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APPLICATION OF LENGTH-BASED SPAWNING POTENTIAL RATIO METHOD AND ANALYSIS OF THE STRUCTURE OF THE ELECTRONIC CATCH ASSESSMENT SURVEY IN MARINE WATERS OF MAINLAND, TANZANIA

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ABSTRACT

In fisheries management, reliable and accurate information is important for good decision making. The objectives of this study were to assess the applicability of LB-SPR as a tool for fisheries management at a small-scale and asses the electronic catch assessment survey in marine waters of mainland Tanzania. This study identified the use of mobile phones as an important tool for improving data collection. In general, for the tuna and tuna-like species, the larger species were represented as immature fish in the catches and subsequently, the estimated SPR was low. However, the smaller tunas were generally caught after or during maturation and their SPR values were higher. Three species of reef fishery were found to have less than 20% SPR. The results could have been affected in some cases by a few numbers of samples and inaccuracy in measuring the length of fish and identification. Structure of the frame survey data and catch assessment survey was revised and a more efficient and robust stratification of the structure of crafts and their associated gears was developed, hence reducing the complexity. The percentage of missing landings due to absence or inconsistency of crafts-gear combination in the eCAS system was estimated to be 17%. The estimated total catch of six months (June – November) for marine waters in 2019 was 59,912 metric tons, for the whole year it can lead to landings of 120,000 metric tons.

Keywords: Frame Survey, catch assessment survey, LB-SPR, tuna and tuna like, reef fishes, small pelagic.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

ABBREVIATIONS

BMUs	Beach Management Units
EEZ	Exclusive Economic Zone
FAO	Food and Agriculture Organization
IOTC	Indian Ocean Tuna Commission
LGAs	Local Government Authorities
MLF	Ministry of Livestock and Fisheries
SADC	Southern Africa Development Community
TAFIRI	Tanzania Fisheries Research Institute
TSHS	Tanzanian Shilling
WWF	Worldwide Fund for Nature
MOF	Ministry of Finance
TANFIS	Tanzanian Fisheries Information System
DSFA	Deep Sea Fishing Authority
SADRFIS	Southern African Development Community-Regional Fisheries Information Systems
RECOMAP	Regional Coastal Management Programme
ICT	Information and Communication Technology
IUU	Illegal Unregulated and Unreported
TAFICO	Tanzania Fishing Cooperation
eCAS	Electronic Catch Assessment Survey
FS	Frame Survey

1 INTRODUCTION

The United Republic of Tanzania is a coastal state on the Western Indian Ocean situated in the eastern part of Africa, it lies just south of the equator between 1º-11º45' S and 29º 21'- 40º25' E. The country has a total surface area of 945,040 km^2 whereby 881,000 km^2 is in Mainland and 2,000 km^2 is in Zanzibar. The country has a coastline of about 1,424 kilometres stretching from the Northern border with Kenya to the Southern border with Mozambique which covers a territorial sea of 64,000 km^2 and an exclusive economic zone (EEZ) of about 223,000 km^2 (MLF, 2018). Besides marine resources, the country shares three great Lakes of Victoria, Tanganyika and Lake Nyasa (Malawi); medium and small lakes; rivers; natural and manmade dams; ponds and wetlands (Fig. 1) (Kolding & Zwieten, 2006).

More than 4.5 million Tanzanians earn their daily incomes solely on fishing or other activities related to fishing such as the construction of fishing boats, net mending, and fish trade. In terms of nutrition, fish contributes approximately 30% of the nation's animal protein. Moreover, annual fish consumption per capita in Tanzania is currently 8.2 kg, (MLF, 2018), this is much below the global fish consumption for 2017 which was estimated to be 20.5 kg, (FAO, 2018). For that reason, there is a need for promoting fish consumption in the country. In 2018, the sector contributed about 1.7% to the GDP and the economic growth of the fisheries sector was 9.2% (MOF, 2018).

The marine fishery sector plays a significant role in the development of coastal economy of both mainland Tanzania and Zanzibar. Marine fisheries are essentially composed of artisanal fishing units, mostly operating in the inshore waters targeting demersal resources. The main and most productive fishing grounds being habitats such as coral reefs, mangrove creeks, seagrass beds and sandbanks. Other important fishery resources located further offshore include small and medium pelagics as well as tuna and tuna-like species. The marine fisheries frame survey conducted in 2018, indicated that about 53,000 people were employed as full-time fishers, operating over 9,200 fishing vessels (MLF, 2019).

Annual fisheries statistic reports are prepared by the ministry and include estimated landings and other associated information such as country fish stock potential, total number of vessels, export and import data. Information on illegal unregulated and unreported fishing (IUU) is not captured systematically. Pre-catch information such as stock status, reference points, information of climate are considered important although it has been long time since they were collected. Market information such as fish price and data from processing factories are not well captured.

Figure 1: Map of Tanzania showing major water bodies, Source: (Ministry of Lands and Human Settlements Development, 2015)

Trends of marine waters catch landings for the past 19 years have been stable around 50,000 tons, although number of vessels has increased from five to nine thousand, with presumable higher effort and therefore lower CPUE (Fig.2) (MLF, 2018).

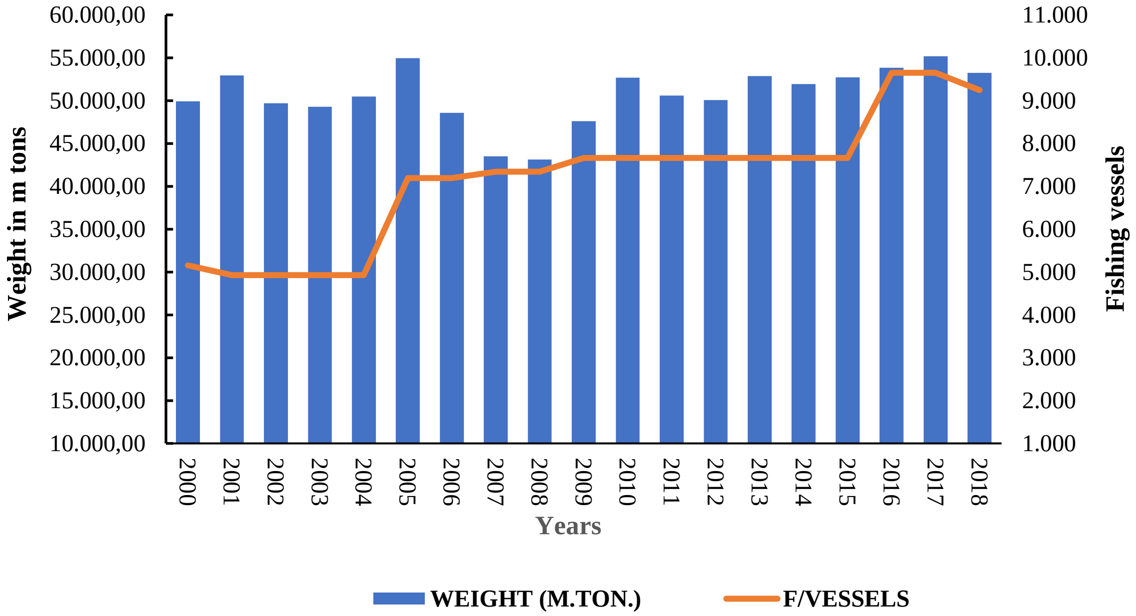


Figure 2:Trend of Marine water landings in metric tons and number of fishing vessels 2000-2018

The artisanal fishery dominates all freshwater bodies as well as in the territorial waters of the Indian Ocean. It is characterized by the use of simple, traditional fishing gears that are mostly used in depths less than 30 metres. The fishing vessels are generally small, ranging between 6 to 11 m in length, mainly paddled or motorized by outboard engines and few have inboard engines. The artisanal fishery accounts for the vast majority of the fish landed in Tanzania, which is estimated to 95% of the total catch.

Commercial fisheries are mainly concentrated in the exclusive economic zone (EEZ) for tuna and tuna-like species. The fishing in the EEZ is currently done by distant water fishing nations. However, the Tanzania government is in progress to re-establish its former fishing company (TAFICO) which will also engage in industrial fishing in the its EEZ (MLF, 2018).

1.1 Problem statement

Despite of the significance of data collection systems, other aspects of fish biology is not integrated with the system which is designed for collection of data to support management of fisheries resources. Further, the electronic catch assessment survey structure does not produce desired estimates due to the complexity of crafts and gear structure (Appendix 5). Among the issues which may affect the quality of data reported in Tanzania is double recording such as catches from Zanzibar or other landing sites being reported once landed at Ferry-Market in Dar es Salaam. This might have significant impact on data management and estimation of the total catch (Wanyonyi et al., 2016).

1.2 Marine water fisheries data collection and statistics databases

In Tanzania, catch landings have been collected in marine water since 1965 just after the establishment of the Fisheries Department in the Ministry of Agriculture and Fisheries. FAO has engaged in supporting the Tanzania government to improve the overall quality of its fisheries data collection system for many years. This has been through projects, training activities, publications, and software and databases development (Barange et al., 2017).

In 1989, Tanzania Fisheries Information System (TANFIS) was introduced through an FAO project whereby a sample-based survey was introduced but was no longer operational from 1995. From 2002 until 2005 catch assessment survey (CAS) was supported under the Southern African Development Community-Regional Fisheries Information Systems (SADC-RFIS) program. CAS database was updated with support from the Regional Coastal Management Programme (RECOMAP) and Worldwide Fund for Nature (WWF) in 2009. This database was not functional until 2012, when a tailor-made training course for districts fisheries officers in sample-based survey was organized by the FAO, under FAO Fish Code STF Project and UNU-FTP Programme. In 2017, mobile phone data collection pilot study started in collaboration between the Ministry of Livestock and Fisheries in Mainland Tanzania, Tanzania Fisheries Research Institute (TAFIRI) and Worldwide Fund for Nature (WWF) and from 2018, mobile data collection was scaled up in other marine waters districts. The CAS sampling scheme involves data collection by trained members of Beach Management Units (BMUs) who are also the members of the statistics committee and fisheries officers from district authorities.

1.3 Fisheries frame surveys

Fisheries frame surveys are conducted to provide data and information on the composition, magnitude, and distribution of fishing effort, key characteristics of the fishery, social amenities, facilities, and services at the landing sites. This information is necessary for the evaluation of the fisheries resource management initiatives such as outcome of monitoring and surveillance operations (Hassan, Ali, & Daniele, 2016).

Marine waters frame survey in mainland Tanzania was conducted from 1967 to 1991 on an annual basis in collaboration with regional or district fisheries officers (Hamidu, 2012). From 1992 the main aim was to conduct frame surveys every two years depending on the availability of funds. Since 1992, frame surveys have been conducted in 1998, 2001, 2005, 2007, 2009, 2016 and the most recent survey was conducted in 2018.

1.4 Marine waters sampling protocol/scheme

1.4.1 Stratification and Selection of Sampling Units

Tanzania adopted sample-based approach for estimation total catch because it is a more efficient way to collect data compared to the total enumeration. This method is effective and easy to implement even when there are financial and human constraints to cover all water bodies. Sample-based approaches use the mean catch per fishing day from a landings sample and the mean number of fishing days per vessel-gear combination, which is multiplied together to give the mean catch per vessel. The total catch can then be obtained by multiplying the total number of vessels (a raising factor) obtained from a frame survey or vessel register (Gertjan, 2017).

In the current catch assessment survey (eCAS), primary sampling strata is the administrative district and minor strata for collecting data are the landing sites. CAS covered 17 marine coastal districts. Data collection is done in two/three landing sites selected as representative for the entire district. Since catch and effort are relatively homogenous within a fishing unit, FAO has recommended a vessel and gear combination as primary sampling unit. Sampling units that operate in the marine waters are also identified and grouped according to the mode of propulsion. The marine water sampling protocol requires only ten days of data collection per month. Each year the Ministry produces random dates for data collection in each month and circulates to data enumerators. A minimum of 32 samples per fishing unit per month is preferred; this number gives a minimum of 10% relative error and 90% probability of accuracy (Stamatopoulos, 2002).

A team of data enumerators who form the primary interface between fishers, districts and the Fisheries Department collects data using the mobile app known as eCAS. Enumerators are from Mkinga, Muheza, Tanga, Pangani, Bagamoyo, Kinondoni, Ilala, Kibiti, Kigamboni, Mkuranga, Rufiji, Kilwa, Mafia, Lindi Rural, Lindi Municipal, Mtwara Rural, and Mtwara Municipal districts. Before introduction of mobile data collection in 2018, data collection was through paper based questionnaires. Information such as species names, weight, fishing effort, time and price of fish are recorded into an electronic form and retrieved in the centralized database which is managed by the Fisheries Department. The main role of the department is to analyse, and further process the received data.

1.4.2 Data Analysis and Dissemination

Fisheries data received in the database provide information that allows calculation of total catch, catch per unit of effort (CPUE), total fishing effort, value of the catch, catch composition and other indices. Database management at the ministry is conducted by staff at the statistics section whereby queries from the database produce reports such as CPUE per district, total catch per district, the value of catch per district and catch composition by species per each district (FAO, 1998). Further analysis to produce annual reports is accomplished by using excel or any other software. Before submission of the fisheries annual report to stakeholders, a team of experts at the ministry discuss on the report and validate it before it is circulated to the stakeholders. The report produced is used for planning, formulation of policy and guide a management in decision making concerning the trend in catch and effort for the particular year. The final compiled report is submitted to other stakeholders including FAO.

1.5 Objectives of the study

The overall objectives of this study are:

a) To assess the applicability of LB-SPR as a tool for fisheries management for small-scale marine fisheries
b) To improve the process of data validation, quality assurance and assessment by analyzing the combination of available primary sampling units.

The specific objectives are:

a) To assess biological data from tuna and tune like species, reef fishery and small pelagic species collected through mobile phone using length based spawning potential ratio (LB-SPR).

b) Explore the structure and complexity of the currently registered primary sampling units for estimation of total catch, based on data from the frame survey and the eCAS survey, to assess how complex the primary sampling unit can be, based on the current sampling activity.

2 LITERATURE REVIEW

2.1 Data validation

In fisheries data collection, validation can be implemented at all levels within the system and specifically during data collection, entry processing and analysis. In data entry with computers or mobile phone, restrictions, should be designed within a system in a such a way that human errors are avoided or minimized. The data validation framework includes:

Source of data	Sources of errors	Validation method
Survey data (Frame survey and Catch assessment)	Wrong recording of data in the frame survey questionnaire or mobile app.	Direct observation of data from the field to discover errors that occurred during its collection. Errors coming from data entry can be minimized through using Intelligent Character Recognition (ICR) (Zio, et al., 2016) In Tanzania, data validation for fisheries statistics is done at all levels; district fisheries officer is responsible for cross-checking all data originating from landing sites, officials at Ministry of Livestock and Fisheries are responsible for checking if the received data were collected according to the protocol. In case of any faults, communication through mobile phones is done to remedy errors (FAO, 2003).
Fishing activity in EEZ	Underreporting of catch data.	In commercial fishery, usually competent authorities responsible for fisheries governance have been using an onboard observers to provide more reliable information for the validation step, though this approach is expensive and not practical for the small-scale fishery (Hintzen, et al., 2015).
Statistical reports	Inefficient in data analysis methods	Validation meeting and consultations which involves multi-disciplinary stakeholders.

2.2 Quality assurance of the fisheries data collection

In fisheries data, collection measurement errors may influence the quality of data. Errors related to the quality of fishery data on stock assessment are mainly random errors and errors caused by the wrong taking of measurements (Megney, 1989). Random errors are caused by unknown and unpredictable situations in taking samples, such as poor weather during a sampling or poor usage of a measuring scale. Random errors often have a Gaussian normal distribution tendency, in implanting quality assurance for fisheries data the mean (M) of several measurements of the same quantity is the best estimate of that quantity, and the standard deviation (S) of the measurements shows the accuracy of the estimate (Cotter & Pilling, 2007). Typical errors occur as outliers in the collected data sets and before data analysis, data cleaning can help to remove them (Chen, 2002).

In other cases, it has been reported that the problem of lack of quality data may result from deliberately disregarding of some data that are considered as not important (Maunder & Kevin, 2014). This kind of negligence occurs in a sample-based survey whereby larger fish are sampled, and smaller ones are abandoned. Using random sampling can help to have the same chance of vessels-gear combination and their associated catch being sampled. In Tanzania, enumerators have been trained to sample every third vessel coming from the water (FAO, 1998).

When people who participate in fisheries data collection are well trained on standard operating procedures for data collection, they can collect data with good quality and cost for inspection and supervision will be minimized. Chen (2002) mentioned factors that may influence the quality of fisheries data of interest for management, including the level of literacy of data enumerators and proper use of technology. Additionally, the Ministry of Livestock and Fisheries in Tanzania conducts quarterly field visits in all districts to inspect data collection. The Ministry has formulated catch monitoring sheets for each district, samples collected are evaluated against the targets.

2.3 Use of Mobile phones in collection of fishery statistics

Globally, more than 20 countries have started trials of using mobile devices in fisheries data collection. A few countries, including Canada, Scotland and United Kingdom have incorporated mobile devices into their fisheries management system. Nisanala (2015) found that countries such as Madagascar, South Africa, Solomon Islands, Honduras, and Mozambique started pilot studies to assess the feasibility of using mobile phones in fisheries management since 2013. Nevertheless, in recent years there has been a promising future for the growth of mobile phone usage in Africa and in 2017 it was forecasted that the ownership of mobile phones will increase by 158% by 2023 (Ericsson, 2018).

In fisheries data collection users can opt for designed data collection applications (Apps) or use Open Data Kit (ODK) forms. ODK forms can be created just like other conventional paper-based forms used in sample-based survey. ODK forms supports a wide range of questions and answer types and is designed to work well without network connectivity, user can design question depending of the type of survey. At the end of the sampling day, a connection is made with the internet through the mobile phone network and newly collected data are sent to the country-specific server in the cloud. On the other hand, further studies on advantages and disadvantages of ODK forms over other developed Apps are needed. In contrast, users recommend the use of ODK although it requires well-trained enumerators and database managers (Gertjan, 2017).

2.3.1 Comparative advantages of using mobile phones in fisheries data collection over paper-based tools.

Use of smartphone encourages communities to collect more data on landings than paper-based form, when mobile phones given to the community are also used for other purposes. Similarly, data collection through mobile phones has proven to increase accuracy, provide images of new fish species and geographical positions. Earlier studies have demonstrated the potentiality of smartphones in assisting monitoring of illegal, unreported, and unregulated fishing (Gleasonal, et al., 2019)

Although the use of smartphones has higher initial costs such as buying mobile phones and credit for data, it has potential in reducing the time and cost relatively when compared to paper-based methods (FAO, 2017). Likewise, when compared with paper-based data collection systems, the use of mobile phones is thought to reduce challenges such as lost papers, lag times. (Humber, et al., 2017).

The conceptual diagram of status quo and high-tech fishery-dependent data collection systems (Fig.3) developed by Gleasonal, et al. (2019) describes in detail how the use of technology can improve fisheries data collection systems. Introduction of mobile phone data collection can reduce time of processing data from the point of collection into the organization for management decision- making. The paper-based data collection is often slow and with time lags. Many issues related to manual data recording have raised inaccuracy and unreliability on the stored data. Paper logs often impose a top- down flow of information of which often does not give room for the data collector to get feedback and exchange of information among themselves. Although it is important to recognize associated risks which may arise with introduction of technologies, still it is a good approach toward improvement of data collection. (Stephen et al., 2018).

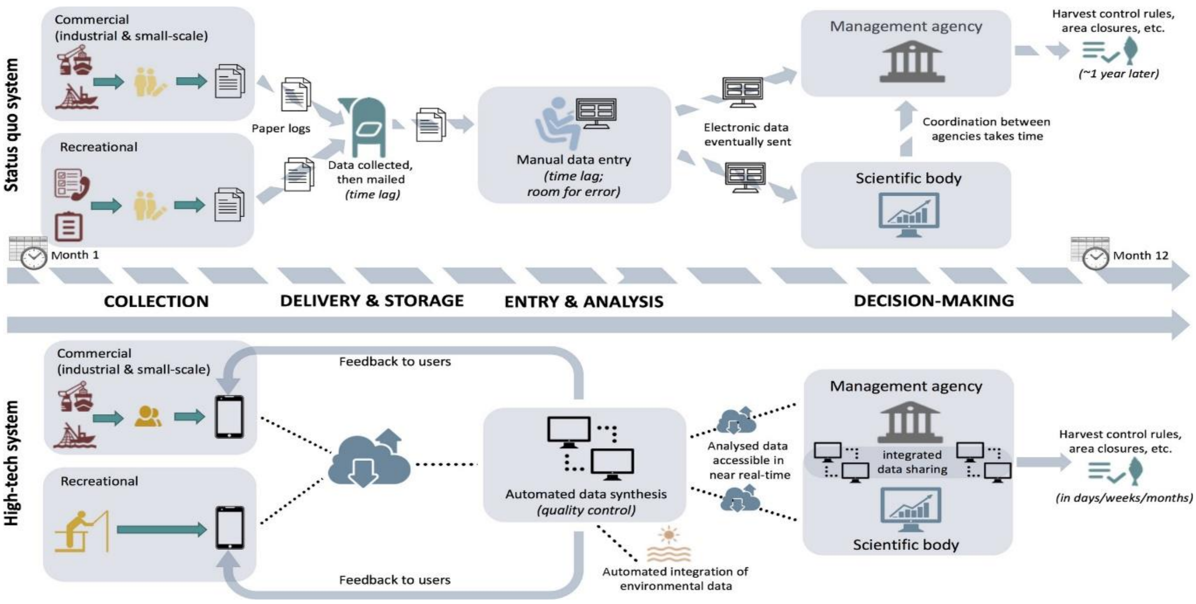


Figure 3: A conceptual diagram of status quo (Top) and high-tech (bottom) fishery-dependent data collection systems (Gleasonal, et al., 2019)

2.4 Biology and characteristics of the tuna and tuna like species, reef fish and small pelagic fish species assessed

2.4.1 Tuna and tuna like species

Tuna and tuna like species form a Scombroids group of pelagic fish which ranges from about 30 cm to over 3 m in length. Most of them, especially the tunas and billfishes, are migratory species which moves in schools. Tunas show distinct migratory routes, spawning and feeding locations (Anulekshmi, Sarang, Kamble, & Akhilesh, 2018). Tuna occurring in mainland Tanzania are classified as coastal or neritic species. The principal species of tuna are kawakawa (*Euthynnus affinis)*, skipjack (*Katsuwonus pelamis)*, yellowfin (*Thunnus albacares*), bigeye (*Thunnus obesus*), Indo-Pacific king mackerel (*Scomberomorus guttatus)* and bullet tuna (*Auxis rochei)*. Being highly valued, they are significant both as a source of food and income for Tanzanians (IOTC, 2013). See table 1 for pictures and biological information of the species, and table 2 for habitats, feeding and distribution of tuna and tuna like species.

Table 1: Photos and scientific names of assessed tuna species

English name	Latin name	FAO CODE	Image
Kawakawa	*Euthynnus affinis*	KAW	
Skipjack tuna	*Katsuwonus pelamis*	*SKJ*	
Yellowfin tuna	*Thunnus albacares*	YFT	
Indo-Pacific King mackerels	*Scomberomorus guttatus*	GUT	
Bigeye tuna	*Thunnus obesus*	BET	
Bullet tuna	*Auxis rochei*	BLT	

Table 2: Habitats, feeding and distribution of tuna and tuna like species

Latin name	HABITATS, FEEDING AND DISTRIBUTION
Euthynnus affinis	Prefer water temperatures ranging from 18 to 29ºC and depth range 0 – 200 m, sometimes they may be found to depths of over 400 m. This species is a predator feeding on fish, crustaceans and gastropods. Species like *Atherina brevicepts*, *Apogon spp*, *Eutrumes teres*, *Atherinomonus spp*, *Engraulis japonicas*, *Atherina afra* and *S. ocelatus*. Its food constitutes 90% fish prey of the overall prey biomass. Live throughout the Indo-west Pacific in open waters close to the shoreline. Its commonly found in the coastal areas over continental shelves (Pillai & Palanisamy, 2012)
Katsuwonus pelamis	Inhabits the upper mixed layer of the ocean. The distribution of *K. pelamis* includes the offshore waters with temperature ranging from 14.7 to 30°C. Collette, (1995) indicated that this species prefers depth range between 0 - 260 m. Usually found in tropical water between 63°N - 47°S and 180°W - 180°E. Main prey taxa found in the stomachs of skipjack tuna juveniles were fish larvae, Euphausiacea, Copepoda, Amphipoda, and Cephalopoda. Cannibalism was also found in the larvae and juveniles of skipjack and other tuna (Dragovich & Thomas, 1972).
Thunnus albacares	*T. albacares* is found worldwide in tropical and subtropical oceans but more in tropical latitudes. They prefer depth range of 1-250 m and temperature between 15°C - 31°C . Geographical distribution is within 59°N - 48°S, 180°W - 180°E. Squids are the most prevalent prey species accounting for 37-61% of food items. Two percent of food items of yellowfin tuna followed by teleost fishes and crabs (*Charybdis sp*.). Cuttlefish, shrimps, octopus and stomatopods were the other components reported (John, 1998).
Scomberomorus guttatus	The mackerel is a neritic tuna species which prefer a habitat in less-clear waters with lower salinity and mean annual habitat temperature of 28°C. Its mostly found in the depth range of 15 - 200 m in tropical zones within 38°N - 7°S, 49°E - 134°E. It is widely distributed in African, Asian and Australian coastal waters. It is predominantly piscivorous and feeds mainly on small schooling fishes (especially sardines and anchovies), squids, panaeids and crustaceans (Collette, 2001).
Thunnus obesus	Bigeye tuna are widely distributed among the 3 major oceans between 45°N and 40 S except the Mediterranean Sea especially in tropical waters with 250 m depth (Fonteneau & Pilar, 2004). Fischer (1974) has reported water temperatures in which the species has been found range from 13 to 29 °C, but the optimum range lies between 17 and 22 °C The main foods of bigeye are squid, and fish, which were found in 75% of the stomachs, and crabs. Jumbo squid, *Dosidicus gigas*, made up half the volume of individual food items (Seiji, 2018).
Auxis rochei	Bullet tuna (*Auxis rochei*) is an epi and meso-pelagic fish that chose a seasonal coastal distribution in temperate and tropical areas. In East Africa it is commercially exploited by artisanal fisheries (Macías, 2005). This species is distributed between 61°N - 51°S and 180°W - 180°E, it prefers water with 50m depth. The optimum temperature of surface waters under which they are found is between 27.0° and 27.9°C or 31ºC. Bullet tuna is an epipelagic offshore predator feeding on whatever abundant resource is available in the environment with a preference for planktonic crustaceans, small cephalopods and fish larvae (Mostarda, Campo , Castriota, & Esposit, 2007).

2.4.2 Reef fish

Reef fishes are fish that inhabit coral reef environments. They live amongst or in close relation to coral reefs. Coral reef fishes include emperors, snappers, sweetlips, parrotfish, surgeonfish, rabbitfish, groupers, and goatfish. They are among the key fisheries resources to the livelihoods of artisanal fishermen in the East African coast (Jiddawi, 2002). Information about common reef fish in mainland Tanzania are in Tables 3 and 4 below.

Table 3:Photos and scientific names of assessed reef fish species

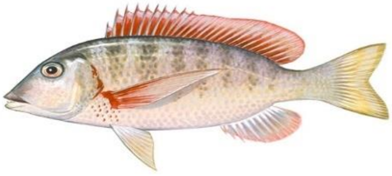
English name	**Species name**	**FAO CODE**	**Image**
Sky emperor	*Lethrinus mahsena*	LTQ	
Thumbprint emperor	*Lethrinus harak*	LTK	
Dusky parrotfish	*Scarus niger*	SCAR	

Table 4: Habitat, feeding and distribution of studied reef fishes

Latin name	HABITATS, FEEDING AND DISTRIBUTION
Lethrinus mahsena	*L. mahsena* is a non-migratory species. It inhabits coral reefs and adjacent sandy and seagrass areas to a depth of 100 m. Its distribution is within 28°N - 26°S, 32°E - 82°E in a temperature range of 22.5-29.7°C. It feeds mainly on echinoderms (most frequently sea urchins), crustaceans and fishes; mollusks, tunicates, sponges, and polychaetes (Hassan, Ali, & Daniele, 2016). Bautil and Samboo (1988) observed spawning for *L. mahsena* to occurs throughout the year with two peaks of spawning activity in December-January and May-June.
Lethrinus harak	The thumbprint emperor (*L. harak*) is a common marine species across the Indo-Pacific region ccupying a range of habitats, including mangroves, seagrasses and reefs. It is commonly found in water depth range of 0 - 20 m between 32°N - 32°S and 31°E - 155°W. Water temperature favourable for its growth range between 22.8-31.5°C. It usually consumes hard- or soft-shelled sessile or slow-moving invertebrates, such as mollusks, sea urchins and certain crustaceans. (Carpenter at all, 1996).
Scarus niger	The dusky parrotfish (*S. niger*) is widely distributed in Indo-Pacific waters; from the Red Sea south to Sodwana Bay, South Africa and east to the Society Islands.

Latin name	HABITATS, FEEDING AND DISTRIBUTION
	This species is commonly found within 0-20m water depth in tropical between 30°N and 27°S. They are all diurnal herbivores, mainly feeding on the short epilithic algae (turf), and they are among the common fishes in East Africa found in coral reefs (Froese and Pauly 2005).

2.4.3 Small pelagic species

Small pelagics are small schooling fish that feed on plankton and live in the surface and near-surface waters over the continental shelf of most of the coast. They play a fundamental role in marine ecosystems by converting energy from lower trophic levels into food for larger fish, marine mammals and seabirds. Information about small pleagic species assessed in this project can be found in tables 5 and 6 below (Isaacs, 2016).

Table 5: Picture of assessed small pelagic fish species

English name	Latin name	FAO CODE	Image
Indian anchovy	*Stolephorus indicus*	ESI	

Table 6: Habitat, feeding and distribution for studied small pelagic fishes

Latin name	HABITATS, FEEDING AND DISTRIBUTION
Stolephorus indicus	Anchovies are tropical small neritic pelagic resource, often found in mixed schools. *S. indicus* in combination with other anchovies, contributes to 3.8% of Indian commercial fishery. Sukumaran et al, (2019) noted that, this species was found in the marine brackish water at the depth range of 20 - 50 m within the tropical zone, 30°N - 37°S, 23°E - 144°W. Its preferred temperature for growth is between 24.2 - 28.7°C. It is distributed along Indo-West Pacific from South and East Africa to Society islands, north to Hongkong (China), south to Gulf of Carpentaria (Australia) and Red Sea. The food consists generally of planktonic crustaceans, bivalve larvae, fish larvae, post larvae and diatoms (Fricke, Golani, & Brenda, 2015).

2.5 Length based spawning potential ratio

Small scale fisheries in tropical countries are commonly characterized by having poor fisheries data due to the lack of technical competence and high costs of collecting other size-based techniques which relay on age. A number of length-based methods have been developed and utilized to assess biological parameters data (Pauly & Morgan, 1987). SPR is a reproduction relative rate index in an exploited stock, commonly used as an immediate management tool for establishment of reference points for fisheries (Hordyk, 2017). Main assumption rely on the principle that, for any unfished stock, reproductive efficiency left by fishing impact which has a 100% SPR of virgin stock fishing activity can causes mortality which in turn reduce SPR from 100% to a lower level SPR (Prince, Adrian, Loneragan, Sainsbury, & Hordyk, 2015).

Quantitatively, assessment of fisheries with well-studied biological parameters resulted in establishment of a SPR 40% as a conservative proxy for MSY, and SPR 20% as a proxy when recruitment rates are likely to be impaired for finfish. In expanding the theory of Beverton–Holt Life History, it is suggested that LB-SPR can be used, comparatively by taking information about inadequately examined species using close related species (Prince et al., 2015). Precision of parameters used during LB-SPR will also determine the accuracy of estimated SPR these parameters are information as M/K ratio and L_{50}.

Consequently, ensuring that high quality, representative length data are collected for the stock should be an important research priority, and care must be taken in designing a rigorous sampling programme to collect length data. One of the assumption for LB-SPR is that, in case larger fish are missing from sampled length frequency data its assumed that it is because of fishing activity, thus F/M will be overestimated and SPR underestimated (Hordyk, Sarah, Kotaro, & Loneragan, 2014).

3 METHODOLOGY

3.1 Study area

This study was carried out in 17 marine coastal administrative districts which are: Mkinga, Muheza, Tanga, Pangani, Bagamoyo, Kinondoni, Ilala, Kibiti Kigamboni, Mkuranga, Rufiji, Kilwa, Mafia, Lindi Rural, Lindi Municipal, Mtwara Rural, and Mtwara Municipal (Fig. 4). These are marine coastal districts covering an area of about 1,424 kilometres long, extends from north in Jasini landing site bordering with Kenya at latitude 39°11’S and longitude 04°44’E, to the south in Msimbati landing site at latitude 10°22’S and Longitude 40°21^{0}‘E bordering Mozambique (MLF, 2019).

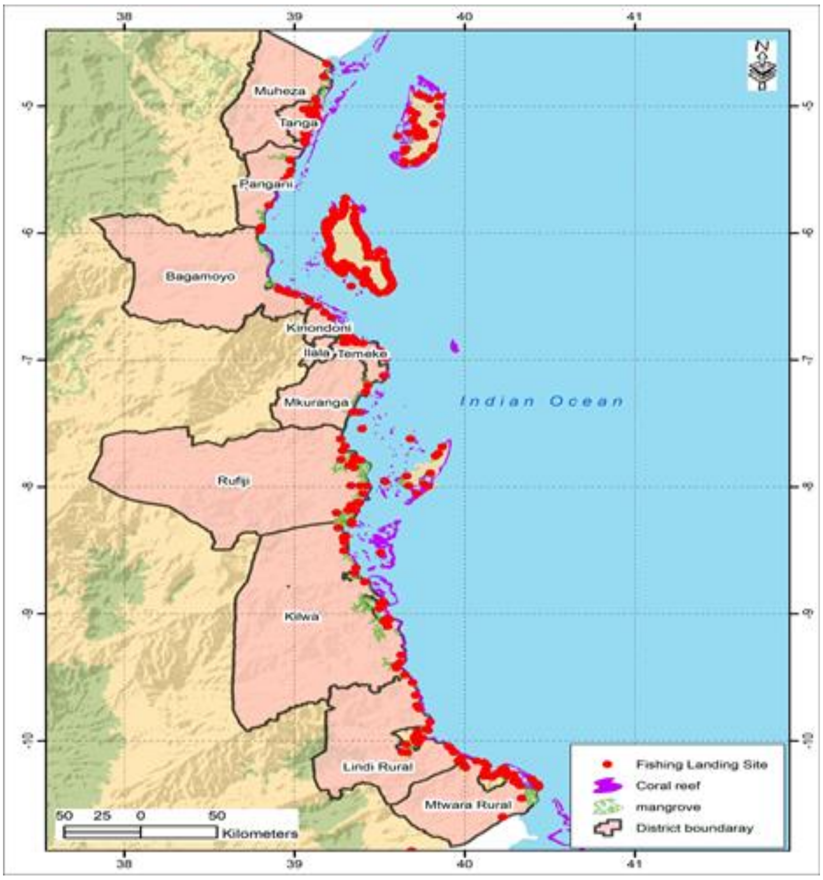


Figure 4: Study area, Coastal Districts where routine data collection is conducted. (red colour stands for Fishing Landing Sites) Source: Ministry of Livestock and Fisheries

3.2 LBSPR for tuna and tuna like species, Reef fishes, and small pelagic

Length frequency data for tuna and tuna like species was collected from January to October 2019 from five districts along the coast namely Kinondoni, Kilwa, Tanga city, Mtwara, Mafia and Kigamboni. These districts are involved in the implementation of tuna and tuna like species strategy which was developed by the government of Tanzania in collaboration with WWF. The overall goal is to support sustainable management and utilization of tuna and other highly migratory resources to optimize biological, environmental and socio-economic benefits to the Tanzanian people (MLF, 2015). Data collection is among the priority activities of the strategy. Sampling for additional length frequency data of the reef and small pelagic fishes was conducted for 10 days between 1-14/January/2020 with support from UNESCO-GRO-FTP. This exercise aimed at evaluating the feasibility of using mobile phones in data collection with the aim of reducing limitations for using paper-based forms in data collection. Sampling used same enumerators who take part in the routine CAS.

During sampling, fork length (FL: fish length from the front to the fork in the centre of the tail) of all fish landed by the fishermen was measured with a flexible tape. Firstly, analysis of tuna and tuna like species was conducted for *K. pelamis*, *T. albacares*, *E. affinis*, *S. guttatus*, *T. obesus* and *A. rochei.* Secondly, analysis was done for various species, where the reef fishes *Lethrinus mahsena (LTQ)*, *Lethrinus harak (LTK)* and *Scarus niger (SCAR)* and the small pelagic *Stolephorus indicus (ESI)* were selected.

Biological parameters such as L_{50}, $L_{95,}L_{\infty}$ L_{opt} and L_{max}, M/K ratio for the mentioned species were adopted from https://www.fishbase.se and other previous studies and used as inputs to the LB-SPR model (Table 7). This model is used to analyse data-limited fisheries, it does not require the natural mortality rate (M), rather it uses the ratio of natural mortality and the von Bertalanffy growth coefficient (M/K), which is believed to vary less across stocks and species than natural mortality (Prince, Adrian, Loneragan, Sainsbury, & Hordyk, 2015), which is difficult to estimate for exploited stocks (Kenchington, 2014). Analysis of length frequency data using LB-SPR relies on equilibrium of the resources which being analysed, and it assume that the length composition data is representative of the exploited population at steady state. This method is reliable tool for establishing biological reference point which will help in developing management strategies for data-limited fisheries (Jatmiko, Fathur , & Zulkarnaen, 2017). Analysis of data was conducted using LB-SPR package available for the statistical program R (Hordyk, 2017).

Table 7: Life history parameters for the analysed species in this study.

Name of the species	Code	L50	L95	Lo	L∞	Lmax	M	K	M/K ratio	References
Euthynnus affinis	KAW	43	56	60.7	67.86	100	0.86	0.7	1.23	Mudumala, et al., 2018, (CMFRI , 1985)
Katsuwonus pelamis	SKJ	37.8	45.1	58	92	110	0.57	0.5	1.33	Pillai & Palanisamy , 2012 and Grande at al, 2010
Thunnus albacares	YFT	98.1	120	144.7	207	239	0.65	0.52	1.25	Zhui at all, 2011, (Itano, 2000)
Scomberomorus guttatus	GUT	40	46.5	48.5	73.5	76	1	0.6	1,66	Rashid, Mustafa, & Dewan, 2010 (Devaraji, 1987)
Thunnus obesus	BET	119.8	153.9	136	207	250	0.35	0.23	1.52	Dai at all, 2009 and Guo at al , 2011)
Auxis rochei	BLT	23.6	34	27.9	42.3	50	1.18	0.61	1.93	Jasmine, et al., 2013
Lethrinus mahsena	LTQ	29.6	36.29	40	58.5	65	1.74	0.32	1.04	D.R. Bellwood, 2014
Lethrinus harak	LTK	24.5	31.2	30	60	50	0.26	0.9	1.69	(Nyang'wara, 2002)
Scarus niger	SCAR	17.5	23.6	25.4	50	40	0.73	0.36	1.04	(Choat, Axe, & Lou , 1996)
Stolephorus indicus	ESI	9	10.5	9.8	16.3	17	2.67	1.34	1.98	(Silvetre, Federizon, & Paul , 1987)

3.2.1 Structure and complexity of the currently registered primary sampling units for estimation of total catch

A frame survey in the marine water was conducted from 23rd to 26th March 2018, along the mainland of Tanzania, covering 17 administrative districts (Fig. 1). The fisheries frame survey as a census-based approach provide information but not limited to fishing crafts, fishing gears, number of fishers, number of landing sites and the available essential fisheries related facilities, services, and infrastructure (MLF, 2019).

Catch assessment data from January-November, 2019 were extracted from electronic catch assessment database (https://smartcas.net), which receives and stores data from a mobile app. The mobile app data collection platform is designed as the conventional data collection questionnaire, (see appendix 6). It contains all variables required for effort extrapolation and their associated reports.

The first step was to conduct an exploratory data analysis (EDA) of frame survey data and catch assessment data in R. EDA is an initial step in analysing a complex structure of data which helps to produce reliable compatibility between variables and removing outliers In this study, the whole structure of frame survey and CAS data visualize and restructured so as to come up with a simplified structure which can produce best estimates. Gear which operate similarly were grouped together and primary sampling units produced. Descriptive statistics was used to produce plots which later were used to depict suitability of the structure for estimation of total catch (Kemp & Meaden, 2002).

The second step was to produce estimates such as total catch, total effort and catch per unit effort. This exercise was conducted in R using scripts and steps as illustrated in Hjörleifson (2020). The procedure follows the same principle as demonstrated in Stamatopoulos (2002). The principal equation is: Catch = CPUE x Effort

In sample-based fishery effort is normally derived from:

- A *census-based frame survey* providing the raising factor F that expresses the total number of crafts as counted during frame survey
- An *active days survey* to determine the time raising factor A expressing number of days with fishing activities for each month then an average day were calculated by removing non-working days such as public holidays.
- A *sample-based boat activity survey* to determine the BAC (Boat Activity Coefficient) expressing the probability that any crafts will be active on any given day.
- Effort = (Boat Activity) x (Total boats) x (Active days) Or it can abbreviated as;
  Effort = BAC x F x A

Overall CPUE is derived from:

- A *sample-based landing survey* to determine sample mean CPUE
  Hence the generic formula to estimate catch is:
  Catch = CPUE x Effort or expressed fully as Catch = CPUE x BAC x F x A

In our study these variables were firstly estimated by each strata (District) and then aggregated for all districts.

4 RESULTS

4.1 Length frequency distribution and LB-SPR for tuna and tuna like species

In general, for the tuna and tuna like species, the larger species were represented as immature fish in the catches and subsequently the estimated SPR was low. However, the smaller tunas were caught after or during maturation and their SPR values were higher.

Most of yellowfin tuna (*T. albacares*) were caught between 50-100 cm with peak around 80 cm or well below the L_{50}, of 98.1 cm (Fig. 5). The estimated SPR for *T. albacares* was exceptionally low (Table 8). Few (132) samples bigeye tuna (*T. obesus*) were recorded. The length frequency distribution had two peaks, a short around 65 cm and high around 90 cm (Fig. 5). Those values are well below the L_{50} of 120 cm and subsequently the estimated SPR was low (Table 8). A total of 1,292 samples of *E. affinis* were assessed, samples species caught ranged from 20-75 cm. The highest peak was observed around 60 cm, a bit higher than the length at first maturity (50 cm) and around the L_{opt} of 61 cm (Fig. 5). SPR for *E. affinis* was 54% (Table 8). Length frequency of 2682 of skipjack tuna (*K. pelamis*) ranged between 31 cm and 80 cm. The highest peak was around 55 cm, slightly higher than 38 cm length at first maturity (L_{50}) of the species (Fig. 5). Further, most were caught around the L_{opt}. The estimated SPR was 21%. Few (total of 146) samples of *S. guttatus* were obtained, the length frequency distribution of the samples showed that the cohort used has a modal length of 50 cm – 76 cm, many measured close to the species L_{max}. The highest peak was around 55 cm or above the L_{opt} (Fig. 5). The anticipated SPR was 100% (Table 8). A total of 388 samples of *A. rochei* were assessed, the length frequency distribution of the samples showed that the cohort used has a modal length of 25 – 65 cm. The highest peak was at 30 cm with few samples falling out of the L_m. (Fig.5). The SPR estimation was 100% (Table 8).

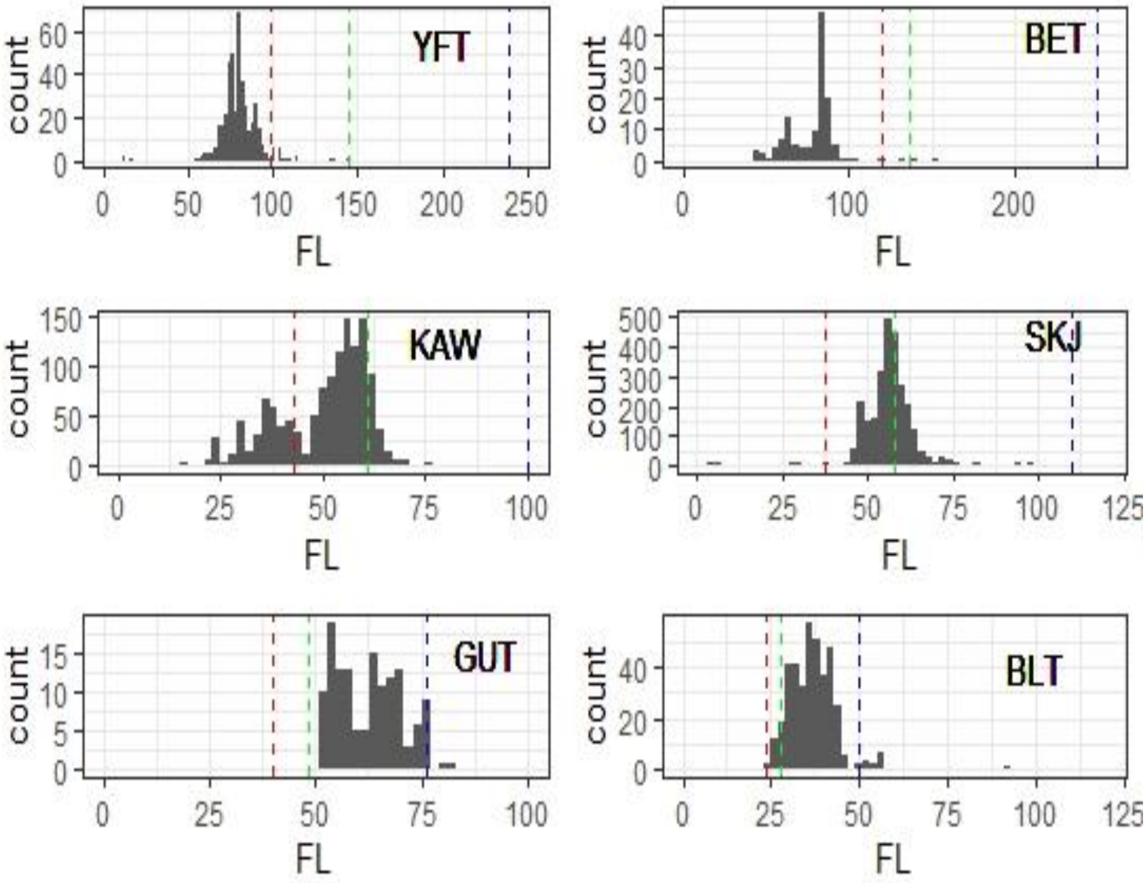


Figure 5:Length–frequency data of *T. albacares (YFT)*, *T. obesus (BET)*, *E. affinis (KAW)*, *K. pelamis (SKJ)*, *S. guttatus (GUT)* and *A. rochei (BLT)* from samples collected in in Kinondoni, Tanga city, Mtwara Rural, Mafia and Kinondoni Districts during January-September 2019. The correspondence L_m, $L_{opt.}$ and L_∞ are plotted as dotted red, green, and blue lines (see table 8).

Table 8:Spawning Potential Ratio (SPR),selection at 50% and 95% and F/M ratio for *T.albacares* (YET), *T. obesus* (BET) , *K. pelamis* (SKJ), *E. affinis* (KAW), *S. guttatus* (GUT) and *A. rochei* (BLT)

Name of the species	Code	SL50%	SL95%	F/M ratio	SPR
Euthynnus affinis	KAW	59.87	83.2	1.69	0.54
Katsuwonus pelamis	SKJ	55.12	64.43	5.38	0.21
Thunnus albacares	YFT	74.23	84.3	11.23	0
Scomberomorus guttatus	GUT	52.51	53.82	0	1
Thunnus obesus	BET	79.15	102.49	8.71	0
Auxis rochei	BLT	36.88	45.31	0	1

4.2 Length frequency distribution and LB-SPR for reef and small pelagic species

In general, for the reef fishes, the peak in the length frequency distribution was reached prior to their maturity (L_{50}). Overall the sample size was also small, or 89 samples of *L mahsena*, 90 samples of *L. harak* and 195 samples of *S. niger*. The selectivity curve was steep, and few fishes were caught above the L_{opt} (Fig. 7). The SPR estimates were all low, or below the recommended lower reference point (<20 %). SPR for the two emperor species (*Lethrinus sp.*) was 3% and 1% for the dusky parrotfish (*S. niger*).

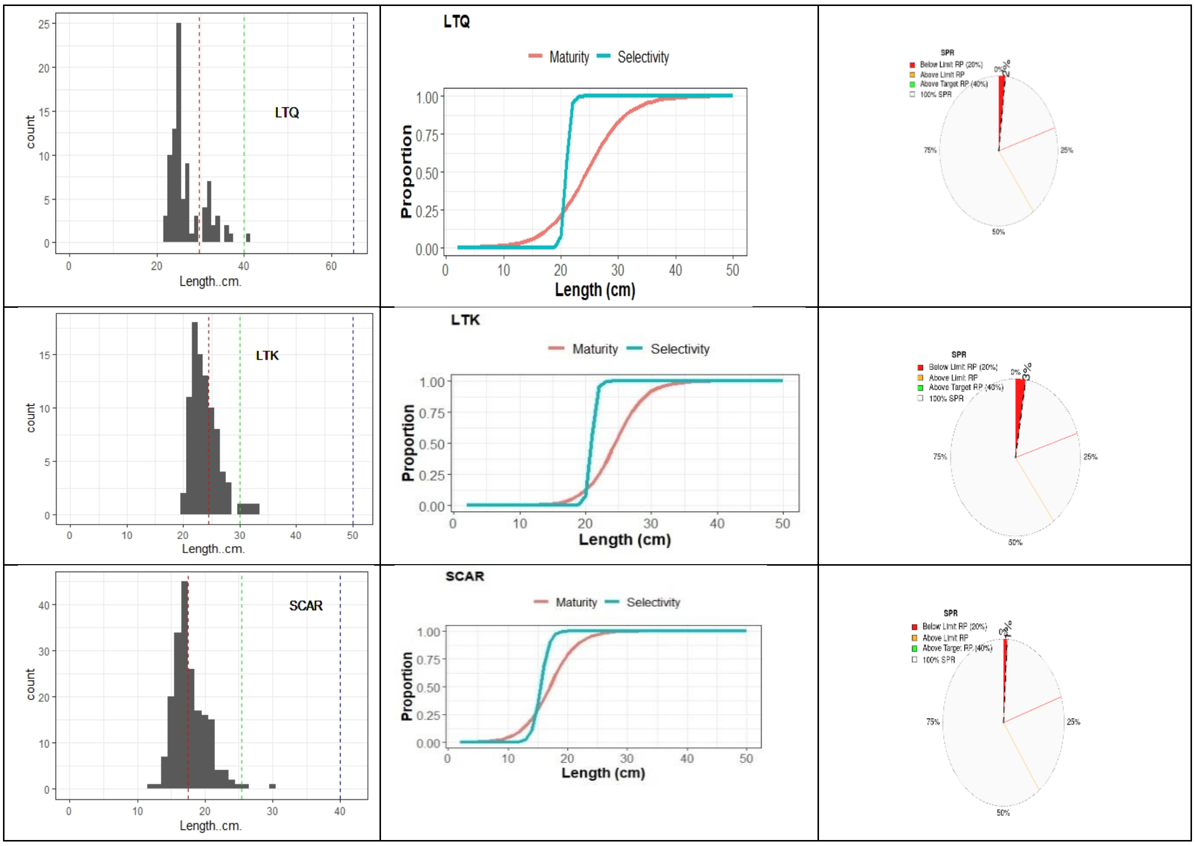


Figure 6: Mean Focal length, maturity, selectivity and SPR for *L. Mahsena* (LTQ), *L. harak* (LTK) and *S. niger* (SCAR)

Length for *S. indicus* mean modal class was between 5 and 25 cm and some value were larger than the L_{max} available in literature. This might due to lack of skills in measuring fish length among enumerators, so it was not possible to estimate SPR for the small pelagic. Indian anchovy (*Stolephorus indicus)*. Comparison for L50 and L95 showed that SL_{50}, was usually around 6 cm, but as high as 7 cm in Lindi Urban District. Results for SL_{95} was lower at Kigamboni and Mkinga around 6.8 cm and the remaining districts had SL_{95} around 7.5cm. district estimation of SPR was not feasible due to individual measured larger than the L_{max} of 17 cm (Fig. 7 and 8).

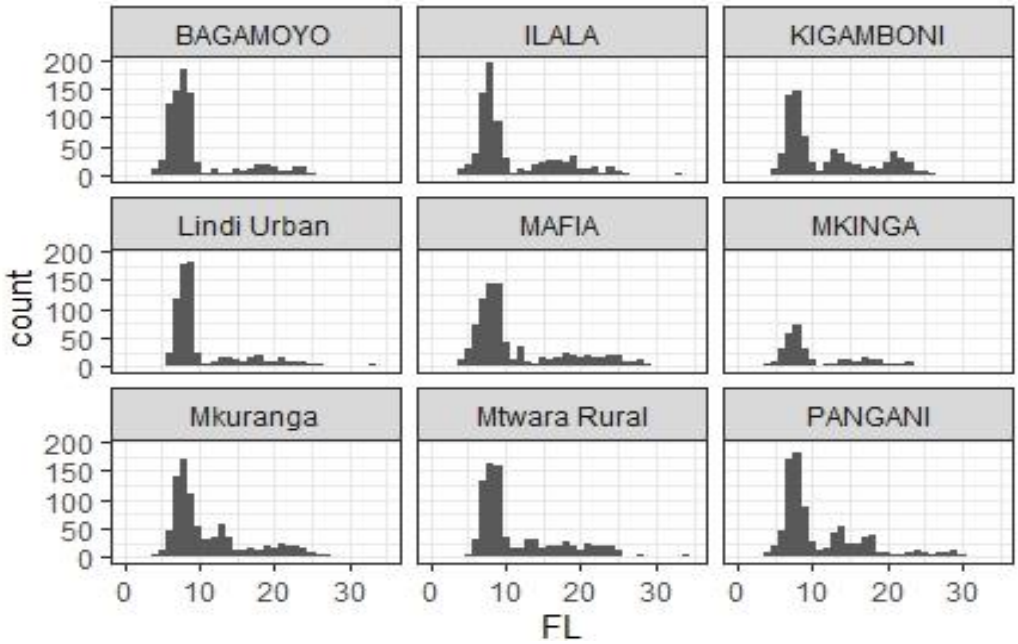


Figure 7: Comparison of length frequency of *S. indicus* in different districts

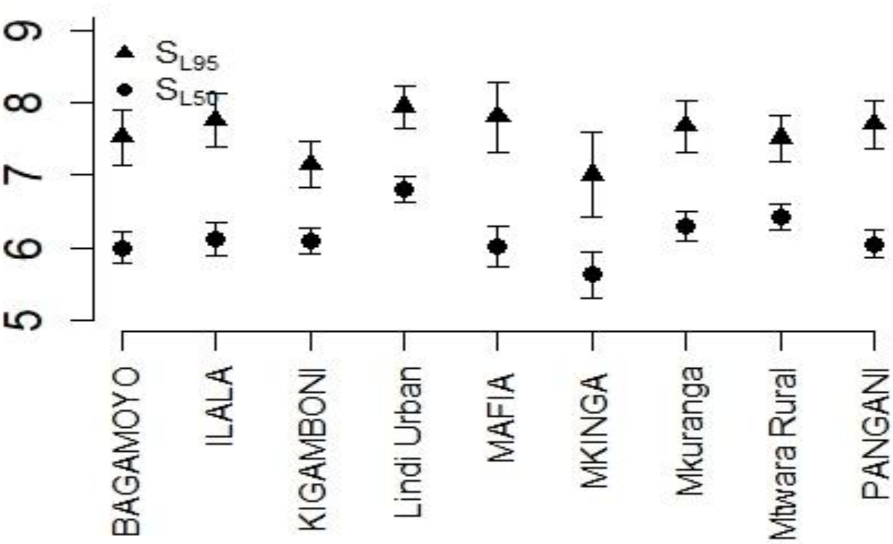


Figure 8: Comparison of estimated selectivity at $SL_{50\%}$ and $SL_{95\%}$ for *S. indicus* between districts

4.3 Structure and complexity for estimation of total catch

One way of reducing errors in sampling is to stratify crafts from fthe rame survey in order to reduce the complexity of having too many craft and gear combinations. Here, eight types of crafts were reduced to six by using new codes (ncode) which categorised types of crafts according to their sizes and than further another step, based on the propulsion mode as powered or non-powered.

The second step was to classify gears according to the mode of operations as cast nets, line, nets, seine, spear or traps. This procedure reduced the number of gear-type from the current 20 in the frame survey data to 7 types and hence reducing the complexity of having too many gears in the system. After analysis, the smallest groups were powered cast net with 6 records and non-powered cast nets with 42 records.

Analysis for catch assessment survey data on new craft classification was conducted in similar manner. This resulted in canoe, boat, Lcanoe (Large Canoe), Scanoe (Small canoe), Scanoeff (Small canoe foot fishers) and sail. In this exercise, lift nets and no gears entries were categorized as others (see number of samples and records in appendices 1 and 2). A new categorization of craft-gear into a more simplified structure will be consistent with the FAO generic approach Art Fish (Gertjan, 2017).

The last step was to explore the structure for frame survey and catch assessment data using new categorization as powered and non-powered crafts (with gears) per district (Fig. 9). Results showed that some districts did not provide feasible amount of combinations with catch assessment craft and gear combinations because they were so few in number. The red horizontal line in the graphs displays the number of samples required (32) for each craft and gear combination for 90% accuracy (Stomapoulos, 2002). Most of the districts were on average below that mark the with exception of Bagamoyo, Kibiti, Kilwa and Tanga city. Each record of landings in eCAS usually had only one species of fish attached to it, but in the database there where up to seven species per landings. That raises concern that only the most dominant fish is recorded.

Analysis of CPUE for each combination indicated that powered boat-seine had the highest average CPUE of 525 kg/per trip, non-powered boat-sp had the lowest CPUE (6.57kg/per trip). Generally, powered boats had higher CPUEs than non-powered boats. Those results are from the 2019 data in figures 10 and 11 and in appendix 3. Total landings in marine waters of Tanzania for half year (June – November) was estimated 59,911 tonnes (including missing data, see appendix 4) plus landings from estimation. Estimation for the whole year can lead to 120,000 metric tonnes. Percentage of missing landings was 17%. (data not seen in eCAS but recorded in the frame survey)

Table 9: Classification of Frame survey crafts according to their sizes and proposed simplification in two steps propulsion mode and data from all districts collected in 2018. Twenty one craft were added in as they were seen in the eCAS in 2019.

CRAFT	CODE	Size based code	New Categorization	Numbers
PLANKED CANOE	PC	Lcanoe	Powered	283
OUT-RIGGER CANOE	OC	Lcanoe	Powered	1018
BOAT	BT	BOAT	Powered	509
BOAT/NGWANDA	AB	BOAT	Powered	201

DUG-OUT CANOE	DC	Scanoeff	Non powered	3977
CANOE	DC	Canoe	Non powered	9
FOOT FISHERS	FF	Scanoeff	Non-Powered	845
DHOW	DO	Sail	Powered	840
TOTAL				**7703**

Table 10: Classification gears from frame survey into a simpler new classification and data from all districts collected in 2018. Twenty one gear type were added in as they were seen in the eCAS in 2019.

Na	Gear_type	Code	New Classification	Number
1	Beach seines	BS	Seines	70
2	Cast net	CN	CN	46
3	Dema Traps	TR	TR	366
4	Fence Traps	TR	TR	42
5	Gill net	GN	Seines	2238
6	Handheld Net	HLN	Line	2
7	Hook and line/Handline	HL	Line	2597
8	Hook and line/Handline (Without Hooks)	HL	Line	7
9	Lift net	LN	Others	4
10	Long lines	LL	Lines	207
11	Monofilament	MN	nets	12
12	Mosquito Net	M	nets	1
13	Other gear	OTHERS	Others	49
14	Purse Seine Net	PS	nets	19
15	Ring Net	RN	Nets	472
16	Scoop net / Kinganja	SN	Others	38
17	Seine Net	SN	Seine	73
18	Shark Nets	SH	nets	369
19	Spear	SP	SP	898
20	Traps/Baskets	TR	TR	193
	Total			**7703**

Table 11:New Classification of crafts according their sizes from eCAS June-November,2019

Na.	CODE	New Classification for Crafts	New categorization	Number
1	PC	Lcanoe	Powered	1663
2	OC	Lcanoe	Powered	2077
3	BT	BOAT	Powered	1197
4	AB	BOAT	Powered	300
5	DC	Scanoe	Non powered	3387
6	FF	Scanoeff	Non powered	384
7	DO	Sail	Non powered, powered	7
8	MS	Sail	Non powered, powered	687
	TOTAL			**9702**

Table 12:New classification of gears in eCAS (New Codes)

Na	Gear type	nCode	Number
1	HL	HL	2,478
2	GN	nets	1,687
3	TR(DM)	TR	1,452
4	SP	SP	998
5	SK	nets	652
6	CN	nets	34
7	LL	Lines	749
8	RN	Nets	1559
9	TL	TRAPS	93
	TOTAL		**9702**

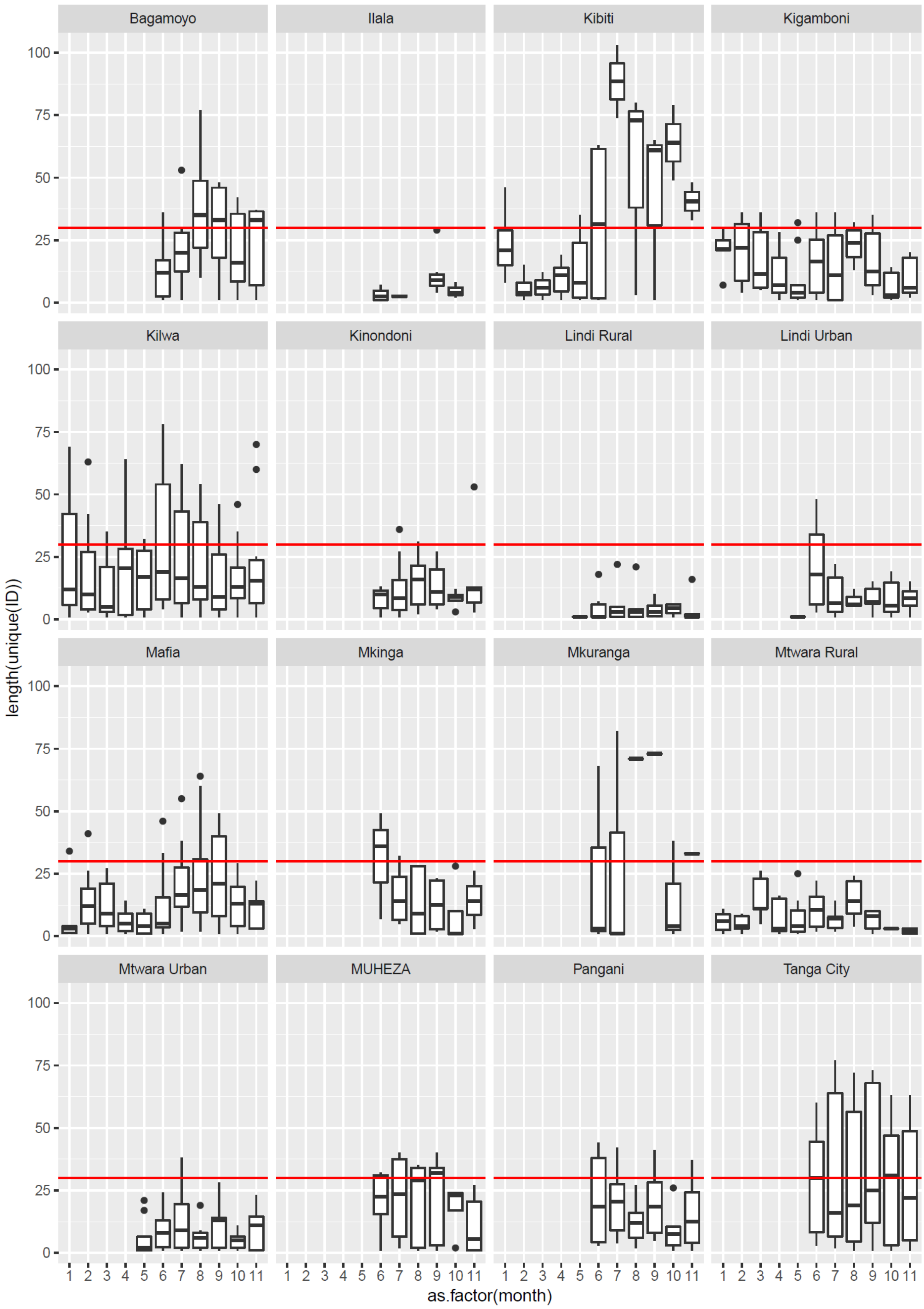


Figure 9: Box plot of the number of samples of each Craft_gear category (the new proposed structure for Frame Survey and Catch assessment data) for each district during the months January -November 2019 for data collected through mobile phone in mainland Tanzania.

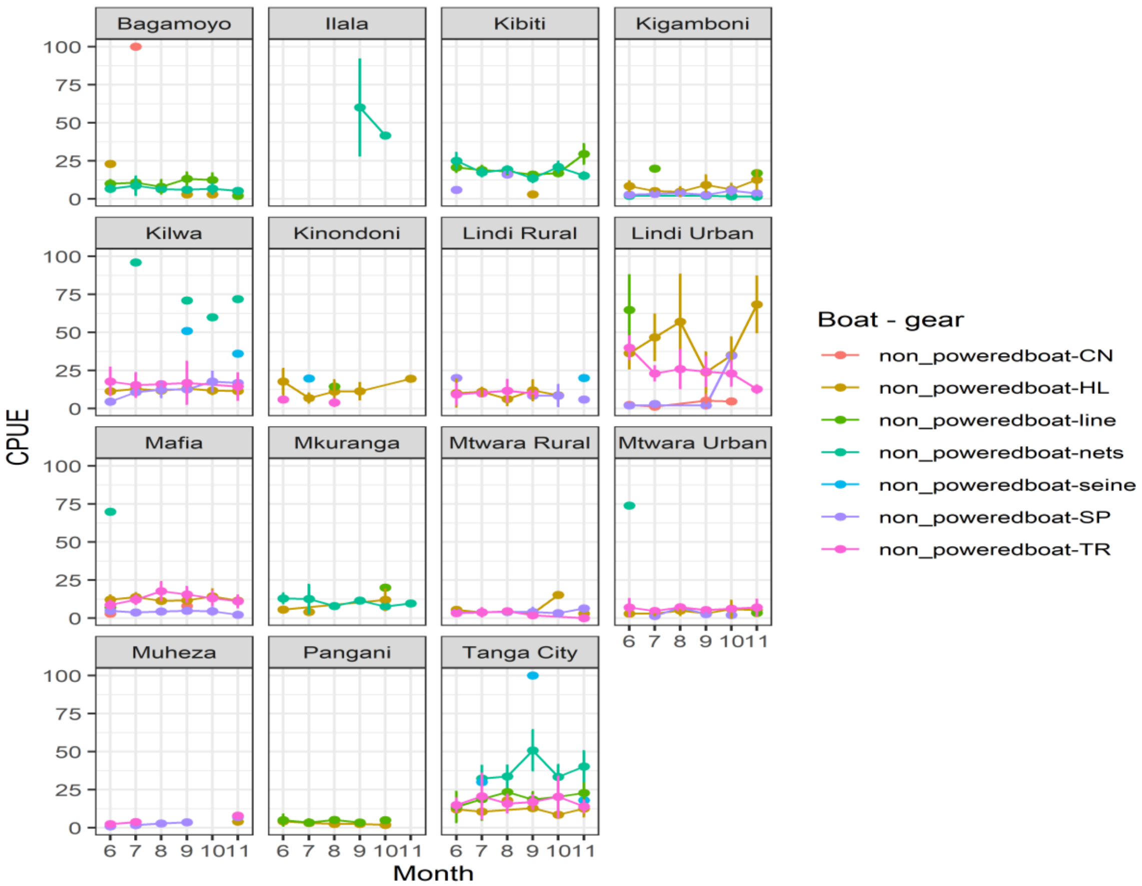


Figure 10: CPUE per trip for Non_poweredboat (new categorization) per district for Six-month from June-November 2019.

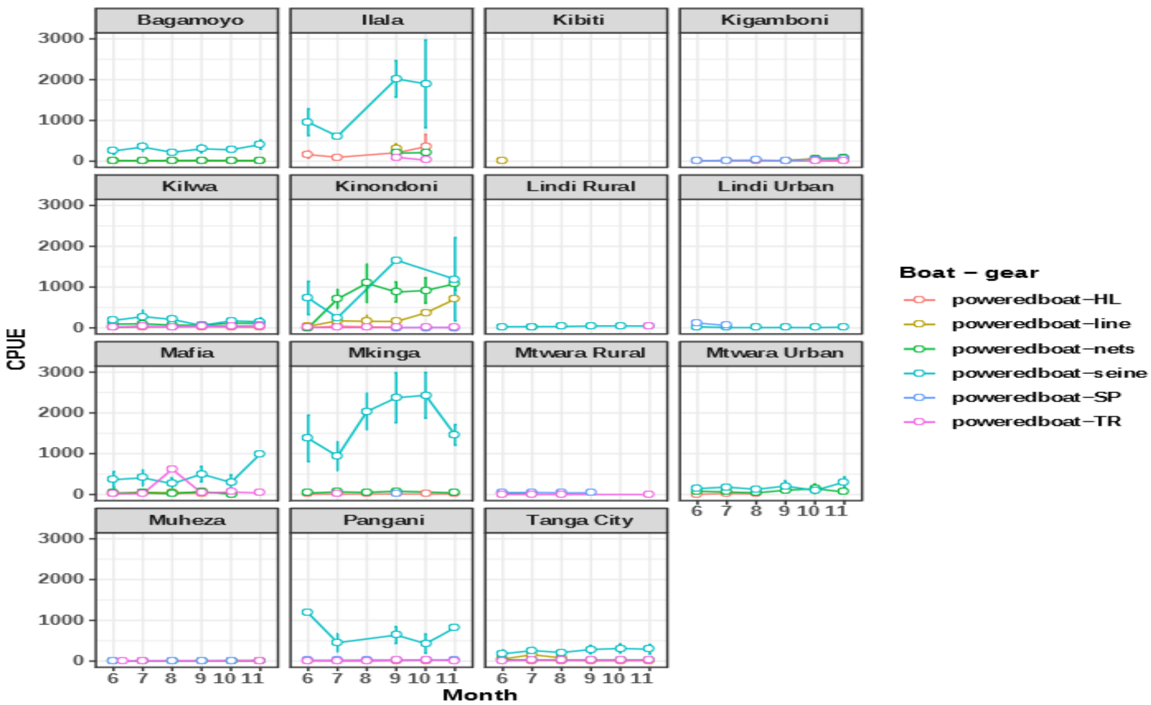


Figure 11: CPUE per trip for Powered_boat (new categorization) per district for Six-month from June-November 2019

5 DISCUSSION

5.1 Length frequency distribution and LB-SPR estimates

In data poor countries like Tanzania information on size at maturity are very important when it comes to effective management for ensuring that fish are only caught when they have attained L_{50} and close to the L_{opt} estimate. Chong et al. (2019) compared the LB-SPR method used in this study with other data limited stock assessment methods such as Thompson and Bell (TB), length-based integrated mixed effects (LIME), and length-based risk analysis (LBRA), and found that TB and LB-SPR were the most reliable and accurate assessment methods.

In this study, most fishermen caught juvenile yellowfin tuna (*T.albacares*). These finds correspond to study conducted by Maldeniya & Joseph (1986) and Karpinski & Hallier (1988) in Sri Lankan waters. A study conducted by IOTC in 2017 to assess indicators of stock status for large-pelagic fish based on length composition from drift-net fisheries for small scale fishers in Zanzibar indicated that there was high exploitation rate of *T. albacares*. This is an indication that small scale fishers caught juveniles *T. albacares* which reflected overfishing (Froese, Amanda , Henning , & Didier , 2008). The LB-SPR model interprets the absence of the large individuals from the size structure as evidence for a high level of exploitation (Hordyk, 2017). Similarly, yellowfin tuna along the coast of Kenya showed modal length of 65 – 90 cm relatively close to our results (Mueni, et al., 2019). However, these results could mean that mature *T. albacares* are not found within the artisanal waters of Tanzania and applying LB-SPR from specific region on a such widespread stock as yellowfin is questionable.

In support of that, other studies conducted using long liners fishing in Tanzanian EEZ have indicated that specimens of tuna had sizes ranging from 80 to 139 cm (Ariz, Delgado, & Santana, 2005) which was far from the results we have. Almost, 40-50% of *T. albacares* landed in the West Indian Ocean countries comes from small scale fishers. Status of yellowfin tuna for 2019 showed that, apart from poor quality of reporting from small-scale vessels in Indian Ocean, yellowfin tuna was showing overfished nature and needs improvement (Rattle, 2019). Separation of tuna species is still an issue of concern particularly for small yellowfin and bigeye tuna, as these two species often swim together. Tagging programmes for small scale fishing of tuna recorded bigeye tuna with 43-65 cm focal length (Murua & Francis, 2015). Results from this study showed that bigeye tuna caught were juvenile, most of them are below L_{50}. Zhui et al. (2011), reported that bigeye tuna inhabiting the Atlantic, Indian and Pacific Ocean, can reached sexual maturity at a size of 100 to 130 cm, they assessed the L_m at 110 cm for unsexed fish.

Kawakawa (*E. affinis*) exhibited bimodal length with individuals below 48 cm and others above which had reached maturity. In this study, the spawning potential of the cohort was 54%, which is above the reference level of SPR. This study does not conquer with reports from IOTC (2016) which showed that Kawakawa is not subjected to overfishing. In contrast, estimated SPR was low for skipjack tuna (*K. pelamis*) or 21%, a sign of relatively high exploitation.

Most *S. guttatus* appeared between L_{opt} and L_{max}. These results suggest that *S. guttatus* can reach its L_{opt} before it is caught with estimates of SPR 100%. However, few individuals measured close to L_∞ raise concerns about proper species identification. The estimated SPR of the relatively small bullet tuna (*A. rochei*) was also 100%, with individuals above the L_{max}. These measurements of large individuals are suspicious and highlight the importance of training on species identification.

The three reef fish species analysed in this study all had low SPR values, well below the 20% reference point limits. Similar results have been shown in studies on *L. mahsena* in Tanzania, with smaller fish mainly sampled and difficultly finding large individuals (Stephen , Andrew , Lindsey , Mario , & Matthew , 2018). The study for assessment of maturity of *L. harak* conducted in the coast of Kenya showed that L_{50} was 32.5 cm (Kulmiye, Ntiba, & Kisia, 2002), which was close to the value used in current study. The selectivity curve for *L. harak* was steep. This could have occurred due to the quality of data used in this study and high selectivity of gillnets and *dema* traps used by reef fish fishers. Change in mesh size, or another form of management may influences the selectivity of the fishery

The Indian anchovy was mostly caught between its L_{50} and L_{95}. Selectivity at SL_{50} for Mafia, Bagamoyo and Mkinga is below 6 cm indicating that there is higher fishing pressure in those districts than others. Change of mesh size from 10 mm to 8 mm have contributed to high selectivity of *dagaa* seine (Paul, 1996). All districts measured individuals greater than the L_{max} of 17 an error caused by lack of skills in measuring fish length or identification.

The accuracy of results from this study might have been affected by the number of samples collected. For example, the minimum sample size required is recommended to be ten times the number of length classes in the sample for analysis of length-frequency data (Gerritsen & McGrath, 2006).

5.2 Assessment of catch sampling with a new Craft gear category

To improve estimation of total catch in a fishery with multiple gears and multiple species as that of mainland Tanzania is complex. Assessment of fisheries in these circumstances is done by implementing a random sampling strategy of the landing sites by restructuring types of crafts and gears into simple categories (Cowx, Van der Knaap, Muhoozi, & Othina, 2003). In the current CAS and frame survey setup in Tanzania, for the marine waters, there are registered seven different crafts types, which creates large number of combinations. The complexity of the craft and gear data from frame and catch assessment surveys were simplified and analysed. The outcome of a fewer number of combinations on the structure of recorded data.

Quality of data in terms of number of samples required for each district and actual collected samples was not good. Comparison on the number of samples collected per each month from each district was made. Ilala, Lindi Rural showed fewer samples when compared to Kilwa District, Tanga city and Kibiti. In the case of Ilala, which had an incredibly low number of samples, Ferry fish market serves as an auction place. The Ferry fish market should have an efficient data collection to record landings which were not recorded from the source because more than 50% of the total landings from nearby districts lands at Ilala. (Van, Pet, Machiels , Tumuljadi , & Setyohadi , 1996)

Accuracy and reliability of catch data depends on the sample size collected. Stomatopoulos, (2002) illustrated that a population size of 3000 needs 32 samples for 90% accuracy, For 95% accuracy, 123 samples for each fishing unit are needed. Most districts with the exeption of Kibiti, Kilwa, and Tanga City had less than 32 samples on average for each Craft_gear combination. Inconsistency in monthly sampling was observed in several districts such as Mkuranga, Ilala and Kinondoni Districts.

6 CONCLUSION

LB-SPR is an easy method to apply and will be beneficial for estimation stock status and aid in gear restriction or modification in mainland Tanzania using data collected from the mobile app. There is a sign of overfishing for many species investigated as SPR was less than 20%. The proposed structure of Craft_gear combination has improved the level of accuracy in estimation of the total catch. Observations on the trend of estimated catch per year indicated a significant difference between reported catch per district and total estimated catch from the database. This calls for a close examination on the estimation of total catch and sampling program. The current observation of catch sampling with a new Craft_gear category showed that if data enumerators will be encouraged to take more samples it's possible to get close to a desired 90% level of accuracy.

7 RECOMMENDATIONS

- Considering the importance of knowing the stock status, the Ministry should profoundly engage in monitoring catch statistics and cooperate with Tanzania Fisheries Research Institute (TAFIRI) in the collection and analysis of life history parameters required for assessment of stock status.
- Since many fishing grounds are common and shared by fishermen, the final estimation of total catch could consider larger strata (combining districts) to avoid mismatch between the frame survey and CAS.
- To reduce errors that may be associated with ad-hoc and costs of frame surveys, it is better to improve information on vessels and gears by strengthening the vessel registration system from all fishing areas.
- The programme for using Mobile phone in sampling fish should be upgraded and emphasis put on regular training in fisheries data collection and species identifications through the BMUs, which is in line with strengthen community participation.

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APPENDIX 1: NUMBER OF NEW CRAFT_GEAR CATEGORY IN FRAME SURVEY 2018, PER DISTRICT.

Frame survey new category per District	Bagamoyo	Chalinze	Ilala	Kibiti	Kigamboni	Kilwa	Kinondoni	Lindi Rural	Lindi Urban	Mafia	Mkinga	Mkuranga	Mtwara Rural	Mtwara Urban	Muheza	Pangani	Tanga City	Total
Non_poweredboat-CN	1	0	0	0	0	12	0	1	12	1	7	0	0	0	0	3	7	44
Non_poweredboat-HL	23	0	61	43	27	647	82	113	53	196	29	8	177	195	2	24	87	1767
Non_poweredboat-line	11	0	2	4	5	1	19	38	4	5	1	2	20	1	0	28	2	143
Non_poweredboat-nets	59	149	10	636	116	136	54	31	40	98	16	307	40	12	1	15	49	1769
Non_poweredboat-other	0	0	5	0	12	5	0	0	0	1	0	0	0	1	0	0	0	24
Non_poweredboat-seine	2	1	1	0	0	3	3	1	7	0	4	0	16	10	0	3	5	56
Non_poweredboat-SP	0	0	17	11	31	102	4	192	25	154	19	1	101	18	3	25	19	722
Non_poweredboat-TR	1	0	0	0	2	72	4	44	15	21	31	4	50	14	4	16	39	317
Poweredboat-CN	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	6
Poweredboat-HL	171	2	45	2	16	116	63	4	21	36	105	0	5	10	44	37	160	837
Poweredboat-line	19	4	2	1	6	11	2	1	1	4	5	1	3	1	2	2	6	71
Poweredboat-nets	43	16	7	40	53	120	45	11	13	114	39	56	110	1	33	105	44	850
Poweredboat-other	1	0	0	0	7	8	0	1	0	0	2	0	0	2	1	6	18	46
Poweredboat-seine	46	0	67	1	6	135	24	8	16	33	66	1	4	31	12	28	105	583
Poweredboat-SP	0	0	1	0	4	36	5	1	2	12	28	11	6	1	34	9	26	176
Poweredboat-TR	8	0	3	0	17	58	7	12	0	31	42	0	6	1	6	66	35	292
Total	**389**	**172**	**221**	**738**	**302**	**1462**	**312**	**458**	**209**	**706**	**395**	**391**	**538**	**298**	**142**	**368**	**602**	**7703**

Appendix 2: Total number of samples (landings) per simplified Craft_gear combination in Catch assessment survey, per District, during June to November 2019.

Craft_gear for CAS	Bagamoyo	Ilala	Kibiti	Kigamboni	Kilwa	Kinondoni	Lindi Rural	Lindi Urban	Mafia	Mkinga	Mkuranga	Mtwara Rural	Mtwara Urban	Muheza	Pangani	Tanga City	Total
Non_poweredboat-CN	1	0	0	0	0	0	0	31	2	0	0	0	0	0	0	0	34
Non_poweredboat-HL	4	0	1	167	354	38	23	114	248	0	8	65	77	1	17	30	1147
Non_poweredboat-line	67	0	386	4	0	2	0	8	1	0	1	0	1	0	24	41	535
Non_poweredboat-nets	289	12	403	11	6	0	0	0	2	0	365	0	1	0	0	142	1231
Non_poweredboat-seine	0	0	0	0	5	3	1	0	0	0	0	0	0	0	0	5	14
Non_poweredboat-SP	0	0	4	118	46	0	12	15	114	0	0	56	8	9	0	0	382
Non_poweredboat-TR	0	0	0	0	25	4	13	67	86	0	0	60	57	23	0	93	428
Poweredboat-HL	197	14	0	147	69	73	1	0	14	155	0	0	9	174	106	372	1331
Poweredboat-line	149	10	2	23	8	52	2	0	35	1	2	0	3	8	0	12	307
Poweredboat-nets	155	19	0	10	204	162	6	0	41	30	0	5	63	198	1	214	1108

Poweredboat-seine	123	47	0	0	150	31	93	120	219	162	0	0	144	0	67	389	1545
Poweredboat-SP	0	0	0	55	96	28	0	9	0	3	0	28	0	179	217	1	616
Poweredboat-TR	0	8	0	5	287	92	6	0	109	7	0	11	1	33	118	347	1024
Total	**985**	**110**	**796**	**540**	**1250**	**485**	**157**	**364**	**871**	**358**	**376**	**225**	**364**	**625**	**550**	**1,646**	**9702**

Appendix 3:Average BAC and CPUE for non-powered and powered crafts, from all Districts during June – November 2018.

Na	**Category**	**Ave-BAC**	**Ave-CPUE**
1	Non_powered-CN	0.506	17.8
2	non_powered-HL	0.591	12
3	non_powered-Line	0.605	15
4	non_powered-nets	0.701	27.3
5	non_powered-seine	0.77	39.3
6	non_powered-sp	0.587	6.57
7	non_powered-TR	0.594	12.3
8	Poweredboat-HL	0.616	27.3
9	Poweredboat-Line	0.559	77.4
10	Poweredboat-nets	0.623	122
11	Poweredboat-seine	0.601	525
12	Poweredboat-SP	0.648	29.2
13	Poweredboat-TR	0.697	32.4

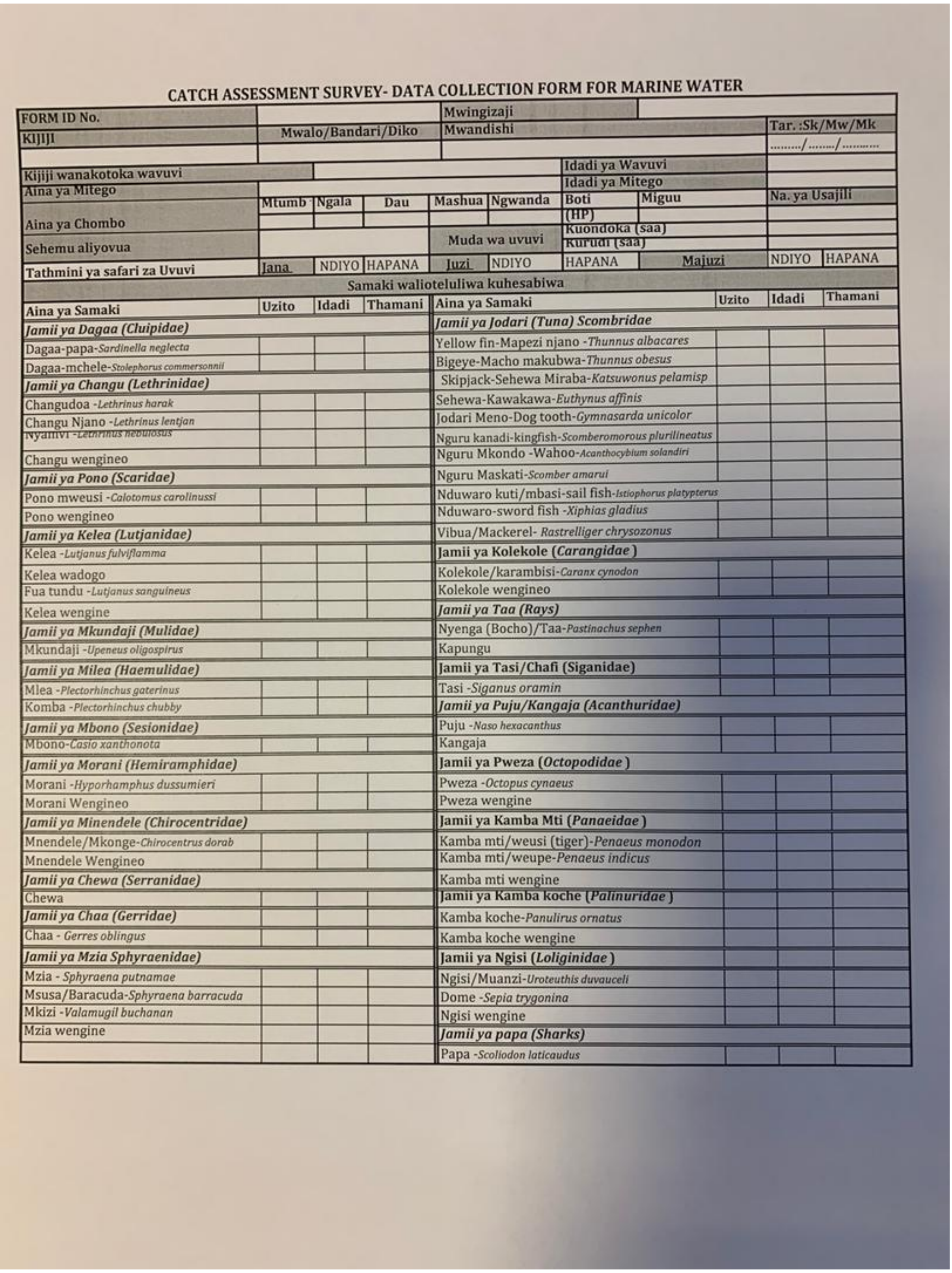
Appendix 4: Missing landings due to the missing data in CAS, from all Districts during June – November 2018.

Na	Craft_4	Sum	Mean_BAC	Mean_CPUE	_Effort	Landings
1	non_poweredboat-CN	213	0.51	17.79	3,209.68	57,101.06
2	non_poweredboat-HL	1,054	0.59	11.95	18,576.66	222,027.47
3	non_poweredboat-line	570	0.6	15.01	10,269.63	154,102.19
4	non_poweredboat-nets	2,325	0.7	27.33	48,565.75	1,330,968.00
5	non_poweredboat-other	144	NaN	NaN	NaN	NaN
6	non_poweredboat-seine	311	0.77	39.26	7,139.99	274,921.00
7	non_poweredboat-SP	1,027	0.59	6.57	17,975.02	118,182.00
8	non_poweredboat-TR	562	0.59	12.25	9,952.00	121,931.00
9	poweredboat-CN	36	NaN	NaN	NaN	NaN
10	poweredboat-HL	477	0.62	27.34	8,760.12	239,528.00
11	poweredboat-line	133	0.56	77.42	2,215.12	171,499.00
12	poweredboat-nets	1,772	0.62	122.47	32,914.76	4,030,963.00
13	poweredboat-other	276	NaN	NA	NaN	NaN
14	poweredboat-seine	354	0.6	525.42	6,343.43	3,332,971.00
15	poweredboat-SP	422	0.65	29.21	8,146.53	237,988.00
16	poweredboat-TR	295	0.7	32.43	6,123.81	198,616.92
	TOTAL	**9971**	**8.1**	**944.45**	**180,192.50**	**10,490,798.64**

Appendix 5: The list of craft types commonly used in Tanzania Source: Ministry of Livestock and Fisheries-Tanzania

Craft type	Size range	Propulsion	Gear in use
Dugout canoe	3-5m	Paddle	Hand lines
			Basket
			Traps
Mashua	Up to 12m	Sail	Longlines
		Engine	Shark nets
		Engine	Purse seine
		Engine	Drift nets
		Engine	Gill nets
Boat	7 to 9 m	Engine	Gillnet
			Shark nets
			Purse seine
Ngalawa	4-7m	Paddle	Gillnet
		Sail/engine	Shark nets
		Paddle	Traps
Dhow	10 m	Sail/Engine	Purse seine
Hori (dingi)	3-5m	Paddles	Ringnet
		Poles	Gillnet
Plunked canoe	5 - 7 m	Sail	Gillnet
		Paddle	Longline
		Paddle	Handline

Appendex 6:Data collection form for Marine waters



CATCH ASSESSMENT SURVEY- DATA COLLECTION FORM FOR MARINE WATER

FORM ID No.				Mwingizaji					
KIJIJI	Mwalo/Bandari/Diko			Mwandishi				Tar. :Sk/Mw/Mk	
								......../......./..........	
Kijiji wanakotoka wavuvi						Idadi ya Wavuvi			
Aina ya Mitego						Idadi ya Mitego			
Aina ya Chombo	Mtumb	Ngala	Dau	Mashua	Ngwanda	Boti (HP)	Miguu	Na. ya Usajili	
Sehemu aliyovua				Muda wa uvuvi		Kuondoka (saa)			
						Kurudi (saa)			
Tathmini ya safari za Uvuvi	Jana	NDIYO	HAPANA	Juzi	NDIYO	HAPANA	Majuzi	NDIYO	HAPANA

Samaki walioteluliwa kuhesabiwa

Aina ya Samaki	Uzito	Idadi	Thamani
Jamii ya Dagaa (Cluipidae)			
Dagaa-papa-*Sardinella neglecta*			
Dagaa-mchele-*Stolephorus commersonnii*			
Jamii ya Changu (Lethrinidae)			
Changudoa -*Lethrinus harak*			
Changu Njano -*Lethrinus lentjan*			
Nyamvi -*Lethrinus nebulosus*			
Changu wengineo			
Jamii ya Pono (Scaridae)			
Pono mweusi -*Calotomus carolinussi*			
Pono wengineo			
Jamii ya Kelea (Lutjanidae)			
Kelea -*Lutjanus fulviflamma*			
Kelea wadogo			
Fua tundu -*Lutjanus sanguineus*			
Kelea wengine			
Jamii ya Mkundaji (Mulidae)			
Mkundaji -*Upeneus oligospirus*			
Jamii ya Milea (Haemulidae)			
Mlea -*Plectorhinchus gaterinus*			
Komba -*Plectorhinchus chubby*			
Jamii ya Mbono (Sesionidae)			
Mbono-*Casio xanthonota*			
Jamii ya Morani (Hemiramphidae)			
Morani -*Hyporhamphus dussumieri*			
Morani Wengineo			
Jamii ya Minendele (Chirocentridae)			
Mnendele/Mkonge-*Chirocentrus dorab*			
Mnendele Wengineo			
Jamii ya Chewa (Serranidae)			
Chewa			
Jamii ya Chaa (Gerridae)			
Chaa - *Gerres oblingus*			
Jamii ya Mzia Sphyraenidae)			
Mzia - *Sphyraena putnamae*			
Msusa/Baracuda-*Sphyraena barracuda*			
Mkizi -*Valamugil buchanan*			
Mzia wengine			

Aina ya Samaki	Uzito	Idadi	Thamani
Jamii ya Jodari (Tuna) Scombridae			
Yellow fin-Mapezi njano -*Thunnus albacares*			
Bigeye-Macho makubwa-*Thunnus obesus*			
Skipjack-Sehewa Miraba-*Katsuwonus pelamisp*			
Sehewa-Kawakawa-*Euthynus affinis*			
Jodari Meno-Dog tooth-*Gymnasarda unicolor*			
Nguru kanadi-kingfish-*Scomberomorous plurilineatus*			
Nguru Mkondo -Wahoo-*Acanthocybium solandiri*			
Nguru Maskati-*Scomber amarui*			
Nduwaro kuti/mbasi-sail fish-*Istiophorus platypterus*			
Nduwaro-sword fish -*Xiphias gladius*			
Vibua/Mackerel- *Rastrelliger chrysozonus*			
Jamii ya Kolekole (*Carangidae*)			
Kolekole/karambisi-*Caranx cynodon*			
Kolekole wengineo			
Jamii ya Taa (Rays)			
Nyenga (Bocho)/Taa-*Pastinachus sephen*			
Kapungu			
Jamii ya Tasi/Chafi (Siganidae)			
Tasi -*Siganus oramin*			
Jamii ya Puju/Kangaja (Acanthuridae)			
Puju -*Naso hexacanthus*			
Kangaja			
Jamii ya Pweza (*Octopodidae*)			
Pweza -*Octopus cynaeus*			
Pweza wengine			
Jamii ya Kamba Mti (*Panaeidae*)			
Kamba mti/weusi (tiger)-*Penaeus monodon*			
Kamba mti/weupe-*Penaeus indicus*			
Kamba mti wengine			
Jamii ya Kamba koche (*Palinuridae*)			
Kamba koche-*Panulirus ornatus*			
Kamba koche wengine			
Jamii ya Ngisi (*Loliginidae*)			
Ngisi/Muanzi-*Uroteuthis duvauceli*			
Dome -*Sepia trygonina*			
Ngisi wengine			
Jamii ya papa (Sharks)			
Papa -*Scoliodon laticaudus*			