Review of the Tanzanian prawn Fishery

By

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Penaeus semisulcatus

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DEDICATION

This thesis is dedicated to my late parents ***Silas Makorwa*** *and* ***Magreth Omolo****, my brothers and sisters* ***Phortinatus, Godfrey, Jenifer and Elizabeth*** *who have given me support throughout my life.*

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ABBREVIATIONS

CPUE	Catch per unit effort
CPUA	Catch per unit Area
EAMFRO	East African Marine Fisheries Research Organisation
FAO	Food and Agriculture Organisation of the United Nations
GRT	Gross registered tonnage
HP	Horse power
IMS	Institute of Marine Sciences
LOA	Length over all
MFV	Marine Fishing Vessel
MNRT	Ministry of Natural Resource and Tourism
MSY	Maximum sustainable yield
MLFD	Ministry of Livestock Development and Fisheries
MOP	Mwananchi Ocean Product
TAFICO	Tanzania Fishing Corporation
TAFIRI	Tanzania Fisheries Research Institute
USD	United States dollar
WIO	Western Indian Ocean

ABSTRACT

A review of the prawn fishery of Tanzania from its development in early 1980’s to closure in 2008 has been performed based on three major data sets; industrial prawn and fish catch data from Fisheries Division, river discharge data from Pangani Basin Water Office and prawn trawl survey data for 2009 from TAFIRI. Results show that prawn abundance (CPUE) and Pangani river discharge have been declining significantly over time while numbers of fishing boats and fishing days portrayed an increasing trend up to 2004. Furthermore the decline in prawn abundance was significantly associated with river discharge and fishing effort. However, a trawl survey conducted by TAFIRI in 2009 to assess the stock size of prawns has shown improvement in all fishing Zones of Tanzania

Key words: Prawn biomass, catch rate, species composition, by catches, river discharge, fishing effort, Zones, Tanzania

1 INTRODUCTION

1.1 General background information

Shrimp is commercially one of the most important marine resources in the world, 60% of which is traded internationally (FAO, 2009). Fisheries records indicate that over 16% of global fishery exports constitutes shrimp products (FAO, 2009). In the world market, total shrimps constitute about 6 million tons while wild prawn harvest constitute only 3.5 million tons (FAO, 2009). In five countries of the Western Indian Ocean (WIO) region (Madagascar, Mozambique, Kenya, Tanzania and South Africa), annual total landed catches are about 24,000 tonnes (Fennessy et al., 2008). In Tanzania, the shallow water prawn fishery is the most important marine fishery in terms of export. However its contribution to the national economy is less than that of the freshwater Nile perch fishery in lake Victoria (Wilson, 2004). For example in 2002, Central government of mainland Tanzania collected US$6.7 million as fishery revenue from export royalties of which 85% was collected from the export of Nile perch related products from Lake Victoria (Wilson, 2004).

1.2 Coastal Tanzania

The coastal area of Tanzania covers five regions including; Mtwara, Lindi, Dar es Saalam, Coast and Tanga, these areas are dominated by five prawn species out of eleven reported prawn species in the region (Table 1). Marine territorial waters[1] of the Tanzania covers 64,000km^2 (MNRT, 1997) and 223,000km^2 as Exclusive Economic Zone (EEZ[2]) in the Indian Ocean (Tanzania, 2003). The continental shelf is narrow and lacks upwelling which is important for productivity of the ocean (Nhwani, 1988). The length of the coastline from the North latitude 4°38'S (Kenyan border) to the south (Mozambican boarder) latitude 10°30'S encompassing Zanzibar and Pemba islands is approximately 1,424km long (MNRT, 1997). The coastline has eight major 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 (Iversen et al., 1984). These rivers provide favourable environment for prawn post larvae and juveniles by reducing salinity in estuaries (Teikwa and Mgaya, 2003).

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[1] coastal waters extending to 12 nautical miles from the baseline of a coastal state/ sovereign territory of the state

[2] Sea zone over which a country has special rights (jurisdiction) over the exploration and use of marine natural resources, 200nm from the baseline

They also facilitate growth of mangrove forests (Robertson and Duke, 1987) which are nursery grounds for shrimps. The estimated area of mangrove forests in coastal Tanzania is about 115,901ha (Semesi, 1992, Francis and Bryceson, 2000).

1.3 Development 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 (Chando, 2005) using R/V 'Manihine'. During this period, the emphasis was on taxonomy rather than assessment of the stock (Iversen et al., 1984). In the late 1960s, a Japanese firm known as Mwananchi Ocean Products (MOP) entered into the fishery with R/V 'Sagama Maru' belonging to the Kanagawa Prefectural Government in Japan (Mwamoto, 1990, Rumisha and Sanders, 1990). However this company collapsed by early 1970's. By the year 1974 the Government of Tanzania established a parastatal organization known as Tanzania Fishing Cooperation (TAFICO) for the purpose of promoting the prawn fishing industry. During that period, *Penaeus indicus* and *Penaeus monodon* were the main targets. In 1999 the company was officially closed due to poor administration, poor maintenance of boats and financial losses (SUNDAY-NEWS, 2011).

The commercial prawn fishery became more intensive after implementation of liberalisation policy[3] in 1987 when foreign vessels from Kenya and Greece were licensed to the fishery up until 2003 when a maximum number of 26 vessels were reached (Abdallah, 2004). During this period, most of the foreign trawlers that were registered in Tanzania were marketing their products to Europe. Trawlers with factory shore frozen products went directly to Portugal, England, Spain, Belgium and Holland, Greek registered trawlers were transporting to Greece (Gibbon, 1997).

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[3] Relaxation of political and economical laws restriction by the Government to private institutions frame work in mid 1980's

1.4 Categories of Prawn fishers in Tanzania

The Tanzanian prawn fishery comprises artisanal and commercial fisheries. The former deploy simple fishing gears i.e. locally made Stake traps (semi-permanent "V" shaped traps), boat-seines and drift nets commonly used in Rufiji, set gill-nets, Cast nets mainly in protected bays and river mouths, Beach seines and Lift nets mainly in Pemba (Mahongo and Medard, 1995, Haule, 2001) and operate very close to the shore. Rectangular net pieces (*chandoma*s) are used by old women for beach-seining of small prawns in Rufiji and Saadani which are then smoked or sun-dried to cater for the local market (Mahongo and Medard, 1995). Commercial fishers use double-rigged side trawlers fitted with one net on each outrigger boom.

1.5 Fishery conflicts

Commercial fishers, artisanal fishers, environmentalists and the resource managers always enter into conflicts due to resource use either directly or indirectly. Some of these conflicts are due to damage to artisanal nets done by trawlers when operating very close 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 (Mahongo and Medard, 1995, Fennessy et al., 2008).

2 LITERATURE REVIEW

2.1 Shrimp life cycle (Biology)

Prawns are short lived species with a life cycle of 12 to 18 months (Gulland and Rothschild, 1984, 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 (Fig 1). 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 (Rothlisberg et al., 1983). In nursery they spend three to four months (Garcia and Re Reste, 1981) and grow to juvenile stages, while the adults migrate back to the open sea for spawning (Ulltang et al., 1980).

In Tanzania, shrimp spawning peak is mainly seasonal (Bwathondi et al., 2002). Spawning migration to the open sea begins during the short rain season which runs from October to December (Mwakosya, 2004), spawning peak in January to March and new recruits (first adult-like form) appear in the coastal waters from February to May (Nhwani et al., 1993). The new recruits appearing in February are those spawned in early spawning period. Adults and pre-adults are found in large numbers along the coast during the heavy rain season between March and May. Large population of juvenile prawns are recruited to the fishable areas due to increased lower salinity in estuaries (Teikwa and Mgaya, 2003). The post-larvae of *Penaeus latisulcatus* and *Penaeus indicus* at Chwaka bay in Zanzibar have maximum influx from spawning areas to protected bays and estuaries (nursery area) in February to March (Subramaniam, 1990). Their dominance in nursery areas shows difference in preference with bottom substrate. *Penaeus indicus* is more abundant in muddy and mangrove sheltered bays while *Penaeus latislucatus* is more on sand flats with rich growth of sea grasses (Subramaniam, 1990).

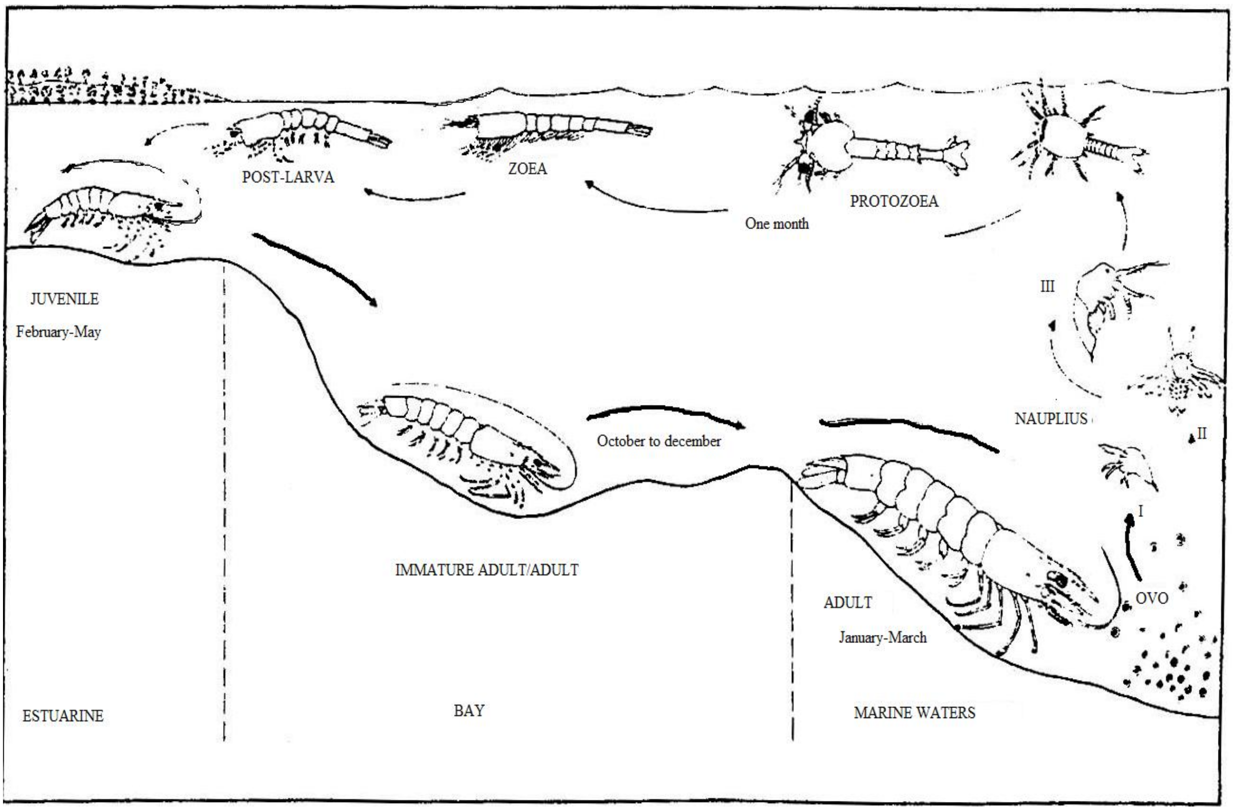


Fig 1: Life cycle of shallow water prawns/penaeids of Tanzania (modified from Ulltang et al., 1980).

2.2 Prawn species composition and distribution

There are about 318 species of prawns in the world (Yap et al., 1979). Eleven of them have been identified in the Tanzanian marine waters as shown in Table 1 below.

Table 1; Prawn species composition in the Tanzanian marine waters

No	Scientific name	Common name
1	*Penaeus (Fenneropenaeus) indicus*	White prawn
2	*Metapenaeus monoceros*	Brown prawn
3	*Panaeus semisulcatus*	Tiger prawn
4	*Penaeus monodon*	Giant prawn
5	*Penaeus (Marsupenaeus) japonicus*	Flower prawn
6	*Exhippolysmata ensirostris*	Hunter shrimp
7	*Macrobranchium rude*	Hairy river prawn
8	*Nematopalaemon tenuipes*	Spider prawn
9	*Metapenaeus stebbingi*	Peregrine Shrimp
10	*Penaeus (Melicertus) canalculatus*	Witch prawn
11	*Penaeus (Melicertus) latisulcatus*	Western king prawn

Source: Proposal for assessment of the effectiveness of closure of commercial prawn trawling in Tanzania (Mwakosya et al., 2009)

Only the first five prawn species are dominant in the region with economical value (Bwathondi et al., 2002, Mwakosya, 2004 , Chando, 2005). Results from various dermersal trawl surveys done in Tanzania have shown dominance of small fin-fish species in all prawn fishing zones (Table 6). Most dominant fish species that have been found in shallow coastal waters of less that 20m depth are Leiognathidae (*Leiognathus leusiscus, Leiognathus equulus, Leiognathus fasciatus, Secutor insidiator* and *Gazza minuta)*, Sardinella (*Sardinella sirm, S. gibbosa, S. albella, and S. leiogaster)* and scads *(Decapterus maruadsi, D. macrosoma, Alute mate)* (Bwathondi et al., 2002, Mwakosya, 2004 , Iversen et al., 1984). With regard to prawns, *Penaeus indicus* has been the most dominant in all fishing zones of Tanzanian constituting almost 60% of the total prawn catches (Teikwa and Mgaya, 2003, Mwakosya, 2004).

Table 2: Percentage prawn species composition and distribution in the region

Fishing ground	*P. indicus*	*M. moroceros*	*P. semisulcatus*	*P. monodon*	Reference
Bagamoyo	50	31	19	-	(Mwakosya, 2004)
	50	-	-	50	(Teikwa and Mgaya, 2003)
	16	37	47	0.2	(Bwathondi et al., 2002)
Kisiju/Rufiji	81	3	8	4	(Mwakosya, 2004)
	36	58	5	0.5	(Bwathondi et al., 2002)

2.3 Fishing effort and prawn catches.

In the shallow water shrimp fishery of mainland Tanzania, there has been a tendency of increasing effort (vessels and fishing days) and corresponding increase in prawn catches. For example, from 13 fishing vessels with 650 tones of prawn catch in 1988 to 25 vessels with 1320 tons of shrimps catch in 2003 (Table 3). Increase in fishing pressure by number of trawlers and fishing days in the near shore was due to prawn export value (Ngusaru, 2000). In 1992 after a trawl survey on prawn catches, TAFIRI made recommendations in a report submitted to the Fisheries Division to reduce fishing effort from 14 vessels to 8 vessels of 500Hp and 800 fishing days from 1560 fishing days after evident declining CPUE (Wilson, 2004, Bwathondi et al., 2002). This decision of reducing effort was never implemented (Wilson, 2004) and effort continued to increase until the end of 2004 when some of industrial fishers voluntarily ceased fishing on account of low CPUE.

Table 3: Number of registered prawn trawlers in Mainland Tanzania and Total annual landings from the year 1988-2007

Year	Number of shrimp trawlers	Number of Fishing days	Shrimp Catch (in Kg)
1988	13	1,476	650,929
1989	13	2,166	688,837
1990	9	1,574	960,686
1991	13	1,315	669,016
1992	15	1,560	663,852
1993	10	1,462	597,211
1994	16	2,513	1,014,087
1995	18	2,108	795,436
1996	12	1,779	769,651
1997	16	2,091	699,059
1998	17	2,778	995,564
1999	17	2,252	688,006
2000	20	3,352	909,715
2001	20	3,882	1,193,685
2002	23	2,521	926,079
2003	25	3,664	1,320,056
2004	25	3,037	661,062
2005	14	1,528	467,037
2006	13	1,082	312,076
2007	10	666	202,455

Source: Annual Statistics, Department of Fisheries, Ministry of Livestock Development and Fisheries. Tanzania

2.4 By-catch

Most countries use by-catch[4]as source of fishmeal and oil. Others process into different forms like sausages, fish fingers, fish paste etc. Global discard[5] has drastically been reduced from 27 million metric tonnes in the 1990s (Alverson et al., 1994) to 7.3 million metric tonnes for total recorded landings of 78.4 million metric tonnes (Kelleher, 2004). Tropical shrimp trawl fisheries alone account for over 27 percent of the total estimated discards at sea (Kelleher, 2004, Zeller and Pauly, 2005). In the Western Indian Ocean (WIO region), annual discards at sea is estimated at 80 000 - 100 000 tonnes with total landing of around 24 000tonnes per annum (Fennessy et al., 2004).

Most prawns fishing vessels in Tanzania lacks sufficient storage facilities particularly in periods of high prawn catches where attention is focused on prawns rather than finfish which are mostly discarded at sea. In periods of low prawn catches, subsequent amount of by-catch is preserved onboard for local markets (Nkondokaya, 1992). Due to small mesh size of the trawl gears used for prawn fishery (40 to 45mm) and higher prices on prawn compared to other small tropical fishes in Tanzania, discards at sea by fishing companies are quite significant (Nkondokaya, 1992, Mahika, 1992). Most of the species that are caught as by-catch and are then discarded include; *Pellona ditchela, Leiognathus equulus Pomadasys stridens, Pelates quadrilineatus, Leiognathus leusiscus, Leiognathus fasciatus, Secutor insidiator* and *Gazza minuta* (Iversen et al., 1984, Bwathondi et al., 2002, Mwakosya, 2004). These fishes that are discarded simply because of their low export market value are in high demand by local communities as food (Nkondokaya, 1992).

[4] By-catch is unwanted portion of the catch taken while fishing for specific targeted species, it comprises discard
[5] Discard is the portion of the by-catch that is thrown in the sea

Table 4: Number of species by-catch in prawn fishery along coastal Tanzania

No	Number of by-catch species	Zones covered	Period covered (in months)	Reference
1	87	Zone 1 and 2	2	(Mwakosya, 2004)
2	108	Zone 1 and 2	6	(Bwathondi et al., 2002)
3	79	Zone 2	10	(Nhwani et al., 1993)
4	46	Zone 1 and 2	4	(Nkondokaya, 1992)
5	62	Zone 1	2	(Mahika, 1992)

2.5 Seasonality, weather patterns and catches.

In tropical areas, prawn catches are mostly associated with increased river run off. For example, rainfall in the Zambezi river influences recruitment to offshore fishery due to decreased salinity in the estuaries, causing large populations of juvenile prawns to be recruited to the fishable area (Gammelsrød, 1992).

Wind speed and direction influence ocean currents which may have significant effect on dispersal of larvae and success of post larvae recruitment into the fishery as has been observed in the Gulf of Mexico (Vance, 1985).

Temperature influences spawning activity, survival of larvae offshore and settlement of post larvae inshore. Temperature has been related with prawn catches in Gulf of Mexico (Vance, 1985) and has shown positive relation with densities of juvenile *P. indicus* and *M. stebbingi* in Mozambique from January to June with water temperature variation of 13°C (18°C and 31 °C) (Macia, 2004). In coastal mainland Tanzania, this effect may be important but has not been studied as in Mozambique.

Rainfall along coastal Tanzania occurs during the interchanging monsoons, which are mainly Northeast monsoon (*Kaskazi*) from October to March and Southeast monsoon (*Kusi*) from March to October. Southeast monsoon is associated with low air temperatures and solar insulation, strong winds and rough sea, high cloud cover, terrestrial run off and discharge, while the northeast monsoon has warmer air temperature, lower wind speed and calm sea (McClanahan, 1988). All major rivers in coastal Tanzania discharge water into the Indian Ocean causing coastal water to become less saline during southeast monsoon due to heavy rains occurring in March and May. These periods of heavy rainfall coincides with high prawn catches in Tanzania (Mwakosya, 2004 , Semesi et al., 1998, Teikwa and Mgaya, 2003).

2.6 Sustainability of the prawn fishery in Tanzania (MSY)

Tanzanian prawn stock size has been studied and maximum sustainable yields (MSY[6]) have been established using Fox model from early 1970's to 2002 as illustrated below.

Table 5: estimated MSY for different years in the Tanzanian coastal waters

Year	Method	MSY (metric tonnes)	Reference
1977	Fox model	2000	(FAO/IOP, 1979)
1982	Fox model	1000	(Iversen et al., 1984)
1990	Unknown	1050	(Mushi and Kalikela, 2002)
2002	Fox model	827	(Bwathondi et al., 2002)

Over past three decades since 1970s, there have been progressive declines of the mean biomass values and MSY with time (Table 6). The decline may have been caused by changes in the environment such as reduced freshwater discharge causing lower carrying capacity. This means that the underlying assumptions of steady state in the calculation of MSY values have not been present. The roughly fitted Schaefer model (Fig 2) on the shrimp catch and effort has shown no sign of biological overfishing under steady state assumptions, contrary to what has been reported in the previous surveys (Bwathondi et al., 2002, Mwakosya, 2004). There are no observations on the descending part of the curve, which would have been the definition of overfishing under steady state (Fig 2).

[6] Largest catch that can be taken from the fishery over many years without causing the population to collapse (Jennings et al., 2001)

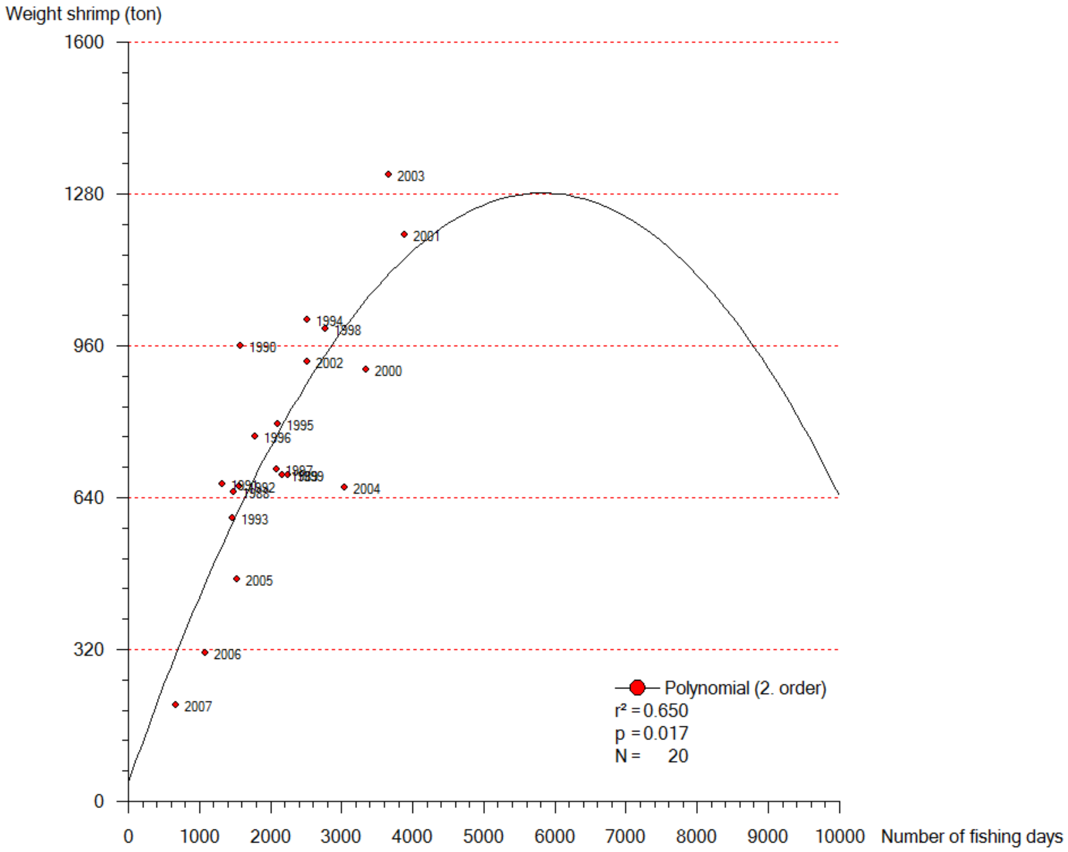


Fig 2: Yield (shrimp catch) versus effort (number of fishing days) from 1988 to 2007. Superimposed with a 2nd order polynomial (Schaefer model).

Table 6: Changes of mean biomass with time from different surveys in different zones

Year	Study	Objective	MSY (Mt) (Fox model)	Mean Biomass (Mt)	Reference
1988	Stock assessment	Preliminary assessment of shallow water shrimp fishery of Tanzania	740 at Rufiji and 297 in Bagamoyo	594 at Rufiji	(Sanders, 1989)
1992	Stock assessment	Assessment on the Crustaceans resource of the Rufiji-Mafia channel	543.5 at Rufiji	369 at Rufiji	(Nhwani et al., 1993)
2001	Stock assessment	Prawn abundance and distribution in the Bagamoyo and Rufiji delta	189.47 at Bagamoyo and 638.3 at Rufiji	41.66 at Bagamoyo 279.91 Rufiji	(Bwathondi et al., 2002)
2003	Stock assessment	Assessment of Tanzanian prawn fishery resources		19 at Bagamoyo and 95.5 at Rufiji	(Mwakosya, 2004)

2.7 Management measures

Management measures and policies have been formulated and enforced by the Fisheries Division from early 1987 after Liberalisation Policy to ensure sustainable harvest of the prawns (MNRT, 1997). Input management measures were introduced to control the level of effort through restrictions on fishing power, vessel licenses, fishing time, gross registered tonnage (upper limit 150GRT), closed season and introduction of vessel observers.

Table 7: Management measures established in Tanzania to prawns fishery

	Management masures	Year of establishment
1	Registration fees and Fishing license	1987
2	Vessel observer	1987
3	Fishing zones and rotational fishing	1988
4	Fishing time	1990
5	Fishing seasons	1990
6	Vessel capacity	1997
7	Fishery closed	2007

2.8 Registration fees and Fishing license

This regulation was passed in 1987 where all vessels were to be registered for the first time by the Fisheries Division in Tanzania before being licensed for fishing. Registration fees were based on gross registered tonnage, flagship and shore infrastructure 'land processing facility' (Wilson, 2004). For example, vessels registered in Tanzania with land processing facility were charged USD 2.4/GRT for fishing and fishing vessel licence while vessels without land processing facility were charged USD 108/GRT for fishing and 162/GRT for fishing vessel licence (Wilson, 2004). Fishing licence was paid annually and it was mainly meant to track the number of active vessels that were involved in fishing. Together, registration fees and fishing licences were ways of collecting Government revenue.

2.9 Vessel observers

This measure was introduced in 1987 with objectives of resolving the conflicts between industrial and artisanal fishers concerning industrial fishing activities near shore, and to ensure that all regulations were followed. Observers from the Fisheries Division were supposed to be onboard in each of the fishing vessel licensed to the fishery, but due to lack of financial support, the Fisheries Division opted to deploy only one or two observers to monitor all fishing activities of all vessels in the fishing zone (Haule, 2001).

2.10 Establishment of Fishing zones and rotational fishing.

This regulation was established in 1988, one year after the Government had allowed several foreign vessels from Kenya to be licensed to the prawn fishery. The Government through Fisheries Division introduced rotational trawling (Fixed number of vessels per fishing Zone per season and alternation in subsequent season) to ensure that effort is not concentrated in one fishing Zone (Haule, 2001). Before this regulation, most of the Kenyan fishing vessels were concentrated in Zone 2 (Kisiju and Rufiji) where high catch rates were obtained (Nkondokaya, 1992). The rotational system was also intended to encourage fishing vessels to search for new grounds and minimize conflicts among trawl operating companies and between these companies and artisanal fishermen (Mongi, 1990). However the problems still existed between industrial and artisanal fishermen. To resolve this problem, regulation of fishing time was introduced.

2.11 Fishing time

This regulation was established to resolve the conflict between Industrial and artisanal fishermen. It was initiated in 1990 to restrict industrial trawlers from fishing at night and allowing artisanal fishers set their nets at night and haul at dawn (Haule, 2001). During day time (06:00am to 06:00Pm) artisanal and industrial fishers were both fishing together because captain could see set nets. This regulation reduced fishing time for industrial fisherman from 24 hours in a day to 12 hours (Haule, 2001).

2.12 Fishing seasons

Fishing seasons were established in 1990 to protect immature shrimps. The season was being opened for seven months from March to September for Industrial fishers. This was necessary because data collected by TAFIRI showed higher prawn juveniles in catches from November to March. In 1992 after TAFIRI has carried out another trawl survey, 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 survey (Bwathondi et al., 2002). However, this recommendation was never implemented.

2.13 Vessel capacity

Regulation on fishing vessel capacity was introduced in 1997 to prohibit vessels with engine capacity of more than 500Hp from fishing (Haule, 2001). This was successful because only vessels with less than 500Hp were allowed to fish from 1997 (Wilson, 2004)

2.14 Statement of the problem

Several studies on prawn stock size and distribution have been conducted since 1970’s (Table 5 and Table 6) and fisheries regulations have been in place since 1987, but prawn stock size has been fluctuating over time. However, variation in stock size with long term environmental changes has never been studied in coastal Tanzania. Long term changes in the environment can influence the stock size and distribution of the prawn stocks. In Mozambique for example, Zambezi river runoff influences recruitment to offshore fishery (Gammelsrød, 1992). This study was intended to find out the cause of the fluctuation of the Tanzanian prawn stock size, whether it is attributed to fishing pressure or environmental factors. Using the 2009 trawl survey data, the study focused to explore improvement (if any) in the stock size since the closure of the prawn fishery in 2008.

2.15 Objective of this study

The main objective of this work was to review the prawn fishery of Tanzania.

Specific objectives;

- To estimate prawn biomass in Tanzanian coastal waters using fisheries independent data (trawl survey 2009).
- To determine catch rates (catch per hour) in all fishing Zones covered in the trawl survey of 2009.
- To determine variation in prawn species composition in all fishing zones (2009 trawl survey).
- To determine the magnitude of fish by-catch in 2009 shrimp trawl survey.
- To determine long term variation of prawn abundance to river discharge (environment) for the past two decades.

3 MATERIALS AND METHODS

3.1 Study area

The survey of 2009 covered Tanzanian coastal mainland from Zone 1 to Zone 3 as shown in the table below.

Table 8: Fishing Zones of mainland Tanzania

	Name	Geographical Location (Longitude/Latitude)
Zone 1	Bagamoyo & Sadani fishing grounds	$05^o25'$S, 039^oE to $06^o30'$S, 039^oE
Zone 2	Kisiju (Mafia channel and Rufiji delta)	$06^o30'$S, 039^oE to 08^oS, 039^oE
Zone 3	Kilwa (Jaja and Kilwa)	08^oS, 039^oE to 10^oS, 039^oE

Fig 3 shows the location of the prawn fishery Zones. Zone 1 receives fresh water from three main rivers; Ruvu, Wami and Pangani. It is the least productive zone by area contributing about 25% of the total annual prawn catches (Mhitu and Mwakosya, 2008). Dominant prawn species at Zone 1 are *Penaeus indicus* and *Metapenaeus monoceros.* Zone 2 receives fresh water from Rufiji River. It is the most productive fishing Zone by area contributing about 45% of the total annual prawn catches. Dominant prawn species in this Zone are *Metapenaeus monoceros* and *Penaeus indicus* (Mhitu and Mwakosya, 2008). Zone 3 is the second most productive by area contributing about 30% of the total annual prawn catches (Mhitu and Mwakosya, 2008). Dominant prawn species in this zone are *Metapenaeus monoceros*, *Penaeus semisulcatus* and *Penaeus indicus*.

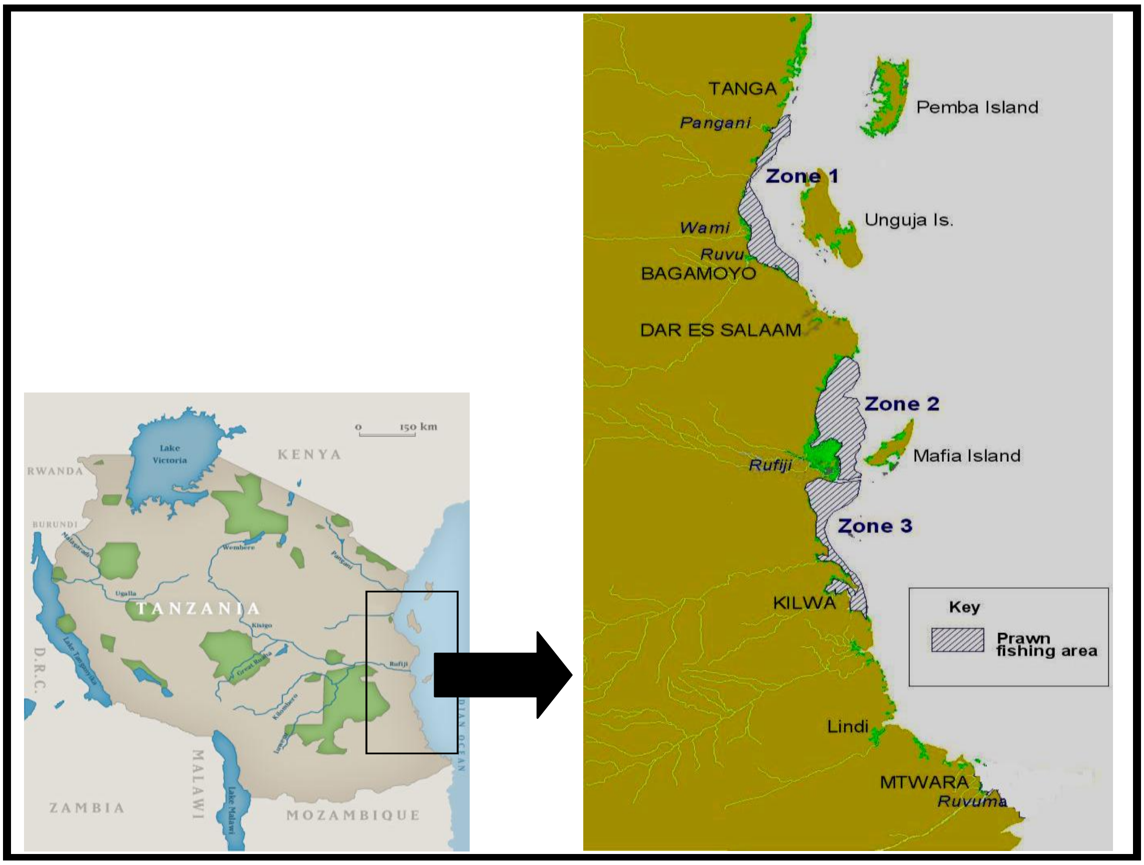


Fig 3: Prawns fishing zones of Tanzania (*Source: IMS database 2010*)

3.2 Vessel and gear specification

Sampling was carried out in 2009 using two hired commercial trawlers, MFV Helena and MFV Serena. All vessels were double- rigged side trawlers fitted with one net on each side of the outrigger boom, tickler chain was incorporated during operation of those vessels.

Table 9: Specification of fishing vessels and gears used in 2009 trawl survey

	MFV Helena	MFV Serena
Size LOA (m)	23	23
Engine power (HP)	295	365
Capacity (GRT)	92	94
Code end mesh size (mm)	45	50

3.3 Sample Collection

During fishing the trawling speed was maintained at 3 knots and average trawling time per haul was two hours. Fishing was carried in daytime from 6.00 AM to 6.00 PM according to the government regulation (Haule, 2001). A total of 106 hauls were made in the survey, 33 in Zone 1, 47 in Zone 2 and 26 in Zone 3 (Appendix 2). About four hauls were made per day and samples were taken randomly in each haul. When the catch was brought on board, sorting was done by first removing all large sized fishes, and from whole catch, a sub-sample was taken which incorporated small fish and prawns. When the catch was small, the whole catch was used as a sample without fraction (Ratio of total catch to sample). Prawns from the sample total weight was measured and then sorted to species level. Prawn's individuals from each species weight (± 0.1g), total length (± 0.1 cm), carapace length (± 0.1 cm), sex, maturity stage (for females) were also recorded. The fish were sorted and identification was done up to species or family level (Bianchi, 1985, Fischer and Whitehead, 1974). 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, towing duration, fish weight and type of species (Annex 1).

3.4 Industrial fisheries catch and effort data

The Fisheries Division is a government organ responsible for collection of monthly catch data from industrial fishers (prawn fishery inclusive). The output from industrial fishery data is not species specific due to multispecies nature of the tropics. Only major groups of fishes are recoded e.g. all prawn species together as one group and finfish second group (Appendix 1).

3.5 Data analysis

Biomass estimation, catch rates, and other parameters were analysed in Pasgear II (Kolding and Skålevik, 2009) and all relationships were taken at significant level less than 0.05 ($p < 0.05$). All regressions were made in STATISTICA package.

3.6 Biomass estimation

Biomass has been estimated by using swept area method (Sparre and Venema, 1998) in Pasgear II (Kolding and Skålevik, 2009).

$$B = \frac{\overline{Cw/a}}{q} * A$$ Where

Cw = catch weight (Kg)

A = Total area under investigation (nm^2)

a =Area swept by the trawl (nm^2)

q = Catch ability coefficient

Area swept by the trawl was calculated as

a = **D** * **h** ***X2** where **D** = **V** * **t**

D = Distance trawled (nm)

h = Head rope length (m)

t = Time of trawling (hr)

V = Velocity of the trawl (nm/hr)

X2 =Fraction of the head rope length (X2=1), this has been used so as to compare with previous surveys which used the same value (Bwathondi et al., 2002, Mwakosya, 2004 , Nhwani et al., 1993).

This method estimates total biomass from area swept by the trawl, with some crucial assumptions.

- The bridles had no herding effects which in fact they are known to exhibit (Sparre and Venema, 1998).

- Wing spread was assumed to be constant (X2*h) while it is usually known that it changes with trawling speed, warp length and current velocity.

- 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.

  The total fishing area under investigation for Bagamoyo was $138.3nm^2$ and $888.9nm^2$ for Rufiji (Nhwani et al., 1993, Bwathondi et al., 2002, Mwakosya, 2004)

3.7 Confidence limits

The estimate of the standard error for each stratum mean is given by (Cochran, 1977)

$$se(\bar{y}_i) = \sqrt{\frac{s_i^2}{n_i}},$$

Where s_i^2 is from $s_i^2 = \frac{\sum_{k=1}^{n_i}(y_{i,k} - \bar{y}_i)^2}{n_i - 1}$

The standard error of the stratified mean ($\bar{y}_{st}$,), i.e. the square root of the variance of $\bar{y}_{st}$, is calculated as

$$se(\bar{y}_{st}) = \sqrt{\mathrm{var}(\bar{y}_{st})},$$

Where $\mathrm{var}(\bar{y}_{st})$ is defined by $\mathrm{var}(\bar{y}_{st}) = \sum_{i=1}^{L} W_i^2 \frac{s_i^2}{n_i}$

If the sample size is "large" enough, then the Central Limit Theorem states that each time a survey is conducted there is a 95% chance that the true mean lies in the interval (Cochran, 1977)

$$\bar{y}_{st} \pm t_{(n-1)} se(\bar{y}_{st}),$$

Where *t* is from Students t-table with (n-1) degrees of freedom and α = 0.025.

4 RESULTS.

4.1 Species Composition

Five prawn species *Penaeus indicus, Metapenaeus monoceros, Penaeus semislucatus, Penaeus monodon* and *Panaeus japonicas* were encountered in 2009 survey as shown in Fig 4. A total of 113 by-catch fish species were recorded in 2009 survey. Species composition by number of all by-catch species with percentage more than 1 are shown in Appendix 5. Most dominant species above 10% by number in Zone 1 was *Pellona ditchela.* Zone 2 *Johnius sina*, *Leiognathus equulus* and *Pellona ditchela* and Zone 3 *Gazza minuta* and *Pomadasys stridens*.

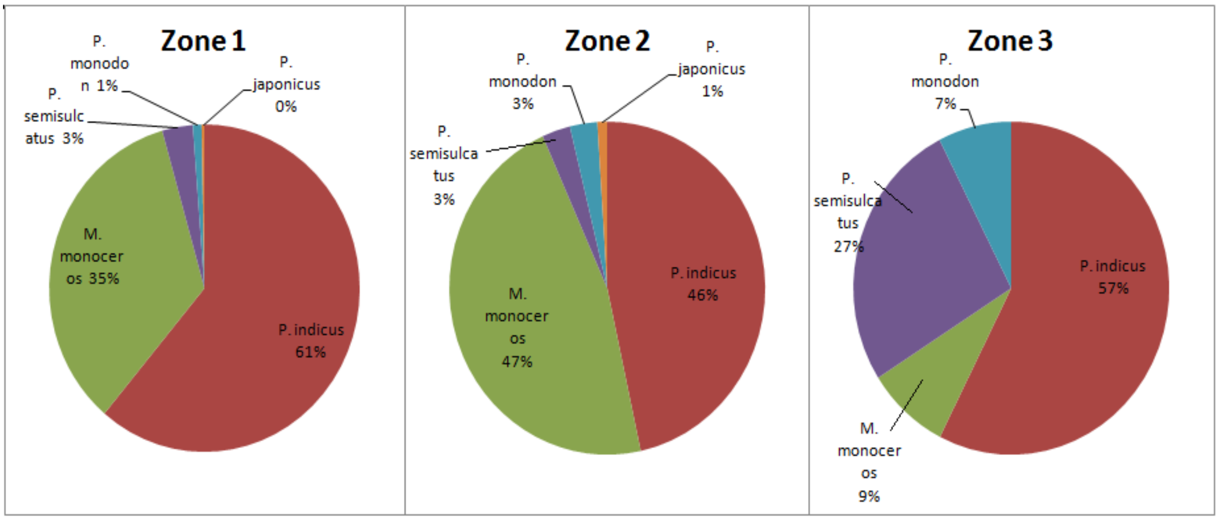


Fig 4: Percent composition of prawn species by number of the trawl catches in 3 fishing Zones of Tanzania, computed from the 2009 trawl survey data.

4.2 Biomass estimates

There have been a declining trend in prawn MSY and mean biomass in coastal Tanzania from 1977 to 2004 as shown below (Fig 5). Results of the 2009 survey showed improvement in stock biomass from 114 tonnes in 2004 to 355 tonnes in 2009, i.e. from 19 to 89 tonnes at Zone 1 and 95 to 266 tonnes at Zone 2. The same survey showed more prawn biomass by area at Zone 2 (Table 10) and more than 50% of all prawn biomass at this Zone was contributed by *P. indicus.*

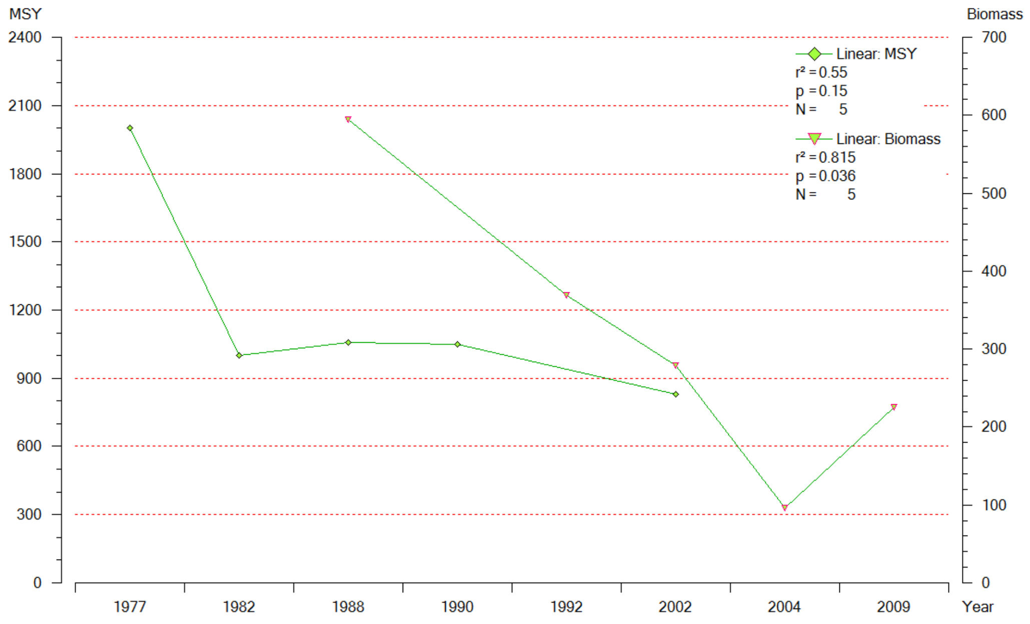


Fig 5: Trend in mean biomass at Zone 2 and MSY of coastal Tanzania (Zone 1 and 2) from 1977 to 2009.

Table 10: Biomass of Prawn species in two fishing Zones of Tanzania 2009

Species	**Zone 1 (tonnes)**	**Zone 2 (tonnes)**	**Total biomass (tonnes)**	**Confidence limit**
P. Indicus	27	146		
P. Semisulcatus	42	8		
M. Monoceros	16	75		
P. Monodon	3	34		
P. Japonicus	0.4	4		
Total	89	266	355	244 to 466

4.3 Species by-catch

Estimated total biomass by swept area method of all by-catch species at Zone 1 was 484 tonnes and 2,027 tonnes at Zone 2, while total biomass of prawns at Zone 1 was 89 tonnes and 266 tonnes at Zone 2. These results suggest that, catching 1 Kg of prawn would correspond to 5 Kg of by-catch at Zone 1 and 8 kg of by-catch at zone 2.

4.4 Survey catch per unit effort (CPUE)

In the 2009 survey, Zone 1 (Bagamoyo) had higher prawn catch per unit effort than all other zones i.e. 63.5 Kg/hour in Zone 1, 30.4 Kg/hour in Zone 2 (Kisiju) and 14.6 Kg/hour in Zone 3 (Kilwa) Fig 6. In terms of species, *Penaeus indicus* had more catch rate than other prawn species in Zone 2 and 3 while in Zone 1 it was *Penaeus semisulcatus* (Appendix 4).

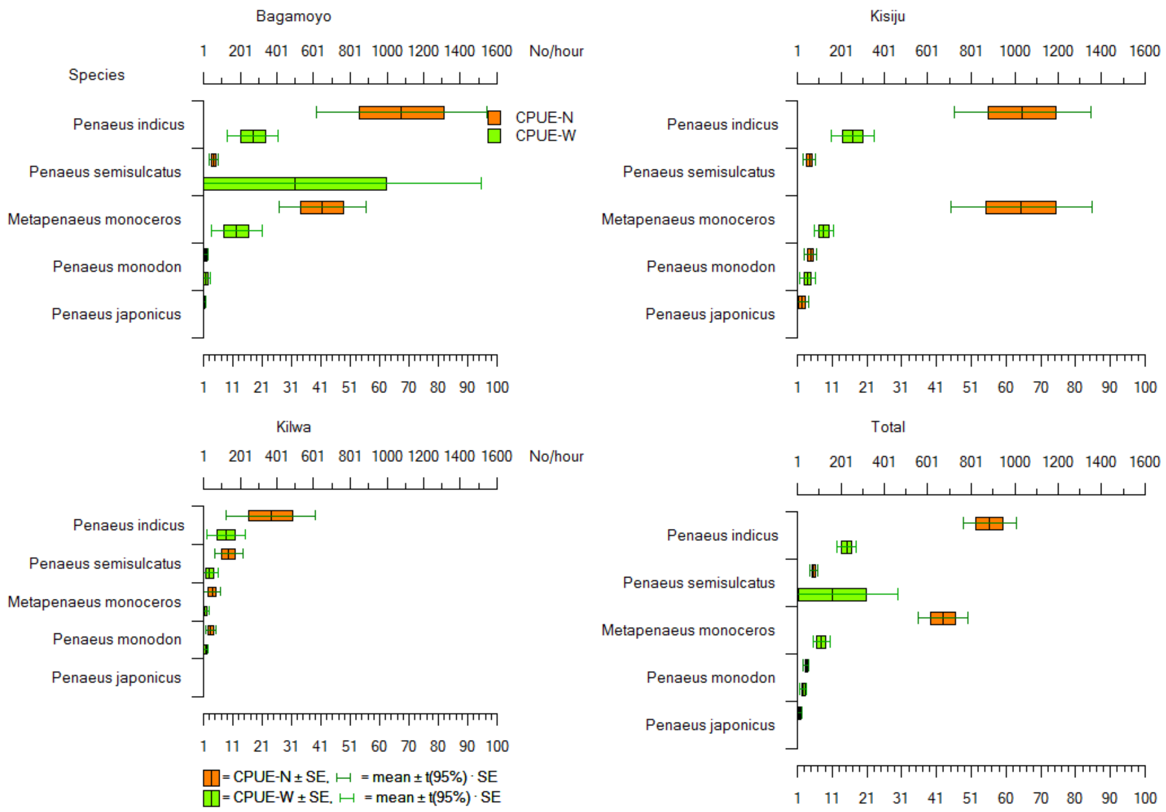


Fig 6: Catch rate (Kg/hour and No/hour) of prawn species by fishing ground from 2009 trawl survey

4.5 Catch by month

There was no significant difference in catch rate (No/hour) by months for survey made in 2009. Observation showed slightly higher catch rate in May than other months surveyed.

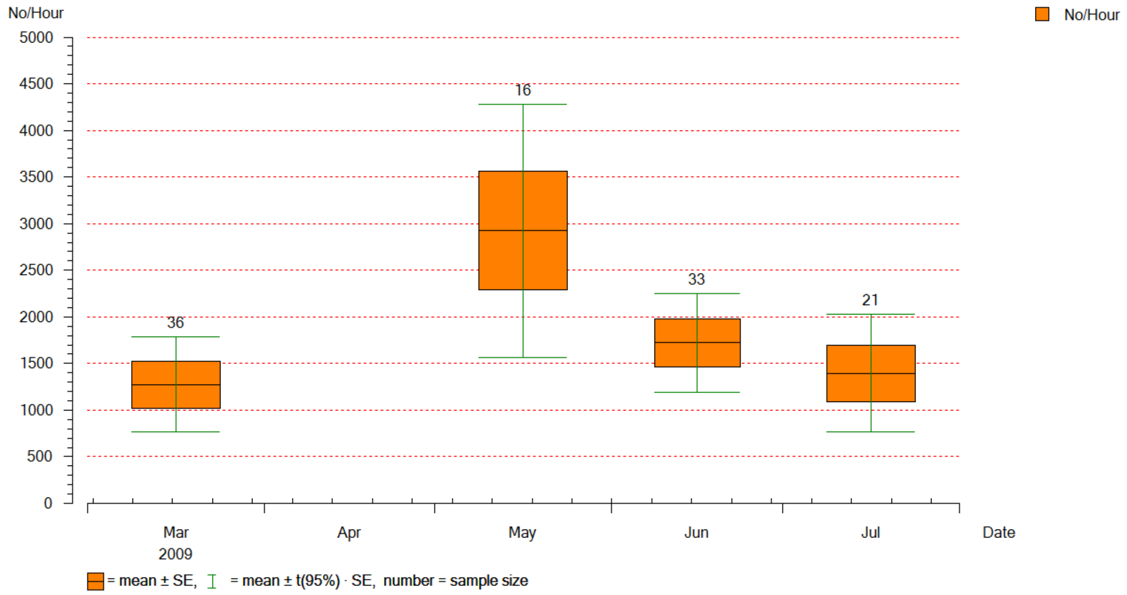


Fig 7: Catch rate (No/hour) by months for the entire sampling period in 2009

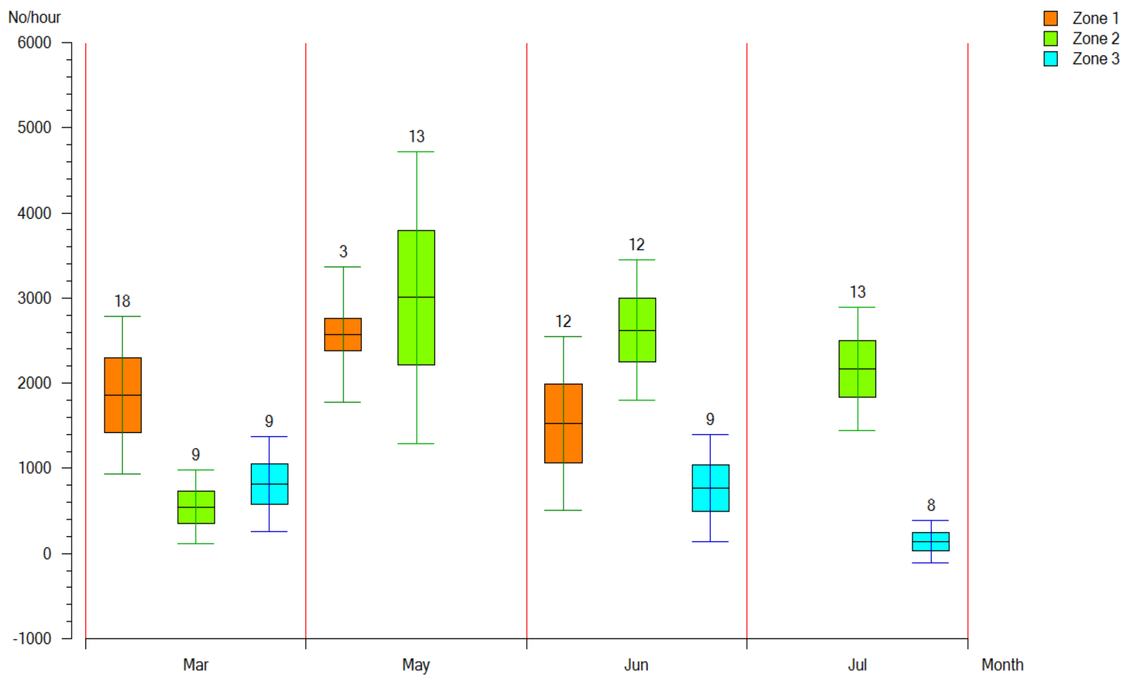
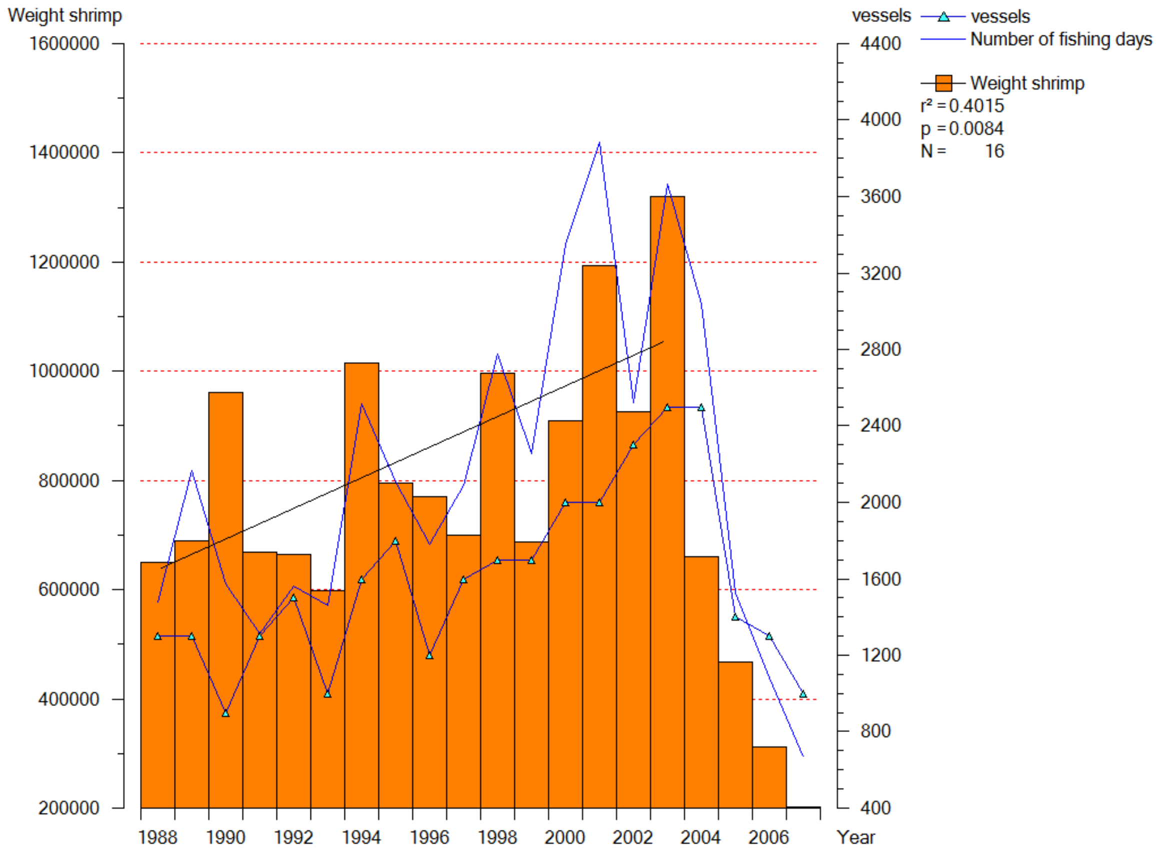


Fig 8: Catch rate (No/hour) by months and Zones for the entire sampling period in 2009

4.6 Industrial Catch and fishing effort

There have been increasing shrimp catches, number of fishing vessels and number of fishing days from early 1980's to 2003 when the maximum number of 23 vessels were reached (Fig 9). After 2004 there was strong drop in prawn catches, number of fishing vessels and number of fishing days. By-catch in the same period was relatively stable (Appendix 3). Regression analysis shows that shrimp catch were significantly associated with fishing effort over time (with number of vessels, R=0.72, P< 0.002, with number of fishing days R=0.89, P<0.0009).



Fishing vessels has been scaled 100 times

Fig 9: Industrial prawn catch and effort over the past 19 years from 1988 to 2007

4.7 Industrial catch per unit effort CPUE

CPUE (annual tonne per boat and tonne/day) has been declining over time since late 1980s (Fig 10). After 2004 there was strong decrease in fishing effort and prawn abundance (Fig 11), while expectation was increased prawn abundance with decreasing effort. This finding suggested that other factors than fishing effort was influencing the decline.

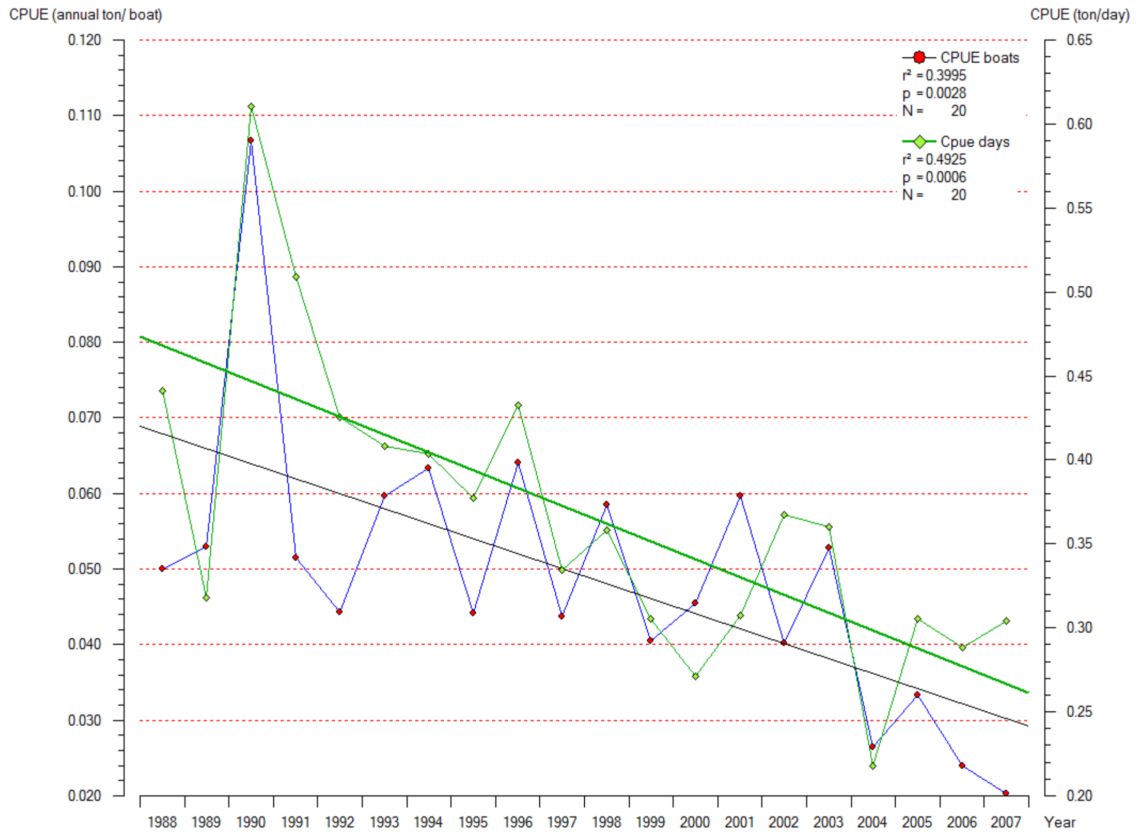


Fig 10: Prawn catch per unit effort over the past 19 years from 1988 to 2007

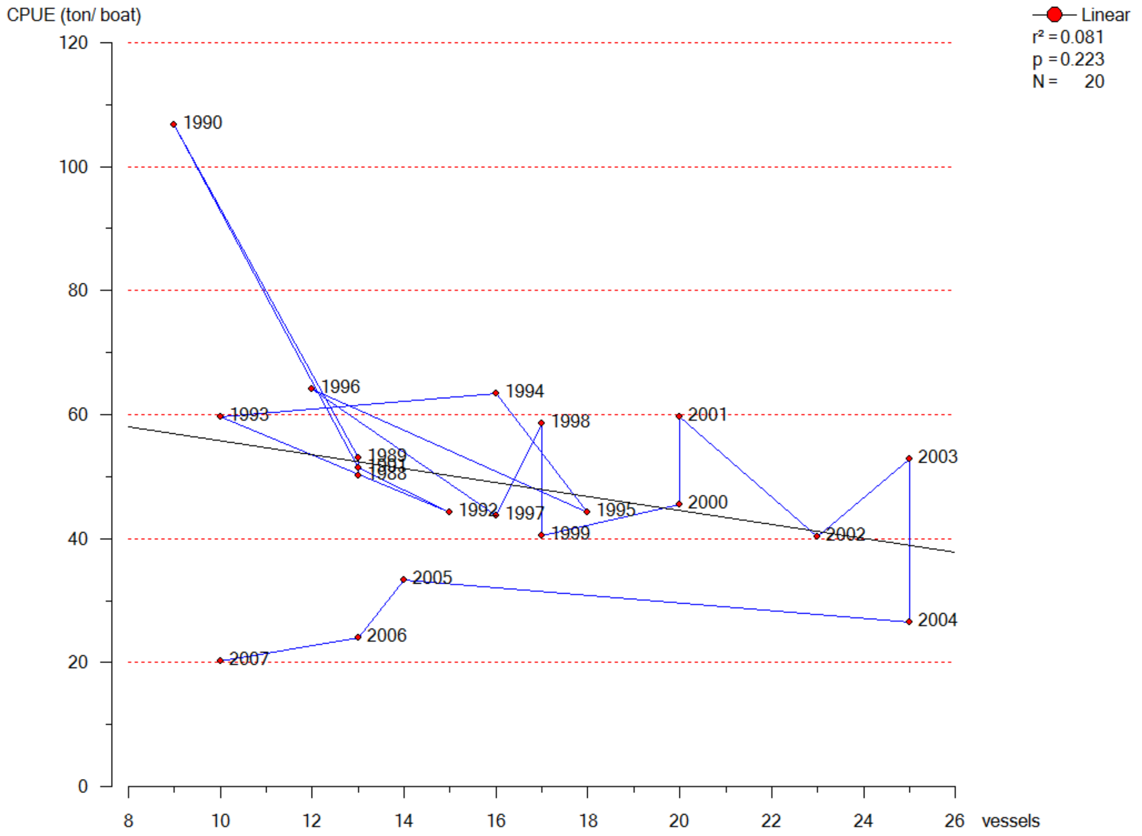


Fig 11: Catch per unit effort (annual ton/boat) versus effort (boat) from fishery development to closure in 2007

4.8 River discharge

In coastal Tanzania, there are six major permanent rivers that drain into the three main fishing Zones. Due to in-accessibility of river discharge data from other rivers, only Pangani river was used and assumed to be representative of all rivers in the region. River discharges from 1981 to 2010 showed a significant declining trend ($p < 0.0001$).

Fig 12: Pangani river discharge data from 1981to 2010

4.9 Industrial CPUE (Kg/day) and river discharge.

Linear regression between industrial CPUE (Kg/day) and mean annual discharge was significant (R=0.56, P<0.05). Multiple regressions of both effort (number of vessels and fishing days) and environment (river discharge) are confounded because they both have the same trend, while simple regressions (one by one) are both significant.

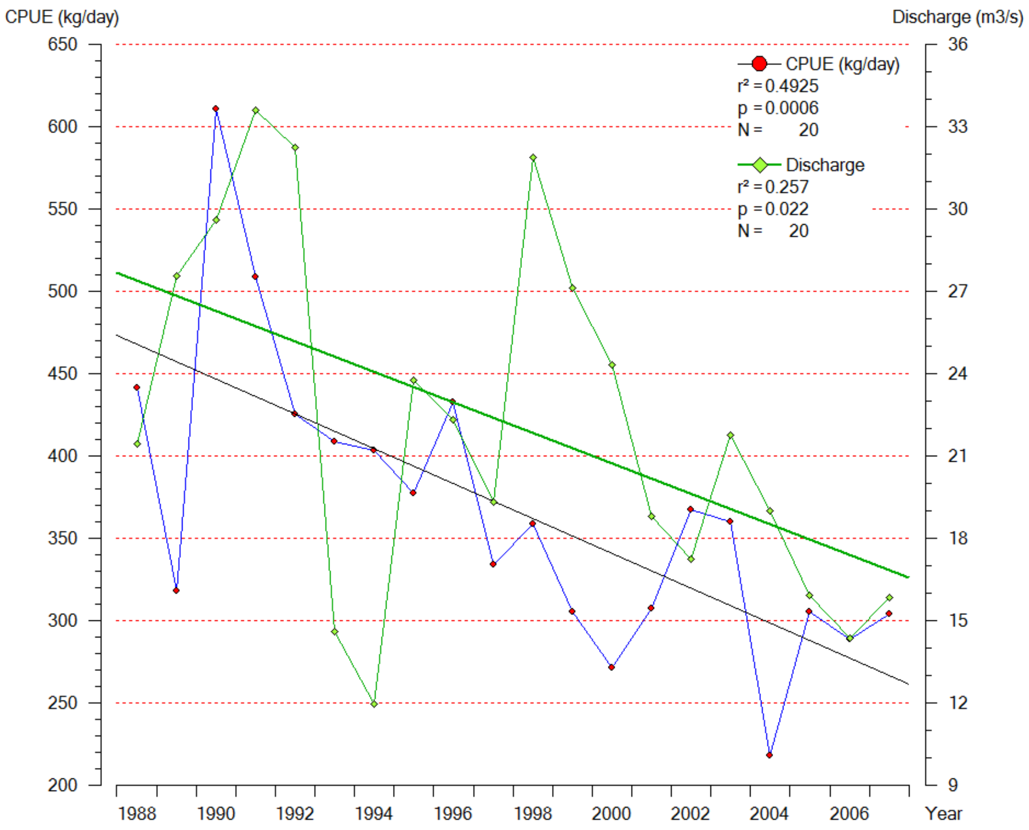


Fig 13: Trend of CPUE (Kg/day) and river discharge from 1988 to 2007

4.10 Representativeness of the Pangani river to Rufiji.

The peak flow of rivers in coastal Tanzania occurs between March and May (Iversen et al., 1984, Bwathondi et al., 2002). Due to in-accessibility of river discharge data from other rivers, available overlapping data range of the Pangani and Rufiji river from 1983 to 1989 has been compared to see if the use of Pangani can be justified. Result showed annual mean discharge of the Pangani and Rufiji rivers from 1983 to 1989 had the same trend (Fig 14) hence these two rivers are somewhat correspondence.

Fig 14: Annual mean discharge of the Pangani river and Rufiji rivers from 1983 to 1989

5 DISCUSSION

5.1 Species composition

Five prawn species *P. indicus, M. monoceros, P. semisulcatus, P. monodon* and *P. japonicas* were encountered in the 2009 survey. *P. indicus* was the most dominant species by number in all the three fishing Zones of Tanzania. At Zone 1 and 2 it was followed by *M. monoceros, P. semisulcatus, P. monodon* and *P. japonicas* while at Zone 3 it was followed by *P. semisulcatus*, *M. monoceros*, and *P. Monodon*. Most of the previous surveys (Table 2) had the same dominance of *P. Indicus* at Zone 1 and 2 while Zone 3 was not covered. The 2001 survey was contrary to all the other surveys by showing dominance of *P. semisulcatus* at Zone 1 (Bwathondi et al., 2002). *P. semisulcatus* is a nocturnal prawn with the tendency of burying itself in the mud, the use of tickler chain when trawling makes it susceptible for the trawl net. Before incorporation of tickler chain in trawls, *P. semisulcatus* was the least abundant prawn species in all the fishing Zones of Tanzania (Bwathondi et al., 2002). In the 2009 survey, tickler chain was used and *P. semisulcatus* was the second dominant prawn species by number at Zone 3 and third in Zone 1 and 2.

P. japonicas was clearly identified in the 2009 survey but was not encountered in previous surveys when industrial fishery was intense. *M. stebbingi* was not encountered at all in the 2009 survey and in the previous surveys but was reported in 2001 (Bwathondi et al., 2002) and is common in our neighbouring country, Mozambique (Macia, 2004). This appearance and disappearance of these species in different surveys may be due to mis-identification of species, difference in sampling period or temperature variation as has been observed in Mozambique. For example in Mozambique, the density of juvenile *P. indicus* was positively related with increased temperature while *P. semisulcatus* was negatively related (Macia, 2004), these differences were due to annual temperature variation. The three prawn species i.e. *M. stebbingi*, *M. monoceros and P. indicus* are distinguished by their serrations on the carapace and colour on the tail. It was possible that during previous surveys these three species were mixed in identification. *P. semisulcatus* and *P. monodon* are large and easy to identify.

Observations made on the 2009 survey and the previous surveys shows that the order of prawn dominance has remained relatively stable since the 2003 trawl survey (Mwakosya, 2004). *P. indicus* is the most dominant species by number of all prawn species from all Zones. The findings of this study complies with previous findings which showed dominance of *P. indicus* by almost half of the total prawn trawl catches in Tanzania (Subramaniam, 1980a), Sofala Bank Zambia (Gammelsrød, 1992) and Malindi-Kenya (Mwatha, 2006).

5.2 Biomass estimates

Despite the fisheries regulations imposed on prawn stock size (Table 7), there have been declining trends in prawn MSY and mean biomass in the coastal regions of Tanzania since early 1970s (Fig 5). This survey like previous ones (Table 6) showed more prawn biomass by area at Zone 2 than 1 (Table 10). This biomass is more than that estimated in 2003 (Mwakosya, 2004) of 19 tonnes in Zone 1 and 96 tonnes in Zone 2. Result of the 2009 survey has shown improvement due to low fishing pressure and more discharge that was observed in 2009 of $21 m^3/s$.

All biomass estimates that has been made in this region from the previous surveys have been under-estimated due to increased effective swept area when deploying swept area method by serious assumption made on head rope length (H) i.e. fraction of the head rope length (X_2) equals to one. This implies that the length of the curved head rope is equivalent to effective length of the head rope ($H*X_2$). Also, this survey used the same assumption for comparative purposes. In the tropical regions, the recommended fraction of the head rope length that should be used in swept area method is 0.5 (Pauly, 1980) which is half the effective swept area that has been in use and doubles the biomass. However, the use of 0.5 as fraction of the head rope length couldn't change the trend of biomass in the region. Despite of all prawn biomass estimates that have been made from previous surveys (Table 6), there have been no output control to the fishery due to multispecies nature of the tropical fishery.

All biomass estimates that have been made in the 2009 survey and the previous surveys come from trawlable areas while other fraction of the prawn biomass is also found in non trawlable areas like fringing reefs and mangrove forests where artisanal fishers operate (Mwakosya et al., 2009).

In Tanzania, *Penaeus indicus* contributed to almost 50% of all prawn biomass in the catch, the same result of higher *P. indicus* by weight with respect to other prawn species was also observed in late 1970's (Subramaniam, 1980a).

5.3 By-catch

A total of 113 by-catch fish species were identified in the 2009 survey. This is the highest amount of by-catch species in the prawn fishery ever reported in Tanzania. There has been fluctuation in the number of by-catch species along the coastal waters of Tanzania as seen in Table 4. Difference in number of species might have been influenced by the sampling period and area covered. For example (Bwathondi et al., 2002) and (Mwakosya, 2004) covered the same Zones but had big difference in numbers of by-catch species due to sampling time. The former covered six months and had 108 by-catch species while the latter covered two months and had 97 species. The survey done in 2009 (after closure in 2008) had more by-catch species by number than all other previous surveys.

The results from this study show a low proportion of shrimp to by-catch in all the Zones. Catch to by-catch ratio was approximately 1:5 at Zone 1 and 1:8 at Zone 2. This observation is contrary to what has been observed when fishing pressure was high, where there were more by-catch at zone 1 than 2 (Nkondokaya, 1992, Bwathondi et al., 2002, Mwakosya, 2004). This by-catch to catch ratio can be reduced if rigid separator grids are deployed when trawling (Mahika, 1992). However mortality rate of escapees, swimming ability differences between shrimps and fishes to rigid separator grids which justifies necessity of rigid separator grids have never been studied in small by-catch species of Tanzania. The use of rigid separator may have severe impacts on the ecology of prawn by allowing more of the prawn predators to dominate in the fishery. Also may deprive society with small fishes that are in high demand and affordable.

Globally, prawn catch to discard ratio is 1:10 (Kelleher, 2004), however in the WIO region annual discard in prawn catch reaches 76% (Fennessy et al., 2004). This corresponds to an average ratio of 1:7 of prawn catch to by-catch in Tanzania.

In countries with food insecurity like Tanzania where small finfish species are preferred in local markets, catching 1kg of prawn and discarding 7kg of other fishes is uneconomical to the society but economical to the industrial fishers. Alternative was to catch small fishes for local market as a target and prawn as by-catch. This could be worth for the society and fisher, but would require larger fishing vessels for valuable prawn by-catch. On the other hand selling fish by-catch at sea (which seems possible as was done in 2009 trawl survey) could increase the return and subsidise the running cost of the prawn fishery.

5.4 Survey catch rates

Trawl survey made in 2009 showed higher catches of *Penaeus indicus* per individual prawn species in the Tanzanian coastal waters. On average, the catch rate was higher at Zone 1 (63.5Kg/hour) followed by Zone 2 (30.4Kg/hour) and lowest at Zone 3 (14.6Kg/hour). Present catch rate at Zone 2 is lower than 63.2kg/hr (Nhwani et al., 1993) and higher than 4.68 kg/hr (Bwathondi et al., 2002). This indicates that there have been some improvements in stock size. There have also been some changes in order of catch rates (Kg/hour), the previous surveys showed Zone 2 to be the most productive zone by area (Table 6) with higher catch rates in terms of kg/hour (Mhitu and Mwakosya, 2008). The current survey (of 2009) shows Zone 1 to have higher catch rate (Kg/hour) than the other two Zones. This might have been due to difference in environmental changes that has occurred in these Zones. However, the productive ground by area (138.3nm^2 for Zone 1 and 888.9nm^2 for Zone 2) is still Zone 2 as shown in Table 10. Direct observation showed many small sized prawns at Zone 2 and few large prawns at Zone 1 (personal obs). This has been validated by having higher catch rate at Zone 2 in terms of number per hour while Zone 1 had higher catch rate in terms of kg per hour.

Catch rates were slightly higher in May compared to other surveyed months. May is always associated with heavy rains (Bwathondi et al., 2002, Mwakosya, 2004) causing more fresh water and organic matter influx into the sea. Less saline water due to heavy rain triggers movement of adult and juveniles from the nursery ground (estuarine) to more saline open ocean. These factors are likely to have an influence on catches. Normally the periods of high rainfall coincide with high prawn catches (Semesi, 1998, Teikwa and Mgaya, 2003, Mwakosya, 2004).

5.6 Exploitation or environment

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 (Fig 9). CPUE (annual tonne per boat and kg/day) has been declining over time since the late 1980’s until 2007. Results from this study show that the decline in prawn abundance (CPUE) was correlated with both river discharge and fishing effort from early 1988 to 2007. In 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 in prawn abundance during this period (Fig 11). It may therefore likely that river discharge in combination with fishing effort were the major causes of fishery collapse and not fishing effort alone as suggested by TAFIRI (Mwakosya et al., 2009, Mhitu and Mwakosya, 2008). Also, in Mozambique 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 before.

5.7 Fishery and management interventions.

There has been a lot of research on the prawn's resource since early 1970's (Table 5, Table 6). However there has been little interaction between research and the fishery. For example in 1992 after a trawl survey on prawn catches, TAFIRI recommended a reduction of fishing effort from 14 vessels to 8 vessels after evidence of declining CPUE (kg/hour) (Wilson, 2004, Bwathondi et al., 2002). This decision was never implemented (Wilson, 2004) and effort continued to increase until the end of 2004 when some of industrial fishers voluntarily ceased fishing on account of low CPUE (Wilson, 2004) (Fig 10).

The biomass estimates that have been made on various surveys from late 1980's (Table 6) have been of little use in the prawn fishery of Tanzania since output control measures such as total allowable catch or quotas to the fishery do not exist. However limited input control measures such as vessel capacity, fishing season, and fishing time have been in place to reduce catching power of fishers and thus reducing fishing mortality. The response of fishing mortality to effort control is difficult to quantify because it depends on behavioural changes of fishers to regulations.

MSY in principle is a steady state concept of the largest catch that can be taken from the fishery over many years without causing the population to collapse. In Tanzania the various MSY estimates show a declining trend from early 1970's to closure (Fig 5). This decline may have been caused by changes in the environment such as reduced freshwater discharge causing lower carrying capacity which violates the assumption of MSY estimates. However despite several estimates, MSY have never been part of the fishery management measures due to lack of output control.

Most of the previous surveys (Table 6) concluded that, there have been biological overfishing (over exploitation) but they did not take into account environmental aspect. However, there are no indications of decline in catch with high effort (Fig 2), which is the technical definition of overfishing under steady state. This indicates that decline in the prawn stock size that ultimately resulted in the closure of the fishery was influenced by other factors in combination with fishing effort but not only biological overfishing by industrial fishers as has been reported (Bwathondi et al., 2002, Mwakosya, 2004).

5.8 **Quality of data**

Industrial catch and effort data from the Fisheries Division has been recorded based on catch records given by industrial fishers. The problem associated with the use of the catch statistics data is on the precision and accuracy of the records. There can be errors in recording or intentional reporting of lower catches due to tax on weights of prawn catches. Despite of the errors, data still contain useful information of what is happening at sea.

6 Conclusion and Recommendations

In the light of the findings of this study, the following conclusions can be drawn;

- Prawn abundance in the coastal mainland Tanzania has likely been influenced by a combination of river discharge and fishing effort from early 1980's. Management of this type of fishery is difficult if environmental aspects of the fishery drive the prawn population more than human induced factors (fishing mortality).

- The last survey of 2009 shows a slight improvement of the prawn stock biomass compared to the previous survey in 2004.

- The average ratio of prawn catch to by-catch is high (1:7) in the fishery. Instead of discards, this amount of by-catch can be utilised as source of protein in different forms whether sun dried or smoked as it is affordable and easily to be sold in the local markets.

- Further research on state of mangroves should be done and can be of significant value in recovery of the prawn fishery in Tanzania.

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8 Appendix

Appendix 1: Number of licensed trawlers, fishing days, fish catch and Prawn Catch

Year	Number of shrimp trawlers	Number of Fishing days	Shrimp Catch (in Kg)	Fish Catch (in Kg)	Shrimp Catch per day (in Kg)	Fish Catch per day (in Kg)	Fish/shrimp catch
1988	13	1476	650929	988249	441.01	669.55	1.518213
1989	13	2166	688837	978501	318.02	451.75	1.420512
1990	9	1574	960686	647467	610.35	411.35	0.673963
1991	13	1315	669016	460772	508.76	350.4	0.688731
1992	15	1560	663852	462852	425.55	296.7	0.697222
1993	10	1462	597211	398112	408.49	272.31	0.666619
1994	16	2513	1014087	575806	403.54	229.13	0.567807
1995	18	2108	795436	765540	377.34	363.16	0.962416
1996	12	1779	769651	598716	432.63	336.55	0.777906
1997	16	2091	699059	610498	334.32	291.96	0.873314
1998	17	2778	995564	537875	358.37	193.62	0.540272
1999	17	2252	688006	609524	305.51	270.66	0.885928
2000	20	3352	909715	958126	271.39	285.84	1.053216
2001	20	3882	1193685	1010312	307.49	260.26	0.846381
2002	23	2521	926079	296349	367.35	117.55	0.320004
2003	25	3664	1320056	931159	360.28	254.14	0.705394
2004	25	3037	661062	862357	217.67	283.95	1.304502
2005	14	1528	467037	868966	257.14	524.74	1.860593
2006	13	1082	312076	792635	282.03	627.88	2.539878
2007	10	666	202455	642173	353.02	786.84	3.17193

Source: Annual Statistics, Department of Fisheries, Ministry of livestock development and Fisheries. Tanzania

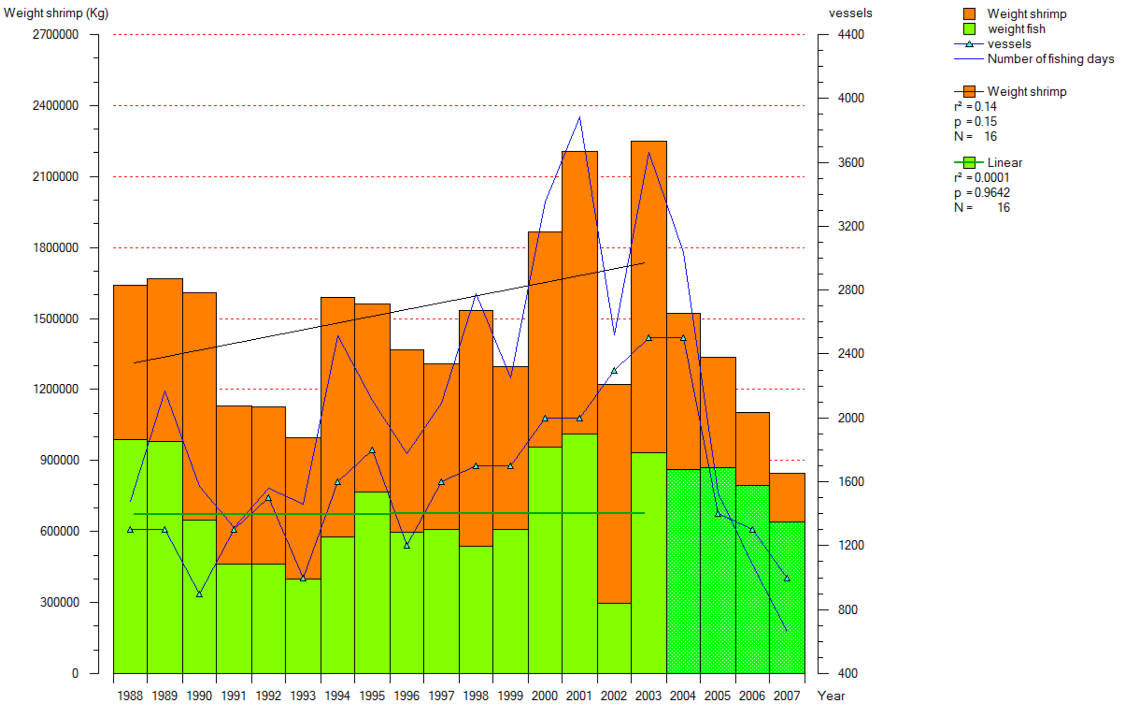
Appendix 2: Sampling design during 2009 trawl survey

Date	**Haul No and Depth**	**Zone 1**	**Zone 2**	**Zone 3**	**Total**
17/03/2009	# Haul	1			1
	Min Depth	15.4			15.4
	Max Depth	15.4			15.4
18/03/2009	# Haul	3			3
	Min Depth	4.4			4.4
	Max Depth	6.95			6.95
19/03/2009	# Haul	4			4
	Min Depth	4.8			4.8
	Max Depth	7.9			7.9
20/03/2009	# Haul	4			4
	Min Depth	6.7			6.7
	Max Depth	8.2			8.2
21/03/2009	# Haul	3			3
	Min Depth	4.95			4.95
	Max Depth	8.45			8.45
22/03/2009	# Haul	3			3
	Min Depth	4.25			4.25
	Max Dept	5.25			5.25
24/03/2009	# Haul		4		4
	Min Depth		4.75		4.75
	Max Depth		5.8		5.8
25/03/2009	# Haul		4		4
	Min Depth		3.5		3.5
	Max Depth		5.5		5.5
26/03/2009	# Haul		1		1

	Min Depth		4.85		4.85
	Max Depth		4.85		4.85
27/03/2009	# Haul			3	3
	Min Depth			10.5	10.5
	Max Depth			22.45	22.45
28/03/2009	# Haul			4	4
	Min Depth			7.3	7.3
	Max Depth			18.5	18.5
29/03/2009	# Haul			2	2
	Min Depth			10.5	10.5
	Max Depth			10.6	10.6
20/05/2009	# Haul	3			3
	Min Depth	4.55			4.55
	Max Depth	19.95			19.95
23/05/2009	# Haul		1		1
	Min Depth		8		8
	Max Depth		8		8
24/05/2009	# Haul		4		4
	Min Depth		4.25		4.25
	Max Depth		6.35		6.35
25/05/2009	# Haul		4		4
	Min Depth		4.15		4.15
	Max Depth		5.95		5.95
26/05/2009	# Haul		4		4
	Min Depth		2.1		2.1
	Max Depth		6.1		6.1
19/06/2009	# Haul	4			4

	Min Depth	4.45			4.45
	Max Depth	16.2			16.2
20/06/2009	# Haul	4			4
	Min Depth	4.35			4.35
	Max Depth	6.75			6.75
21/06/2009	# Haul	4			4
	Min Depth	2.35			2.35
	Max Depth	6.55			6.55
23/06/2009	# Haul		4		4
	Min Depth		3.95		3.95
	Max Depth		5.1		5.1
24/06/2009	# Haul		4		4
	Min Depth		4.5		4.5
	Max Depth		6.55		6.55
25/06/2009	# Haul		4		4
	Min Depth		2.25		2.25
	Max Depth		6.4		6.4
26/06/2009	# Haul			4	4
	Min Depth			5.1	5.1
	Max Depth			20.4	20.4
27/06/2009	# Haul			4	4
	Min Depth			6.6	6.6
	Max Depth			16.65	16.65
28/06/2009	# Haul			1	1
	Min Depth			11.5	11.5
	Max Depth			11.5	11.5
20/07/2009	# Haul		1		1

	Min Depth		6.7		6.7
	Max Depth		6.7		6.7
21/07/2009	# Haul		4		4
	Min Depth		4.15		4.15
	Max Depth		6.8		6.8
22/07/2009	# Haul		4		4
	Min Depth		4.6		4.6
	Max Depth		6.1		6.1
23/07/2009	# Haul		4		4
	Min Depth		2.25		2.25
	Max Depth		5.3		5.3
24/07/2009	# Haul			3	3
	Min Depth			25.95	25.95
	Max Depth			28.55	28.55
25/07/2009	# Haul			4	4
	Min Depth			7.75	7.75
	Max Depth			25.9	25.9
26/07/2009	# Haul			1	1
	Min Depth			7.6	7.6
	Max Depth			7.6	7.6
Total	# Haul	33	47	26	106
	Min Depth	2.35	2.1	5.1	2.1
	Max Depth	19.95	8	28.55	28.55



*** fishing vessels has been scaled 100 times more

Appendix 3: Showing industrial prawn and fish catch with effort over the past 19 years from 1988 to 2007

Appendix 4: Catch rates in all prawn fishing Zones of Tanzania

	Zone 1		**Zone 2**		**Zone 3**	
Species	**No/Haul**	**Weight(kg)/Haul**	**No/Haul**	**Weight(kg)/Haul**	**No/Haul**	**Weight(kg)/Haul**
P. indicus	1080.2	17.7	1036.1	16.8	367.6	8.6
P. semisulcatus	56.7	31.7	55.8	0.8	137.2	3
M. monoceros	649.6	12.2	1030.1	8.5	47.2	1.3
P.monodon	15.2	1.7	61.1	3.9	39.9	1.6
P. japonicus	5.1	0.3	22.3	0.4		
Total	1806.7	63.5	2205.4	30.4	591.9	14.6

Appendix 5: Percentage species composition by number of all species with more than 1% for the entire sampling period

	Bagamoyo		Kisiju		Kilwa		Total	
Species	**No**	**% No**	**No**	**% No**	**No**	**% No**	**No**	**% No**
Leiognathus equulus	415936	9.8	722163	14.4	225837	6.6	1363936	10.8
Pellona Ditchela	693752	16.4	611727	12.2	45504	1.3	1350983	10.7
Johnius sina	345666	8.2	759861	15.2	6054	0.2	1111581	8.8
Penaeus indicus	404176	9.6	475664	9.5	95257	2.8	975096	7.7
Gazza minuta	116185	2.7	127993	2.6	510060	15	754238	6
M. monoceros	228028	5.4	476717	9.5	14106	0.4	718851	5.7
Upeneus Sulphureus	223233	5.3	161618	3.2	108995	3.2	493847	3.9
Polynemus Sextarius	215427	5.1	183652	3.7	63958	1.9	463037	3.7
Pomadasys stridens	44531	1.1	18906	0.4	382283	11.2	445721	3.5
Pelates Quadrilineatus	45888	1.1	10539	0.2	284618	8.4	341046	2.7
Thryssa Vitrirostris	149363	3.5	147321	2.9	30129	0.9	326814	2.6
Leiognathus Leuciscus	200651	4.7	14121	0.3	87053	2.6	301824	2.4
Trichiurus Lepturus	171151	4	21539	0.4	94641	2.8	287331	2.3
Secutor Insidiator	49636	1.2	73466	1.5	112597	3.3	235699	1.9
Sphyraena barracuda	111152	2.6	17546	0.3	76559	2.3	205257	1.6
Upeneus Taeniopterus	93653	2.2	70812	1.4	32084	0.9	196548	1.6
Arius Africanus	67195	1.6	125441	2.5	3823	0.1	196460	1.6
Pomadasys maculatus	37718	0.9	57481	1.1	111223	3.3	206422	1.6
Johnius dussumieri	30203	0.7	116729	2.3	24921	0.7	171853	1.4
Gerres filamentosus	22987	0.5	11795	0.2	137322	4	172103	1.4
Terapon puta	29601	0.7	30889	0.6	91818	2.7	152308	1.2
SQUILLIDAE	41016	1	87244	1.7	2114	0.1	130375	1
Sillago sihama	16089	0.4	27857	0.6	76258	2.2	120203	1

Annex 1, Table of raw data from the 2009 trawl survey (submitted separately)