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POPULATION DYNAMICS AND STANDING BIOMASS OF INDIAN WHITE PRAWN (*PENAEUS INDICUS*) AND BROWN SHRIMP (*METAPENAEUS MONOCEROS*) ALONG THE COAST OF TANZANIA

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ABSTRACT

The Indian white prawn *Penaeus indicus* and Brown shrimp *Metapenaeus monoceros* were the most abundant and economically important species in Tanzanian coast. In this report, the population dynamics of *P. indicus* and *M. monoceros* were investigated and the standing biomass of these species and all combined prawn species were estimated. The catches of penaeid prawn from industrial and artisanal fishery where compared. The analysis based on the available data from scientific surveys on catch, effort and biometric obtained from 2009, 2011 and 2015 and fisheries based data from Fisheries Department from 1983 to 2007 for industrial fishery and 1988 to 2013 for artisanal fishery. The abundance distribution of these species differ in season, and fishing zone. The catch per unit effort (CPUE) and biomass indices also differ by fishing zone and season. The *P. indicus* were more abundant in Zone I while *M. monoceros* were more abundant in Zone II. The high biomass indices were higher in May and June coincided with rains season which brings high nutrient contents, high productivity and enhanced recruitment. There was increase of artisanal catch which correlate with the close of the industrial fishery as this trend showed before the industrial fishery started. This paper recommend more studies including Catch Assessment Survey (CAS) are needed in order to established and formulate the sustainable management measures of prawn fishery.

Keywords: Penaeid prawns, Size structure, Abundance, CPUE, Biomass, Tanzania

This paper should be cited as:
Motola, H. D. 2016. *Population dynamics and standing biomass of Indian White prawn (Penaeus indicus) and Brown shrimp (Metapenaeus monoceros) along the coast of Tanzania*. United Nations University Fisheries Training Programme, Iceland [final project]. http://www.unuftp.is/static/fellows/document/hak15prf.pdf

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ABREVIATIONS

CAS	Catch Assessment Survey
CPUE	Catch per unit effort
GDP	Gross domestic product
HP	Horse power
MFV	Marine Fishing Vessel
MLFD	Ministry of Livestock Development and Fisheries
MRI	Marine Research Institute
MSY	Maximum sustainable yield
SWIOFP	South West Indian Ocean Fisheries Project
TAFIRI	Tanzania Fisheries Research Institute

1 INTRODUCTION

The Tanzanian coast stretching from latitude 4°49'S at the border with Kenya to latitude 10°28'S to the border with Mozambique make a coastline of over 800 km. The continental shelf is narrow with the 200 km contour depth about 4 km offshore, except at the Zanzibar and Mafia Channels where the shelf extends for up to 80 km (Francis & Bryceson, 2001). The large islands include Zanzibar (two islands of Unguja and Pemba) and Mafia, and there are also many smaller islands, islets and reefs along the coast (Figure 1). The area of the shelf to the 200 m depth contour for both mainland Tanzania and Zanzibar combined is about 30,000km^2 (Francis & Bryceson, 2001).

The coastline has eight main permanent rivers; Rufiji, Pangani, Ruvu, Wami, Mbwemkuru, Matandu, Lukuledi and Ruvuma with peak outflow in March-May. Their outflows are restricted along the shore due to ocean currents and wind patterns that deflect water masses parallel to the shore. These rivers provide favourable environment for prawn post larvae and juveniles by reducing salinity in estuaries (Teikwa & Mgaya, 2004).

The influence of the fresh water outflow from rivers is restricted to inshore waters, most probably due to the prevailing wind and current conditions. Coastal waters are generally warm with surface temperatures ranging between 25°C in August/September and 30°C in March. The depth of the upper mixed layer reflects seasonal variations of wind speed and direction, varying from approximately 20 m below the surface in March to November, to 100 m depth in June and July.

1.1 Statement of the problem

There are six dominant prawn species that are reported to occur in the Tanzanian coastal waters (Bwathondi, et al., 2002); *Penaeus indicus, P. monodon, P. semisulcatus, P. latisulcatus, P. japonicus and Metepenaeus monoceros,* all with significant economic value. Tanzania's prawn fishery industry is the most important of the marine fisheries in terms of income and export value (Ngusaru, *et al.* 2000), and estimated catches over the past two decades, have ranged up to 2,600mt/yr. The prawn resources together with other finfish species, contribute significantly to the social and economic welfare of the coastal communities. The prawn fishery provides employment and income to fishers and business people, and government revenue and foreign earnings for the country.

Specific fishing seasons were established in 1990 to protect immature shrimps. For industrial fishers the fishing was open for seven months from March to September. This was necessary because the study conducted by Nkondokaya (1992) showed higher prawn juveniles in catches from November to March. It was further recommended to extend the closed season from four to five months starting 1st December to 30th April each year after evident declining catches in the another survey by Bwathondi et al. (2002). However, this recommendation was never implemented.

Figure 1: A map of Tanzania showing geographic location with major water bodies and rivers.

During the 2008 trawl survey, reports (Mwakosya, *et al.*, 2008) show a serious decline in prawn stocks on the Tanzanian coast that was linked to higher levels of resource exploitation. The report was discussed in a joint meeting involving the Fisheries Division, TAFIRI and prawn fishery stakeholders (small, medium and large-scale fishers) and a resolution was passed to close the industrial fishery. It was further directed that during the closure period TAFIRI should carry out a systematic research to monitor prawn stocks and assess the effectiveness of the closure. So as from 2008 the industrial shrimp fisheries was stopped. Since the closure, the annual revenue contribution from the fishery sector to the national economy has decreased significantly.

1.2 History of the prawn fishery in Tanzania

The first prawn trawl survey was carried out in 1959 by the East African Marine fisheries Research Organisation EAMFRO using R/V "Manihine". During this period, the importance was on taxonomy rather than stock assessment (Silas, 2011). Commercial prawn trawling in Tanzania waters commenced in 1969 after an exploratory shrimps fishing survey jointly conducted by the Government of Tanzania and Japan. Actual industrial shrimp fishing started 1982 after acquisition of a shrimp trawler by the Tanzania Fishing Cooperation (TAFICO) a parastatal organization. In 1985, the government policy changed towards liberalized economy following structural adjustment and economic liberalization, many companies entered the fishing industry.

The government licensed three foreign trawlers in 1987, increasing the total number of licensed trawlers to seven. As more vessels entered the fishery, fishing effort increased and the abundance and sizes of prawns declined in most locations (Bwathondi *et al.* 2002). Decline of prawn catches lead to resource use conflicts between commercial trawlers and artisanal fishers and among the commercial trawlers themselves. At that time, *Penaeus indicus* and *Penaeus monodon* were the main targets (Abdallah, 2004).

Zoning and rotation of fishing vessel on fishing grounds was introduced in 1988 just a year after the government had licensed foreign fishing vessels. The objective of this regulation was to spread fishing effort evenly over the fishing grounds and minimize environmental degradation on a particular fishing ground where most of the fishing vessels seemed to cluster (Haule 2001). The regulation was also aimed at encouraging fishing vessels to search for new fishing grounds and minimize conflicts which were starting to arise among trawlers and artisanal fishers (Mongi 1990). At first, five zones were delineated. With time some of the zones were merged together to form three zones. Although this measure seemed to work to reduce conflict among trawlers, it did not solve the conflict between artisanal fishers and trawlers. Artisanal fishers complained that they are denied their livelihoods by trawlers who destroy their fishing gears. As the conflict grew the need to introduce new measures to try to protect artisanal fishers became more apparent.

Over the years, a combination of locally owned, private (foreign ownership) and joint venture ownership of licenses has existed. The numbers of licenses increased to 20 in the mid 1990' and up to 25 licenses were issued in 2004. The fishery was closed in 2008 due to declining catch rates and user conflict with artisanal fishers. During this period, most of the foreign trawlers that were registered in Tanzania were marketing their products to Europe (Silas, 2011). Trawlers with freezing capability transported their products (shrimp) directly to Portugal, England, Spain, Belgium and Holland, while Greek registered trawlers were transporting to Greece. It is unclear when the artisanal fishery commenced, but it has been in operation for several hundred years and the fishery has continued until because the closing applied only for industrial fishery (Bwathondi *et al,* 2002).

Commercial fishers, artisanal fishers, environmentalists and the resource managers always enter into conflicts over the use of the resource. Some of these conflicts are due to damage to artisanal nets done by trawlers when operating very close to the shore, complain of the reduction of prawn stocks done by trawlers as artisanal fishermen connect it with inshore trawling, habitat destruction caused by trawlers and incidental catches that are disposed at sea as by-catch (Fennessy *et al*., 2008).

1.3 Trends in catch, effort and CPUE

P. indicus and *M. monoceros* generally dominate trawled prawn catches (~80-90%) with *P. monodon*, *P. semisulcatus* and *P. japonicas* together contributing the remainder. Depending on the area being trawled and the time of day, the other species can assume greater prominence. Catch rates are highest from April to June (coinciding with the rainy season), declining towards the end of the year; Zone 2 consistently produces the highest catches. Trawl catch records (no of boats and catch) were available from 1982 but during that time prawns were not identified to species level. Trawling effort (in terms of numbers of boats and fishing days) increased steadily from the mid 1990's, despite recommendations to the contrary, and despite declining CPUE, until the mid 2000's, when effort and catch dropped sharply, and the trawl fishery was closed in 2008 in order to allow stock recover (Figure 2). The artisanal catch (mainly *P. indicus* and *P. monodon*) information is less accurate, being very variable; without effort data, these data cannot be easily interpreted but it is clear that the artisanal catch is substantial.

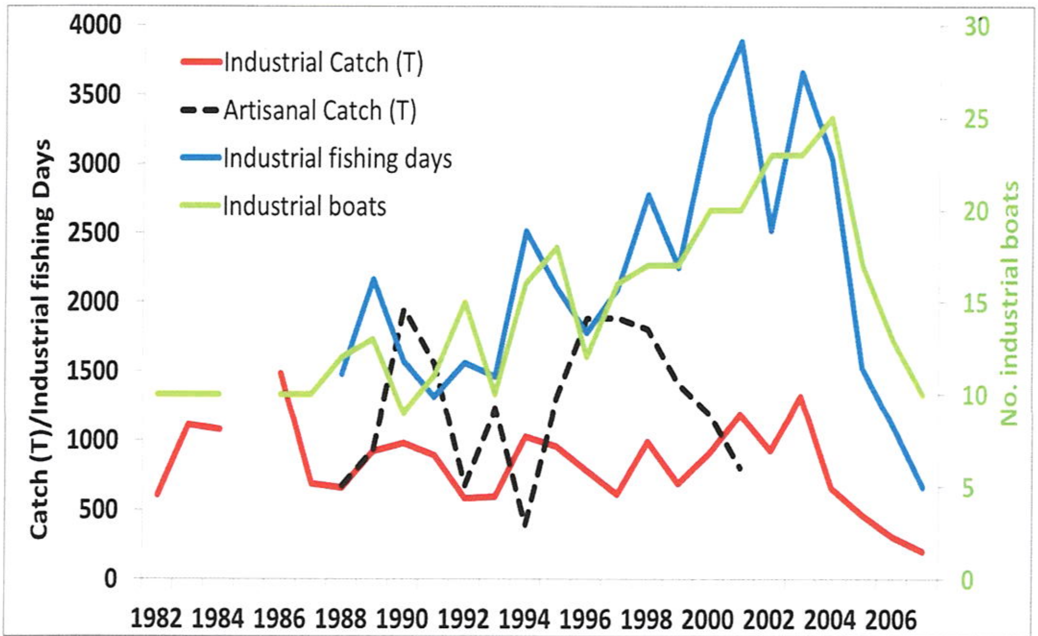

Figure 2: Trends in catch and effort of Tanzanian prawn fisheries data since 1982 to 1987 from Sanders et al. (1988); data from 1988 onwards are from Tanzanian Department of Fisheries.

1.4 Rationale of the study

The prawn fisheries has over the decades been of great importance to the Tanzania societies, both economically and socially (Abdallah, 2004; Mwakosya, 2004).

Crustacean have been recognised as an important economical and food resource found in varying quantities along Tanzania's coast. Historical commercial landings show the importance of this resource, especially in the north coast of the country. Statistics information from fisheries for the years 1997 to 2006 indicated that the fishing effort in terms of the number of fishing days and fishing vessels has been increasing up to the year 2003 thereafter the effort started to decrease. On the industrial prawn production there was a fluctuating trend from 1997 to 2003 thereafter the prawn production the resource continued to decrease. Due to that fact the government decided to close the fishery in the year 2007 and it is still closed. During the moratorium period two major surveys were conducted (Mwakosya *et al,* 2009) in order to assess the effectiveness of the closure. The results from the two surveys indicated that since closure of industrial prawn fisheries (2007), to-date the resource is slowly recovering. Further monitoring of the resource was suggested and include studies covering small scale fishers, socio-economics and ecology for better understanding the dynamics of the fishery during the moratorium.

The prawn fisheries have directly supported over 40 thousand people in Tanzania, making a significant contribution to the gross domestic product (GDP) of the country. The reduction in the production of prawns is therefore of considerable concern as a potential threat to the local economy. Since the closure of the industrial prawn fishery, the annual revenue contribution from the fishery sector to the national economy has decreased significantly. The decrease of the fishery income after industrial prawn fishery closure increase the politician's pressure to know when the fishing will be opened. Currently, the Ministry of Livestock and Fisheries Development is planning to re-open the industrial fishery for few licensed trawlers so as to boost the contribution to the national economy through licensing fees and revenue generation to increase contribution to the national economy. This cannot be properly implemented without research information on the actual status of the prawn resource at present. Therefore, the information from this study will be crucial for resource managers to decide on the number of trawlers to be registered at the start for sustainable utilization of the available resource. There are speculations that production from the artisanal prawn fishery is higher due to the large number of fishers, albeit operating at a very low catch per unit effort. This study will addrress this speculation and analyse the actual situation.

The Tanzanian prawn stocks potential is not well known, as only a few research programmes have been conducted on the fishery. FAO (1970) estimated a potential of 2,000 metric tons. In early 1980's there was an intensive fish stock assessment that was done by an FAO research vessel "Fridtjof Nansen" that determined among other resources the potential prawn fishery resource along the Tanzanian coast at 1000 metric tons.. TAFIRI in 2001 conducted a survey of the resources, and gave an estimation of 497 metric tons of the prawn stock. These research programmes lead to the closure of the industrial prawn fishery in 2007 a decision made during stakeholders meeting to allow recovery of the fishery. This project aims to come out with most recent standing biomass of mainly two commercially important Penaeidae species namely; white prawn (*Penaeus indicus)* and brown prawn *(Metapenaeus Monoceros)* in order to come out with the sustainable management measure.

1.5 Overall objective

The overall objective of this study is to determine the exploitation status of the two prawns species (*Penaeus indicus and Metapenaeus Monoceros),* in order to provide advice on their optimal exploitation and management measures in Tanzanian coast.

The analysis are based on the available data on catch, effort, biometric, obtained from surveys conducted in 2009, 2011 and 2015. Furthermore, the status of the prawn stocks will be examined using biological survey data from May to November 2015, industrial catch data from 1983 to 2007 and artisanal catch data from 1988 to 2013.

1.6 Specific objectives

i. To determine relative abundance and distribution of *Penaeus indicus* and *Metapenaeus Monoceros* in each fishing zone and season.
ii. To establish catch per unit effort (CPUE) of *Penaeus indicus* and *Metapenaeus Monoceros*.
iii. To calculate biomass indices of *Penaeus indicus* and *Metapenaeus Monoceros* by fishing zone and season.
iv. To compare the catches of penaeid prawn from artisanal and industrial fishery.

2 LITERATURE REVIEW

2.1 Biology and life history of prawn

Prawns are short lived species with a life cycle of 12 to 18 months (Gammelsrød, 1992). Their life cycles involve planktonic larvae with a variety of naupliar, protozoeal, zoea and post-larval stages, followed by juvenile and adult stages (Figure 3). Tropical shrimps spawn offshore, the larvae migrate to the inshore nursery areas for shelter and food in dry season using a combination of tidal currents and diurnal vertical migration patterns (Gammelsrød, 1992). In nursery they spend three to four months and grow to juvenile stages, while the adults migrate back to the open sea for spawning (Ulltang, Brinca, & Silva, 1980).

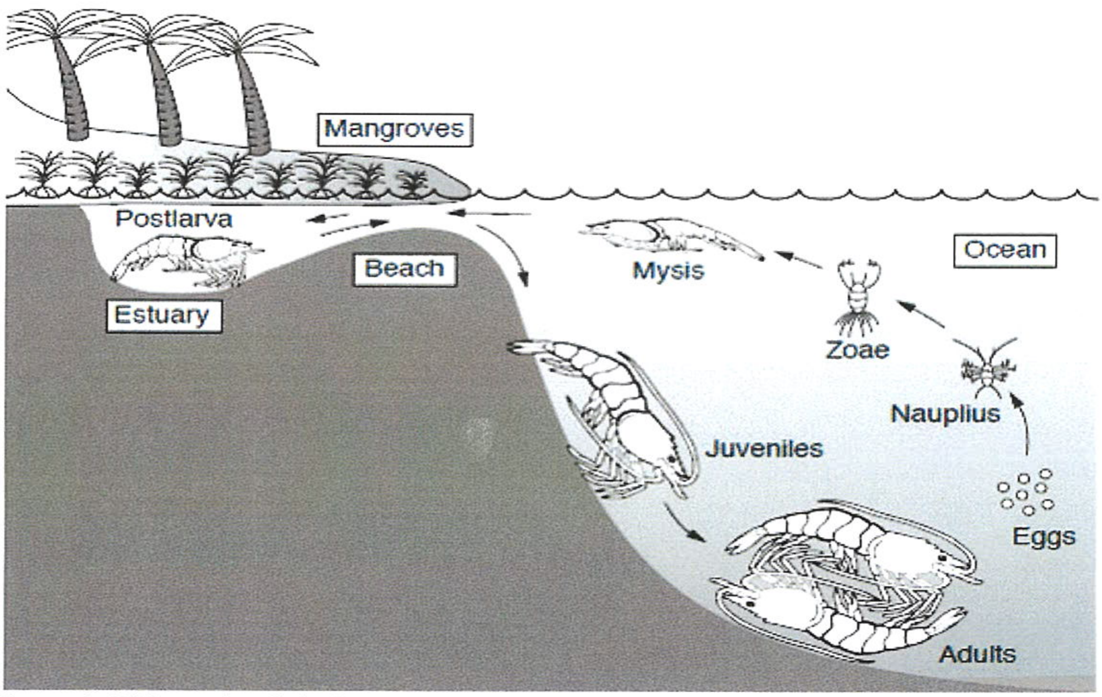

Figure 3: Life cycle of shallow water penaeid prawns (Rosenberry, 2009).

Eleven species of prawns have been identified in the Tanzanian marine waters. However, according to the prawn resource studies conducted by TAFIRI from 1993 to 2003 (Nhwani, et *al.,* 1993; Bwathondi, et al., 2002; Teikwa and Mgaya, 2003), only six species (*Penaeus indicus, P. monodon, P. latisulcatus, P. semisulcatus, P. japonicus and Metapenaeus monoceros)* are frequently encountered in most of the prawn fishery operations, which are normally conducted in the three designated fishing zones; Bagamoyo as zone 1, Rufiji/Mafia channel (commonly referred to as the Kisiju fishing area) as zone 2 and Jaja/Kilwa as zone three (3) (Figure 4).

Several studies have been conducted in Tanzania on prawn fishery in different aspects of the fishery. The taxonomic study done by Brusher (1974) revealed the presence of *Penaeus semisulcatus, P. monodon, P. japonicus, Metapenaeus monoceros* and *M. stebbingi* along the East African coast. Eight Penaeid prawns species identified by Bianchi (1985) on her survey to Tanzanian coast, five of them were the same as identified by Brusher (1974) and the other three were *P. canaliculatus, P. indicus* and *P. latisulcatus.* During an assessment of the by-catch composition of finfish in the shrimp fishery of the country by Nkondokaya (1992) identified the by-catch composition and suggested means of reducing the by-catch as well as the alternative utilization of by-catch.

The Indian white prawn (*Fenneropenaeus indicus*, formerly *Penaeus indicus*), is one of the main commercial prawn species of the world. The species found in the Indo-West Pacific from eastern and south-eastern Africa, through India, Malaysia and Indonesia to southern China and northern Australia (Sea Life Base 2010). The adult *P. indicus* grow to a length of about 22 cm (9 in) and live on the seabed to depths of about 90 m. The early developmental stages take place in the sea before the larvae move into estuaries (Figure 1).

P. indicus is a marine decapod with estuarine juveniles. It prefers mud or sandy mud at depths of 2–90 metres. After hatching, free-swimming nauplii are obtained, which further passes through protozoea, mysis and then to postlarval stage, which resembles the adult prawn. The postlarvae migrate to the estuaries, feed and grow until they attain a length of 110–120 mm, and these sub adults return to the sea and get recruited into fishery (FAO, 2010).

Metapenaeus monoceros is a species of prawn in the family Penaeidae. It is also known as speckled shrimp, brown shrimp and pink shrimp, is native to the Indo-West Pacific from Durban to the Red Sea along the African coast and around India. *M. monoceros* is found up to a depth of 170 metres (560 ft) but commonly found between 10 m and 30 m. They prefer sandy or sandy mud bottoms. They live in brackish water or marine ecosystem (Otero *et al.*, 2013).

2.2 Recruitment pattern

Recruitment intensity is the number of recruits per time unit, and recruitment pattern is the variation of recruitment intensity in time (Sparre et al. 1989). The term recruitment is used to indicate the entry of other stages of the fishes to areas like nursery grounds or estuaries, etc. In these cases the term recruitment will bear its own specific definition in relation to the stages of the fishes.

M. monoceros is believed to be a continuous breeder with two major spawning seasons. These seasons were found to vary with time and location and environmental factors. In Tunisia, spawning seasons are May–June and October–November. In Egypt, May and July–October were found to be the spawning seasons. In Turkey spawning occurred between November and January. In India, December–April and August–September are the two main spawning seasons. (Otero *et al.,* 2013).

2.3 Biomass estimation

According to catch and effort data of 1988, Sanders (1989), made a preliminary assessment of the shallow water shrimp fishery of Tanzania and Nhwani *et al.,* (1993) also made an assessment on the Crustaceans resources of the Rufiji-Mafia channel and the by-catch composition from trawlers in 1992. The study indicated significant decline of over 30% in the biomass of Prawns when compared to the previous estimates made by Sanders (1989). Bwathondi *et al.,* (2002) made study of the prawn abundance and the distribution in the Bagamoyo and Rufiji delta was done by and compared results with the previous studies that were done by Sanders (1989) and Nhwani *et al.,* (1993) in the same area. The mean estimated biomass for Bagamoyo was 41.7 tons and for the Kisiju area 279.91 tons. The result indicated a significant decline of the biomass and changes in the by-catch composition. In 2007, the Government of Tanzania put a total ban to commercial fisheries. This is because observations from both catch data and stock assessment studies indicated a downward trend in the prawn landings (Mwakosya, 2004; Mwakosya, *et al.,* 2009).

3 METHODOLOGIES

3.1 Study areas/sites

The prawn fishery in Tanzanian coastline of over 800 km located in three fishing zones as shows in Table 1 and Figure 4 (Francis & Bryceson 2001; Mhitu and Mwakosya, 2008).

Table 1: The Geographical Location of the study area

Zone	Name	Geographical Location (Longitude/Latitude)	Size (Km^2)	Depth range (m)
1	Bagamoyo & Sadani fishing grounds	05°25''S, 039°E to 06°30''S, 039°E	1,254.8	3 - 20
2	Kisiju (Mafia channel and Rufiji delta)	06°30''S, 039°E to 08°S, 039°E	2,178.6	3 - 14
3	Kilwa (Jaja and Kilwa)	08°S, 039°E to 10°S, 039°E	1,575.5	3 -29.5

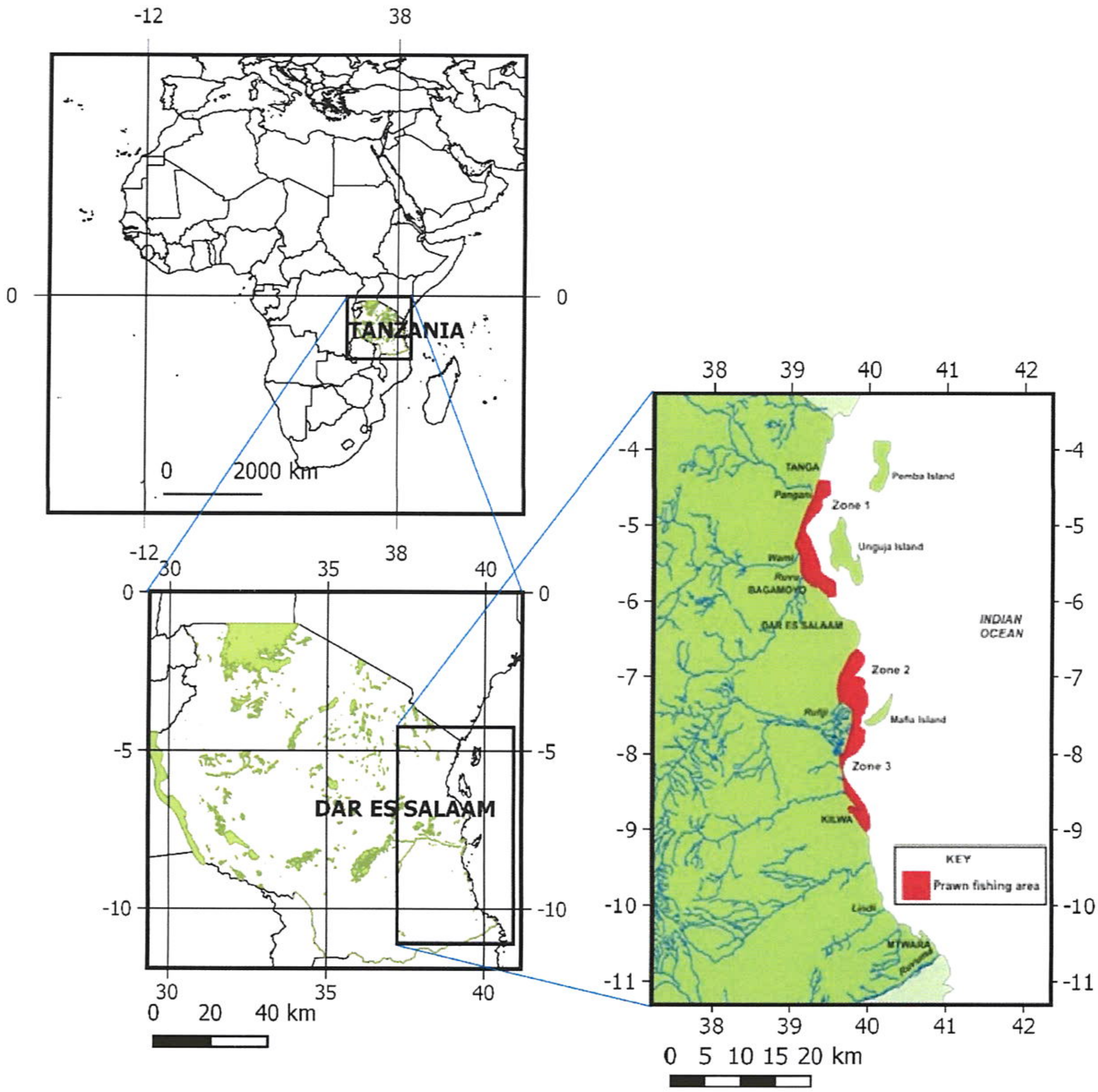

Figure 4: A map of Tanzania coast showing three prawns fishing zones: Zone 1 receives fresh water from three main rivers; Ruvu, Wami and Pangani, Zone 2 receives fresh water from Rufiji River and Zone 3.

3.2 Data and data collection

3.2.1 Biological data

Four vessels MFV Elena, MFV Serena, MFV Vega and MFV Hunasa were used for surveys in three zones in 2009, 2011 and 2015 (Table 2). Surveys in 2009 and 2011 covered all three zones using one vessel from Zone I through Zone II to Zone III, while during 2015 survey two vessels were used by alternating them between 3 zones as shown in Table 2. But due to unavoidable reason, Zone III were studied only in June and July in 2015. During 2011 survey, data collected in many days per month compared to 2009 survey. Also there were difference in sampling month in all surveys except for June. The survey was stratified by depth and distance from shore. Samples were collected using a shrimp trawl to determine species composition and magnitude of each species. Biological data and samples were collected to assess the basic biology of prawn species. Environmental data (water temperature, salinity, density and dissolved oxygen) were collected through the use of a CTD to explain patterns in distribution and/or abundance. Biological data for some of dominant bycatch species were also collected. A total number of 15 days were selected randomly within a month spent on collection of biological and environmental data.

Table 2: Overview of the sampling surveys from 2009 to 2015

Vessel	Engine power	Period	Zone	Number of Stations
Elena	295	March; 2009	I, II &III	38
Serena	365	May–July,2009	I, II&III	48
Vega	365	Feb & June, 2011	I, II &III	32
Serena	365	May & June, 2015	I	15
Serena	365	June & July, 2015	III	9
Hunasa	450	June & July, 2015	II	15
Serena	365	August, 2015	II	15
Serena	450	August & September, 2015	I	24
Hunasa	365	September & October, 2015	II	14
Serena	365	October, 2015	I	15

Daily recording of total catch for prawns and fish bycatch before and after grading was conducted. Trawling was done using two bottom nets and trawling was only done during the day time (6h00 to 18h00), at speed of 2.5-3 knots. The mean footrope length used for swept-area biomass estimation were 0.027 km for 2009 km, 0.011 km for 2011 and 0.018 km for 2015. Prawn's individuals from each species were measured according to the following; weight (0.1g), total length (0.1 cm), carapace length (0.1 mm), and sex and maturity stage were also recorded for the females. The fish were sorted and identification was done up to species or family level. The total weight, individual weight, number and length for each category in a sample was measured and recorded. All information about each trawl haul was recorded i.e. date, position, fishing ground, fishing site, haul number, depth, bottom type, towing speed and towing duration.

3.2.2 Industrial and artisanal fisheries catch and effort data

The Fisheries Division is a government organ responsible for collection of monthly catch data from industrial fishers (1983 - 2007). The output from industrial fishery data is not species specific due to multispecies nature of the tropics. Only major groups of fishes are recorded e.g. all prawn species combined together as one group and finfish as another group (Appendix 1). The current study used catch datasets from 1988 to 2013 in order to compare the artisanal catches before and after closure period. However, the industrial and artisanal catch data were not recorded into species level.

3.3 Data analysis

3.3.1 Size Structure

Length frequency distribution graphs of prawn species were drawn to indicate the size structure of individuals caught during the survey.

3.3.2 Length weight relationships

The length weight relationship of the shrimps will be established.

$$W = a * (Lc)^b$$

Where
Wt = individual wet weight
Lc = carapace length, *a* and *b* are the regression parameters to be determined.

3.3.3 Spatial distribution of prawn species in three fishing zones

The number of individuals sampled were standardised by dividing by haul duration, therefore the abundance were establish of each tow. The abundance were mapped with their respectively latitude and longitude in R using ggplot2, mapdata and ggmap packages.

3.3.4 Determination of Catch Per Unit Effort (CPUE)

The total catch for each haul and time spent in fishing was calculated to established catch rates and CPUE from different fishing zones at sampling month.

$$CPUE = \frac{\overline{CW}}{t}$$

Where,
$\overline{CW}$ = mean catch weight (kg)
t = time spent in trawling (hr)

3.3.5 Biomass indices estimation

Biomass was estimated by using swept area method as described by Sparre and Venema (1998). The data collected during the current surveys was used to make estimates of the total biomass of the area. The data collected during the surveys were used to estimate the total biomass of the area (B) using the following formula;-

$$B = \frac{\overline{CW}/a}{q} \times A$$

Where,
$\overline{CW}$ = mean catch weight (kg)
A = total area under investigation (km^2)
a = area swept by trawl
q = catchability coefficient

The value of q was considered to be 1 under the assumption that all prawns found in the trawl path were retained in the cod-end of the net.

The swept area a is given by;
$a = D \times fr \times 2$
and $D = V \times t$

Where,
V = velocity of the trawl over the ground when trawling
t = time spent trawling
fr = length of the foot rope which is equal to the width of the path swept by trawl. From the recorded catch in weight (kg) of a haul and the calculated swept area. The catch weight per area was calculated using the formula;

$$CPUA = \frac{\overline{CW}}{a}$$

The average biomass per unit area was estimated using the following formula;

$$\bar{b} = \frac{\overline{CW}/a}{q}$$

4 RESULTS

4.1 Size Structure

Carapace length-frequency distributions plotted for each month and zone in 2009, 2011 and 2015 are presented in Figures 5 and 6. The plots of *P. indicus* indicated the highest mode at 3.5 cm in May 2009 in zone I (Figure 5), while four modes (1.75cm, 2.75cm, 4cm and 5cm) were observed in May 2015 in zone II. The missing plots in year 2009 and 2015 were due to sampling protocols. In general more peaks were observed in Zone I than Zone II and Zone III and the peaks decrease from March to October in all years.

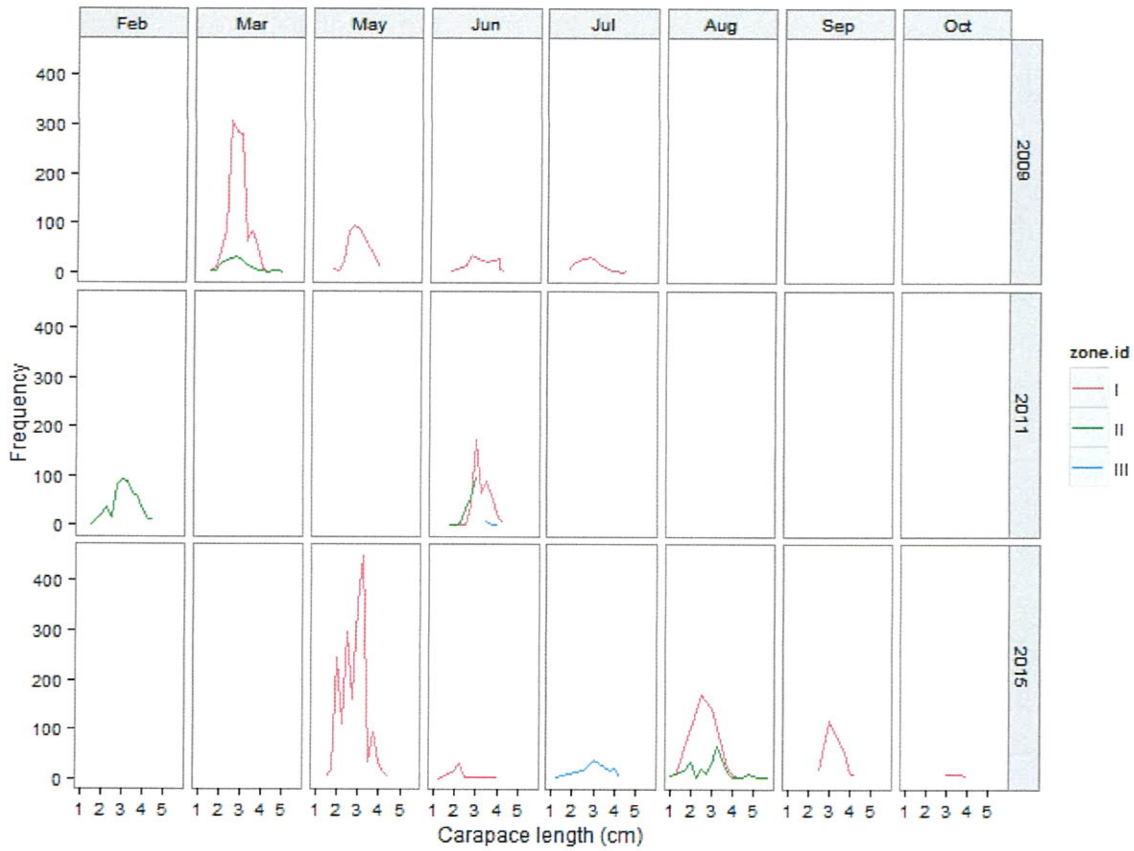

Figure 5: Monthly length frequency distribution of *P. indicus* sampled during 2009, 2011 and 2015 surveys from all three fishing zones (I, II and II).

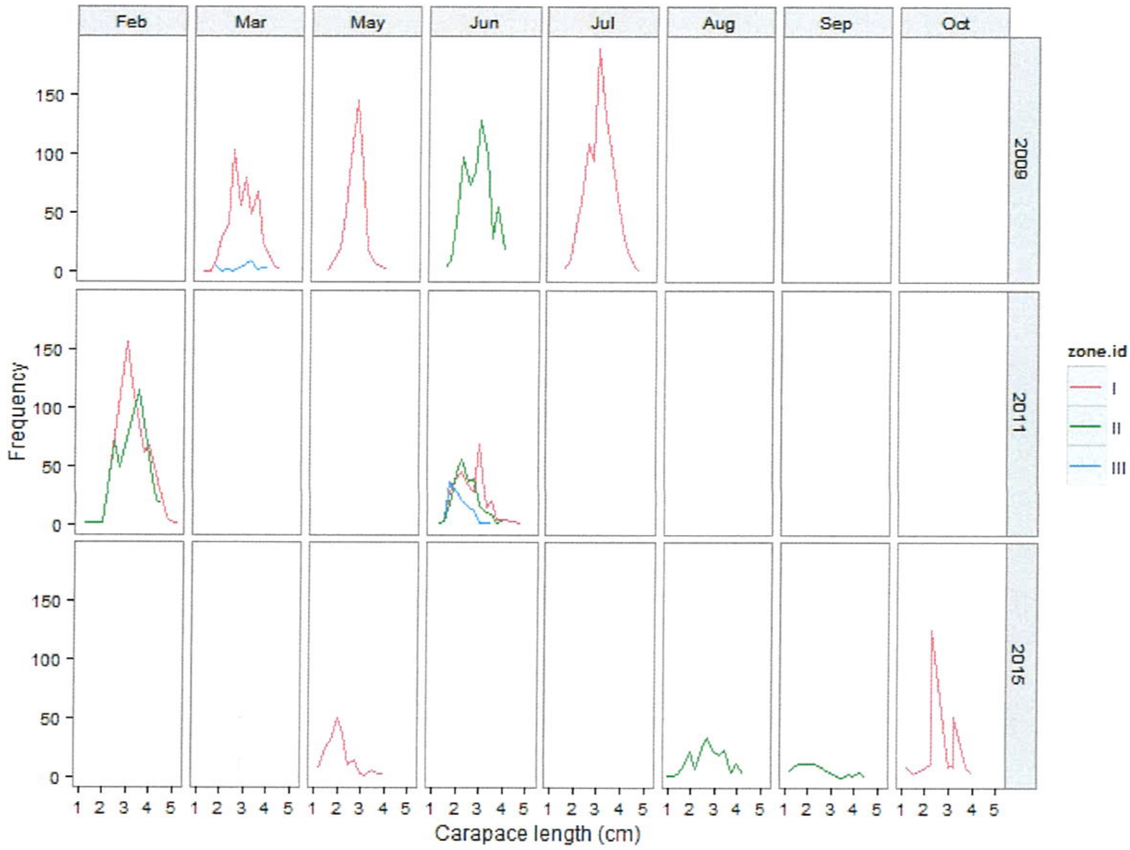

Figure 6: Monthly length frequency distribution of *M. Monoceros* sampled during 2009, 2011 and 2015 surveys in Zone (I, II and III).

The results show that during 2009, *M. monoceros* had the highest mode at 3.0 cm in July followed by 2.75cm in May at Zone I (Figure 6). The highest mode in 2015 occurred at 2.5cm in October in Zone I while the lowest mode was observed in September at 1.75 cm in Zone II. The June 2011 survey showed all three zone whereby the highest mode occurred in Zone I at 3 cm followed by Zone II at 2.25 cm and lastly Zone III at 1.75 cm.

4.2 Length-weight relationships

The length-weight relationships were established from 2015 samples whereby 639 individuals of prawns were analysed; 328 individuals were *Penaeus indicus* and 136 *Metapenaeus monoceros* (Figures 7 and 8). Results of the length-weight analyses indicated that all prawn species exhibited allometric growth (Figures 7 and 8), the phenomenon whereby parts of the same organism grow at different rates. In addition to this, the animal with the higher slope value (b) is increasing in weight per unit increase in length at a faster rate than the animal with the lower slope value. Based on this, *Metapenaeus monoceros* with b value of 2.71 are therefore indicated to grow at a faster rate than *Penaeus indicus* with b of 2.6 and 2.5 in May and June respectively.

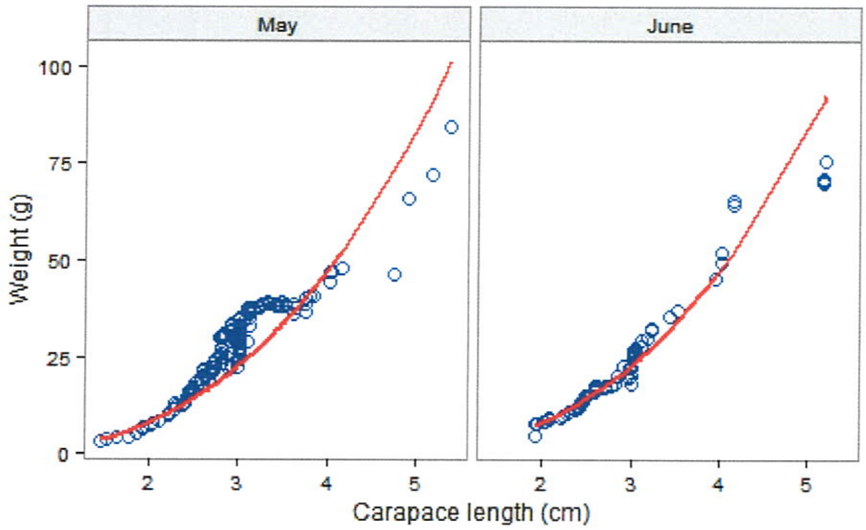

Figure 7: Length-weight relationship of P. indicus in May and June 2015 survey in Zone I (Bagamoyo).

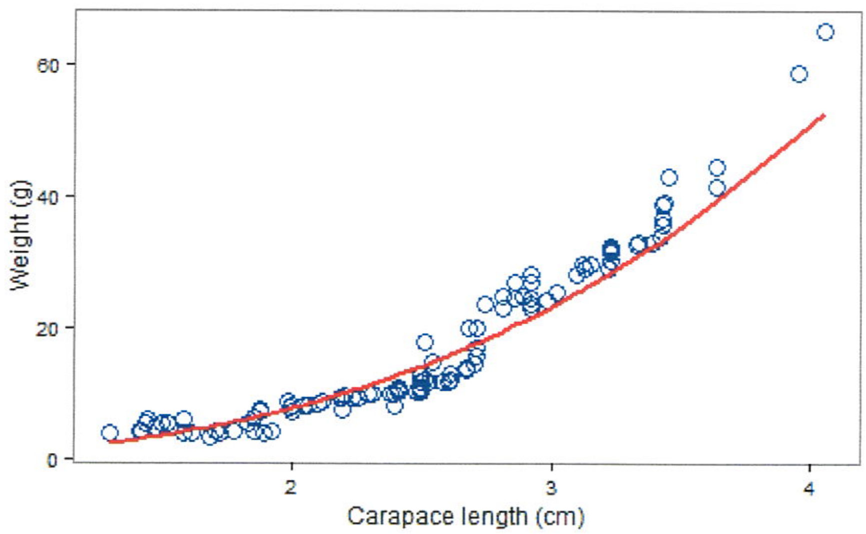

Figure 8: Length-weight relationship of *M. monoceros* in May 2015 survey in Zone I (Bagamoyo).

4.3 Spatial and temporal distribution of *P. indicus* and *M. monoceros*

The spatial distribution of prawn species caught from March to July 2009, February & June 2011 and May to November 2015 were established. The distribution of *P. indicus* were shown in Figure 9. The *P. indicus* were almost available in all fishing zones except in 2015 because the sampling done in May 2015 covered only Zone I while Zone III was sampled only in June and July. The distribution were clearer in 2009 and 2011 because during these survey the sampling were done equally in all three Zones.

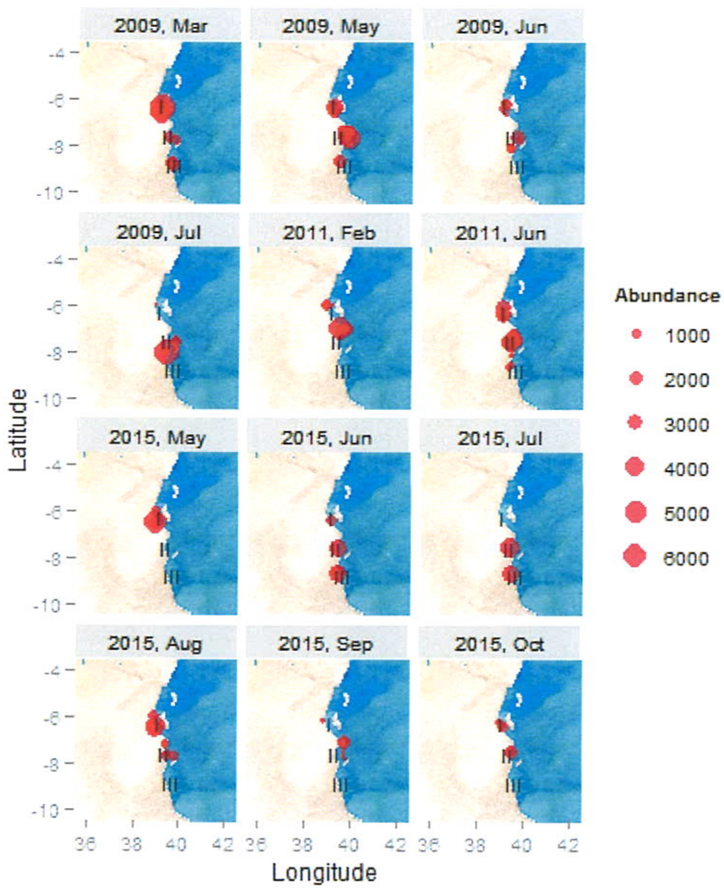

Figure 9: Spatial distribution of *Penaeus indicus* in prawn fishing zones (I, II and III) in Tanzanian coast in 2009, 2011 and 2015.

The overall spatial distribution of *P. indicus* was greater than the *M. monoceros*. It had a northerly distribution and greater abundance in 2009 and 2011 compared to 2015 (Figure 9). This distribution pattern can also be explained by the sampling period, the 2015 started on the mid of May while the 2009 survey started on March and 2011 started on February.

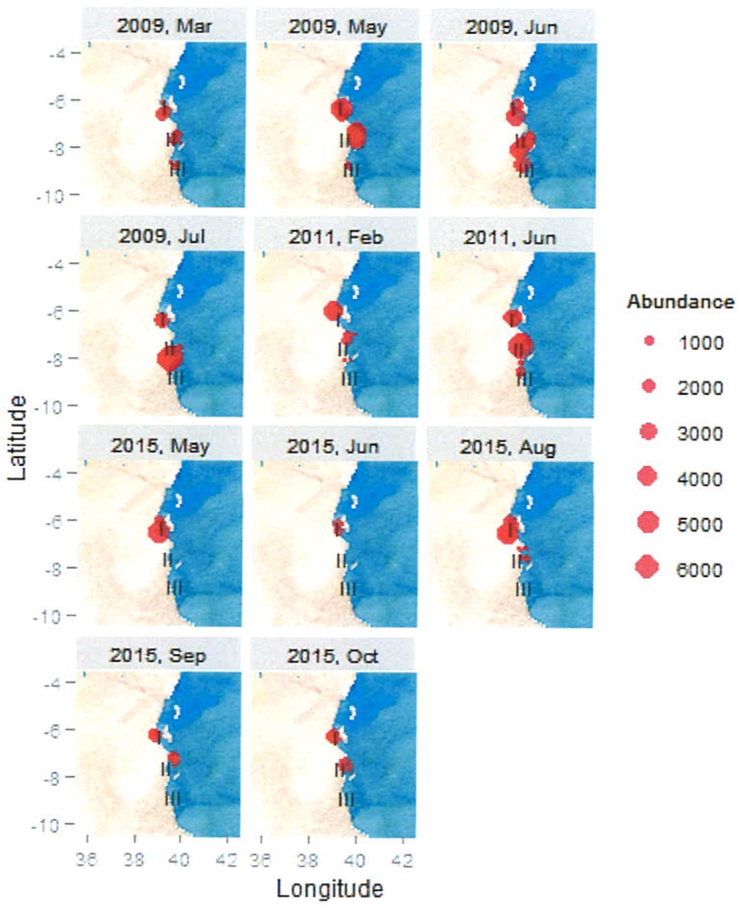

Figure 10: Spatial distribution of *Metapenaeus monoceros* in prawn fishing ground in Tanzanian coast in 2009, 2011 and 2015.

M. monoceros were more abundant in (Zone II) in 2009 and 2011 compared to 2015, whereby in year 2015 it was more abundant in Zone I. (Figure 10). The less abundant of *M. monoceros* in Zone III is due to its preference to shallow and mud habitat which are more general in Zone I and II compared to Zone III due to large inflow of freshwater from rivers.

Table 3: Percent species composition by number of all prawn and shrimp caught in all surveys (2009, 2011 and 2015).

Species	2009	2011	2015
Penaeus indicus	45.69	45.75	48.55
Penaeus semisulcatus	5.90	5.89	1.83
Penaeus monodon	0.76	0.44	0.22
Metapenaeus monoceros	45.25	43.43	49.38
Penaeus japonicus	0.13	4.47	0.02
Squilla mantis	2.27	0.02	
Macrobranchium rude	0.01		

4.4 Catches, fishing effort and catch per unit effort

4.4.1 CPUE determination

CPUE were calculated using fishing time as the unit for effort. The results for prawns catch rates for Zone I & II indicated increasing trend from March to May, thereafter catches in Zone I decreased, while those in Zone II continued to increase. The trend in Zone III showed high catch rates in March and decreased continuously throughout the study period.

4.4.2 Industrial catch rate for all prawn species in Tanzania

The plot of industrial catch rate for all prawn species in Tanzania shown the highest catch of 610.35kg/day in 1990 as indicated in Figure 10. The catch rates drastically decreased to 377.34kg/day in 1995. CPUE increased steadily from the mid-1990s, and declined in 2000 and in mid-2000s the CPUE dropped sharply, and the trawl fishery was closed in 2007 in order to allow stock recovery (Figure 11).

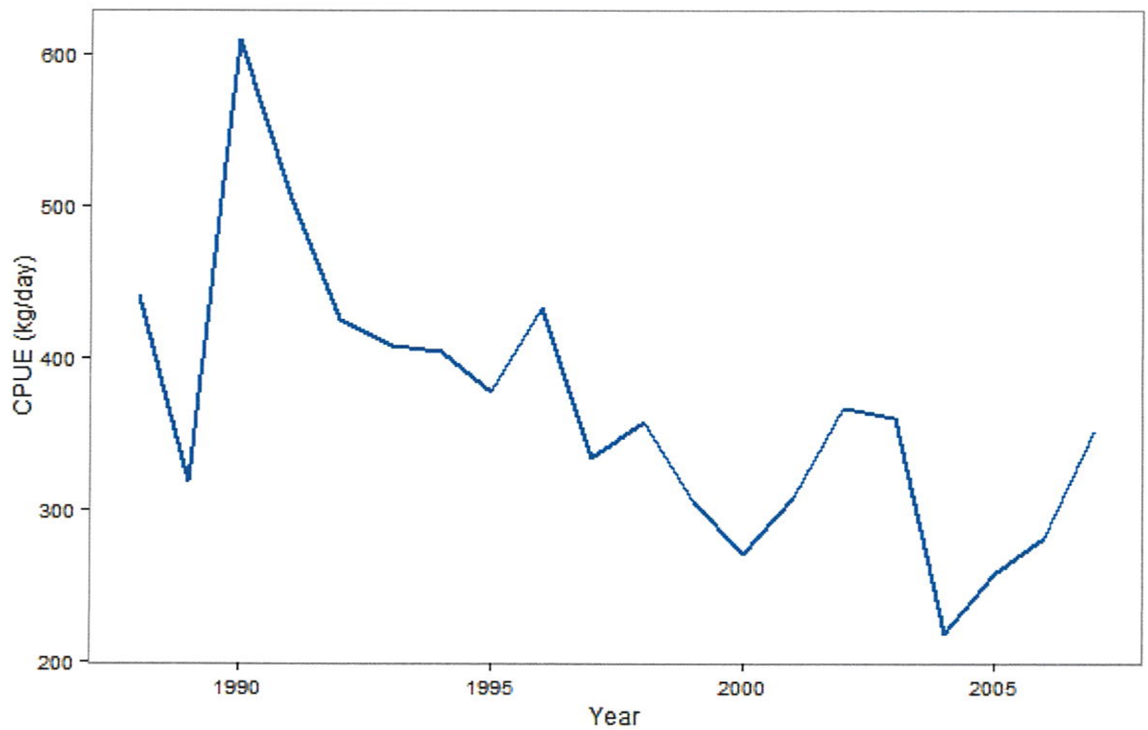

Figure 11: Trend of fishing effort from industrial fisheries in all fishing zones of Tanzania since 1988 to 2007 (Data from Tanzania Department of Fisheries)

4.5 Estimation of biomass indices of *P. indicus, M. monoceros* and total prawn catch

Biomass index for different fishing zones were calculated using fishing time as the unit for effort (standardized the catch with tow length). The results for prawn index for zones I, II and III were indicated in Figure 12 to 14. The results showed that the biomass indices of *P. indicus* differ between months and zones. Apart from other reasons, the high value of biomass index in 2011 survey was caused with the different sampling protocol in 2011. During 2009 and 2011 surveys all zones were equally covered compare to 2015 whereby zone III were covered only June and July. The biomass estimates for *M. monoceros* during the three surveys differ in month, year and zones. The biomass index was highest in Zone II followed by zone I while the biomass index was lowest in zone III. The lowest biomass was observed in July 2009 (Figure 11). The total biomass estimates for all prawn for all surveys also showed the different in value as shown in Figure 13. A general trend in all years is a decrease in biomass index towards the end of the year.

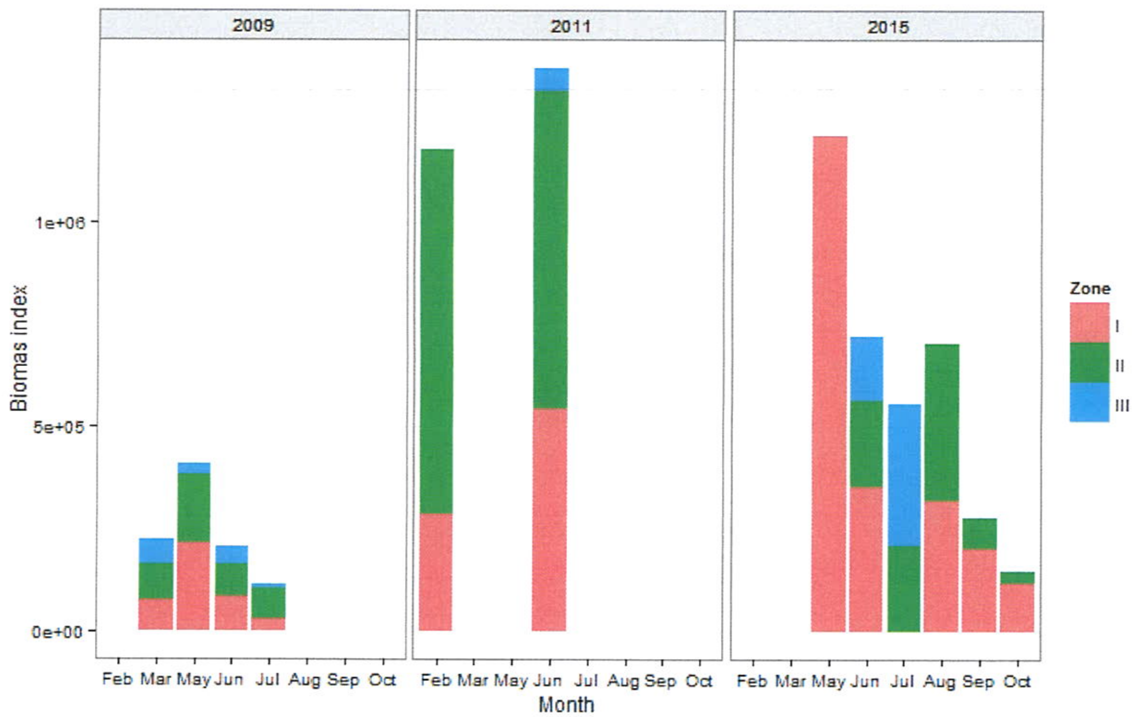

Figure 12: Monthly Biomass index of *P. indicus* by year from three prawn fishing zones

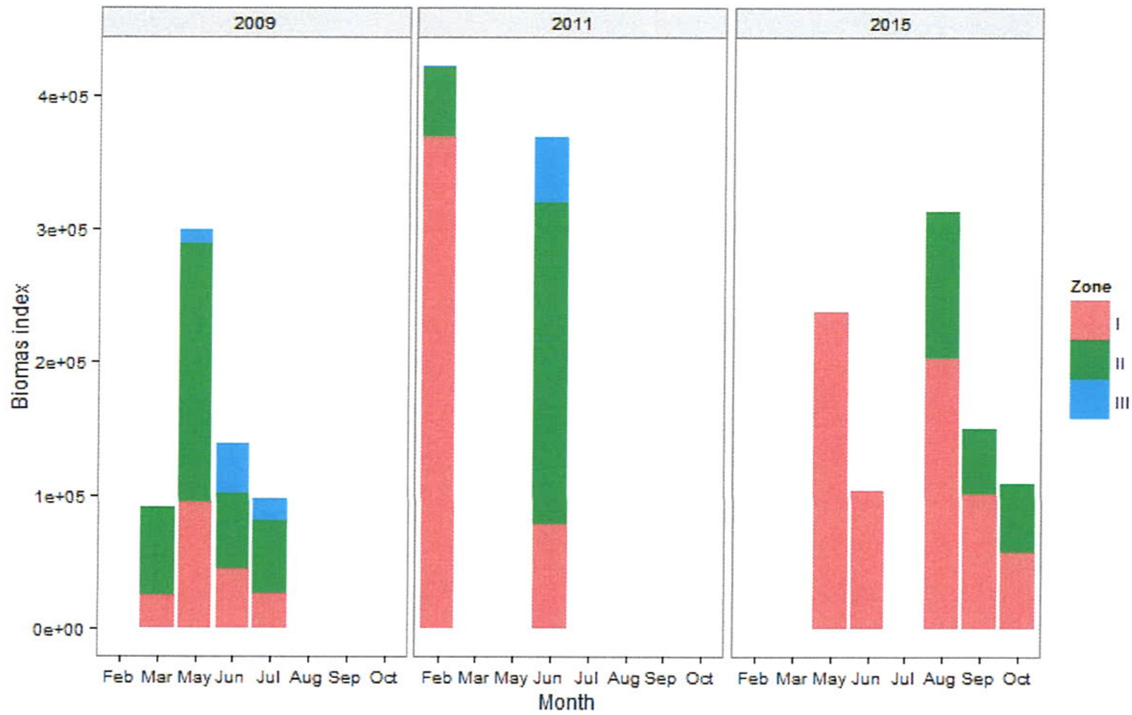

Figure 13: Monthly Biomass index of *M. monoceros* by year from three prawn fishing zones

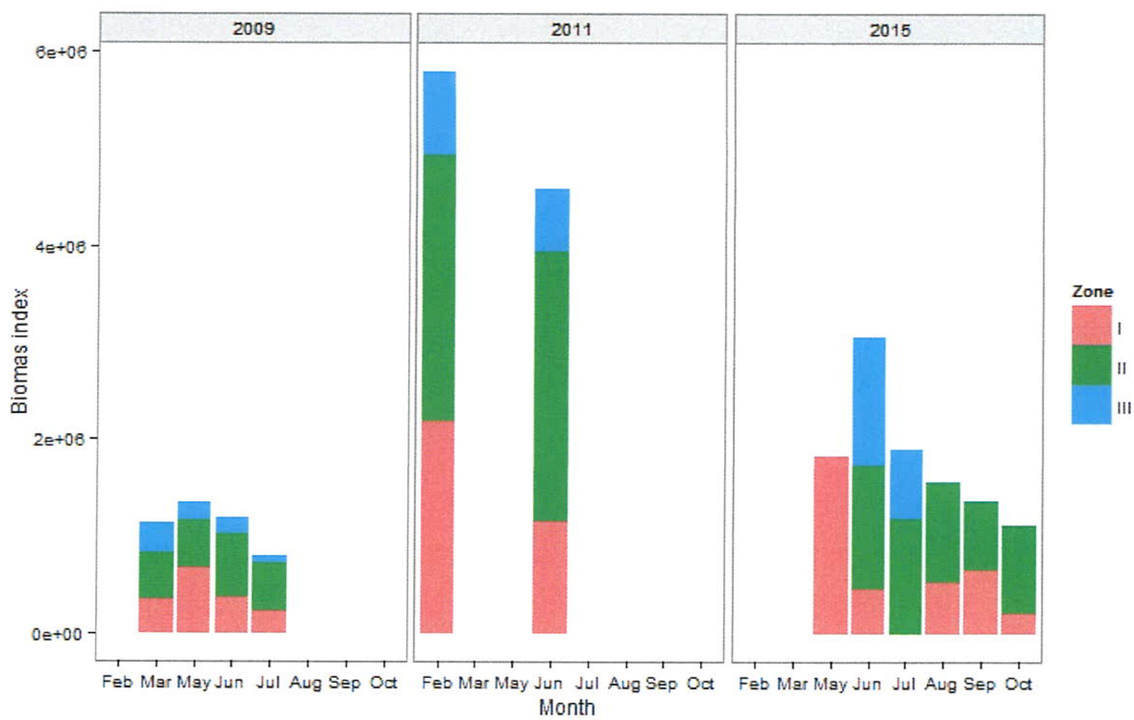

Figure 14: Monthly Biomass index of total prawn caught by year from three prawn fishing zones during surveys

4.6 Comparison of artisanal and industrial fishery

The data from artisanal and industrial fishery were compared in order to determine the interaction between them (Figure 15). Continuous trawl catch records of prawns were not identified to species level. The catches increased steadily from the mid-1990s, until, the mid-2000s.The effort and catch dropped sharply after 2003, and the trawl fishery was closed in 2007 in order to allow stock recovery. The artisanal catch (mainly *P. indicus* and *P. monodon*) were very variable, they declined at the end of 1990s, and then abrupt increased after closure of industrial fishery.

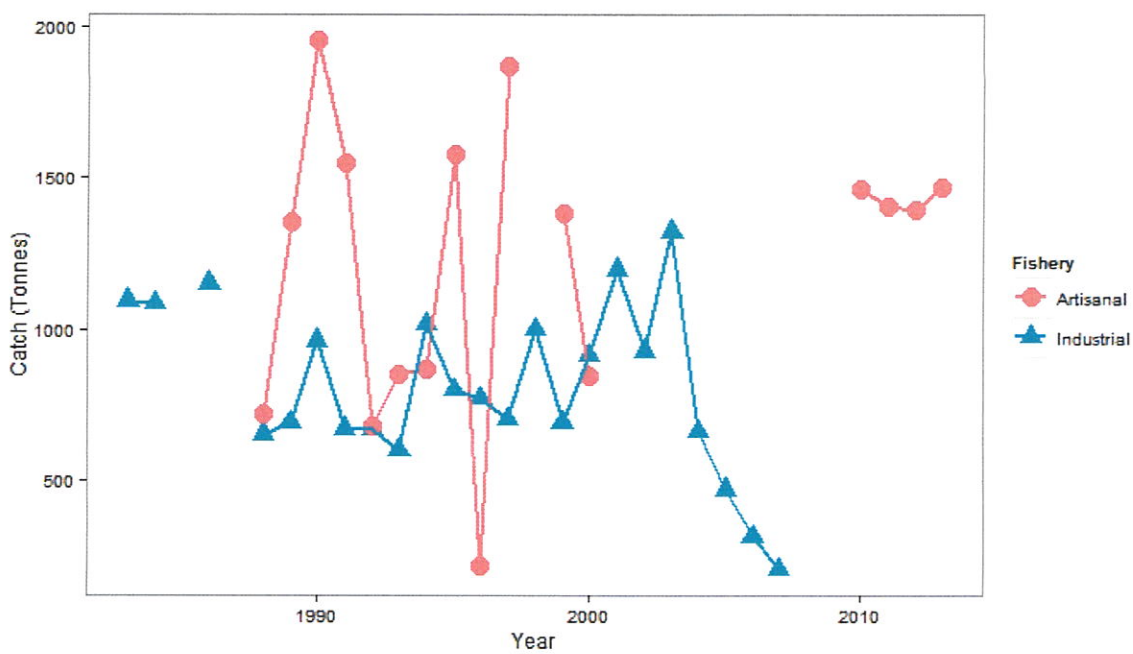

Figure 15: Trend of catches from artisanal and industrial fisheries in all fishing zones of Tanzania since 1988 to 2014 (Data from Tanzania Department of Fisheries)

5 DISCUSSION

5.1 Status prawn and life history

The study detect differences in life history of the two main species, for example difference in distribution between zones, months and years. During this study *P. indicus* were larger than *M .monoceros* with maximum carapace length of 5.25 cm whereby modal length ranged between 2.25 cm and 3.5 cm for *P. indicus*. The study indicated that the modal length of *M .monoceros* ranged between 1.75 and 2.5 cm. The results from this study are in agreements with Bwathondi *et al* (2002) who found similar patterns of modal length. This information alarms that the population is dominated by juveniles (recruits) as the adults reach 4.75 and 5.25cm for *P. indicus* and *M. monoceros* respectively. The size of *P. indicus* and *M. monoceros* in this study showed the species specific seasonal life, the highest mode of *P. indicus* appeared between March to May while it appeared in May and June for *M. Monoceros*. The observed mode suggests recent recruitment event, which occurred in different month for both species. The small sized prawn had highest mode during the study suggesting that the impact of the fishery had affected the large prawn as showed in another study (Mwakosya *et al.,* 2009).

The present survey revealed the difference in spatial distribution of *P. indicus,* and *M. monoceros*. Although, both species appears to be distributed in all fishing zones and in all years, *P. indicus* were more abundant in Zone I while *M. monoceros* were more abundant in Zone II. This could be due to the preference of shallow water of *M. monoceros* and Zone II is more shallow compared to Zone I and it also receives more fresh water from inflow rivers than the other zones.

The low abundance during 2015 survey may be due to less river discharge in combination with fishing effort from artisanal fishery and not fishing effort alone as suggested by (Mwakosya *et al.,* 2009, Mhitu and Mwakosya, 2008). These species are the target prawn species within the Western Indian Ocean region.

This study suggested the same findings as in Mozambique where by the environment (in the form of river run off) and fishing effort has been the driving force behind fluctuation of catches in Sofala Bank (Gammelsrød, 1992). Other factors like deforestation of the mangroves (Turpie, 2000) and pollution in catchment areas, may have exacerbated the problem. The inclusion of long term environmental factors in relation to prawn fishery in Tanzania has never been studied. The study observed improvement in the stocks recruitment for *P. indicus* but these finding needs more study which will cover all the seasons in order to cover the whole life cycle. The study showed that *P. indicus* recruits earlier than *M. monoceros* as suggested by Bwathondi, *et al*. 2002.

The study, also indicated improvements of biomass between 2009 and 2011 but the biomass decreased between 2011 and 2015. Two reasons may explain this trend, one could be due to the different sampling periods as in 2011 the data was collected in February and May where high juvenile abundance was observed due to long rainfall seasons. Another reason may be a high pressure in artisanal fishery, because the artisanal fishery take place in shallow water lagoon at estuary and may lead to adults overfishing especially during December to March where mature prawn are spawning. The study showed a high biomass index from March to May during the rain seasons whereby there was a high recruitment as suggested in previous studies (Mhitu and

Mwakosya, 2008). Based on findings from this present study it is suggested the the fishing season (March-September) needs to be adjusted to the targeted species and fishing zone. For example *P. indicus* reach the highest mode in March and May while *M. Monoceros* reach at highest mode in June and July. In terms of distribution by zones; Zone II should be continue with the previous fishing seasons while Zone I could be adjusted to August. The high biomass indices were higher in May and June coincided with rain season which brings high nutrient contents, high productivity and enhanced recruitment.

5.2 Growth

In fisheries research, length-weight relationships are important for the estimation of weight where only length data are available and as an index of the condition of the animal (King, 1995). It is assumed that heavier prawns of a given length are in better condition. The values of exponent *b* in the present study were below 3.0, a value which shows allometric growth. Teikwa and Mgaya (2003) related length-weight deviation to growth as animals change their body shape during growth. Although the change of exponent *b* values depends primarily on the shape and fatness of the species, various factors such as seasons, sampling time, sex and type of fishing gear may be responsible for the differences in parameters of the length-weight relationships. Other factors include temperature, salinity, food (quantity, quality, size), stomach fullness, health, habitat, stage of maturity and size of the specimen caught (Beverton, 1996). The exponent *b* may vary probably due to differences in the sampling time and the general body condition. Thus, differences in the exponent *b* of length-weight relationships from this study could potentially be attributed by the combination of one or more of the factors given above. Difference in growth rate may be influenced by factors such as genetic, food, physical-chemical parameters, environmental conditions and food abundance.

5.3 Interaction between artisanal and industrial prawn fishery

The annual industrial prawn statistics have shown an increase in prawn catches and effort from 1988 to 2003, and a strongly declining trend from 2004 to 2007. CPUE (annual tonne per boat and kg/day) has been declining over time since the late 1980's until 2007. From 2004 to 2007, there was a strong decline in fishing effort in terms of number of fishing vessels and fishing days. If the prawn stocks were only influenced by the fishery, then the expectation was that prawn abundance would increase as a result of declining effort but in contrary, there was a sharp decline. The artisanal fishery had resumed again after decrease in 1995 to 2000, this increase correlate with the close of the industrial fishery as the trend showed before the industrial fishery started was high but it was decreased after introduction of industrial fishery.

The observed difference in biomass among the fishing zones and months from this study are in agreement with reported findings from the previous studies. For instance Nhwani, *et al.*, (1993) and Bwathondi, *et al.*,(2002) found that Rufiji (zone II) contributed up to 80% of the fishery. Furthermore, Nhwani, *et a.l* (1993) and Mwakosya, (2004) observed seasonal variation in catch rates with high peaks during rainy season. The high catch rate peak (in June) for zone II lagged behind by one month compared to high catch rate peak in zone I in 2015. This result suggest that fishing zone I and II may be two different ecosystems.

Previous studies by Sanders, (1989), Nhwani, *et al.,* (1993), and Bwathondi, *et al.,* (2002) showed that recruitment patterns for prawn in this region goes together with the onset of rain season (May to June) and nutrient availability, thus leading into high productivity and higher abundance of prawns. The catch rates were higher in May and June coincided with rains season. *P. indicus* and *M. monoceros* observed to be dominant species throughout the study. The catch rates negatively correlated with fishing effort suggesting overexploitation of the stock. The low catches observed in zone III suggested that the area is no longer very productive for prawn fishery compared to Zones I and II.

6 CONCLUSIONS AND RECOMMENDATIONS

In conclusion, biomass estimates obtained in this study show there is no increase on the prawn resource compared to the previously findings. This can be an indicator of higher exploitation rates on the prawn resource in the artisanal fishery, hence strong management measures should be imposed. Furthermore, the closure should be continued while more studies on the life history of prawn are conducted. The beach recording system should be improved at the species levels and the size distribution data should be collected at least for two dominant species in the landing beach. It is recommended that the next surveys cover all zones and months equally in order to understand the spatial and temporal distributions which are important in adjustment of fishing seasons and zonation in both artisanal and industrial fishery.

Emphasis is still required in sensitization and awareness rising to the artisanal fishers on the use of appropriate mesh sizes as stipulated in the fisheries regulations and as suggested in the previous studies (strengthening law enforcement). This could be another threat to prawn fishery if it is not taken into consideration, because prawn nurseries are in coastal brackish waters in the mangrove where artisanal fishery is concentrated.

Despite the closure of the industrial fisheries on prawn the study show there is no increase of the prawn resource. This can be an indicator of higher exploitation rates on the prawn resource by the artisanal fishery, hence strong management measures should be imposed in artisanal fishery. It is further suggested that to carry the scientific catch assessment survey in order to investigate the impact of artisanal fishing.

ACKNOWLEDGEMENTS

I would like to acknowledge and appreciate the Icelandic Government, the United Nations University in Tokyo, the board and staff of the UNUFTP and the Marine Research Institute for the opportunity to participate in this fellowship program especially Dr. Gudmundur Thordarson. I am grateful to the UNUFTP staff; Dr. Tumi Tómasson, Þór H. Ásgeirsson, Mary Frances Davidson and Sigríður Ingvarsdóttir for their help and assistance throughout the program and in the development of this research paper. Special thanks to my supervisor, Dr. Ingibjörg G. Jónsdóttir, for her invaluable guidance and support throughout the project period. I humbly acknowledge her unwavering assistance and much time she dedicated to help in the modelling work.

I wish to thank the Tanzania Fisheries Research Institute Director General for supporting me to attend this programme. This report could not have been completed without the invaluable input of Catherine Mwakosya for supplying data and relevant information. I do acknowledge the Tanzania Fisheries Research Institute, Dar es Salaam Centre researchers for its concerted effort to collect stock monitoring data, which is used in this report.

I wish to extend much appreciation to my wife Millicent Odaa and my beloved son Dylan for their vital support and sincere approval to participate in the six-month program. Finally, I thank my colleagues, Stock Assessment fellows for their assistance at various instances.

To God be the Glory

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