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# STRENGTHERNING OF ARTISANAL FISHERIES DATA COLLECTION AND MANAGEMENT IN TANZANIA

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## ABSTRACT

For good fisheries management, fisheries data must be collected. It is essential for the management agency that the most appropriate and accurate information for management of the fishery is continuously collected, processed and provided in a timely fashion. In fisheries, reliable and accurate information is crucial because only well informed decision makers can make good decisions. This paper is an attempt to devise ways to improve the collection, analysis and management of artisanal fisheries statistics in Tanzania. It describes a simple sampling procedure, community based data collection model and types of data to be collected. The study also comes up with improved analysis methods for easy access of the data. The study elaborates these in marine waters as a pilot area; later on (it is hoped) the model will be introduced to all other water bodies in Tanzania. The great challenge of fisheries management is to choose the best management strategies to achieve the objectives. For this purpose, biological, economical, social and ecological fisheries information are necessary. In order for Tanzania to have all this information, the suggested analysis methods and improved database management system should be introduced.

## ACRONYMES

ACPBL – Average Catch Per Boat Landing
BAC – Boat Activity Coefficient
BS – Beach seine
CAS – Catch Assessment Survey
CPUE – Catch Per Unit Effort
CV – Coefficient of Variation
CN – Cast Net
DA – District Authority
FAO – Food and Agriculture Organisation
FD – Fisheries Division
FF – Fish fences
FU – Fishing unit
GN – Gill Net
GDP – Gross Domestic Production
HL – Hand line
LVFO – Lake Victoria Fisheries Organisation
MS – Microsoft
MNRT – Ministry of Natural Resources and Tourism
RN – Ring net
SSE – Sampling Standard Error
SN – Shark net
SADC – Southern African Development Community
SD – Standard Deviation
TANFIS – Tanzania Fishery Information System
TAC – Total Allowable Catch
TCMP – Tanzania Coastal Management Partnership
TCZCDP – Tanga Coastal Zone Conservation and Development Program
TR – Traps
UNDP – United Nations Development Program
VAS – Vessel Activity Coefficient
VEC- Village Environment Committee

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# 1 INTRODUCTION

The Tanzania fishing industry can be divided into the artisanal (small scale) and commercial (large scale) fisheries. The former is characterized by traditional (low technology) fishing gear and vessels; the latter by more modern fishing gear and mechanized fishing vessels. In terms of output volume, output value and employment artisan fisheries are much more important than industrial fisheries. Historically, artisan fisheries have provided the economic base for the coastal people of Tanzania.

The fisheries management system in Tanzania is based on common property rights. Fishing boats must be licensed, but the licensing system is primarily for monitoring and statistical purposes. The license fee is very low and the fishery is basically open access. Gordon (1954) and Harding (1968) showed that common property fisheries generally operate in a socially suboptimal manner. To achieve more benefits a good fisheries management system is needed. Without a good fisheries management system, the fisheries cannot maximize profit. For successful fisheries management, fisheries information is necessary. Without such information, it is impossible to calculate the optimal fishing effort for any given biomass level and therefore to formulate a good fisheries policy. In fisheries management, the main supply of such information is through monitoring of fisheries input (fishing effort) and output (fish catch) which in most countries is referred to as fisheries statistics. Fisheries statistics is the primary means to measure the social, economical, biological and environmental performance of the fishery (FAO 2002).

Artisanal fish production statistics in Tanzania are poor. The data is unreliable, inaccurate and not reported in a timely manner. This observation has been verified in studies of the Tanzanian fisheries (Berachi 2003, Jiddawi 2001, Katonda 1994 and Linden and Lundin 1996), which have found that artisanal fisheries statistics in Tanzania are not reliable. Partly as a result of this but also due to poor management practice, the fishery exceeded the maximum upper level of harvest i.e. Maximum Sustainable Yield (MSY). Therefore there is a great need for proper management practice in Tanzania of fishery resources. FAO (1997) indicated that, effective fisheries planning and management, particularly in common property or community based coastal resource fisheries, requires a sound knowledge of how to collect, analyse and manage fisheries data. Yet, proper data collection requires significant human, technological and financial resources. These resources are lacking in Tanzania. Therefore, for responsible fisheries management in Tanzania, it is important to find the least costly way to assemble, compile and analyze artisanal fisheries statistics.

## 1.1 Objective of the study

The objective of this study is to devise ways to improve the collection, analysis and dissemination of artisanal fisheries statistics in Tanzania. The ultimate purpose of this data is to lay the basis for proper management of the artisanal fisheries including the official fisheries policy goal of *promoting conservation, development and sustainable management of the fisheries resources for the benefit of present and future generations.*

The study will focus on marine artisanal fisheries as a model (pilot area), and if successfully implemented the model will hopefully be introduced to other water bodies such as Lake Victoria, Lake Tanganyika, Lake Nyasa and other minor waters in the country.

## 1.2 Significance of the study

Currently, there is a high demand and interest from new fisheries investors for artisanal fisheries statistics. In addition, fisheries scientists in Tanzania have for many years been calling for more extensive and reliable fisheries statistics. At the same time one of the Fisheries Division's main problems is a lack of reliable, accurate and timely information on artisanal fisheries statistics since 1997. Fisheries statistics is the basis in policy making and fisheries management. It is necessary for Tanzania to improve artisanal fisheries statistics so as to improve management of the fishery resource.

## 1.3 Organization of the study

The study is organized in the following manner:

Section one gives an introduction of the study, objective and its significance;

Section two provides an overview of Tanzania's fishery. It describes the economic importance of artisanal fisheries in Tanzania. It also gives an account of the present system of data collection and the main issues regarding artisanal fisheries statistics;

The proposed improvements in collection of artisanal fisheries data on marine waters will be presented in section three. In this section the sampling procedure will be elaborated. A community based data collection system will also be proposed to replace data enumerators. It also covers the types of data to be collected;

Section four elaborates on the estimation process for artisanal fish catch production in Tanzania. It also deals with the use of biological data;

Data management and the importance of database management system have been elaborated in section five;

Costs and benefits of the improved system are covered in section six; and

Conclusions on the proposed system and policy recommendations are presented in section seven. It is recommended that this study should be used as a model for other water bodies in Tanzania.

## 2 BACKGROUND

Tanzania is a coastal state in the West Indian Ocean. In addition to the ocean area the country is well endowed with inland water bodies. The country has a total surface area of 945,040 square kilometres (Government 2000). The country shares the three most important inland lakes in Africa with other nations. Lake Victoria is shared with Kenya and Uganda. It is the second largest fresh water lake in the world, with a total surface area of 68,800 square kilometres. Out of this area, Tanzania has 35,088 square kilometres (LVFO 2004). Tanzania shares Lake Tanganyika with Burundi, the Democratic Republic of Congo and Zambia. It is the second deepest lake in the world with a total surface area of 32,900 square kilometres. Tanzania has 13,489 square kilometres (UNDP 1994). Tanzania also shares Lake Nyasa with Malawi and Mozambique. In addition, there are also small lakes like Rukwa, Manyara, Eyasi, Natron and reservoirs such as Mtera and Nyumba ya Mungu. The country's total fresh water area is estimated to be about 54,040 square kilometres, while the marine territorial water area is 64,000 square kilometres (MNRT 1997) within 12 nautical miles with a total marine coastline of 1,450 kilometres long. The country has a significant fishery sector in these extreme marine and inland water areas (Figure1).

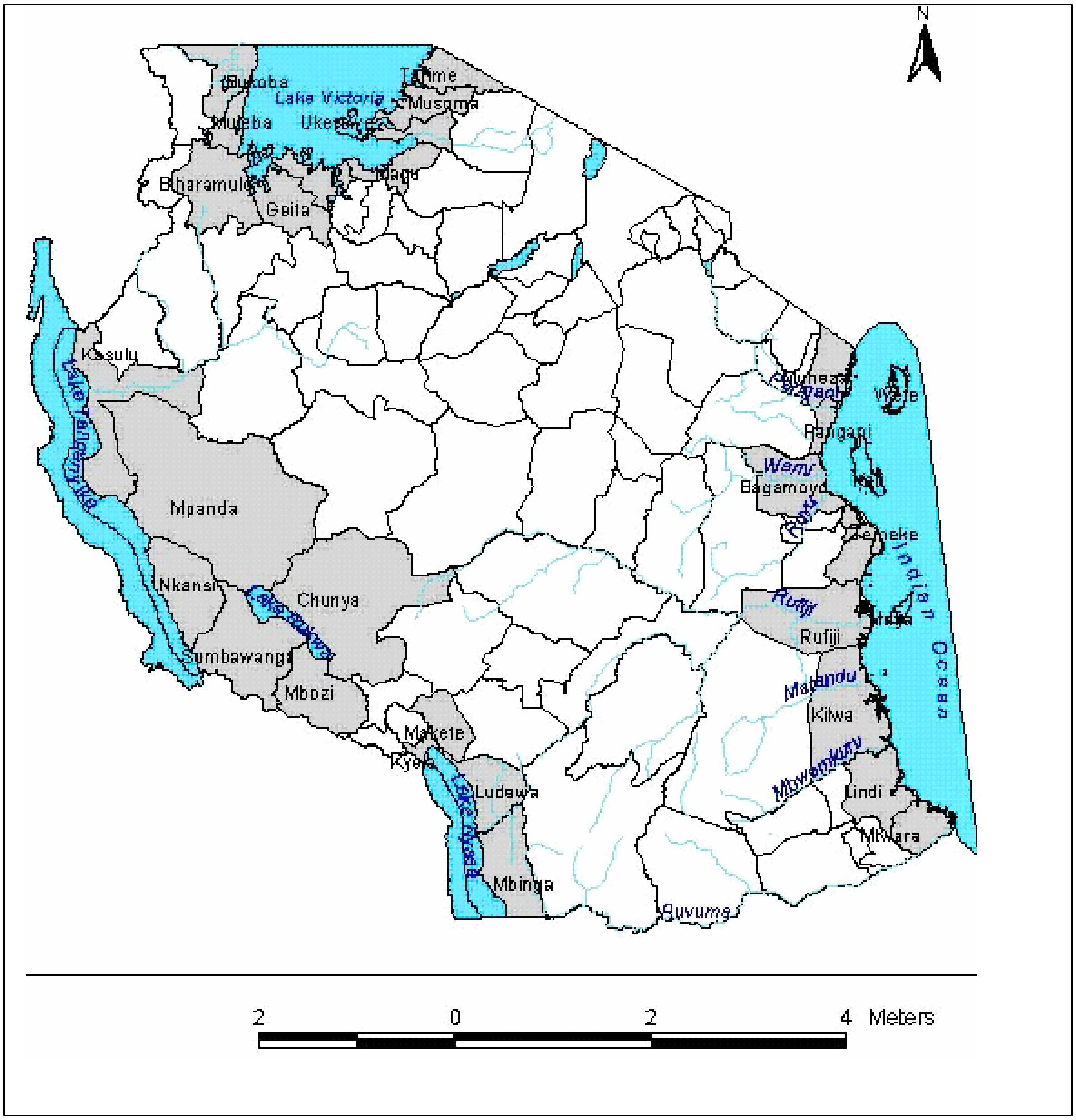


Figure 1: Map of Tanzania.

The fishing industry in Tanzania is divided into artisanal and industrial fisheries. The artisanal fisheries land almost all the freshwater and most of the marine catches (Figure 2). Excluding data from the Exclusive Economic Zone (EEZ) fishery, artisanal fisheries account for more than 99% of the country's total fish catch (Figure 2). This is an average of 338,584 metric tons per year (1990 – 2003).

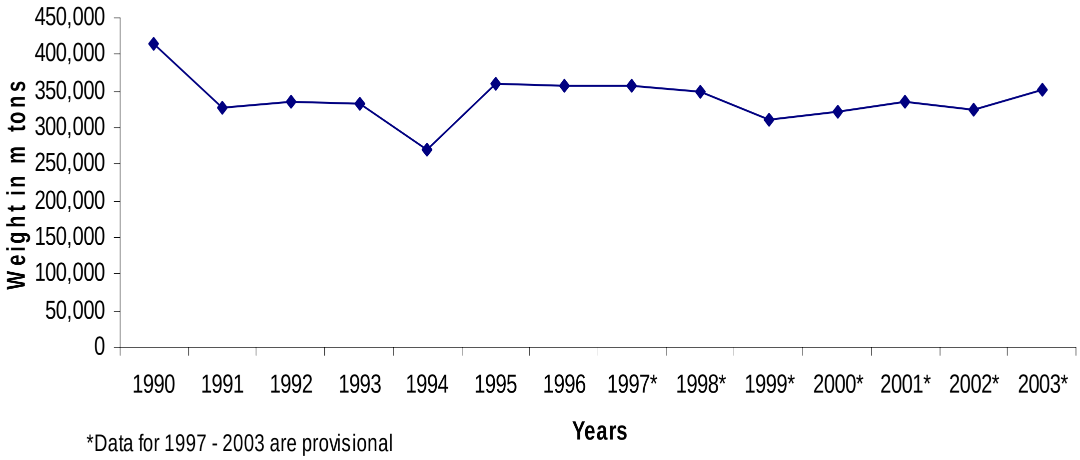


Figure 2: Total fish production from artisanal fishery for 1990 – 2003.

Industrial fishery (prawns trawlers) contributes the remaining 1% (Figure 3). Industrial fishery has an average fish production of 1,660 metric tons per year, with a value of some 2 million USD per year (1990 – 2003). Artisanal fishery supports, through employment, the majority of the coastal communities providing either part time or full time jobs. Fishers are spread out all along the shores and about 158,647 fishers (MNRT 2002) are fully engaged in artisanal fisheries along the entire coast working in both marine and freshwater areas.

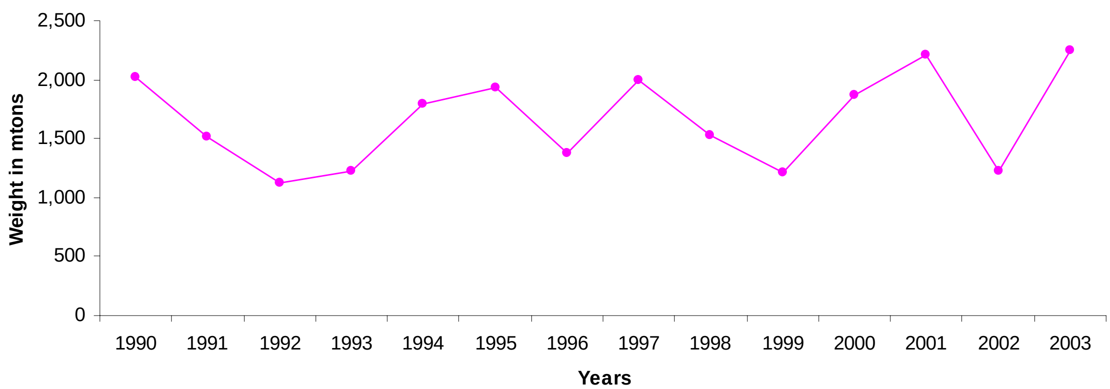


Figure 3: Total fish production from industrial (prawns) fishery for 1990 – 2003.

Artisanal catches are represented by multiple species such as rabbit fish (*Lethrinidae*), parrot fish (*Siganidae*), snappers (*Lutjanidae*), groupers (*Serranidae*), sardines (*Clupeidae*), mackerel (*Scombridae*), jacks (*Carangidae*) and kingfish (*Scomberocoridae*). Other species include sharks, rays and crustaceans (shrimp, lobster and crabs), octopus, sea cucumber, gastropods, bivalves and shellfish. Freshwater species include Nile perch (*Lates*), dagaa *(Restrionebola),* dagaa kauzu *(limnothrissa tanganyikae and stolothrisa miodon*), tilapia (*Tilapians*), cat fish (*Claridae)* mormyrus (*Momyridae*) and bagrus. Others are mbasa (*Ramphochromis spp)* and usipa (*Engraulicyprius sardell*a).

Historically, artisanal fishery was mainly for subsistence. However, any surplus was taken to fish markets for those who lived further from the fishing areas. After the emergence of export markets for Nile perch, dagaa, prawns, lobsters, crabs, octopus and sea cucumber, the fishery has become the main source of income for fishers. The fishery now makes a significance contribution to export earnings (Figure 4).

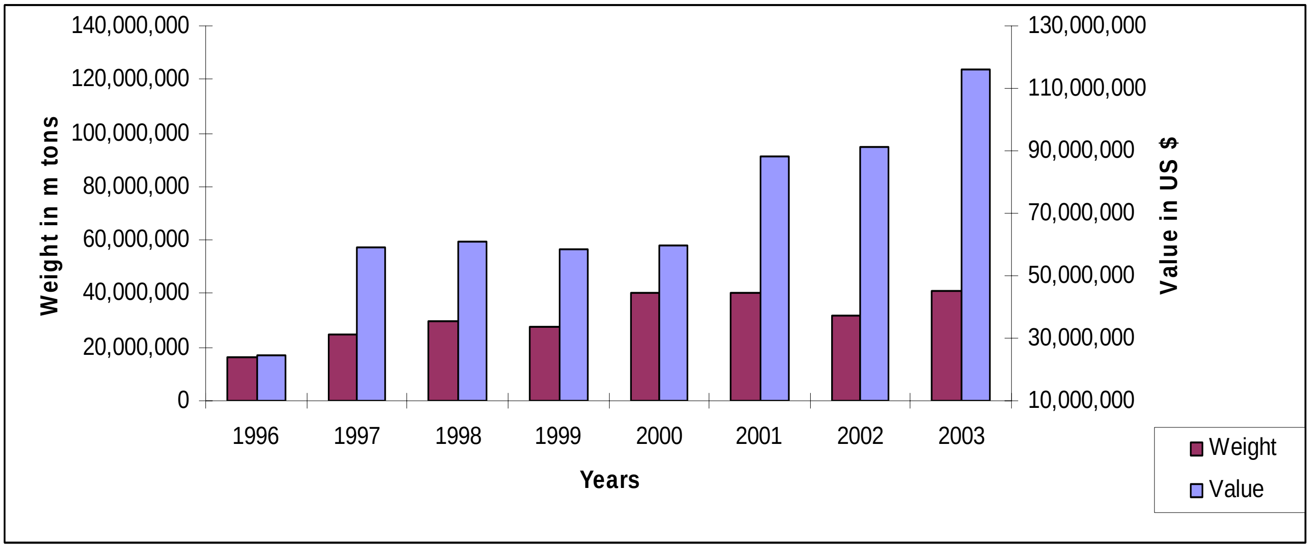


Figure 4: Export performance from artisanal fishery for 1996 – 2003.

Among the total export value obtained from fisheries, on average artisanal fisheries have contributed to more than 88% from 1996 – 2003 (Figure 5).

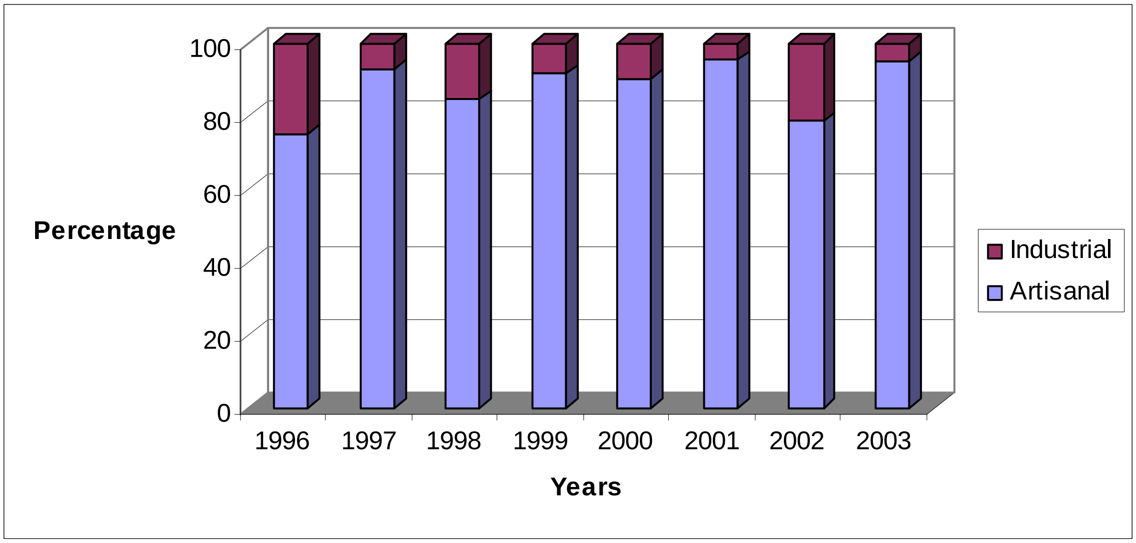


Figure 5: Percentage of export value for artisanal and industrial fisheries from 1996 – 2003.

According to the Fisheries Master Plan 2002, fish provide 30% of the animal protein consumed by the population of Tanzanian. Currently the estimation of fish consumption is 13 kg per person per year. The fisheries sector (both artisanal and industrial) contributes 2% to 3% (BOT 2001) of the National Gross Domestic Production (GDP). Therefore, artisanal fisheries statistics are very important for management of fish resources. In most cases, reliable fisheries statistics provide the basis for best scientific evidence and a better management approach.

## 2.1 Previous data collection system

### *2.1.1 Institutional framework*

The Fisheries Division is under the Ministry of Natural Resources and Tourism. It is the custodian of fisheries statistics in Tanzania. The division is responsible for collection, analysis and dissemination of national fisheries information. Unfortunately, there is not enough manpower and capacity for data collection in the division.
During the centralized administration system (1980s), there was a strong formal link between the Fisheries Division and regional/district administrations. Regional/district fisheries officers and their subordinates were answerable to the Fisheries Division. Therefore in every landing site, field officers were employed at the district level (during that time) as data enumerators. Apart from other fishery related activities, data collection was the main/core activity of the field officer.

### *2.1.2 Data collection*

Fisheries data refers to data that may be of use in the management of a fishery as well as for commercial, recreational, cultural and scientific purposes (Sullivan *et al.* 2000). This kind of data can include biological information, economic information and information concerning the environmental conditions that affect the fishery. Most of the data collected in Tanzania on artisanal fisheries are frame surveys and catch assessment surveys.

The frame survey is the inventory check of fisheries stock variables such as the number of landing sites, number of fishermen and number of fishing units (vessels and gears by type and size). It is also a description of fishing and landing activity patterns, processing and marketing patterns, as well as describing supply centre for goods and services (FAO 1998). The frame survey can also be referred to as a fisheries census and is obtained by complete total enumeration. Previously, the frame survey covered the whole coastline of Tanzania simultaneously, nowadays due to lack of funds, it covers each particular water body separately e.g. Marine, Lake Victoria, Lake Tanganyika, Lake Nyasa etc. Frame surveys are conducted on a biannual basis. However, sometimes the survey is delayed due to logistical problems. The main objectives of the frame survey data are:

- To secure data on the current number of fishermen, number of fishing vessels, number of fishing gears by type and size and some socio-economic information on available facilities at the landing beaches;
- To provide a "raising factor" for estimation of the country's total artisanal fish catch production from the sampling data;
- To provide sampling frames (comparison) for various surveys being conducted and those to be conducted in the future; and
- To provide data that can be used for estimation of fish stock (stock assessment).

Another type of data collected from artisanal fisheries is the catch assessment survey. These are landing surveys which are conducted at selected/chosen landing sites. The collected information include data on catch, species composition, associated effort, and other secondary data such as prices, weight of fish and number of fish caught (for big size fishes). In some cases these refer to input (fishing effort) and output (catch) fisheries data. The main objectives of the catch assessment survey data are:

- To provide total fish production data (of all species, boats and gears) by weight and value per district, region, water body and the whole country;
- To provide total fish production data by species (caught by specific boat/gear type) in terms of weight and value ;
- To provide Catch Per Unit Effort (CPUE) i.e. average catch per fishing boat or fishing gear and also the average per fishing hours; and
- To provide biological parameters, giving yield per recruitment and value per recruitment analysis for the most important commercial species.

#### *2.1.3 Data analysis*

The recorded data used to be reported to the Fisheries Division for analysis. The implementation of UNDP/FAO funded project "Strengthening Fisheries Statistical Unit" (URT/016/89) came up with the estimation of artisanal fisheries data via a two tier approach whereby frame surveys and sample surveys of catch and effort data (the information on daily catches and related effort) were used. The data was analyzed at the Fisheries Division through the dbase II program called Tanzania Fishery Information Systems (TANFIS). The project came to an end in 1994 but the program was used until 1996. From early 1997 the program was unable to analyze any data because the program (TANFIS) was incompatible with the new MS Windows versions and the computers were broken. In addition the computers were not repaired due to lack of funds at the Fisheries Division. Part of the problem was lack of programmers at the Fisheries Division as most of the staff from the statistics unit is marine biologists by profession. Additionally, the division has only four staff members in the statistics unit.

#### *2.1.4 Quality of data*

The Fisheries Division has worked actively with the FAO since 1991 and the regional/district fisheries offices to improve the quality of fisheries data. However, the overall quality of artisanal fisheries data has been unreliable and inaccurate. The reported catch in artisanal fishery from 1997 onwards is provisional (Figure 2), since it was estimated without analyzing collected data. The main reason for this is due to a lack of personnel for recording data at the sampling sites and lack of capacity at the Fisheries Division.

As the data is unreliable and inaccurate, there is room for improvement in the scientific estimation process. This will improve management of the fish resources in the country by using the data during the planning process. The FAO (2002) recommend that, "it is essential to know exactly what is actually being fished from the wild population, as this affects the stock's ability to survive and, more importantly to reproduce". This is why catch and effort statistics, along with other data regarding fish caught, are the key and essential basis for effective fisheries management.

A significant effort has been made by some FAO member countries in the collection, management and use of data related to fisheries. FAO (2003) makes strategies and plans for the improvement of knowledge and understanding of the fishery status and trends as a basis for fisheries policy-making and management. Emphasis was made on effective fisheries planning and management, particularly in common property or community-based coastal resource management areas which require a sound knowledge of the collection, analysis and management of the fisheries data.

### 2.2 Current overview

Artisanal fisheries data is collected on a sampling basis. The primary sampling unit is the landing site. From a list of landing sites obtained from frame surveys, a number of landing sites are randomly selected. The secondary sampling unit is the day. Data is collected for 16 randomly selected days per month.

The basic data is collected from species of specific types by boats using specific gear in specific landing sites. The collected data is entered into 10 computers which are distributed in different districts of the marine sector (Lake Nyasa and Lake Tanganyika respectively).

Aggregating and expanding according to the total number of boats, total number of fishing days and the boat utilization ratio, this data can be used to generate estimates of total landings by species, boat types and fishing gear by districts and landing sites (Appendix 2). These catch trends are usually reported in national annual fisheries statistics reports. This information (especially the catch trend) is crucial for the management of the fishery.

Formal links between the Fisheries Division and the regional/district administration have been broken since 1995 following the implementation of a decentralized administration system, whereby regional/district fisheries officers (and their subordinates) are no longer answerable to the Fisheries Division (section 2.1.1). In 1996, many of the district field officers were laid off at the district level, leaving the data collection activity unperformed. The remaining officers cover all of the many functions coming under the heading of “fisheries” (e.g., registration of fishermen, fisheries regulations and their implementation, fishermen's affairs, advice on resources and their assessment, marketing, aquaculture (seaweed farming) and tax collection at the landing beaches for the district administrations). As a result, since this date a limited amount of data (from sampling sites) has been collected. In the sampling sites where data enumerators have been laid off the data is simply not collected.

## 2.3 Main challenge

Since 1997, national annual fisheries statistics reports, specifically for the artisanal sector, have not been produced (Figure 2). This is due to the lack of manpower and financial resources mentioned above that limit the collection of the basic data from the landing sites as well as a lack of human capacity to analyse the entered data at the fisheries division. It is of the utmost importance to remedy both problems.

Since before 1996, the Fisheries Division had been looking for means to improve the reliability of artisanal fisheries statistics. The shift to a decentralized administration structure in 1996 has made this work very difficult. In 2000 a Regional Fisheries Information System (RFIS) under the SADC project, was established (SADC 2002). The purpose of the project is to provide timely, relevant, accessible, useable and cost effective information to improve the management of marine fisheries resources in the Southern African region (Kenya, Tanzania, Seychelles, Madagascar, Mozambique, South Africa, Angola and Namibia). A Catch Assessment Survey (CAS) database in MS Access was developed. This database is based on the same main principles employed in Tanzania i.e. intermittent frame surveys and collection of catch data from selected landing sites on selected days. It replaces the TANFIS programme that was originally designed by the FAO. A tailor made training course was conducted for 10 days in May 2001 and 10 data entry personnel were trained. Before the completion of the database, the consultant left the project. The project could not manage to find a successor who was capable of completing the database neither was the Fisheries Division able to employ a consultant.

Data is now entered in 10 districts' computers including five in the marine sector. The entered data has not yet been analysed as the database is incomplete and the Fisheries Division staff working in the statistics unit does not have the capacity to finish the work.

Moreover, at the district councils the collection of fisheries data is often perceived to be low in the order of priorities and may therefore be neglected. Thus, the laying off of data enumerators in some landing sites has not been perceived as adversely affecting district activities. The Fisheries Division has tried to put a system of data collection and processing in place. However, this has been somewhat unsuccessful due to limited manpower and other resources. On top of this, analysis of the data already entered in the database is another unfinished challenge before the artisanal fisheries statistics for the past few years may be produced.

## 3 SUGGESTED IMPROVEMENTS

In this paper, the previous system, current status and main challenge for the overall artisanal fisheries statistics in Tanzania have been detailed. Considerable effort must be taken in order to get reliable artisanal fisheries statistics. In summary, unreliable statistics confound fisheries management on three fronts. Biologically, they bring greater uncertainty into the biomass estimation process by reducing confidence in the accuracy of fisheries management advice. Politically, they reduce the public's confidence in the ability of fisheries managers to monitor and manage the resource on their behalf. Economically, they limit the economic and social understanding of the position and viability of the fisheries sector. Therefore, this section will provide broad discussion on sampling procedure, community participation in data collection and the type of data to be collected in marine waters of Tanzania so as to improve artisanal fisheries statistics.

Tanzania's marine artisanal fisheries are based on the use of local, traditional and primitive methods of fishing. According to 2001 frame survey (MNRT 2001), there are 4,927 fishing vessels in marine waters. Out of which 44% are dugout canoes (*mitumbwi*), 30% are outrigger canoes (*ngalawa*), 11% are dhow and the remaining 15% are planked constructed fishing vessels such as *mashua* and *boti* (Table 1). The main means of propulsion are sails and paddles; engines are used only in very few vessels (approximately 8%). The gear mostly used include shark nets, gillnets, hand lines, fish traps, long lines, gillnets, scoop nets, ring nets, cast nets, and fish fences. Generally, there is a wide distribution of fishing vessel types and gear (shark nets, gillnets, hand lines, fish traps and long lines) used in all 13 districts along the coast (Table 1 and 2).

Tanzania has a total of 206 landing sites in marine waters (MNRT 2001). Catches are landed each day in all 206 landing sites. The landed fish is of different species. They are landed from different types of boats using different types of gears and different gear sizes. Table 1 lists the vessel numbers by types in the 13 marine districts of Tanzania:

Table 1: Fishing vessel distribution in marine waters of Tanzania

| **District** | **Fishing vessel types** | | | | | **Totals** |
|---|---|---|---|---|---|---|
| | **Boat** | **Canoe** | **Dhow** | **Ngalawa** | **Mashua** | |
| Muheza | 11 | 101 | 50 | 121 | 9 | 292 |
| Tanga | 30 | 140 | 54 | 130 | 61 | 415 |
| Pangani | 0 | 10 | 4 | 186 | 9 | 209 |
| Bagamoyo | 13 | 51 | 35 | 152 | 19 | 270 |
| Mafia | 74 | 293 | 47 | 266 | 48 | 728 |
| Mkuranga | 13 | 100 | 10 | 77 | 0 | 200 |
| Rufiji | 2 | 207 | 0 | 10 | 0 | 219 |
| Ilala | 83 | 75 | 1 | 48 | 0 | 207 |
| Kinondoni | 56 | 78 | 94 | 215 | 38 | 481 |
| Temeke | 79 | 13 | 12 | 87 | 39 | 230 |
| Kilwa | 33 | 229 | 101 | 54 | 36 | 453 |
| Lindi | 1 | 203 | 29 | 93 | 3 | 329 |
| Mtwara | 8 | 695 | 128 | 56 | 7 | 894 |
| Total | 403 | 2195 | 565 | 1495 | 269 | 4927 |

As can be seen from Table 1 the total number of fishing boats is almost 5000. Thus, the average number of boats per landing place is about 24. Note, however, that many of the landing places are very small, so some landing places may have over a 100 boats.

Table 2 provides information on types of fishing gear used in Tanzanian marine fisheries. The table shows that hand-lines are by far the most frequently used gear. Other important fishing gears are shark-nets, gill-nets, traps and long-lines.

Table 2: Fishing gear distribution in marine waters of Tanzania (Fisheries Division 2001).

| **DISTRICT** | **GEAR TYPES** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Shark nets** | **Gill nets** | **Hand lines** | **Traps** | **Long lines** | **Beach seines** | **Cast nets** | **Ring nets** | **Scoop nets** | **Fish fences** |
| Muheza | 196 | 436 | 532 | 525 | 270 | 0 | 0 | 10 | 3 | 10 |
| Tanga | 128 | 424 | 1208 | 624 | 135 | 0 | 10 | 87 | 17 | 9 |
| Pangani | 157 | 93 | 218 | 1063 | 425 | 0 | 19 | 3 | 86 | 0 |
| Bagamoyo | 124 | 237 | 1798 | 16 | 50 | 26 | 0 | 6 | 15 | 0 |
| Mafia | 565 | 826 | 792 | 1701 | 37 | 5 | 8 | 20 | 34 | 3 |
| Mkuranga | 444 | 294 | 298 | 0 | 4079 | 0 | 0 | 0 | 3 | 0 |
| Rufiji | 74 | 1397 | 95 | 2 | 100 | 0 | 0 | 0 | 0 | 0 |
| Ilala | 20 | 97 | 3171 | 54 | 0 | 0 | 0 | 42 | 16 | 0 |
| Kinondoni | 447 | 66 | 1969 | 492 | 3 | 244 | 104 | 7 | 11 | 0 |
| Temeke | 40 | 53 | 529 | 0 | 30 | 6 | 0 | 28 | 31 | 0 |
| Kilwa | 181 | 257 | 616 | 158 | 0 | 25 | 5 | 20 | 31 | 9 |
| Lindi | 141 | 294 | 535 | 225 | 0 | 50 | 26 | 7 | 0 | 0 |
| Mtwara | 335 | 662 | 1725 | 699 | 48 | 129 | 1 | 62 | 5 | 39 |
| Total | 2852 | 5136 | 13486 | 5559 | 5177 | 485 | 173 | 292 | 252 | 71 |

In small scale (artisanal) fisheries like those described in Tables 1 and 2, it is impractical and nearly impossible to collect data from all landing sites on a daily basis. This is due to limited finances, manpower, low level of technology, difficulties in infrastructure, and geographical conditions. The amount of data from all 206 landing sites is huge as can be inferred from Tables 1 and 2. As a result total enumeration is very difficult and hardly practical. Stamatopoulos, in FAO (2004) underlined that, "in small scale fisheries, the amount of information regarding total landings, species composition, prices etc is so large that the use of a census approach (total enumeration) is impractical and sampling techniques are almost invariably employed". Therefore the most cost effective way for Tanzania to collect artisanal fisheries data is through sampling. This assessment is supported by Papaconstantinou *et al*. (2002), who concluded that in designing fisheries data collection system, sampling procedure minimizes operational costs, time and logistics.

### 3.1 Sampling procedure

The proposed improvements in the artisanal fisheries statistics system will involve sampling in time and space. The primary sampling unit is the landing site. A few landing sites will be selected from a list obtained during the latest fisheries frame survey. The sampling method will be stratified random sampling. The following are few of the reasons for using stratified sampling:

- In marine areas there are 13 administrative districts which can be used as strata.
- Estimates of the fish production are always needed for each district (stratum).
- Every district will be included in the sample; and
- Adequate representation of specific groups of the target population in the sample will be ensured.
- Efficiency of the sample design will be improved, thus making the survey estimate more reliable.

In the sampling procedure, each district is regarded as a stratum. This means that they are all represented in the data. In stratified sampling, every element in each stratum has an equal probability of being sampled. In each stratum (district) a random sample of landing sites will be applied. For instance, from a cluster of 12 landing sites in the Pangani district, two will be sampled i.e. one small and one large landing site (Table 3). Unfortunately, in some districts the selection of landing sites is not completely random due to difficulty in accessibility, conditions of the landing sites (either permanent or temporary sites); and size and type of fishing activities. For that reason only 19 landing sites will be selected where data recording will take place (Table 3). The 19 landing sites will act as representatives of the 206 landing sites. The sample size of 19 is probably too small. However, the justification for this is: (i) limited resources in terms of manpower; and (ii) the belief that there is little variation between landing sites in terms of the relevant variables under study. Temporary landing sites are not included in the sample, because they are very small (only six) and mostly used by very few people. They are also not gazetted as fisheries landing sites. Landing sites vary in terms of size and type of fishing activities. Some are small, with few types of fishing activity while others are large with many types of fishing activity. The accessibility to the landing sites from the fishing communities is also considered in the sampling process. Some landing sites are very remote and hard to reach. The representation of type of fishing vessels and gears in landing site are also taken into consideration in this sampling procedure, as this will determine the type of species caught. The types of fishing vessels and gears are distributed throughout the 13 districts (Table 1 and 2). In Tanzania there is no regulation which limits fishers to move from one landing site to another in any district. They only need a letter of permission from their home district fisheries officer to introduce them to where they are going and inform them of the by-laws of the new landing site, which they must obey.

Table 3: Distribution of sample landing site.

| **Region** | **District** | **Total** | **Landing site size** | | **Sampled landing sites** |
|---|---|---|---|---|---|
| | | **Total** | **Big/Large** | **Small** | |
| Tanga | Muheza | 18 | 2 | 16 | 2 (1B and 1S) |
| | Pangani | 12 | 2 | 10 | 2 (1B and 1S) |
| | Tanga | 25 | 2 | 23 | 2 (1B and 1S) |
| Coast | Bagamoyo | 13 | 1 | 12 | 1 (1B) |
| | Mafia | 34 | 1 | 33 | 2 (1B and 1S) |
| | Mkuranga | 10 | 1 | 9 | 1 (1B) |
| | Rufiji | 15 | 0 | 15 | 1 (1S) |
| DSM | Ilala | 1 | 1 | 0 | 1 (1B) |
| | Kinondoni | 5 | 2 | 3 | 1 (1B) |
| | Temeke | 8 | 0 | 8 | 1 (1S) |
| Lindi | Kilwa | 18 | 0 | 18 | 1 (1S) |
| | Lindi | 18 | 0 | 18 | 2 (2S) |
| Mtwara | Mtwara | 29 | 2 | 27 | 2 (1B and 1S) |
| Total | | 206 | 13 | 193 | 19 (9B and 10S) |

Where:

B means big landing sites which have > 25 boats

S means small landing sites which have < 25 boats

In sampling the data, each major determinant of the dependent variable will be appropriately represented in the sample as y, which is a function of species, vessels, gear and time i.e. y = f (species, vessels, gear, time)

That is to say, each sample from any landing site will contain all variables which will represent that a certain species was caught from a certain type of vessel using a specific type of gear in a particular time (Appendix 1).

A standard error of the mean has been calculated by making use of the following formula:

$$SE = \frac{SD}{\sqrt{n}}$$

Where *n* is the number of observations and the Standard Deviation is calculated by using the Standard Deviation formula:

$$SD = \sqrt{\sum \frac{(x - \bar{x})^2}{n-1}}$$

With data from Table 3 (last column) the obtained sample standard error is 0.022; this measures the variability of the sample means. Statistically, accuracy and precision in sampling is measured by statistical indicators called Coefficient of Variation (CV). CV is a relative index of variability that utilizes the sample variance and the sample mean. CV is the most commonly used relative index of variability, it measures how each sample deviates from the mean and is usually expressed as a percentage.

$$CV = 100 \times \left( \frac{SD}{mean} \right)$$

Experience indicates that CVs below 15% are indicators of acceptable variability in data samples (Stamatopoulos 2002). According to the data in this study, the obtained CV is 6% which is obtained by making use of the sample mean and standard deviation (Table 4). In this case, the CV is acceptable for the smaller sample size with low scores (one or two per district) obtained from the whole population of landing sites.

Table 4 provides information on calculated standard deviation and standard error of the mean as well as the coefficient of variation of the sampling landing sites. In calculating data for Table 4 the variables used were: n = 19 (i.e. sample size), number of observations is 13, mean = 1.461 and square root of n = 4.358899, while n-1 = 18.

Table 4: Statistical parameters for the selected sampling landing sites.

| X | x-mean | x-mean squared | Sum of x-mean/n-1 | SD | SE | CV |
|---|---|---|---|---|---|---|
| 2 | 0.538461538 | 0.015260044 | | | | |
| 2 | 0.538461538 | 0.015260044 | | | | |
| 2 | 0.538461538 | 0.015260044 | | | | |
| 1 | -0.461538462 | 0.011211461 | | | | |
| 2 | 0.538461538 | 0.015260044 | | | | |
| 1 | -0.461538462 | 0.011211461 | | | | |
| 1 | -0.461538462 | 0.011211461 | | | | |
| 1 | -0.461538462 | 0.011211461 | | | | |
| 1 | -0.461538462 | 0.011211461 | | | | |
| 1 | -0.461538462 | 0.011211461 | | | | |
| 1 | -0.461538462 | 0.011211461 | | | | |
| 2 | 0.538461538 | 0.015260044 | | | | |
| 2 | 0.538461538 | 0.015260044 | | | | |
| 19 | 1.11022E-15 | 0.170040486 | 0.009446694 | 0.097 | 0.022 | 6.650 |

Note: Calculated using Excel.

The secondary sampling unit is the day. The data will be collected for 10 days per month. These 10 days will be selected with the help of a random table. This will give 10 days in each month where enumerators go to the landing site for sampling. For consistency of recording and data analysis in the computer, one district fisheries officer will select the days for at least six months at a specific time and notify all landing sites through their respective fisheries officers. That means, during recording days, each of the selected landing sites (19 randomly selected from the sampling procedure) will be sampled to represent the entire marine landing sites.

The recent guidelines on how many samples are required for each type of vessel using particular gear to get an accurate estimate of CPUE is given by Stamatopoulos, in FAO Fisheries Technical paper No. 425, 2002 (Table 5). A key point with sample data is that the more you collect, the smaller the additional increase in accuracy (Table 5). In Table 5, one can see that for a population size of 3000 you only need 32 samples for 90% accuracy, but you need 123 samples for 95% accuracy and 1549 samples for 99% accuracy.

Table 5: Landing survey sampling requirements at various levels of accuracy and population size. (FAO Fisheries technical paper, No. 425 2002).

| Accuracy (%) | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 98 |
|---|---|---|---|---|---|---|---|---|---|---|
| Data population size | Safe sample size for vessel landings | | | | | | | | | |
| 400 | 30 | 36 | 44 | 56 | 73 | 97 | 133 | 188 | 267 | 356 |
| 500 | 30 | 37 | 45 | 58 | 75 | 2 | 143 | 208 | 308 | 432 |
| 600 | 30 | 37 | 46 | 59 | 77 | 106 | 150 | 223 | 343 | 505 |
| 700 | 31 | 37 | 47 | 60 | 79 | 108 | 156 | 236 | 373 | 574 |
| 800 | 31 | 38 | 47 | 60 | 80 | 110 | 160 | 246 | 400 | 640 |
| 900 | 31 | 38 | 47 | 61 | 81 | 112 | 164 | 255 | 424 | 703 |
| 1000 | 31 | 38 | 48 | 61 | 82 | 114 | 167 | 262 | 445 | 762 |
| 2000 | 32 | 39 | 49 | 63 | 85 | 120 | 182 | 302 | 572 | 1231 |
| *see notes 3000 | 32 | 39 | 49 | 64 | 86 | 123 | 188 | 318 | 632 | 1549 |
| 4000 | 32 | 39 | 49 | 64 | 87 | 124 | 191 | 327 | 667 | 1778 |
| 5000 | 32 | 39 | 50 | 64 | 87 | 125 | 192 | 332 | 690 | 1952 |
| 10000 | 32 | 39 | 50 | 65 | 88 | 126 | 196 | 343 | 741 | 2425 |

During the recording days (sampling days), enumerators will record all vessels landing at that particular landing site. The recorded information will include the type of fishing vessel, number of crew members, species composition, type and size of fishing gear, fish catch and catch value (Appendix 3).

The recorded information (variables) for each vessel will include:

- Station – the name of landing site;
- Waters – the name of the water body e.g. Marine;
- Date – the date which data is collected;
- Type of boat – type of fishing vessels, like dug out canoe, planked canoe, dhow etc;
- Registration number – every fishing boat has a registration number;

- Type of gear used in the fishing operation like gill nets, hand lines, traps, scoop nets, etc used by that particular fishing vessel;
- Number of fishing gear and size of gear – number of different fishing gear involved in fishing operation and size e.g. GN 7” * 5 i.e. there are five gill nets of 7” mesh size;
- Number of men – number of fishermen or crew members on the recorded fishing trip;
- Number of fishing units – how many fishing units were involved in the fishing of the recorded catch;
- Arrival time – the time when the boats come ashore;
- Duration of fishing – the time used for fishing the registered catch;
- Species – type or name of the species e.g. *Siganus spp;*
  a) Weight of fish in kilograms
  b) Value of fish in Tanzanian Shillings
  c) Number of fish if they are big enough to be easily counted
- A separate sheet will also be provided for recording length and weight of the most important commercial species; and
- At the end of the month each recorder will be required to give the active fishing days in his/her location

It is expected that every fishing vessel operating from the landing site on the particular day will be recorded since the enumerators are part of the local community in which they live and they are familiar with the fishery. With 10 recording days per month, the expectation of getting enough data from the sampled landing sites to represent the total population of boats in all 206 landing site is high. By limiting the recording to only 10 days, data enumerators should have ample time to perform their other duties.

### 3.2 Community participation in data collection

The collection of data requires enough manpower at the source where the data is recorded. The FAO (1997) requested that states should ensure that timely, complete and reliable statistics on catch and fishing efforts are collected and maintained in accordance with applicable international standards and practices and in sufficient detail to allow sound statistical analysis.

In developed countries, scientific surveys are a vital component of stock assessment. Research vessels and commercial fishing vessels, operating under charter agreements with the research institutions are used to conduct surveys of fish abundance, stock assessment, etc. These surveys are the primary source of fishery-independent data. Paul *et al*. (2002) realized that, fishery-independent monitoring through a sea survey is difficult to maintain by developing nations. They are too expensive and cannot generate the full data needed for the evaluation of status or changes in fish stocks, not to mention the economic aspect of the fishery.

For developing nations, fishery-dependent monitoring can be extremely useful for generating both biological data and fisheries input (fishing effort) and output (catch). This information is highly needed in fisheries management for decision making. In the absence of fisheries staff (data enumerators) to record the data, fishing community members can be used. A few members of the village environmental committees (living closer to the landing site) could be trained and given mandates to collect fisheries data. The community members will represent data enumerators at those landing sites where there are no data enumerators to collect data. Though the data gathering by local people may not always be of the highest quality, their involvement can result in gathering large quantities of reasonably reliable data and perhaps more importantly, enhance a feeling of "ownership" among the community members and motivate them to implement conservation measures (TCMP 2003). Ticheler *et al*. (1998) argued that it is possible to obtain large quantities of reliable data relatively cheaply through the use of local fishermen. This may be seen as the first step in preparing the communities to take up their role in a community–based approach in the management of fish resources.

Data entry personnel have to spend some time on checking the quality of the data recorded by community members before entering it. Bazigos, (1985) suggested that the systematic application of effort towards developing sources of information outside the Fisheries Department, especially with cooperation of fishermen and industry, will ensure that the Fisheries Department does not depend exclusively on first-hand collection of information, but they have to check the data before processing, presenting and interoperating the results for government policy-making.

In order for the community to perform a better job in data collection, community members who are responsible for the statistical collection should be motivated. Somas (2003) recommended that when the community participates in any fisheries information collection they should be assisted or receive assistance to compensate the time lost to their daily activities.

In Tanzania, all the catches or landings in any particular landing site are taxed. The percentage of tax differs from district to district, and depends on the district administration. However, most of them tax about 10% of the value of the total landings. This study proposes tax harmonization in all marine districts. If all marine districts can charge say about 10% of the value of the total landings, 5% should then be given to the district administration as usual, while the remaining 5% should go to local village governments for supporting fisheries management activities like surveillance, data collection etc. This will motivate those who will record the data as compensation for that particular day. Instead of spending their time fishing or farming they will record data at the landing sites and receive some compensation at the end of the day. This has been tried out in the Tanga region during the life of the Tanga Coastal Zone Conservation and Development Project (TCZCDP). Village Environmental committee members collected fisheries and environmental data and the fisheries officers checked the data before analysis. In Lake Victoria fishers involved in the Beach Management Units (BMU) fully participate in data collection for the fisheries frame surveys.

### 3.3 Required data for fisheries management

To manage fisheries for the public good, the pertinent biological and economic data has to be collected. The crucial biological data relates to the fish stock growth function and its response to the harvesting activity. This involves a relationship such as natural mortality, weight gain by age, recruitment and fishing mortality functions.

The economic information relates to the harvesting production function, the harvesting cost function and prices of inputs and outputs. In addition, the cost of management, data collection and research should be taken into consideration.

The most important fisheries information needed for fisheries management is summarized in Table 6 below:

Table 6: Basic data requirements for proper fisheries management.

| **Objectives** | **Data types** |
|---|---|
| Biological | Landings by species per fishing fleet and even per gear, length, weight, maturity, sex and age of each individual fish, natural and fishing mortality per species and intrinsic growth rate biomass |
| Ecological | Impact of fishing gear on physical habitat, changes of physical habitat brought by non-fishing activities, indicator species and biological carrying capacity of the environment |
| Economical | Number of operating vessels in the fishery, fixed cost per fishing unit, variable cost per fishing unit (cost of manpower, cost of fuel, cost of labour, depreciation cost), revenue (income per fishing unit), profitability of each fleet, financial discount rate, destination of landings, dependence on fishery of other sectors of the community (processors, wholesalers etc), infrastructure cost and enforcement cost. |
| Social | Number of fishers employed within the fishery, number of people employed in shore based activities – by gender, by age group etc, and dependence of fishers and shore based workers on the fisheries for their livelihood |

Fisheries data which is collected in Tanzania does not cover these variables (Appendix 3). It is restricted to harvest by species and information about species weight and price. Hence this information is insufficient as a basis for the proper management of fishery resources. For proper management of the fishery, economical and biological monitoring should be gathered together. Economical data will give a clear picture of the fishery industry while biological data is useful in estimating specific biological parameters that are useful in fish stock estimation. Together, they both provide a basis for suggesting fisheries management strategies.

# 4 ESTIMATION PROCESS

## 4.1 Artisanal fish production estimation process

The fundamental approach to estimating the marine sector artisanal landings may be expressed by the relationship:

(*) Total catch = catch per unit effort · total effort.

(Where the variable "total catch" denotes the total catch of some species during a certain period of time, e.g. a year). The variable "catch per unit effort" represents the average catch of this species by active boats during this period and the variable "total effort" represents total vessel activity during the period defined by:

Total effort = total number of boats · number of fishing days · average activity of the boats,

Where, of course, each variable is estimated during the period in question.

Now, there are several types of boats and fishing gear. Hence the actual calculation of equation (*) is much more involved than appears at first sight. Table 7, illustrates a part of this complexity:

Table 7: Some boat/gear type combinations for marine waters of Tanzania.

| **Type of boat** | **Type of gears** | | | |
|---|---|---|---|---|
| | **Traps - 1** | **Hand lines - 2** | **Shark net - 3** | **Gill nets - 4** |
| Dug out canoe (1) | b,g(1,1) | b,g(1,2) | b,g(1,3) | b,g(1,4) |
| Planked canoe (2) | b,g(2,1) | b,g(2,2) | b,g(2,3) | b,g(2,4) |
| Dhou (3) | b,g,(3,1) | b,g(3,2) | b,g,(3,3) | b,g,(3,4) |
| Mashua (4) | b,g(4,1) | b,g(4,2) | b,g(4,3) | b,g(4,4) |
| Ngalawa (5) | b,g(5,1) | b,g(5,2) | b,g(5,3) | b,g(5,4) |

To take this into account we need to classify all observed landings of a given species by (i) boat type, (ii) gear type, (iii) landing site and (iv) time (day). To explain further let us adopt the following notation for these indices:

b= boat type
g= gear type
l= landing site
t= time period

The basic observation is the following

**(1)** $\hat{q} = (i; b, g, l, t)$

$\hat{q}$ = is the landing (catch) of some species by boat number i of type b using gear g in landing site l on day t.

**(2)** $I_{SAMP}(b,g,l,t)$ is the actual sample size for boats of type b using gear g, in landing place l on day t.
An estimator of landings by any boat of type b using gear g, in landing place l on day t is the average:

**(3)** $$\bar{q}(b,g,l,t) = \frac{\sum_{i=1}^{I_{SAMP}(b,g,l,t)} \hat{q}(i;b,g,l,t)}{I_{SAMP}(b,g,l,t)}$$

Where $I_{SAMP}(b,g,l,t)$ is the sample size

An estimator of total landings by all boats of type b using gear g, in landing place l on day t is:

**(4)** $$Q_1(b,g,l,t) = \bar{q}(b,g,l,t) \cdot I(b,g,l,t)$$

Where *I(b,g,l,t)* is the actual total number of boats of type b using gear g, in landing place l on day t.

As the data is sampled for a particular time period, then an estimator of average daily landings by any boat of type b using gear g, in landing site l over the period T is:

**(5)** $$q^o(b,g,l) = \frac{\sum_{i=1}^{T_{SAMP}(l)} \bar{q}(b,g,l,t)}{T_{SAMP}(l)}$$

Where $T_{SAMP}(l)$ is the number of sampled days in location l during the period T.

Since there is more than one landing site in each district, then the average daily landings by boat b using gear g, in a certain district during a month for example will be:

**(6)** $$q^{oo}(b,g) = \frac{\sum_{l=1}^{L_{SAMP}} q^o(b,g,l)}{L_{SAMP}}$$

$L_{SAMP}$ is the number of sampled locations during the period. The variable $q^{oo}$ corresponds to what we referred to as the catch per unit effort in the basic estimation relationship (*) above.

### *4.1.1 Effort*

Fishing effort has three elements in this type of calculation:

#### 4.1.1.1 Frame survey

This is the total fishing effort (number of fishing vessels by type, number of fishing gear by type and size, and number of fishermen) obtained from all fishing communities in that particular district (stratum). This is the data obtained from the last fisheries frame survey.

#### 4.1.1.2 Active Fishing Day survey

This is sometimes called Vessel Activity Survey (VAS). It represents the total number of days with fishing activity during the month. In other words, these are the total days in a month excluding the days which were lost to the whole fleet because of bad weather, religious holidays etc. This can easily be obtained by the data collectors by asking the fishermen at the end of the month how many days were not used for fishing. In the proposed system, it is recommended that a simple monthly form can be designed to collect this data. This number will then be put into the database and (automatically) incorporated into the mathematics behind the monthly estimate of catch.

#### 4.1.1.3 Boat Activity Coefficient (BAC) Survey

Boat activity coefficient survey examines the individual boat activity and aims to identify the probability that any individual boat of a specific boat/gear type will be active on any one day in a certain month. It is an average of how many days do individual boats of a particular type and gear go fishing. If BAC is one it means that chances are that all boats will be fishing every day. BAC assists in accessing the general accuracy of previous frame survey data through sampling.

#### 4.1.1.4 Estimated catch

Therefore, by making use of the catch survey and effort data one can estimate the total catch production either by district or water body for the month or yearly basis.

Therefore:

The average catch of boat type b using gear g, in all landing places (within a stratum) refers to the average catch per boat landed in a district:

$$\text{ACPBL} = \quad q^{oo}(b,g) = \frac{\sum_{l=1}^{L_{SAMP}} q^{o}(b,g,l)}{L_{SAMP}}$$

Where $L_{SAMP}$ is the number of sampled locations during the period.

This gives the average daily catch per boat of type b using gear g in a month for one district. The assumption here is that, the average landings of boat of type b using gear g is the same as the average harvest sampled. That is to say the average catch of boat type b using gear g in other landing sites which were not sampled within the district is the same as the average harvest from the sampled landing site.

If the population within the district are normally distributed then:

$$q^{oo}(b,g,d) = N(\mu(b,g,d),\sigma)$$

$$\sum_{l=1}^{L} q^{oo}(b,g,d)$$

Let **I** be the number of fishing boats i.e. number of boats of type b using gear g, obtained from frame survey data in a particular district, let say the Muheza district.

Then the estimation of fish catch (for example *siganus spp*) by boat type b (dug out canoe) using gear g (traps), let say for Muheza district, in January 2004 will be:

CPUE x I (Active fishing days x Boat Activity Coefficient)

**(7)** $\hat{Q}_2(b,g,d) = q^{oo}(b,g,d) \cdot \bar{I}(b,g,d)(T^* \cdot BAC)$

Where $T^*$ is the active fishing days or the number of fishing days.

Where $\bar{I}$ (*b,g,l*) is the average number of boats of type b using gear g in this particular district during the period in question. If the number of boats going out fishing in each day is the same, then that number will be used instead of average and the formula will be

**(7,b)** $\hat{Q}(b,g,d) = q^{oo}(b,g,d) \cdot I(b,g,d)(T^* \cdot BAC)$

As an example, equation (7) or (7,b) above gives the estimated catch of *siganus spp* caught by dugout canoes using traps for January 2004 in Muheza district.

An equation such as (7,b) will normally lead to estimation errors or biases. The reason is that it is essentially a multiple of two or more stochastic variables and the expected value of a multiple is generally not equal to the multiple of the expectations. In the case of (7.b) the variables on the equation are $q^{\circ\circ}$, *I*, T* and BAC. There are all stochastic because their estimates are based on sampling information. Consequently, unless they are all stochastically independent, the catch estimate $\hat{Q}$ will be biased. To see this, consider the simpler estimator: $\hat{Q} = q \cdot I$. In this case, it is easy to show (Appendix 2.3) that

**(8)** $\hat{Q} = \dfrac{Q}{(1+error)} = \dfrac{Q}{\left(1+\dfrac{Cov(q,I)}{\bar{q}\cdot\bar{I}}\right)}$,

Where *Q* is the true value, *Cov* (*q*, *I*) is the covariance between the two stochastic variables, and *q* and *I* and $\bar{q}$ and $\bar{I}$ are their means.

So if the Covariance is positive, the approximation equation will lead to an underestimate of the true catch and vice versa.

Various equations will be calculated according to the user needs, some of the required equations are elaborated in Appendix 2.

Once the catch by species has been estimated, then the value can be calculated by making use of the recorded prices on the landings.

**(8)** $Value = P \cdot Catch$

Where by P is the sample first sale price at the landing site and Catch is the estimated catch of a certain species as discussed earlier.

The analysis above is for one district, one month and one combination of vessel and gear that has caught one particular species of which there may be 18 (Figure 6) or more depending on the sampling data. The improved Catch Assessment Survey (CAS) database will calculate as follows for all combinations of boat/gear type as taken from the Frame Survey:

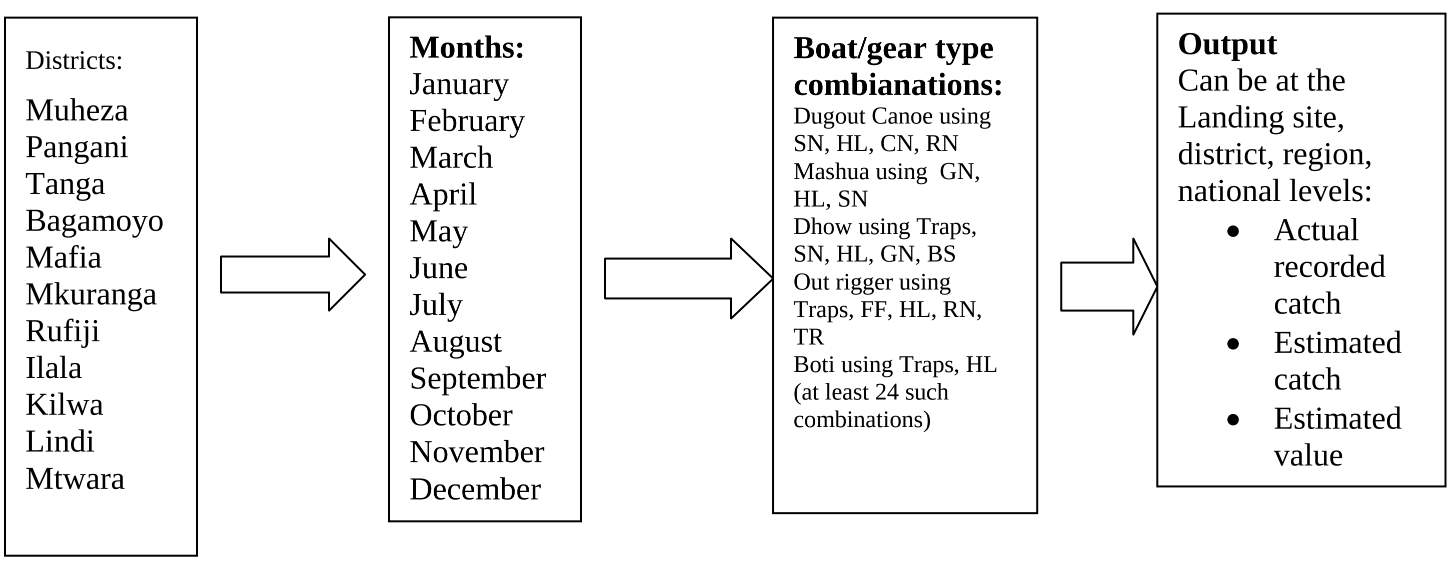


Figure 6: Simplified diagram for the district, month, boat/gear type combinations and output.

### 4.2 Other information

Other information like:

- Number of fishing trips by landing site, by district and by month;
- CPUE by district and by region;
- Number of fishing hours by boat/gear type; and
- Boat and gear efficiency can also be obtained by deriving the information from fishing hours by boat/gear type

All the above information can be obtained easily by writing queries in the CAS database. The database will calculate various type of information according to the data and users request.

## 5 DATA MANAGEMENT

This study is concerned with an improvement of routine artisanal fisheries data collection and management in Tanzania. In order to obtain reliable and updated information, the following steps should be followed (Table 8):

Table 8: Steps to take to obtain reliable and updated information

| Steps | Information |
|---|---|
| Step 1 | Who are the main stakeholders in fisheries, what are their management roles and responsibilities, their main objectives for data needs etc |
| Step 2 | Identify the information requirements of each stakeholder to support their roles in fisheries management |
| Step 3 | Identify manpower and other resources for obtaining required data from the collection to analysis. |
| Step 4 | Design a simple sampling procedure for data collection with respect to potential sources, tools and appropriate stratification to meet requirements mentioned in step 2 |
| Step 5 | Determine the analysis process |
| Step 6 | Design databases and other systems to support the storage, processing and sharing of data and information |
| Step 7 | Disseminate the information |

### 5.1 Need for a database management system

After collection, the data must be stored, and made easily available for analysis and interpretation for management of the fishery resources. Fisheries policy makers, planners and managers rely mostly on processed information and not raw data. This is due to the fact that, the primary data is often very detailed and difficult to interpret. However, for the purpose of scientific analysis, raw data is often preferable. Therefore the data is usually stored in a database. A database is a computer program which can store, edit and find data. A collection of databases is referred to as a Database Management System.

A Database Management System (DMS) is a computer program designed to manage a database and run operations on the data as requested by users (Frost 1984). A good DMS allows a high level of flexibility in filtering, aggregating and transforming the data. It also contains data checks to avoid data entry mistakes and to increase the accuracy of the stored data.

When selecting data sources attention should be focused on collecting raw data where the data flow is “narrowest”. For example information can be collected from the fishing operation (input) and the landing (output) and you can also get information from consumers e.g.:

Fishers → Landing site → Fish mongers/traders

This will simplify data collection and analysis processes and make the DMS easier to operate for users as well as enhance data accuracy. Therefore, the design of a database must be according to the nature of the data as well as the demands of the users. The DMS must be simple, robust and cost effective.

## 5.2 Catch Assessment Survey Database

The database designed by the SADC expert runs under MS Access. Access is currently included in the MS office software package. Access is commonly used as a spreadsheet as well as a program to analyse data. It has the advantage of being relatively inexpensive, and compared with more advanced DMS needs less specialized staff to run and maintain the database environment than many other systems. The current CAS database will be modified and finalised to suit the needs of the Fisheries Division. Expert consultants will be provided by UNU – FTP program to complete the database at the request of the Fisheries Division, Tanzania. After completion, the database will be housed at the Fisheries Division where the data will be analysed centrally. Since the data will be entered at the district level and validated locally, there will be flexibility for district analysis to cater to their needs eg. for the purpose of co-management. The database will be backed up at the Fisheries Division for privacy, easy storing, recovering and security of the data.

# 6 IMPROVED SYSTEM, COSTS AND BENEFITS

## 6.1 Cost of good data collection

Implementation of the improved system for data collection, analysis and management requires financial cost. These costs can be categorised into two main categories: investment costs (Table 9) and running costs (Table 10). The criteria used to estimate these costs are based on the current market price and civil service policy of the country. The running cost estimation was done for one year. However, the implementation of the system is not an end program because data collection and management is a continuous process.

### *6.1.1 Investment costs*

This is the cost which will be incurred during the introduction of the new system to marine districts. The introduction of the system requires transport facilities to go to districts and verify the existence and capacity of the landing sites. It will involve a lot of communication between the Fisheries Division and district authorities. This will be the preparatory phase of the system. Also, awareness creation to village environmental committees and district personnel must be conducted in this phase. The district personnel and village leaders have to understand why the system has been changed and for what purpose. Then data entry personnel, data enumerators and community members who will be selected to record data will be trained. The training will include a theory and practical stage. Fisheries experts responsible for the database should go around the district to install the completed database. After the training, data will be collected and entered in the computer.

Table 9: Investment cost for the improved system of data collection, analysis and management.

| **Activity** | **Time scale** | **Responsibility** | **Cost in USD** |
|---|---|---|---|
| Introduction of the system | 2 months | Fisheries division (FD) | 10,000 |
| Consultation to district authority offices | 2 months | Fisheries division | 15,000 |
| Awareness creation | 1 month | FD, District Authorities (DA) | 25,000 |
| Training (theory and practical) | 2 months | FD, DA and VEC | 40,000 |
| New hardware | 1 month | FD | 10,000 |
| Database installation to the district | 2 months | Fisheries division (FD) | 10,000 |
| Sub total | 6 months | FD, DA and VEC | 110,000 |

VE = Village Environmental committee

### *6.1.2 Running costs*

The running costs of the improved system will include the salary for the personnel who will be responsible for data collection and data entry. It will also include the cost of printing data collection forms and the contract for maintenance of the computers. Monitoring and evaluation will be done by Fisheries Division staff to make sure that data is recorded and entered in the required manner. The district authorities will also be required to take part in monitoring.

Table 10: Running cost for the improved system of data collection, analysis and management per year.

| **Activity** | **Time scale** | **Responsibility** | **Cost in USD** |
|---|---|---|---|
| Salary for data collectors and data entry personnel | 1 year | Fisheries division, District Authorities | 60,000 |
| Computer contract for maintenance | 1 year | Fisheries Division | 5,000 |
| Printing of data collection forms | 1 year | FD | 10,000 |
| Monitoring and evaluation | 1 yaer | FD and DA | 25,000 |
| Sub total | 1 year | FD, DA | 100,000 |

## 6.2 Potential benefits

As outlined in Tables 9 and 10 above, the total cost of establishing an improved data collection system is about 210,000 USD. The estimated cost here does not cover physical facilities like office space etc. The total revenue for marine artisanal fishery based on available data is represented in Figure 7. According to provisional data for 2003, total revenue from marine artisanal fishery was estimated at 35 million USD.

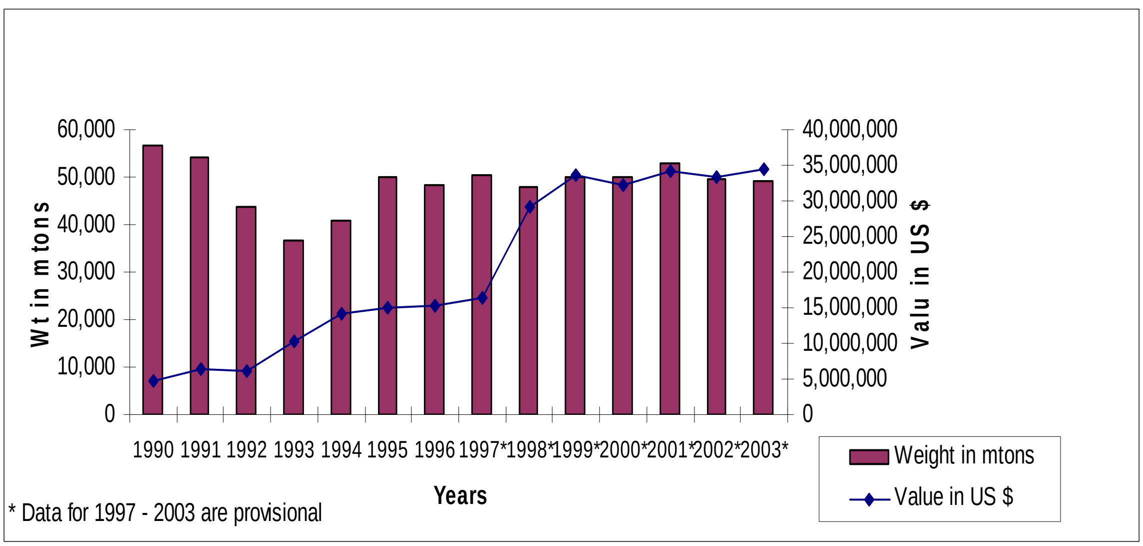


Figure 7: Marine artisanal fish production and their values for 1990 – 2003.

Currently, entry into fishery areas is open access which is known to waste potential economic rents. Based on calculations of this study (Appendix 4), attainable annual rents are as high as 16 million USD which represent a value of some 500 million USD (Appendix 4). To manage the fishery in a sustainable manner, fisheries data is needed. If the data collection effort described in this thesis contributes to this objective, the amount of 210,000 USD per year appears to be a very good investment.

### 6.3 Comparison of potential gains through better data collection

The improved system of data collection and analysis is likely to substantially improve fisheries management in the country. The system will bring potential gains of better data collection. However, in comparison, the cost is very low (approximately 0.6% of the revenue obtained in 2003 (Figure 8)). Based on data from 2003, the revenue from marine artisanal fishery can be estimated at 17 million USD for 2004. Therefore, from the estimated revenue, the cost for better data collection is only 1.2% of the total.

Therefore the introduction of an improved system of data collection and management is a good investment opportunity which will bear fruit over a long time period. The improved system seems to be a good investment opportunity for the fishery sector. In order to have good fisheries management, we need reliable and accurate fisheries data. Reliable and accurate fisheries data will provide necessary management advice since well informed decision makers can make good decisions. Policy makers can use the advice and come up with proper management measures. In doing so the fishery sector can operate at its maximum potential, this will improve the long term benefits of the sector.

## 7 CONCLUSION AND POLICY RECOMMENDATIONS

The study evaluated the collection of artisanal fisheries statistics in Tanzania and came up with an improved system of data collection, analysis and management. The study revealed that manpower, technology and financial limitations are the main sources of unreliable and inaccurate fisheries statistics in Tanzania. However, artisanal fisheries data is a key issue during country budget planning at the Parliament each year.

The recommended improved system, which is based on sampling and community participation in data collection, appears likely to generate more benefits than costs. It also reduces the workload of data enumerators and data entry personnel. As the number of sampling days has been reduced to ten days per month, data enumerators will have more time for other activities for the remaining twenty days.

Artisanal fishery is not particularly high on the political agenda at the district level unless there is a direct revenue benefit. The government should make sure that the whole task of data collection be given to village community members who are closer to the landing sites. Building up data collection and analysis capacity in village environmental committees and of data collectors should be a key task before the implementation of the improved system. This will give data enumerators and data entry personnel at the district level the chance to acquire knowledge related to data collection and processing. The improved system in the artisanal marine fisheries will be used as a model for a similar enterprise in other water bodies within the country.

Further studies are needed to test the accuracy of the estimation method proposed following which the appropriate modifications can be carried out.

Concerning data management, the government should make sure that CAS database is working properly to enable the Fisheries Department to analyze the data. To maintain and develop the database and to support the long term data management system in Tanzania there is a need for a long term commitment from UNU – FTP. Capacity building should be considered not only for the routine operation of the system but also for modification of the system as the need arises. The two sides should collaborate to establish a new database to have clear information in all fisheries statistics in Tanzania. An overall database could be established to input all fisheries statistics data such as frame surveys, catch assessment surveys, export and prawn fishery data.

The utility of accurate and reliable data can be achieved only if the system is operatational (including the database). The output data is going to be used in the management of the fishery. If the exact catch trends, sustainable revenue, yield per recruitment of a commercial important species and cost of the fishery are known policy makers will be able to infer the appropriate fisheries policy and consequently devise management measures to be used for the artisanal fisheries in Tanzania.

The existing management regime is based on open access and community management. The government should take steps to eliminate this common property right. The government should establish a license control mechanism. It is important to find out the total number of fishing vessels operating in the fishery. Then, entry into the fishery can be closed for new comers until at least 2007 (Appendix 4), but existing licenses should be tradable. Those who need fish for home consumption only should be given limited permits. This might be the start of the introduction of total allowable catch (TAC). With accurate and reliable data it will be easier to know exactly how much should be taken out from the stock. By making use of TAC and property rights such as licenses, policy makers may be able to maintain a desired fishing effort so that the fishery operates at a reasonably efficient point from the social perspective.

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## LIST OF REFERENCES


Bazigos, G.P. 1985. Practical guidelines for statistical monitoring of fisheries in limited manpower resources. FAO Fisheries Technical Paper No. 133. FAO Rome Italy [1985]

Berachi, I. G. 2003. Bioeconomic analysis of artisanal marine Fisheries of Tanzania (Mainland). Thesis on fulfilment of the requirement of the Master of Science in International Fisheries Management. University of Tromso, Norway.

BOT, 2001. Bank of Tanzania. Economic Operations report.

FAO, 1997. Technical Guidelines for responsible fisheries. Fisheries Management Article 2.

FAO, 1998. Guidelines for the routine collection of capture fishery data. FAO Fisheries Technical Paper No. 382;

FAO, 2002. The State of the World Fisheries and Aquaculture (SOFIA) 2002 <http://www.fao.org/documents/>

FAO 2003. Strategy for Improving Information on status and trends of capture fisheries. Rome, Italy.

FAO 2004, Safety in sampling – Methodological notes. FAO Fisheries Technical Paper No. T454. Rome, Italy

Frost, R.A.1984. Database Management System. Granada Publishing Ltd. London, UK.

Gordon, S.H. 1954. The economic theory of a common property resource: the fishery. *Journal of Political Economy,* **62**, 124 – 142.

Government, 2000. Tanzania Government report 10/12/2001. <http://www.tanzania.go.tz>

Harding, G. 1968. The tragedy of the commons. *Science.* **162,** 1243 – 1248.

Jiddawi, N. S. 2001. Status and Trends of Tanzania’s Marine Artisanal Fisheries. In: Coastal Communities and the Indian Ocean’s Future Conference. Chennai, India.

Katonda, I. 1994. Historical data on the Fisheries, Fisheries Statistics, Fishing gears and water quality of Lake Tanganyika (Tanzania). FAO, Bujumbura, Burundi, 1994, pp. 1-41

Linden, O. and Lundin, C.J. 1996. Integrated Coastal Zone Management in Tanzania. Proceedings of the National Workshop, May 1995, Zanzibar. The World Bank and SIDA-SAREC, Stockholm, Sweden.

LVFO, 2004. Characteristics of the Lake Victoria Fishery based on Frame survey's 2000 and 2002: With Recommendations for Development and Management of fishery. The Lake Victoria Fisheries Organization Regional working group on Frame surveys 5th – 8th April 2004, Kisumu, Kenya.

Ministry of Natural Resources and Tourism, 1997. Tanzania National Fisheries Sector Policy and Strategy Statement. Government printer, Dar es salaam, Tanzania

Ministry of Natural Resources and Tourism, 2001. Marine Fisheries Frame Survey Report, 2001. Government printer, Dar es salaam, Tanzania

Ministry of Natural Resources and Tourism, 2002. Fisheries Master Plan, Draft Report 2002. Government printer, Dar es salaam, Tanzania

Papaconstantinou et al. 2002. Design of a system for the collection and compilation of basic fisheries statistics in Mediterranean: a case study for Greece. *Fisheries Research* **57,** 155-167. INCORRECT REFERENCE

Paul, et al. 2002. Improving the usage of fisheries statistics in Vietnam for production planning, fisheries management and nature conservation. *Marine Policy* **26,** 13-34. INCORRECT REFERENCE

SADC, 2002. Regional Fisheries Information Systems (RFIS). Project Briefing document for Tanzania. Windhoek, Namibia.

Soma, K. 2003. How to involve stakeholders in fisheries management – a country case study in Trinidad and Tobago. *Marine Policy* **27,** 47 - 58

Stamatopoulos, C. 2002. Sample-based fishery survey: A technical handbook. FAO Fisheries Technical Paper No. 425. Rome, Italy.

National Research Council. 2000. Improving the Collection Management, and Use of Marine Fisheries Data. P. Sullivan (Chair), K. Able, C.M. Jones, K.M. Kaye, B. Knuth, B. Norcross, E. Russek-Cohen, J. Sibert, S.J. Smith, S.K. Thompson, and R. Young. 222 p

Tanzania Coastal Management Partnership (TCMP) 2003. State of the Coast Report. Coastal Resource Centre, University of Rhode Island, US.

Ticheler, et al. 1998. Participation of local fishermen in scientific fisheries data collection: a case study from the Bangweulu swamps, Zambia. *Fisheries Management and Ecology* **5,** 81-92. INCORRECT REFERENCE

UNDP, 1994. UNDP/GEF Project Document, Lake Tanganyika Biodiversity project

# APPENDICES

## Appendix 1: Mathematical sampling theory.

Among the observations are type of species, type of boats, type of gear and time.
Therefore x (species, boat, gear, time) = x(s, b, g, t) by landing site and district
Assume: x is randomly chosen from population (each x(s, b, g, t) is equally likely to appear in the sample)
Sample of size n(s, b, g, t)
Calculate mean will be

$$xmean(s,b,g,t) = \frac{\sum_{i=1}^{n}(s,b,g,t)xi(s,b,g,t)}{n(s,b,g,t)}$$

Therefore the variance for the sample data will be

$$\hat{\sigma}(s,b,g,t) = \frac{\sum_{i=1}^{n(s,b,g,t)}\left(xi(s,b,g,t) - xmeans(s,b,g,t)\right)^2}{n(s,b,g,t)-1}$$

According to central limit theorem (if random sample)
Standard deviation

$$xmean(s,b,g,t) \approx N\left(\mu(s,b,g,t)\right), \sqrt{\frac{\hat{\sigma}(s,b,g,t)}{n(s,b,g,t)}} = N(\mu,\sigma)$$

Expand N(s, v, g, t) total number of units

$$\hat{X} = N(s,b,g,t) \times \hat{x}(s,b,g,t) \approx N(N \times \mu, N \times \sigma) = N(X,E)$$

Here one can calculate constant intervals:

Example $\hat{x} \approx N(10,1)$ If N = 1000 events
Then $\hat{x} \approx N(10{,}000{,}1000)$
But this is only correct if 1) observations are randomly
2) if there is error in N
If these assumption fails, 1) the sampling is bias
2) the confidence intervals are wrong

**Appendix 2:**

*1. Data collection and estimation: Essential structure*

The following applies to a given species of fish. The purpose is to estimate aggregate landings of this species over a given period of time, *T*.

The following is ***observed*** (on-going data collection)

(1) $\hat{q}(i;b,g,l,t)$, all *b* and *g* and some *i*, *l* and *t* (sampling),

where $\hat{q}$ landings are by boat number *i* of type *b* using gear *g*, in landing place *l* on day *t*.

(2) $I_{SAMP}(b,g,l,t)$, all *b* and *g* and some *i*, *l* and *t* (sampling),

where $I_{SAMP}(b,g,l,t)$ is the actual sample size for boats of type *b* using gear *g*, in landing place *l* on day *t*.

An ***estimator of landings*** by any boat of type *b* using gear *g*, in landing place *l* on day *t* is the average:

(3) $$\bar{q}(b,g,l,t) = \frac{\sum_{i=1}^{I_{SAMP}(b,g,l,t)} \hat{q}(i;b,g,l,t)}{I_{SAMP}(b,g,l,t)}$$ , all *b*, *g*, *l* and *t*

where $I_{SAMP}(b,g,l,t)$ is the sample size.

An ***estimator of total landings*** by all boats of type *b* using gear *g*, in landing place *l* on day *t* is

(4) $Q_1(b,g,l,t) = \bar{q}(b,g,l,t) \cdot I(b,g,l,t)$, all *b*, *g*, *l* and *t*

where $I(b,g,l,t)$ is the actual total number to boats of type *b* using gear *g*, in landing place *l* on day *t*.

An ***estimator of average daily landings*** by any boat of type *b* using gear *g*, in landing place *l* over the period *T* is:

(5) $$q^{\circ}(b,g,l) = \frac{\sum_{t=1}^{T_{SAMP}(l)} \bar{q}(b,g,l,t)}{T_{SAMP}(l)}$$ , all *b*, *g*, *l*,

where $T_{SAMP}(l)$ is the number of sampled days in location *l* during the period *T*

An ***estimator of total landings*** by all boats of type *b* using gear *g*, in landing place *l* over period *T* is

(6) $$Q_2(b,g,l) = q^\circ(b,g,l) \cdot T(b,g,l)$$, all *b*, *g*, *l*,

where *T*(*b*,*g*,*l*) is the actual total operating time by all boats of type *b* using gear *g*, in landing place *l*

An ***estimator of average landings*** by any boat of type *b* using gear *g*, over the period *T* is:

(7) $$q^{\circ\circ}(b,g) = \frac{\sum_{t=1}^{L_{SAMP}} q^\circ(b,g,l)}{L_{SAMP}}$$, all *b*, *g*,

where $L_{SAMP}$ is the number of sampled locations during the period.

An ***estimator of total landings*** by gear type *g* (all boat types, and landing places) over period *T* :

(8) $$Q_4(g) = \sum_{b=1}^{B} Q_3(b,g)$$, all *g*,

where *B* is the total number of boat types.

An ***estimator of total landings*** by boat type *b* (all gear types, and landing places) over period *T* :

(9) $$Q_5(b) = \sum_{g=1}^{G} Q_3(b,g)$$, all *b*,

where *G* is the total number of gear types.

An ***estimator of total landings*** (by all boat types, gear types, and landing places) over period *T* :

(10) $$Q_6 = \sum_{g=1}^{G} Q_4(g) = \sum_{b=1}^{B} Q_5(b).$$

*2. Necessary Data*

***On-going data collection:***

- $\hat{q}(i;b,g,l,t)$, all *b* and *g*, and each sampled *l*, *t* and *i*,

where $\hat{q}$ landings by boat are number *i* of type *b* using gear *g*, in landing place *l* on day *t*.

- $I_{SAMP}(b,g,l,t)$, all *b* and *g* and each sampled *l*, and *t*.

- $T_{SAMP}(l)$, each sampled *l*.

***Frame survey***

- Total number of boats employing each gear type in each location at all times;

  $I(b,g,l,t)$, all *b*, *g*, *l*, and *t*.

- Number of operating days for each boat type and gear type in each location

  $T(b,g,l)$, all *b*, *g*, and *l*.

- Number of locations: *L*
- Number of boat types: *B*
- Number of gear types: *G*

*3. Aggregation error*

In section 1 above, it is made clear that to obtain aggregates often (eq. (4), (6) and (8)) two estimates (i.e. random variables) are multiplied together. This may lead to aggregation errors.

To see how this may work consider a typical expression of this type:

$$\sum_{t=1}^{T} x(t) \cdot y(t),$$

where $x(t)$ and $y(t)$ are such stochastic variables indexed on an arbitrary index *t*.

Obviously:

$$\sum_{t=1}^{T} x(t)\cdot y(t) = \bar{x}\cdot\bar{y}\cdot\left(\frac{\frac{\sum_{t=1}^{T} x(t)\cdot y(t)}{T}}{\bar{x}\cdot\bar{y}}\right)\cdot T\ ,$$

where $\bar{x}$ and $\bar{y}$ represent sample means, respectively.

For large samples like fisheries catch statistics

$$\sum x(t)\cdot y(t)/T \approx E(x)\cdot E(y) + Cov(x,y)\ ,$$

where *E*(.) represents statistical expectation and *Cov*(*x*,*y*) is the covariance of *x* and *y*. It follows that

$$\sum_{t=1}^{T} x(t)\cdot y(t) \approx \bar{x}\cdot\bar{y}\cdot\left(1+\frac{Cov(x,y)}{E(x)\cdot E(y)}\right)\cdot T = \bar{x}\cdot\bar{y}\cdot T\cdot(1+error)$$

Taking it for granted that *E*(*x*), *E*(*y*)>0, the sign of error depends on the sign of the covariance

Thus employing the estimator $\hat{Q} = \bar{x}\cdot\bar{y}\cdot T$ for the true relationship, $\sum_{t=1}^{T} x(t)\cdot y(t)$, leads to errors as follows:

$$Cov(x,y) > 0 \Rightarrow underestimate$$
$$Cov(x,y) = 0 \Rightarrow noerror$$
$$Cov(x,y) < 0 \Rightarrow overestiamte$$

In fisheries it is not unlikely that, this covariance is positive (e.g. when harvest per boat is high more boats go fishing and vice versa). In that case, the estimator underestimates the true catch and vice versa.

## Appendix 3: Data recording form

**MINISTRY OF NATURAL RESOURCES & TOURISM**

**FISHERIES DIVISION**

**DAILY RECORD OF FISH LANDING**

REGION ........................................District ............................... Landing Site...............................Waters......................

NOTE: (a) Weight in kilograms
(b) Value in T. Shs.
(c) No. Of Fish

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | | **10** | | | **11** | | | 12 | | | 13 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Type of boat | Registr. No | Type of Gear | No. & size of gear | No of men | No. of FU | Arrival time | Duration for fishing collection | **SPECIES** | | | | | | | | | | | | **TOTAL** | | |
| | | | | | | | | | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c |
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| TOTAL | | | | | | | | | | | | | | | | | | | | | | | |

Recorder's name...........................................  Designation..........................................................

**Appendix 4: Potential rents for marine artisanal fishery 2001-2021.**

| Years | Biomass(t) | Effort | Harvest | Next year Biomass (t+1) | Revenue | Cost | Profit | PV of profit |
|---|---|---|---|---|---|---|---|---|
| 2001 | 100,000.0 | 4927 | 52,934.0 | 127,066.0 | 52,934,000.0 | 24,130,377.0 | 28,803,623.0 | 35,010,983.7 |
| 2002 | 127,066.0 | 5000 | 63,533.0 | 137,672.5 | 63,533,000.0 | 24,850,700.0 | 38,682,300.0 | 44,779,597.5 |
| 2003 | 137,672.5 | 5500 | 75,719.8 | 130,598.9 | 75,719,849.2 | 30,069,200.0 | 45,650,649.2 | 50,329,840.8 |
| 2004 | 130,598.9 | 5600 | 73,135.4 | 129,973.2 | 73,135,380.7 | 31,172,540.0 | 41,962,840.7 | 44,060,982.7 |
| 2005 | 129,973.2 | 5700 | 74,084.7 | 128,701.3 | 74,084,709.7 | 32,295,760.0 | 41,788,949.7 | 41,788,949.7 |
| 2006 | 128,701.3 | 5800 | 74,646.8 | 127,464.4 | 74,646,774.6 | 33,438,860.0 | 41,207,914.6 | 39,245,632.9 |
| 2007 | 127,464.4 | 5900 | 75,204.0 | 126,226.1 | 75,204,012.3 | 34,601,840.0 | 40,602,172.3 | 36,827,367.2 |
| 2008 | 126,226.1 | 6000 | 75,735.6 | 124,988.0 | 75,735,634.2 | 35,784,700.0 | 39,950,934.2 | 34,511,119.1 |
| 2009 | 124,988.0 | 6500 | 81,242.2 | 118,750.6 | 81,242,183.3 | 41,997,200.0 | 39,244,983.3 | 32,286,944.9 |
| 2010 | 118,750.6 | 7000 | 83,125.4 | 112,812.5 | 83,125,420.1 | 48,706,700.0 | 34,418,720.1 | 26,967,967.8 |
| 2011 | 112,812.5 | 7500 | 84,609.4 | 106,889.8 | 84,609,375.0 | 55,913,200.0 | 28,696,175.0 | 21,413,527.6 |
| 2012 | 106,889.8 | 8000 | 85,511.9 | 100,998.2 | 85,511,875.0 | 63,616,700.0 | 21,895,175.0 | 15,560,492.1 |
| 2013 | 100,998.2 | 8000 | 80,798.6 | 100,191.7 | 80,798,567.3 | 63,616,700.0 | 17,181,867.3 | 11,629,364.1 |
| 2014 | 100,191.7 | 8000 | 80,153.3 | 100,038.0 | 80,153,336.4 | 63,616,700.0 | 16,536,636.4 | 10,659,663.2 |
| 2015 | 100,038.0 | 8000 | 80,030.4 | 100,007.6 | 80,030,432.2 | 63,616,700.0 | 16,413,732.2 | 10,076,607.7 |
| 2016 | 100,007.6 | 8000 | 80,006.1 | 100,001.5 | 80,006,077.2 | 63,616,700.0 | 16,389,377.2 | 9,582,529.4 |
| 2017 | 100,001.5 | 8000 | 80,001.2 | 100,000.3 | 80,001,215.1 | 63,616,700.0 | 16,384,515.1 | 9,123,511.1 |
| 2018 | 100,000.3 | 8000 | 80,000.2 | 100,000.1 | 80,000,243.0 | 63,616,700.0 | 16,383,543.0 | 8,688,542.7 |
| 2019 | 100,000.1 | 8000 | 80,000.0 | 100,000.0 | 80,000,048.6 | 63,616,700.0 | 16,383,348.6 | 8,274,704.3 |
| 2020 | 100,000.0 | 8000 | 80,000.0 | 100,000.0 | 80,000,009.7 | 63,616,700.0 | 16,383,309.7 | 7,880,652.1 |
| 2021 | 100,000.0 | 8000 | 80,000.0 | 100,000.0 | 80,000,001.9 | 63,616,700.0 | 16,383,301.9 | 7,505,379.4 |
| | | | | | | | | **506,204,360.1** |