total estimated landed catch for Tanzania mainland by standardized effort. It is acknowledged that this analysis is crude and is likely to have a high uncertainty. Another measure of CPUE calculated was catch per fishermen. Analysis was done for the years in which the frame survey was conducted.

The trend in gear composition for years 1984 - 2011 was also visually examined.

3.3.2 Relationships among variables

The aim of this exercise was to determine if other fisheries parameters such as level of effort, or socio-economic factors such as average income, or environmental variables such as temperature could explain the variation in total landed catch. A multiple regression analysis was applied to the data trend from 1984 – 2011. Some data points on value, average income, and temperature were missing in the series. The missing points on catch value (5) and average income (7) were interpolated using a linear interpolation routine in R based on the available time series. Since the temperature data was more or less stable across the time period, the missing data points (5) were replaced with an average of the time series. This enabled the analysis to be carried out on the entire time series.
The dependent variable, estimated landed catch, was modeled against the independent variables; fishers, gears, vessels, catch value, average income, temperature, and year to find the best model which describes this variable. Year was used as a variable to see if all the effects were just due to temporal changes.

Likewise average income as a dependent variable was modeled against catch, fishers, gears, vessels, catch value, and year to determine the importance of fisheries in income generation.

A default stepwise routine in R was first used to identify the best model based on the Akaike Information Criteria (AIC) (Kutner *et al.*, 2005). This model was then further investigated and variables that were not significant were removed from the model.

3.3.3 Analysis of Variance

An analysis of variance (ANOVA) was performed to determine any significant variation in the total catch landed across different years, months, regions, and districts. Number of fishers, vessels, and gears were also analyzed for any variation among years, regions, and districts. Log-transformed data was used to obtain a normal distribution with equal variance. These were based on data from the recent frame surveys (2001 – 2009) and CAS surveys from 2007

– 2011. Similar investigations were conducted for catch value and average income across years and regions.

3.3.4 Cluster analysis

Cluster analysis aims to find natural groupings such that samples within a group are more similar to each other, generally than samples in different groups. Thus, cluster analysis of species similarity can be used to define species assemblage i.e. groups of species that tend to co-occur in a parallel manner across regions and years (Clarke and Warwick, 2001). A cluster analysis was performed to obtain the hierarchical cluster of species assemblage. The analysis was based on species composition data from 2010 and 2011. The aim was to see if regions were similar in species composition. A pvclust routine (Suzuki and Shimodaira, 2006) was used in R for cluster analysis. The routine uses bootstrap to calculate p-values of clusters, which are identified with less uncertainty.
All the analyses were conducted in the R statistical software (R Core Team 2012)

4 RESULTS

4.1 Demographics

There was an increase in population over the years throughout the coastal regions (Figure 2). However the population growth was considerably higher in Dar es Salaam than the other regions where an increase of 83% was recorded from 1988 to 2002. The increase was also considerably high in other regions Tanga (28%), Coast (39%), Mtwara (26%), and the lowest population growth seen in Lindi region (22 %).

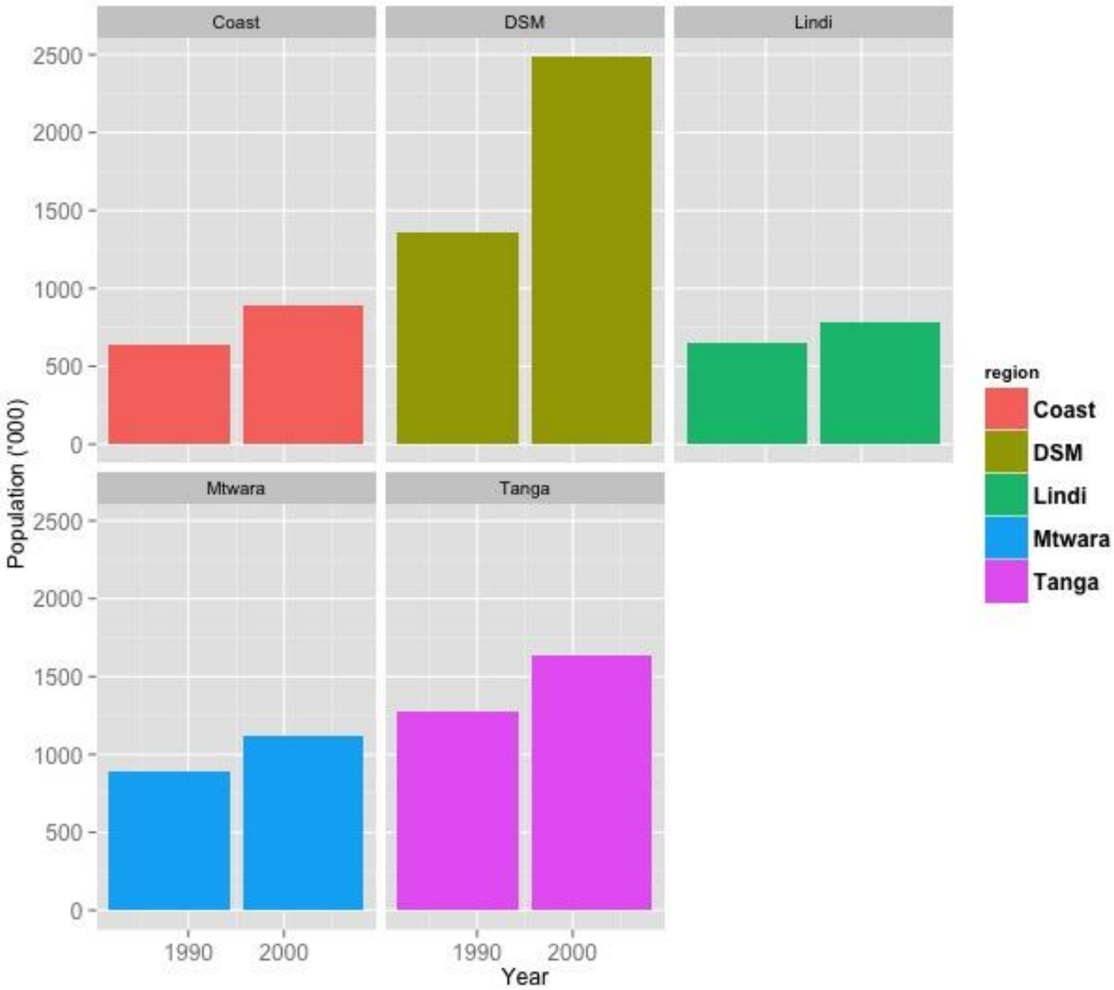

Figure 2: Population of the 5 coastal regions of Tanzania Mainland from the last two census surveys conducted in 1988 and 2002 (Ministry of Industries 2010).

4.2 Catch and effort trends

Total estimated fish landings fluctuated over the years but over the period of time the catch has remained fairly stable (trend line estimated using loess fit). More specifically, relatively higher catches were observed in years 1990, 1991, 1996, and 2005 and years with relatively lower observed catches were 1987, 1993, 1994, 2007 and 2008 (Figure 3a). Numbers of fishers have been going up with a sharp increase witnessed after 2000, coinciding with the observed trend in number of vessels (Figure 3b and 3c). On the other hand, number of gears used in the fishery initially declined then increased from the mid-1990s to date (Figure 3d).

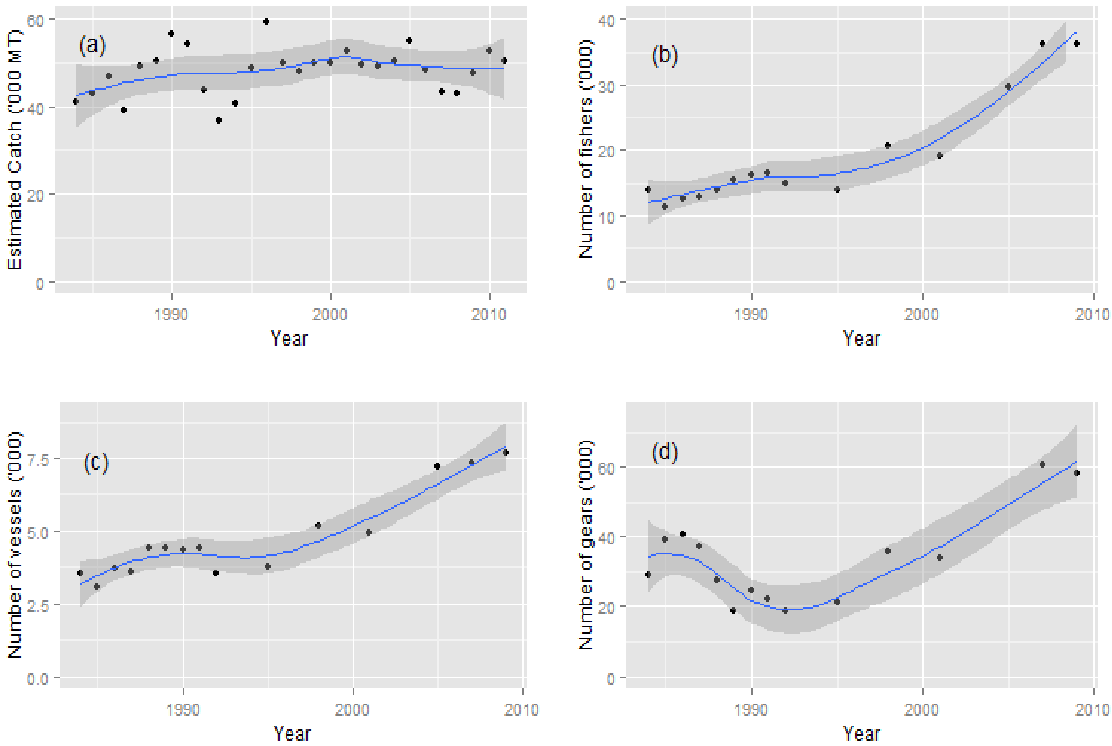

Figure 3: Time trends of (a) total estimated landed catch (b) number of fishers (c) number of vessels (d) number of gears for years 1984-2011. A trend line with standard error was estimated using loess fit for each dataset.

The catch value has generally increased over the years. In last five years the value increased more than two fold (Figure 4a & b). Average income from the coastal area has been increasing steadily (Figure 4c & d).

The standardized catch per unit effort, catch per gear, increased from 1984 - 1995. After that it decreased continuously (Figure 5). The catch per fishermen showed a clear decline over the years (Figure 6).

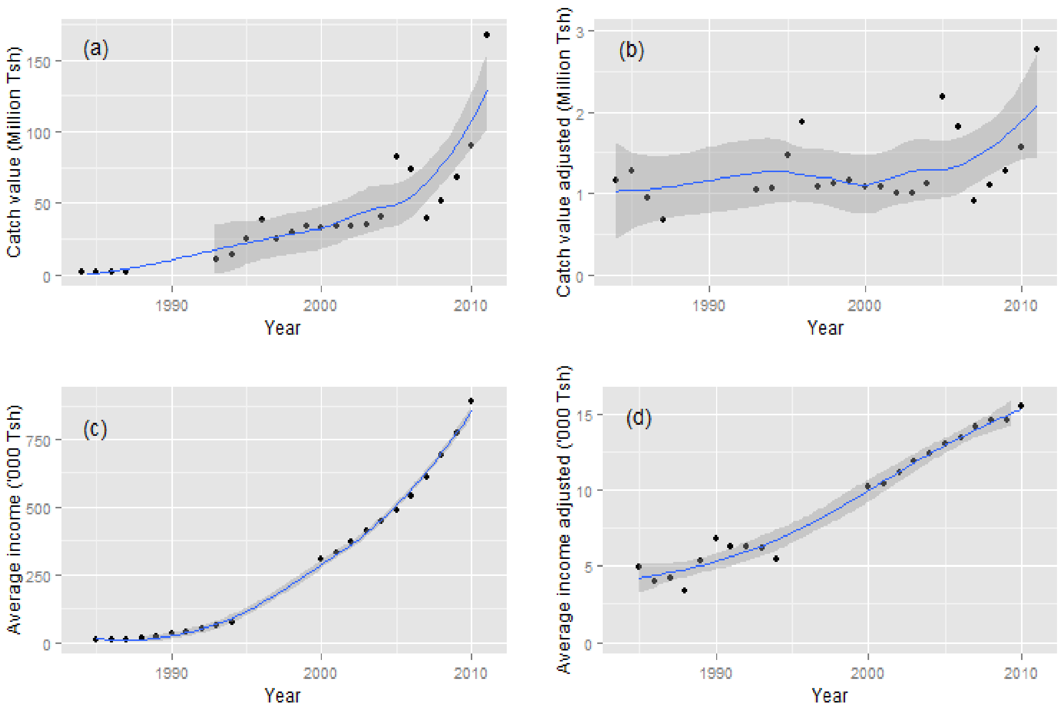

Figure 4: Market value of catch and average income over the years from 1984-2011 (a & c) before (b & d) after the values were corrected for inflation based on consumer price index (CPI).

A total of 15 gear types are used in the fishery which include traps, shark nets, gill nets, handlines, long lines, beach seines, purse seines, ring nets, scoop nets, fish weirs, spears, angling nets, trawl nets, and industrial trawls. Handlines, long lines and gillnets were highest in numbers. The number of fishing gears, in general, increased in the early years (1984 – 1986) after which a decline was recorded in period 1987 – 1993. Subsequently a general increase in different gears types was seen until the recent survey in 2009 where a slight decrease was recorded (Figure 7) for most gear types except longlines. It should be noted that longlines were recorded in different units for 2005 and 2006 therefore, were excluded from the analysis. There was a sharp increase in gillnets from 2005 to 2007. The numbers decreased in 2009. A general decline in traps was seen from 1984 with low numbers recorded in 1998. This fishing gear then increased in numbers in the following years. Beach seines, which are declared illegal, have also been on the rise. Ring nets have increased over the years and dominated the fishery in terms of catch landed per gear, and have been becoming more important to fishermen. Spears, which were declared illegal in the 2009 fisheries regulations, were still being used. Percentage of gear composition has been fairly constant over the years (Figure 8).

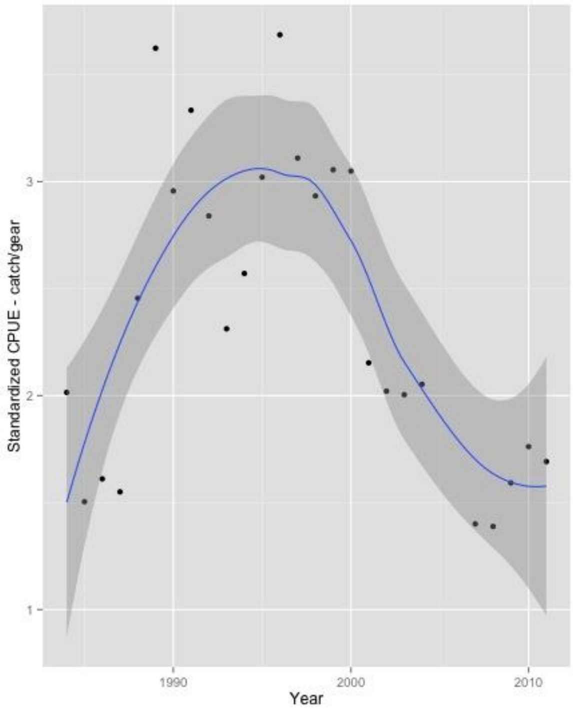

Figure 5: Plot showing the standardized CPUE, catch per gear, of the marine artisanal fishery for years in which frame survey was conducted.

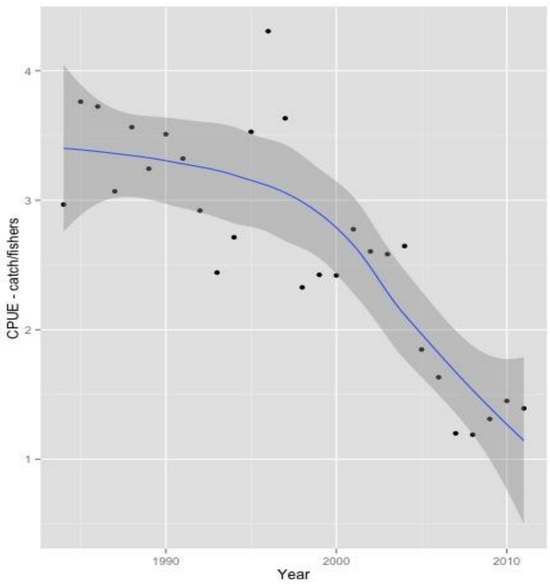

Figure 6: CPUE, catch per fishermen of the marine artisanal fishery for years in which frame survey was conducted.

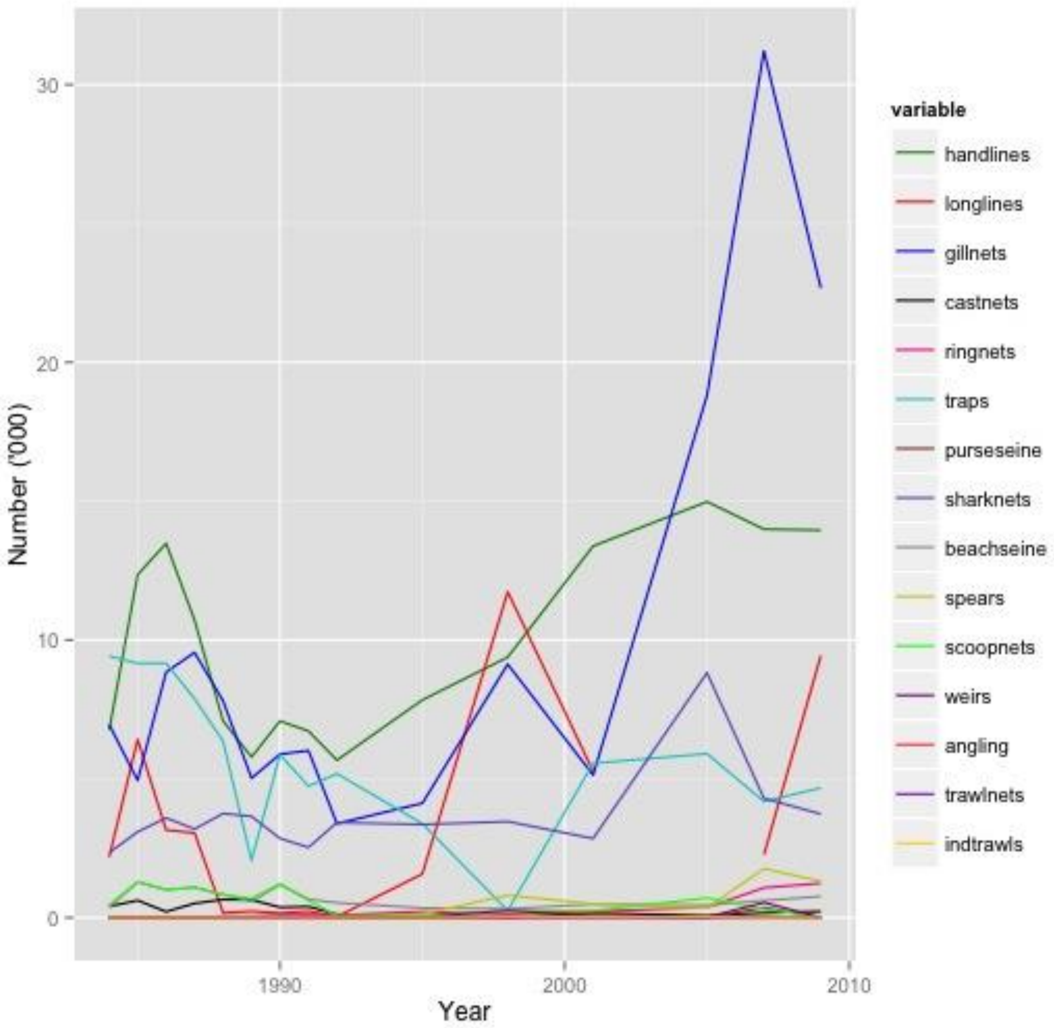

Figure 7: Plot showing the trend in the fishing gears from 1984 to 2011 in the artisanal fishery, Tanzania Mainland.

Figure 9 shows that the Coast region accounted for most of the fishing gears. Handlines were more dominant in Dar es Salaam. Gillnets and longlines were more dominant in the Coast region. It should be noted that data for longlines in 2005 were not included as they were recorded in a different unit. Other fishing gears such as traps, castnets, ringnets, sharknets, beachseines, purseseines and spears were also used in all regions

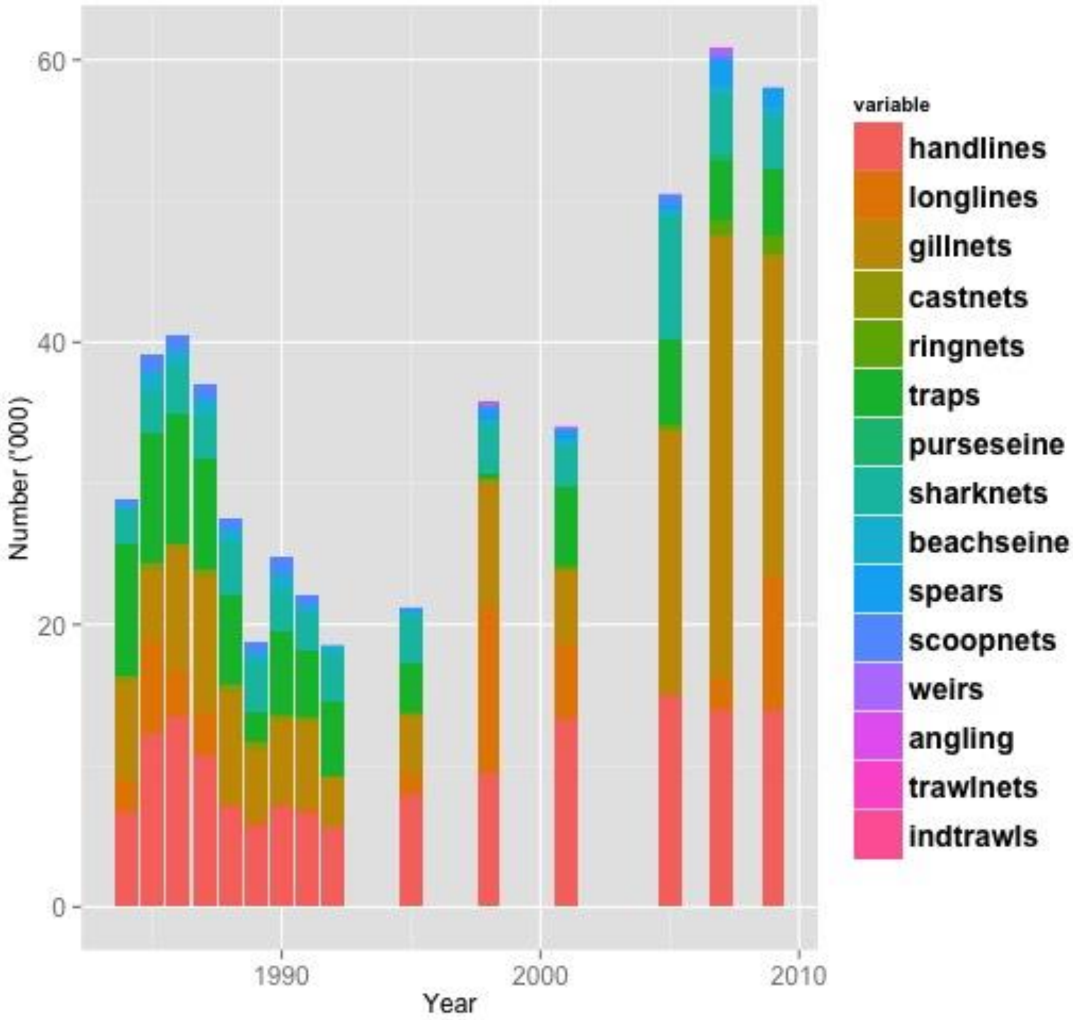

Figure 8: Trend in the fishing gear composition from 1984 to 2011 in the artisanal fishery, Tanzania Mainland

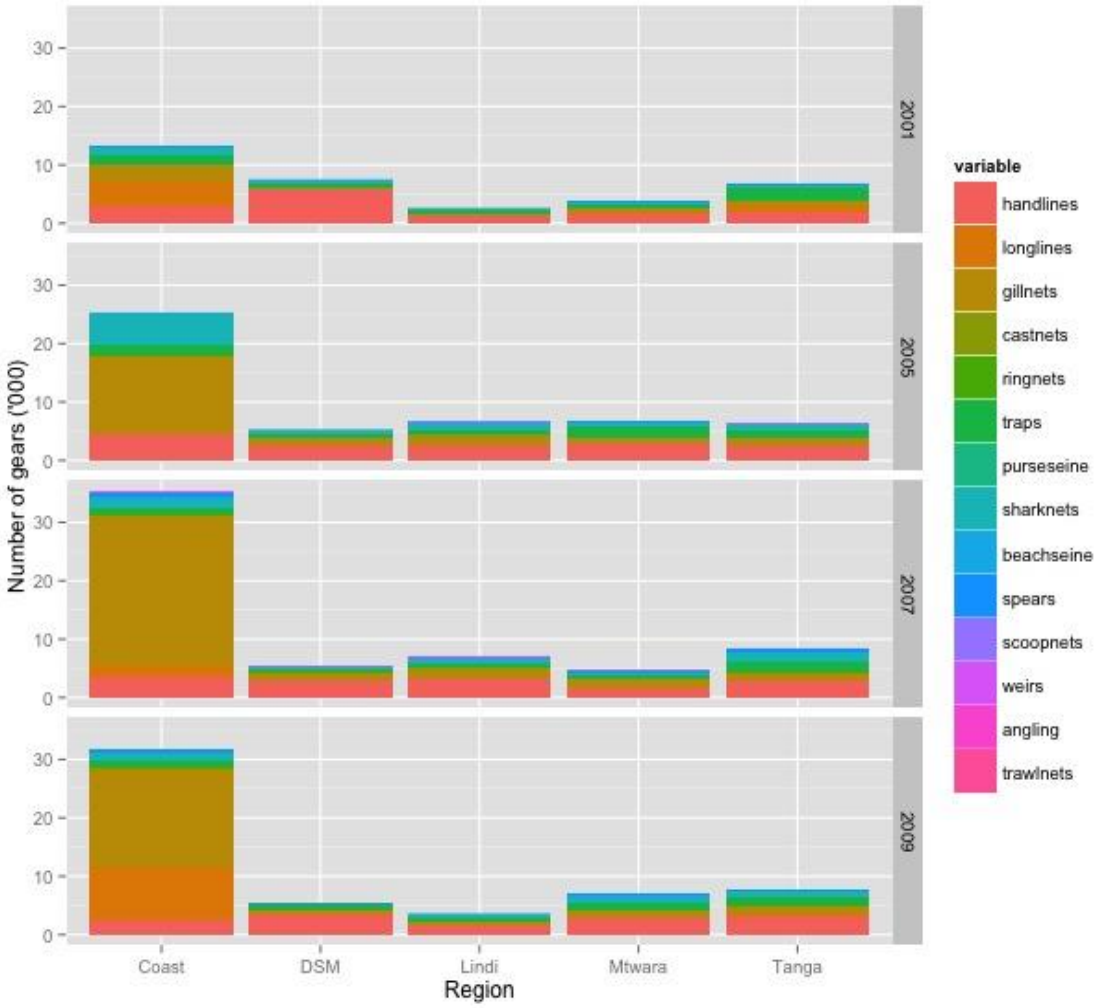

Figure 9: Gear composition across the 5 studied regions from frame-surveys conducted in 2001, 2005, 2007 and 2009.

4.3 Relationships among variables

A scatterplot of log (catch) against the independent (predictor) variables used in the model; year, fishers, vessels, gears, catch value, average income, and temperature, with loess fit are shown in Figure 10. Some form of linear relationship is observed between catch and fishers, vessels, gears, value and average income.

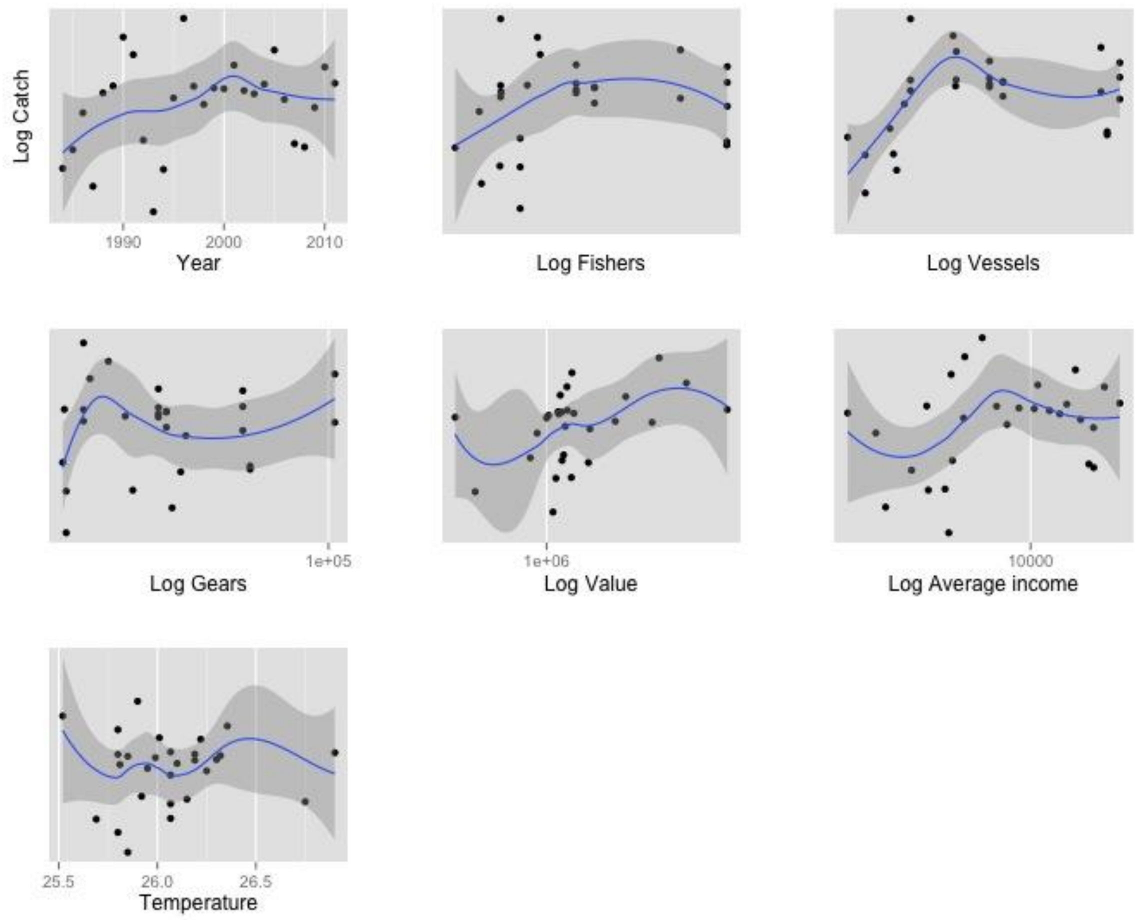

Figure 10: Relationships between log (catch) and year, log (fishers), log (vessels), log (gears), log (catch value) adjusted for inflation, log (average income) adjusted for inflation, and temperature.

The full model identified can be represented as:
log (catch) = constant + log(fishers) + log(vessels) + log(gears) + log(value) + log(average income) + temperature + year
A stepwise default routine in R identified the following model, which yielded the lowest AIC:
log(catch) = constant + log(fishers) + log(vessels) + log(gears) + log(coravincome) + log(corvalue)
A summary of the model showed that average income was not significant therefore this was removed from the model. The final model identified had four predictor variables, fishers, gears, vessels, and value, with an R^2 of 0.7833. The model output is shown below.

```
lm(formula = log(catch) ~ log(fishers) + log(vessels) + log(gears) +
log(corvalue), data = subdat)
      Residuals:
Min       1Q   Median       3Q      Max
-0.10077 -0.03550  0.01324  0.02977  0.09767
      Coefficients:
      Estimate   Std. Error t value  Pr(>|t|)
(Intercept)     7.25506    0.52589    13.796    1.30e-12 ***
log(fishers)  -0.79643    0.11364    -7.008    3.84e-07 ***
log(vessels)   1.22037    0.15360    7.945     4.83e-08 ***
log(gears)    -0.15743    0.03847    -4.092    0.000448 ***
```

```
log(corvalue)  0.19200    0.03953    4.857    6.65e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
      Residual standard error: 0.05752 on 23 degrees of freedom
Multiple R-squared: 0.7833,   Adjusted R-squared: 0.7456
F-statistic: 20.79 on 4 and 23 DF, p-value: 2.303e-07
```

It can be seen that vessels and value have a positive effect on catch whereas fishers and gears have a negative effect.

A scatterplot of log (average income) against the identified predictor variables is shown in Figure 11 with loess fit. The full multiple regression model tested was:

log(average income) = constant + log(fishers) + log(vessels) + log(gears) + log(catch) + log(value) + year

The stepwise function in R identified the following model with two predictor variables; catch value (p = 0.076), and year (p = 2.37e-13) as the significant variables, which explain most of the variability in average income. The model yielded an R^2 of 0.9223.

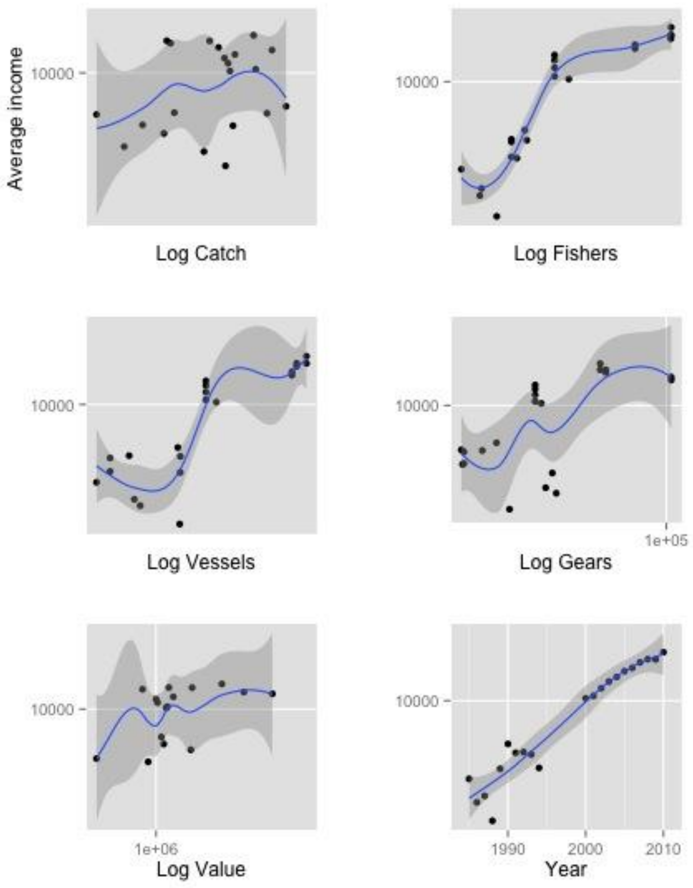

Figure 11: Relationship between log (average income) adjusted for inflation and log (catch), log(fishers), log(vessels), log(gears), log(value) adjusted for inflation, and year.

4.4 Analysis of Variance

A boxplot of total estimated landed catch for 2007 – 2011 are shown in Figure 12. An ANOVA showed significant difference across years in landed catch (df = 3, F=4.8509, p=0.00241). Pairwise comparisons show that the difference in catch was evident in the years

2007 - 2009 and 2010 – 2011 (Figure 1, Appendix I). No significant difference was seen in the different months of the year (df = 11, F = 1.1773, p = 0.2993). The estimated landed catch was significantly different across the regions (df = 4, F = 8.021, p = 2.6E-06). Dar es Salaam recorded the highest catch followed by Tanga and Coastal regions (Figure 12). The difference lay between Lindi and Tanga, Mtwara and Dar es Salaam mostly (Figure 2, Appendix I). The catch was also significantly different (df = 12, F = 13.172, p = 2.2E-06) across the districts within the five regions. Ilala district recorded the highest landings while the lowest catch was observed in Mtwara Mikindani (Figure 12).

Catch value was significantly different (df = 3, F = 8.7289, p = 1.114E-06) in the different years. Differences were observed between the recent years (2011 & 2010) and past years (2009 & 2007). The Mtwara region was different from the rest in terms of observed catch values (df=4, F= 3.2792, p=0.01126).

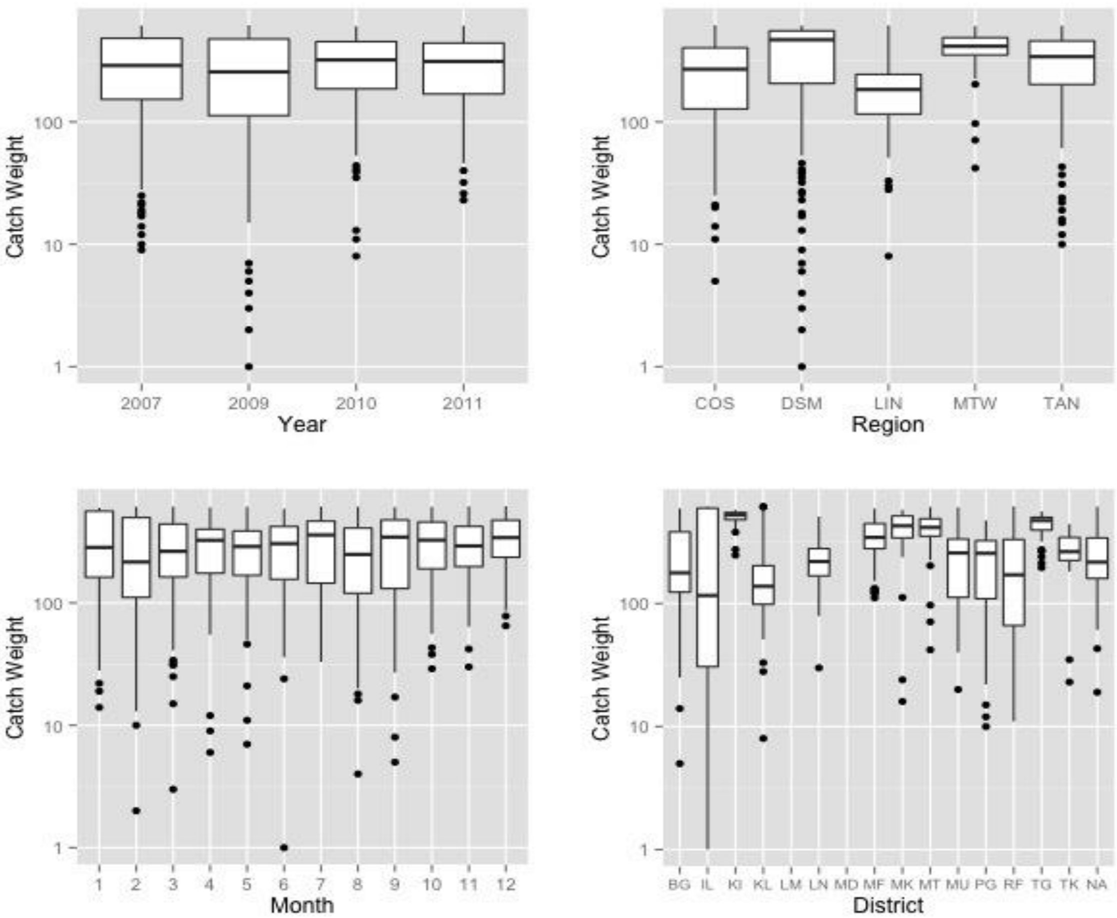

Figure 12: Box plots showing the median with lower and upper quartiles for log catch across years, regions, months and districts for CAS data that were collected in 2007 – 2011.

Number of fishers was significantly different across years (df=3, F=4.854, p=0.01376) with the difference lying between years 2001 & 2009. A tukey test showed that year 2001 was significantly different from 2007 and 2001 (Figure 3. Appendix I) but they were not significantly different across regions (df = 4, F = 2.1716, p = 0.1219). Numbers of vessels did not change significantly over the years (df = 3, F = 0.7077, p = 0.5614). Their numbers were however significantly different across regions (df = 4, F = 8.0635, p = 0.00112). Coast region accounted for the difference recording significantly more vessels (Figure 13 & Figure 5, Appendix I).

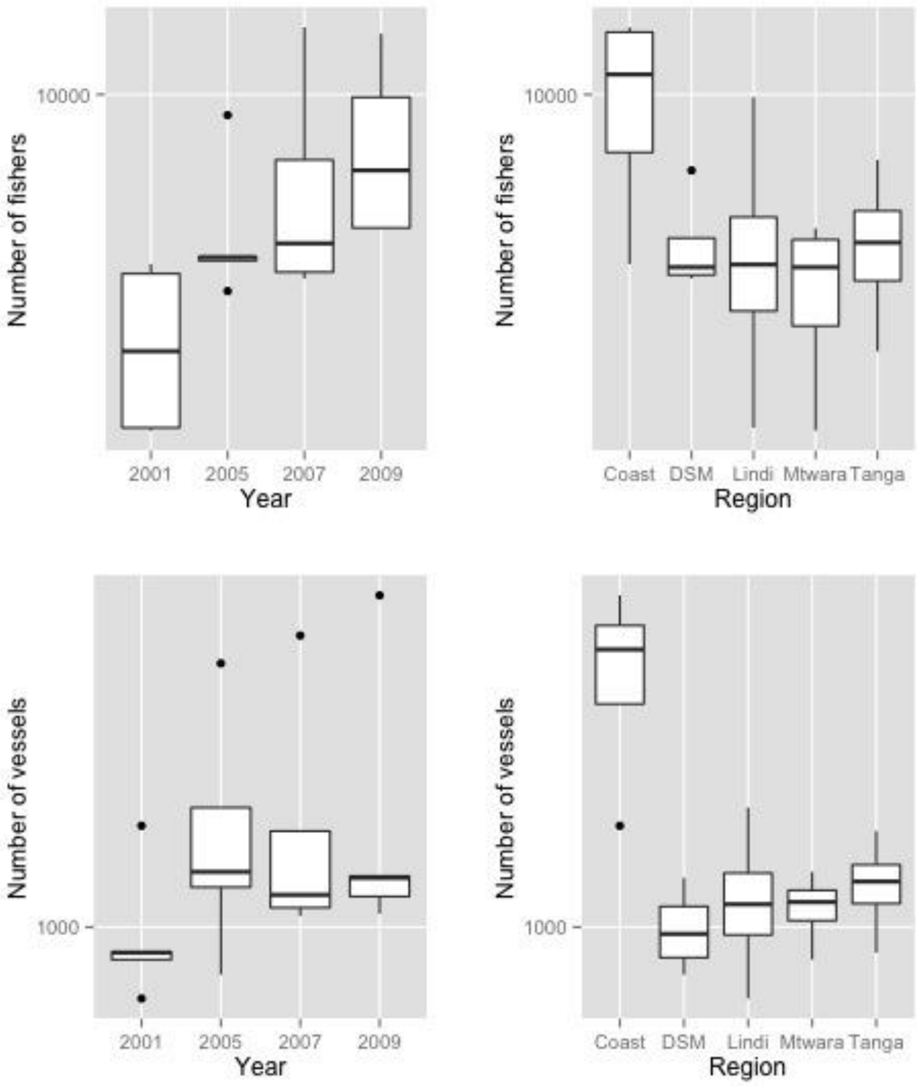

Figure 13: Box plots showing the median with lower and upper quartiles for log (fishers) and log (vessels) across years and regions.

Regions were significantly different in the number of gears observed (df = 4, F=8.0634, p=0.00112) (Figure 14). A pairwise comparison shows that the number of gears was significantly different in Coast region than others (Figure 5, Appendix I).

Average income did not change significantly over the years (df = 3, F = 3.2114, p = 0.0512). On the other hand, it was significantly different across regions (df = 4, F = 5.1042, p =

0.008469) and with Dar es Salaam being significantly different from other regions (Figure 6, Appendix V).

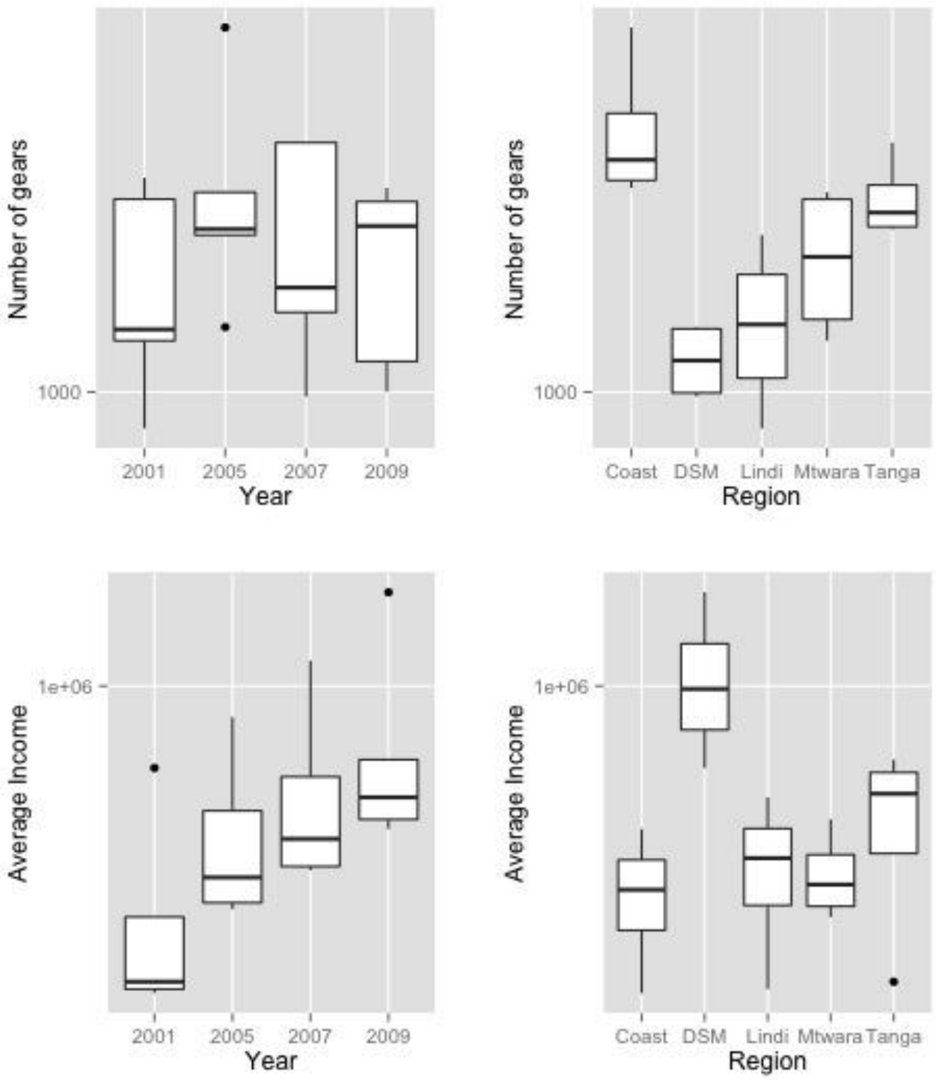

Figure 14: Box plots showing mean values in relationship with gears and average income with years, regions.

4.5 Cluster Analysis

In a hierarchical classification the data are not partitioned into classes in one step. They are separated into a few broad classes each of which is further sub-divided into smaller classes, and each of these further partitioned and so on until terminal classes are generated which are not further sub-divided (Everett, 1980). Similarity between the clusters diminishes moving from lower levels to upper levels.

The inshore fisheries comprised of the following main species groups (Acanthuridae (Aca) Aridae (Ari), Caesionidae (Cae), Carangidae (Car), Clariidae (Cla), Chanidae (Cha), Chirocentridae(Chi), Clupeidae (Clu), Gerridae (Ger), Haemulidae (Hae), Emiramphidae (Emi), Istiophoridae (Ist), Labridae (Lab), Lethrinidae (Let), Loliginidae (Lol), Mugilidae (Mug), Mullidae (Mul), Nemipteridae (Nem), Octopodidae (Oct), Palinuridae (Pal) Penaeidae

(Pen), Rachycentridae (Rac), Rays, Scombridae(J), Scombridae(N), Scombridae (v), Serranidae (Ser), Sharks (Sha), Siganidae (Sig), and Sphyraenidae (Sph).
Cluster analysis was used to find which regions were similar according to the species composition of landed catch. Two clusters were observed at a dissimilarity level of 0.5. The first cluster comprises Coast, Tanga, Lindi & DSM and clustered with a probability of 94. Within this cluster Coast and Tanga regions were the most similar. Mtwara formed cluster 2. The Mtwara region had fewer species than other regions (Figure 15 & 16)

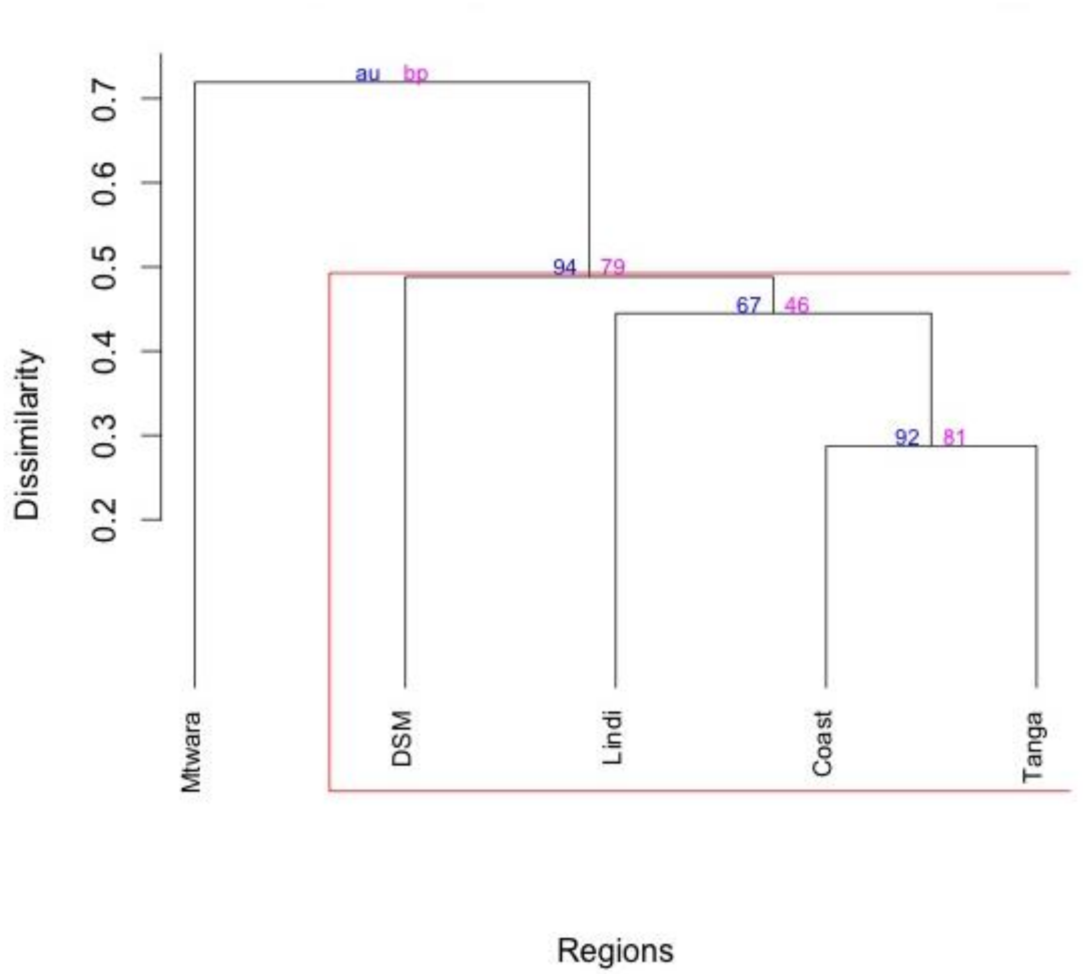

Figure 15: A dendrogram showing clusters of regions that are similar in species composition in catch landings.

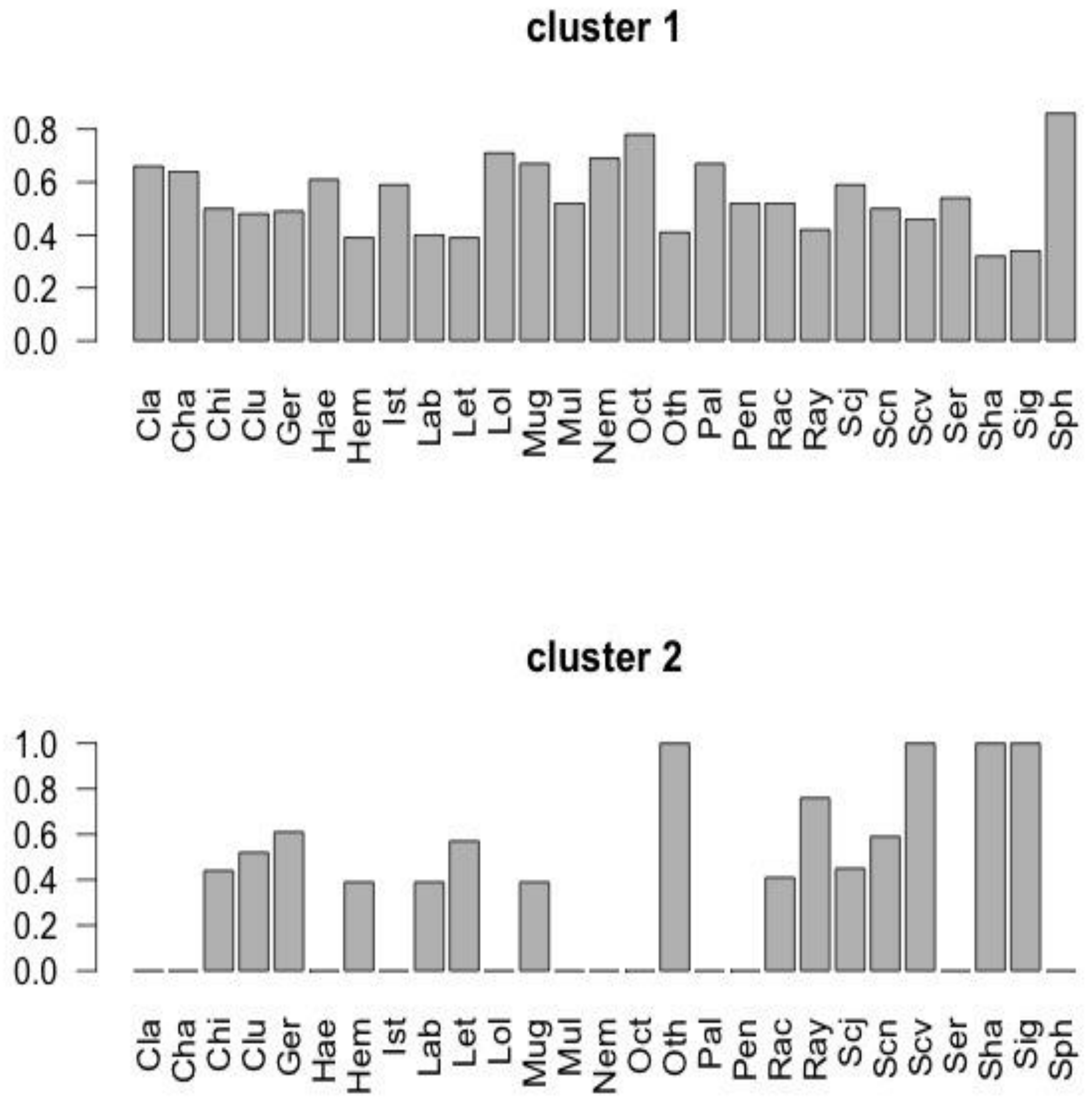

Figure 16: Species comprising the two identified clusters in Figure 15.

5 DISCUSSION

In this study, visual illustrations and descriptive statistics were used to study the patterns in the marine artisanal fishery data from Tanzania mainland. Data on catch and effort series for the period 1984 – 2011 showed that the catches from the coastal region of Tanzania mainland have slightly increased over the time period but have generally remained stable. On the other hand, the effort applied in the fishery i.e the number of fishers, vessels and gears has been increasing in this time period. This has led to a decline in CPUE (catch/gear) from 1995 onwards. Prior to this an increase in CPUE was observed which could be attributed to fewer fishers, vessels and gears operating in the fishery. CPUE is a good indicator for stock abundance and this indicates that the marine artisanal fishery in Tanzania mainland is likely to have reached its exploitable potential and any further increase in effort will not lead to an increase in catch. In the early years i.e. 1984 – 1994 an increase in catch was observed with increasing effort however the fishery was not able to sustain the added fishing pressure in the years that followed. Further, other contributing factors that could be limiting the catch are poor fishing technology, the use of non-motorized small fishing vessels and gears that restrict the fishermen from going far (offshore). This in turn has restricted them for years in the inshore waters, which are believed to be overexploited with high fishing pressures (Jiddawi and Ohman, 2002). It is also important to note that the population over this time has increased considerably, which could have led to the increase in fishing pressures, since Tanzania mainland is a coastal community which relies largely on fisheries for livelihood.

While Tanzania coastal resources provide a wide range of services to support economic development, poverty is still one of the main issues faced by many of coastal communities. Challenges ranging from increasing population, widespread poverty, poorly planned economic development, under-resourced local government institutions and weak implementation of existing policies have made it difficult to manage and improve marine and coastal resources and the quality of life of communities along the coast (Harrison, 2010). Invariably, lack of income generating opportunities has been one of the main causes of over-exploitation of coastal resources. Majority of the people in the coastal area live below the poverty line (Mkenda *et al.*, 2004). These people are therefore unable to afford bigger and motorized vessels that will enable them to explore newer fishing grounds further away from the shore. Lack of capital also leads to lack of formal education and skills thus, the link between decline of fish resources and the degradation of fishing habitats due to use of destructive fishing methods is not easily comprehended.

Competition among the fishermen in the near shore waters, and decreasing CPUE has led to fishermen resorting to fishing methods such as beach seining, small meshed gillnets and other unsustainable methods like dynamite. These methods usually catch smaller and juvenile fish, which makes the fishery unsustainable (Berachi, 2003).

The slight increase in total estimated catch in 2010 to 2011 can be attributed to the efforts that have been made by the government in collaboration with WWF through the Rufiji, Mafia and Kilwa (RUMAKI) program, the Marine Parks and Reserve Units (MPRU), and the Marine and Coastal Environmental Management Project (MACEMP). The efforts range from provision of funds, capital for procurement of fishing vessels, engines, gears and other accessories to the fishermen groups by WWF-RUMAKI and MACEMP. MPRU has the gear exchange program whereby is offering the fishermen legal gears on subject to assertion of the illegal fishing gears. Today, there is a wider range of vessels that enable fishers to go offshore fishing. Many of the traditional dhows and boats are motorized and are used for catching pelagic species. The use of boats has significantly improved catching ability, safety and working conditions for fishermen in the last two years.

The catch value has increased considerably overtime. In last five years the value increased more than two fold. This increase could be attributed to an increase in the price of fuel. Fishermen have to invest more in obtaining the catch, especially where motorized boats are used to explore good fishing grounds. Transportation of fish from the landing sites to the markets, that are usually quite far away, also increases operational costs (NORAD, 2009). The increase in the price of electricity has increased the price for ice and storage facilities (cold rooms). Thus, the value of the catch is most likely increased to compensate for the increased costs. Additionally, the lack of supply due to increasing population and declining CPUE potentially increases the demand and price for fish. In 2006 to 2008 there was an outbreak of rift valley fever in Tanzania and consumption of beef, which is a common source of protein in the country, was banned. The ban resulted in a high demand of fish and fishery products, which contributed to rise of the value fish. In the subsequent years the bird and swine flu also had the same effect, as the consumption of chicken and swine was also banned.

The number of artisanal fishers along the coast has increased considerably over the years and according to the 2009 fisheries frame survey results is estimated at 36,000, which is about 0.52% of the 6,920,690 coastal population (MLFD, 2010). Numbers of vessels have also been going up with a sharp increase witnessed after the year 2000, coinciding with trends in fish value. This has been caused by a number of factors such as commercialization of fishery resources. Fishery resources have been commoditized and become a preference for most people in the country. The presence of an guaranteed market attracts many coastal people to employ themselves in fishing (Richmond *et al*., 2002). The increase in number of vessels also contributed by an implementation of MACEMP, Tanzania Social Action Fund (TASAF) and RUMAKI programs in the coastal areas.

The linear regression analysis showed that most of the variation in average income was due to the differences seen over the years. The catch value of fish only marginally affects average income. This shows that there are other economic factors such as agriculture at play, which are contributing more towards the GDP than fisheries. Even though fisheries is one of the main activities of the coastal population, most of the catch is sold locally and used as staple food, which is probably not accounted for in the GDP It is important to improve the fisheries management and data collection system so that this sector is more representative in the GDP and per capita average income.

Other factors that contributed to rise in average income include improvement in road conditions, infrastructure, and the implementation of the Poverty Reduction Strategy Program (PRSP) through various interventions in the coastal areas. The increase in average income can also be related to the increasing fish demand, which contributed which generates more revenue at the central markets and the landing sites. Also augmentation through the World Bank projects, MACEMP, TASAF, and WWF- RUMAKI projects in the districts of Rufiji, Mafia and Kilwa, could be contributing factors. MACEMP Project has facilitated a total of 470 community sub-projects worth approximately 6.7 million Tshs. A total of 8078 people (4,900 men and 3,178 women) have directly benefited from the initiative in the entire 16 local government authorities of Tanzania Mainland. These projects cover 240 fishing community subprojects, and focus on alternatives of livelihoods to fishing, boat/vessel building and repair, fishing gear making, net mending, fish transport, fish sales, fish processing, food vending and beekeeping. This raises the ratio of population that can depend on other related livelihoods. TASAF have also funded various community subprojects in the coastal areas thus, contributing to an increase in average income. these initiatives, WWF-RUMAKI TASAF and MACEMP could potentially increase the contribution of the fisheries sector towards the GDP and average income of people. Approximately 92% of the Dar es Salaam region is urbanized as a result it has a higher average income compared to other regions. The urbanization also has a positive impact on average income. Average income will also positively influence the number of fishers, vessels and gears operating with higher purchasing

power.
The increase in number of gears could be due to the increase in number of fishers and the average per capita income. The types of gear and their uses vary within and between coastal communities. The fishers use nets of different mesh sizes and various gear types. Longlines and gillnets have shown a sharp increase over the years becoming two of the most dominant fishing gears in the fishery. In the earlier years, 1989 –1991, the increase in number of gears could have been because of an influx of fishermen and fishing vessels from neighboring Zanzibar and Mozambique. This was followed by an abrupt decline in gear numbers until 1995, but later these gears continuously increased in numbers. Since 1990 seine nets have been declining significantly due to the official ban of their use; while ring nets, although still small in number, have been increasingly becoming more important. It is important to note that even though the number of ring nets operating in the fishery is not that high, in comparison with gillnets and longlines, these gears are fairly large and land a lot of catch. Gears like ring nets and beach seines require a crew of about 15-40 people. For example, in Kenya a crew of 30 or above is common for the ring nets and beach seines and such a big crew is necessary (Fondo 2004). (Jiddawi and Ohman 2002) reported that crew size could range from 3 to 30 fishermen per vessel, depending on the type of fishery.
In analysis of temporal and spatial differences in catch and effort data, significant difference was seen across years in landed catch. No seasonality was observed in catches as no significant difference was seen between months. It could be because the weather does not change a lot between seasons because temperature and rainfall were quite stable in the time period studied. The estimated landed catch was significantly different across the regions. Dar es Salaam recorded the highest catch followed by Tanga and Coast region. The difference lay between Lindi and Tanga, Mtwara and Dar es Salaam mostly. The catch was also significantly different across the districts within the five regions. Ilala district recorded the highest landings while the lowest catch was observed in Mtwara and Mikindani. Catch value was significantly different in the different years. Mtwara region was different from the rest in terms of observed catch. There is a higher concentration of artisanal fishers in Coast, Dar es Salaam, and Tanga regions than Lindi and Mtwara regions, as also noted by Magimbi (1997). Even though the number of fishing gears operating in the coast region is highest, most of the catch from this region is landed in Dar es Salaam because of better markets and facilities. The well-improved road infrastructures in Tanga, Dar es Salaam and Coast regions also lead to more fishers operating in these regions.
Mtwara has fewer species than other regions. This region is furthest to the south. Coast and Tanga regions were most similar in species composition. This could be because fishermen target similar fishing grounds and use similar gear types.

6 CONCLUSIONS AND RECOMMENDATIONS

Data on catch and effort series for the period 1984 – 2011 showed that catches from the coastal region of Tanzania mainland have been constant while the fishing effort applied in the fishery i.e the number of fishers, vessels and gears has been increasing. This has led to a decline in CPUE. The stated situations have been caused by a number of factors including population growth, poor fishing technology, the use of non-motorized small fishing vessels and gears that restrict the fishermen from going far (offshore).

Beach seines and spears, which were declared illegal, have been increasing overtime. Ring nets dominated the fishery in terms of catch landed per gear, and have been becoming more important to fishermen. Even though it was proposed for ring nets to be declared illegal, this was not implemented and fishermen continue to use this gear. However in Kenya and Zanzibar had declared it illegal.

The relationship between the catch and other variables ; year, fishers, vessels, gears, catch value was significant. The catch value of fish only marginally affects average income. This shows that there are other economic factors such as agriculture at play, which are contributing more towards the GDP than fisheries.

Dar es Salaam recorded the highest catch followed by Tanga and Coast region. Ilala district recorded the highest landings while the lowest catch was observed in Mtwara and Mikindani. Most of the catch from this region is landed in Dar es Salaam because of better markets and facilities.

The number of vessels and gears were significantly high in Coast region than others. Average income was high in Dar es , which was significantly different from other regions because of the urbanization of the city and most of the economic activities are concentrated within the city.

The region grouped into two clusters according to the similarity in their species composition. The first cluster comprised Coast, Tanga, Lindi & DSM. Within this cluster Coast and Tanga regions were the most similar. Mtwara formed cluster two and had fewer species than other regions.

It is recommended that data collection, entry and analysis should be standardized. There were some inconsistencies in counting and recording the number of long lines. They were counted as number of hooks instead of lines in 2005. CAS database provides for the option for the frame survey, catch assessment survey and biological data (length frequencies). However, fisheries data programmes lack biological data collection. The manner in which data are summarized and compiled for the annual reports was not consistent across the years. Information that is normally found in most reports was sometimes missing. For instance, the catch data were not always complied down to month and region level. In earlier years of survey, species were grouped differently than recent years. Therefore, previous data could not be used in the cluster analysis. Fishing effort data were not articulated at the district level making comparisons of the trends across the districts limited. The catch assessment survey reports were lacking the information on the catch per unit effort (by gears, fishers, boats and time) making it difficult to know the gear efficiencies.

For the responsible fisheries management, evaluation of fishing capacity and analysis of fisheries data must be known and monitored through collection of fisheries input (fishing effort) and output (fish catch). With accurate and reliable data it will be easier to know how much should be taken out from the stock by using reasonable effort. In view of this the government should allocate enough resources for fisheries data collection and improve the monitoring programme for frame-survey and catch assessment survey. Emphasis also needs to be put on collecting biological data such as length-frequency of fish.

Apart from what have been done by MACEMP, TASAF, and WWF- RUMAKI in the coastal areas, more effort should be deployed to make sure that fishermen go offshore fishing. This can be achieved by either giving fishermen access to capital or setting up subsidy programmes to acquire modern fishing gears and motorized boats, which could target new fishing grounds. This will go hand in hand with the promotion of alternative income generating activities, and reduce pressure on the current fishing grounds.

The Fisheries Development Division should maintain and make available the raw data from the sampled fish landing sites. This raw data can be used to potentially improve and optimize survey designs. To reduce data inconsistency fishing gears like gill nets, ringnets, long lines and beach seine definitions should be reviewed and harmonized on counting and recording them. The compiled reports should include all the information that is necessary for fisheries management at all levels.

There should be management plans for ringnet fishery, as its control and monitoring is very difficult. The management plan could focus on defining appropriate mesh size, type of boats and areas that ring net users could be allowed to fish in. The government and communities, through BMUs, could cooperate in the implementation of the formulated management plan.

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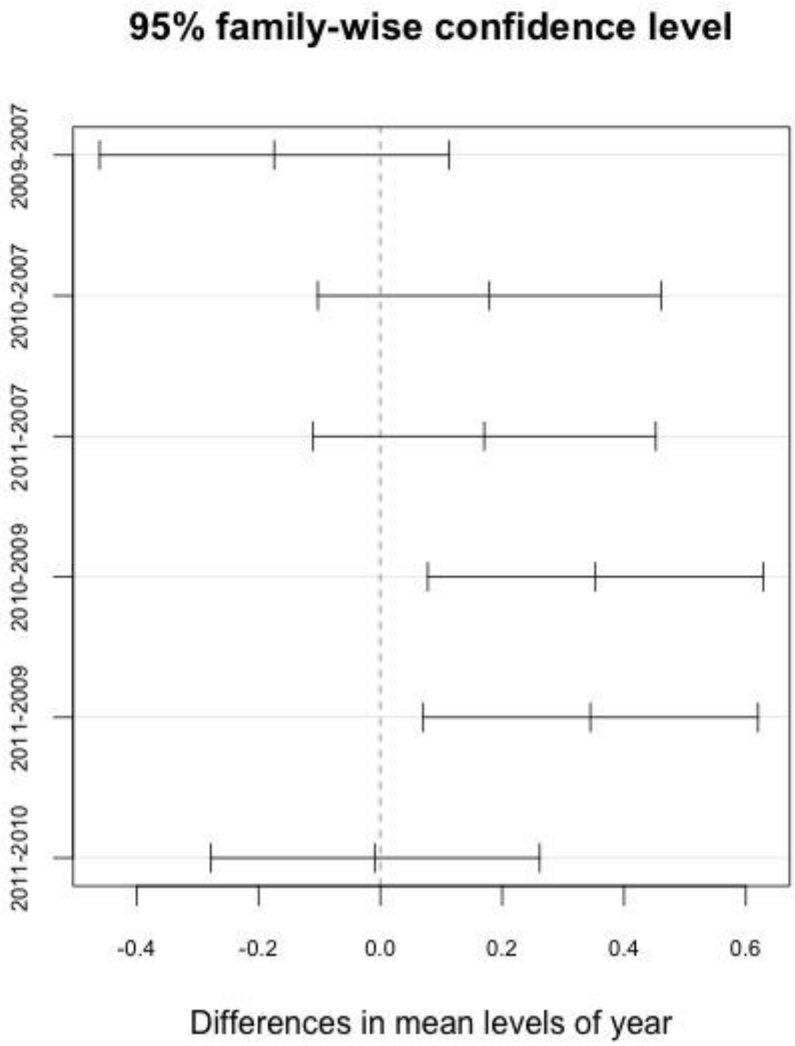
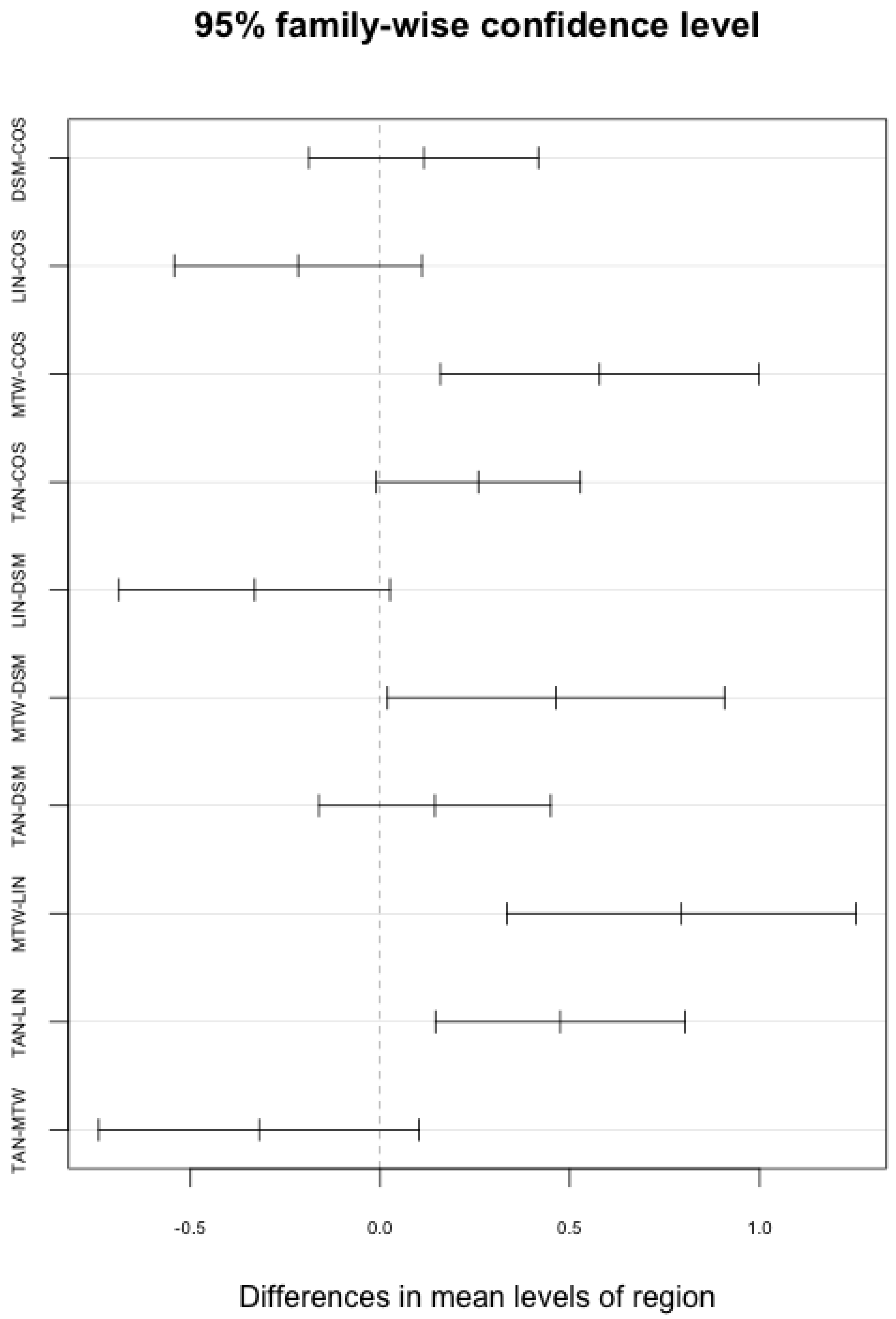
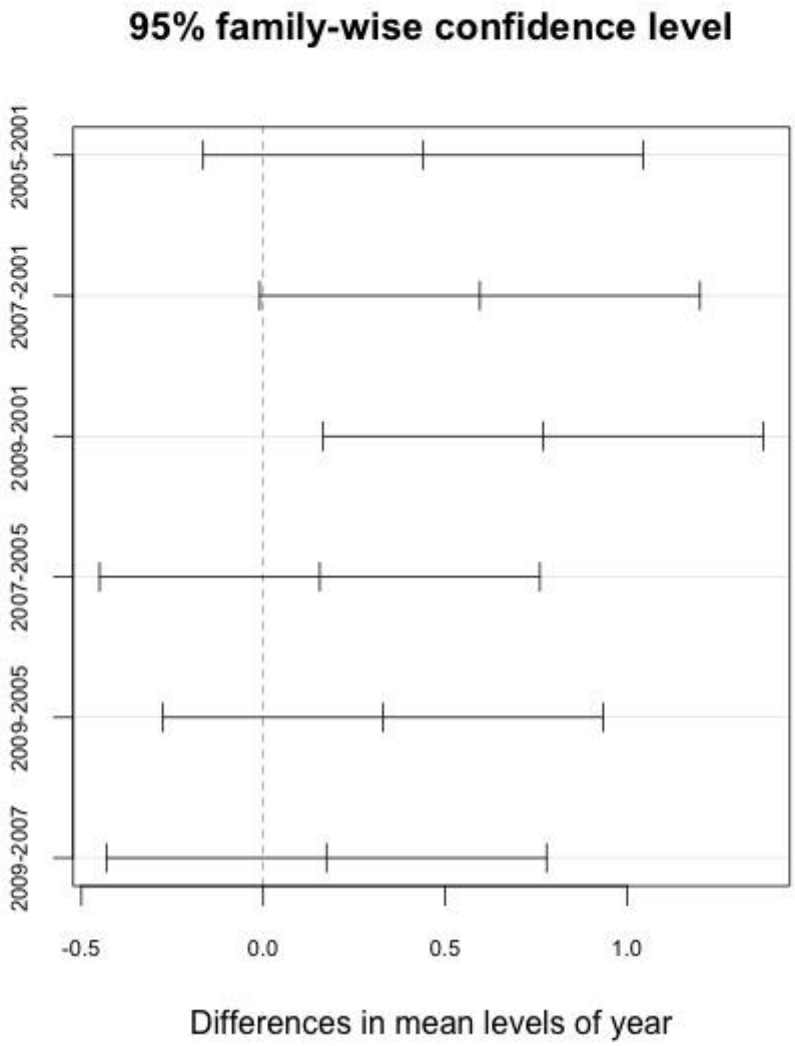
Appendix 1: Tukey pair wise comparisons showing the differences in estimated catch landings across the years at 95% confidence level



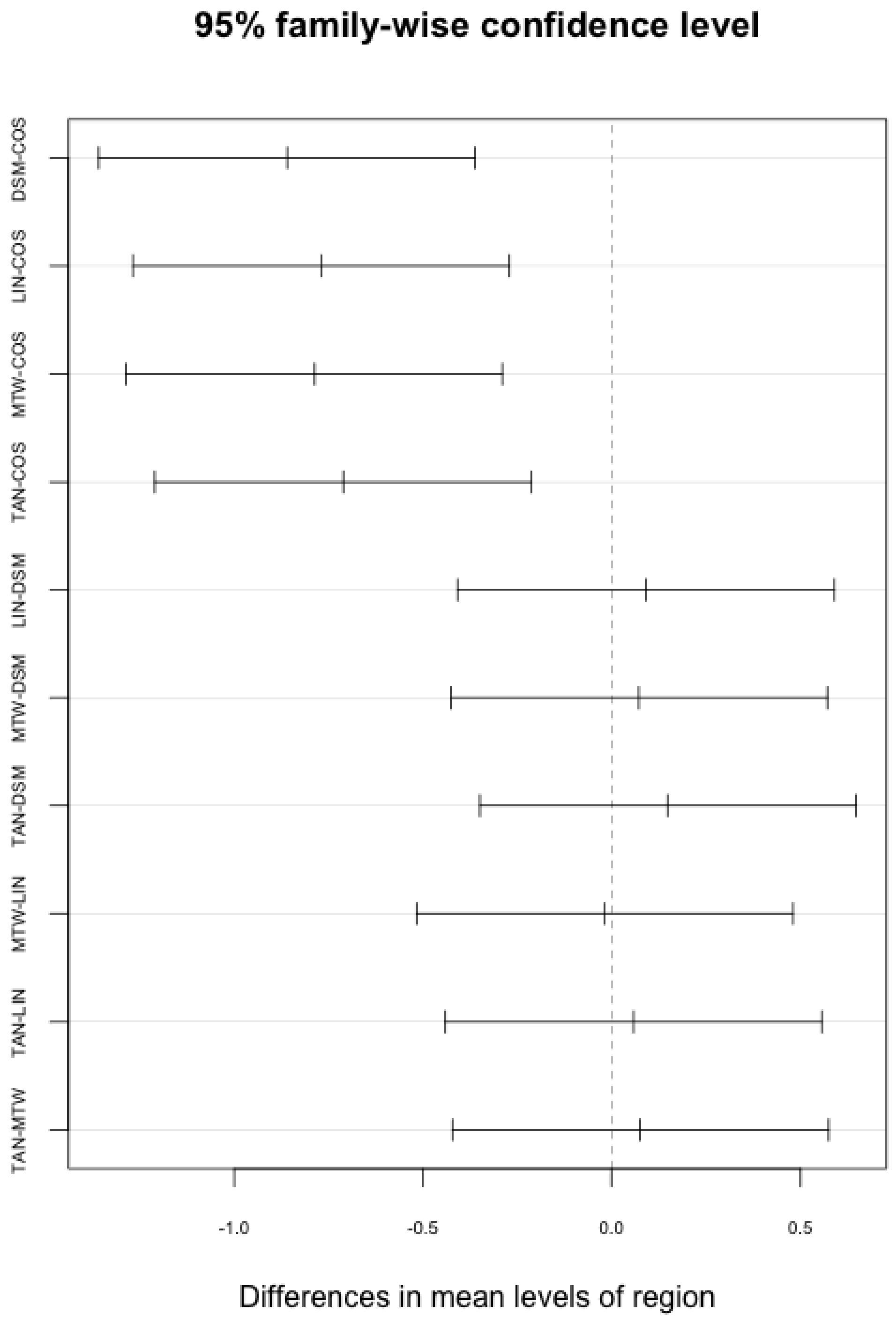
Appendix 2: Tukey pair wise comparisons showing the differences in catch landings across regions at 95% confidence level.



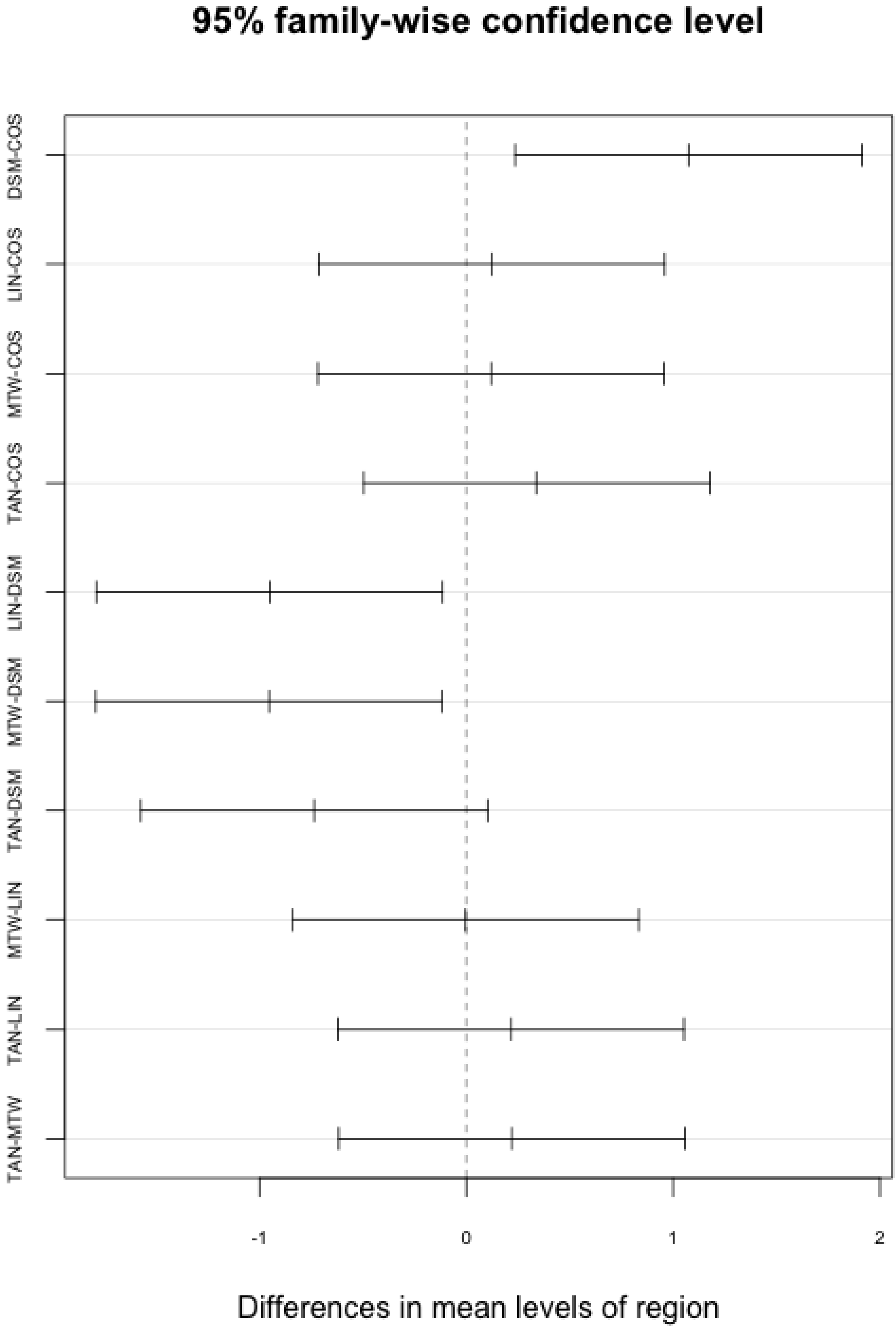
Appendix 3: Tukey pair wise comparisons showing the differences in fishers across the years at 95% confidence level.



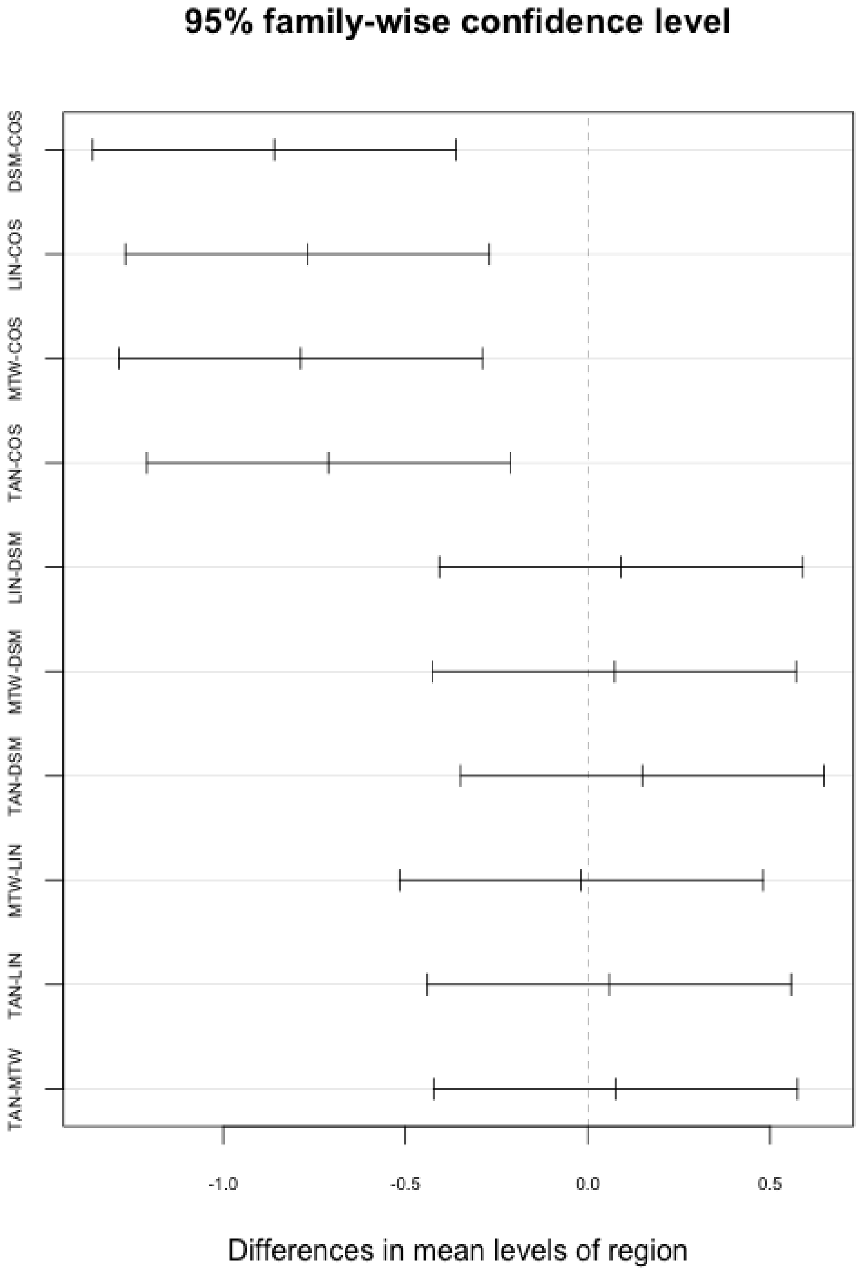
Appendix 4: Pair wise comparison showing the differences in vessels across the regions at 95% confidence level.



Appendix 5: Tukey pair wise comparisons showing the differences in gears across the regions at 95% confidence level.



Appendix 6: Tukey pair wise comparison showing the differences in average income across the regions at 95% confidence level.



Appendix 7:.A table showing the catch and Effort data from 1984-2011

Table 3: Catch and Effort data from 1984-2011

year	fishers	vessels	tcatch	value	avincome	gears
1984	13783	3556	40890	1149553	NA	28895
1985	11392	3045	42847.3	1676269	6517.2	39162
1986	12619	3690	46984.7	1672742	7024.8	40460
1987	12739	3595	39094.7	1561307	9854	37080
1988	13855	4390	49382	NA	16930.4	27549
1989	15491	4399	50242	NA	22431.4	18725
1990	16178	4354	56779.4	NA	34474.6	24750
1991	16361	4402	54342.7	NA	40702.8	22021
1992	15027	3514	43886.2	NA	49982.6	18527
1993	13822	3232	36684.8	10206810	60487.4	18937
1994	13822	3232	40785.4	14227862	73442.2	18937
1995	13822	3768	48761.71	24662431	NA	21137
1996	13822	3768	59508.12	38052517	NA	21137
1997	13822	3768	50210	25350000	NA	21137
1998	20625	5157	48000	29273500	NA	35760
1999	20625	5157	50000	33500000	NA	35760
2000	20625	5157	49900	32180000	306851.8	35760
2001	19071	4927	52934.9	34113718	329559.2	33996
2002	19071	4927	49674.5	33372136	369584.8	33996
2003	19071	4927	49270	34489000	410104.6	33996
2004	19071	4927	50470	40376000	445425.2	33996
2005	29754	7190	54968.6	82452900	489493.6	104058
2006	29754	7190	48590.5	72885750	541299	104058
2007	36247	7342	43498.5	39239352	608609.4	60817
2008	36247	7342	43130.18	51756216	690830.8	60817
2009	36321	7664	47615.8	67930600	773447.6	58061
2010	36321	7664	52683	89639934	890029.6	58061
2011	36321	7664	50592.41	1.67E+08	NA	58061

Appendix 8: A table showing the species composition data from 1984-2011

Table 4: Gear composition data from 1984-2011

year	handlines	longlines	gillnets	castnets	ringnets	traps	purseseine	sharknets	beachseine	spears	scoopnets	weirs	angling	trawlnets	indtrawls
1984	6757	2182	6955	408	0	9418	0	2342	371	0	462	0	0	0	0
1985	12351	6418	4943	622	0	9159	0	3093	1288	0	1288	0	0	0	0
1986	13478	3159	8842	216	0	9159	0	3590	1003	0	1013	0	0	0	0
1987	10708	3052	9549	516	0	7888	0	3193	1087	0	1087	0	0	0	0
1988	7088	176	7810	653	56	6351	0	3751	832	0	832	0	0	0	0
1989	5786	233	5022	645	56	2056	0	3649	588	0	690	0	0	0	0
1990	7083	167	5887	374	96	5873	0	2856	1189	0	1225	0	0	0	0
1991	6721	234	6018	398	104	4736	0	2530	665	0	615	0	0	0	0
1992	5672	34	3388	124	92	5183	0	3427	537	0	70	0	0	0	0
1993	5672	34	3388	124	92	5593	0	3427	537	0	70	0	0	0	0
1994	5672	34	3388	124	92	5593	0	3427	537	0	70	0	0	0	0
1995	7839	1575	4120	49	221	3390	0	3357	350	134	75	25	0	2	0
1996	7839	1575	4120	49	221	3390	0	3357	350	134	75	25	0	2	0
1997	7839	1575	4120	49	221	3390	0	3357	350	134	75	25	0	2	0
1998	9383	11734	9125	0	128	254	15	3463	319	805	256	254	0	7	17
1999	9383	11734	9125	0	128	254	15	3463	319	805	256	254	0	7	17
2000	9383	11734	9125	0	128	254	15	3463	319	805	256	254	0	7	17
2001	13382	5272	5136	173	224	5557	68	2852	485	496	252	72	0	7	20
2002	13382	5272	5136	173	224	5557	68	2852	485	496	252	72	0	7	20
2003	13382	5272	5136	173	224	5557	68	2852	485	496	252	72	0	7	20
2004	13382	5272	5136	173	224	5557	68	2852	485	496	252	72	0	7	20
2005	14980	53549	18802	73	370	5907	0	8820	453	350	710	14	0	10	20
2006	14980	53549	18802	73	370	5907	0	8820	453	350	710	14	0	10	20
2007	13990	2267	31210	169	1076	4185	363	4299	615	1764	306	544	20	9	0
2008	13990	2267	31210	169	1076	4185	363	4299	615	1764	306	544	20	9	0

2009	13955	9437	22666	229	1241	4674	0	3733	768	1315	40	0	0	3	0
2010	13955	9437	22666	229	1241	4674	0	3733	768	1315	40	0	0	3	0
2011	13955	9437	22666	229	1241	4674	0	3733	768	1315	40	0	0	3	0