

## **ARTISANAL FISHERIES STATISTICS IN SIERRA LEONE, COLLECTION METHODS, ANALYSIS AND PRESENTATION**

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### **ABSTRACT**

Fisheries statistics and the management system of the artisanal fisheries of Sierra Leone were critically reviewed. Suggestions are made for new approaches to data collection, data analysis and presentation of results. The current data collection system, though well established in a policy statement is not adequately implemented in the artisanal sector. For the artisanal fisheries, catch assessment data are collected, but little or no biological data are gathered, which prevents the application of most stock assessment models on these data. No socio-economic data are sampled either. Total annual catches of fish in the artisanal sector increased steadily from 2001-2006. Available data on length frequency suggest 2-3 year classes of the most dominant landed species (*Ethmalosa fimbriata*) in the artisanal catch. The management and development of the artisanal fishery sector in Sierra Leone has been devolved to the local councils under the 2004 local government ACT moving the responsibility of management of the small-scale artisanal fisheries to the local councils. It is here suggested that data collection be consistent and catch assessment data synchronised with local survey data, harbour masters and boat owners should be a part of the data collection, data collection should have well focused objectives with respect to data use, and management policies and objectives should be well defined and intended models for management stated. For the short term, data analysis and policies should not be too complex and be consistent with the data collection potential. Schaefer and Fox production models currently used to analyse industrial fisheries data could be applied to artisanal fisheries data in the near future.

Keywords: Sierra Leone, Artisanal fisheries, Co-management, Stakeholders, Data collection

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**ABBREVIATIONS**

AFDEP	Artisanal Fisheries Development Project
CPUE	Catch Per Unit Effort
EU	European Union
FAO	United Nations Food and Agricultural Organisation
GDP	Gross Domestic Product
IMBO	Institute of Marine Biology and Oceanography
ISFM	Institutional Support for Fisheries Management
MFMR-SL	Ministry of Fisheries and Marine Resource of Sierra Leone
MSY	Maximum Sustainable Yield
MT	Metric Tonnes
PRA	Participatory Rural Appraisal
RRA	Rapid Rural Appraisal
SEAFDEC	Southeast Asian Fisheries Development Center
SLAFU	Sierra Leone Artisanal Fishermen Union
SLAAFU	Sierra Leone Amalgamated Artisanal Fishermen Union

## 1 INTRODUCTION

Sierra Leone is located in the Southwestern sector of the great bulge of West Africa between 7°N and 10°N. It is bordered to the north and east by the Republic of Guinea, to the southeast by Liberia, and off the southwest coast by the Atlantic Ocean (Figure 1). It has an area of 71,000 km<sup>2</sup> with a coastline of 510 km including extensive mangroves of about 5,000 km<sup>2</sup> (Ndomahina 2002).



Figure 1: Sierra Leone and neighbouring countries in West Africa. Names of coastal districts are shown in red.

The western Sherbro Island separates two coastal regions. The narrow southern shelf has limited fish resources and is influenced by the eastward flowing Guinea current. The wide northern shelf accounts for the high productivity of fisheries resources in Sierra Leone (Seisay 2008). Thus, most of the fishing activities are concentrated in the north. Three major estuaries; the Scarcies River, the Sierra Leone River and the Sherbro River, as well as the mangrove vegetation around Yawri Bay (Figure 1), are important nursery and feeding grounds for juvenile fish.

Sierra Leone has a population of approximately 5.5 million with a per capita income estimated at 380 US\$. The fisheries sub-sector contributes about 9.4% to the GDP (Jalloh 2009). The country has recently emerged from a civil war.

## 1.1 The Sierra Leone fisheries

The management of the industrial and semi-industrial fisheries is the responsibility of the central government. Data are collected by inspectors onboard every industrial vessel. The Schaefer/Fox production models are used for stock assessment. The data collection for the semi-industrial boats (Std (Std) 5-10 and Ghana boats) is conducted by regularly sampling at 24 of the 641 landing sites around the country. The catch data are used to estimate trends of exploitation, but not for fish stock assessment. From 2004 onwards, the local communities are responsible for the management of low technology small scale artisanal fisheries (Kru canoes, Std 1-3 and Std 3-5 boats).

### 1.1.1 The artisanal fisheries

The small scale artisanal fishery sector in Sierra Leone is a significant source of employment, and is characterised by diverse fishing vessels and gears in operation, making fishing the major activity in the coastal districts. It is a common property resource and still remains an open access fishery (Jalloh 2009). The artisanal fishery is conducted in six coastal districts with a total of more than 7600 boats operating at 641 fish landing sites. Five main types of artisanal fishing vessels operate in Sierra Leone. One man using handlines or castnets normally operates the Kru canoe, propelled by a paddle. The Std 1-3 boat has a crew capacity of 1 to 3 persons and is also propelled by a paddle and uses the same gear. Some Std 3-5 are propelled by a paddle and some are powered by an outboard engine and they have a crew capacity of 3 to 5 persons. The Std 5-10 are boats powered by an outboard engine with a crew capacity of 5 to 10 persons. The Ghana boat, usually the largest, is powered by a 40 horse power engine and has a crew capacity of more than 10 persons (Jalloh, 2009). The motorised boats use a variety of gear like gillnets, driftnets, ringnets, longlines and handlines (Seisay 2008).

The clupeids (*Ethmalosa fimbriata* and *Sardinella maderensis*) constitute about 60% of the total artisanal fishery production of which 30% of the catch are juveniles (Seisay 2008). Jalloh (2009) reported that about 40% of the artisanal fishing gear is surface driftnets targeting juveniles of pelagic species.

The Std 1-3 and 3-5 boats dominate the artisanal fishing crafts (Table 1). The technical development in the different districts is uneven however. The Western Area district is the most technically advanced with 29% semi-industrial crafts (Std 5-10 and Ghana boat), but 71% of the crafts fall under the small scale artisanal fishing crafts (Kru canoe, Std 1-3 and Std 3-5) according to the 2004 local government ACT reclassification of fishing crafts. In Kambia, Port Loko and Moyamba (Figure 1), the distribution is heavily skewed in favour of the small scale artisanal fishing crafts (90%) with only about 10% of semi-industrial fishing crafts. Bonthe and Pujehun are the least motorized districts with 97% artisanal fishing crafts and only 3% semi-industrial fishing crafts. The large Ghana boats almost exclusively operate in the Western Area district (75% of the national total), and the Kambia district (11%).

Table 1: Percentage distribution of fishing crafts by coastal district of Sierra Leone artisanal fisheries.

Coastal District	Fishing Craft/Boat					% total	Total Number of Crafts/Boats
	Kru canoe	Std 1-3	Std 3-5	Std 5-10	Ghana Boat		
Kambia	1.1	71.7	16.2	8.5	2.5	100	791
Port Loko	9.9	68.7	13.3	7.6	0.5	100	1774
Western Area	26.6	29.4	15.3	18.3	10.4	100	1288
Moyamba	9.3	52.2	27.9	10.1	0.5	100	786
Bonthe	9.2	69.1	19.1	2.5	0.1	100	2594
Pujehun	27.2	67.1	2.6	0.8	2.3	100	386
Grand total							7619

The artisanal fishery is further classified into the following minor segments; artisanal ringnet fishery, artisanal inshore driftnet fishery, artisanal offshore large surface and midwater driftnet fishery, artisanal hook and line fishery, castnet and beach seines (Seisay 2006). The artisanal ringnet and driftnet fisheries mostly target small pelagic species like *E. fimbriata* and *S. maderensis*. The hook and line target demersal species, while the large offshore driftnet fishery target sharks, rays and barracudas mostly.

The artisanal fishery sector provides direct employment to about 30,000 Sierra Leoneans and approximately 200,000 people, mostly women and children are involved in fisheries related activities like fish processing and marketing. It also provides employment for youths in technical areas like boat repairs, engine repairs, boat building etc (Seisay 2006).

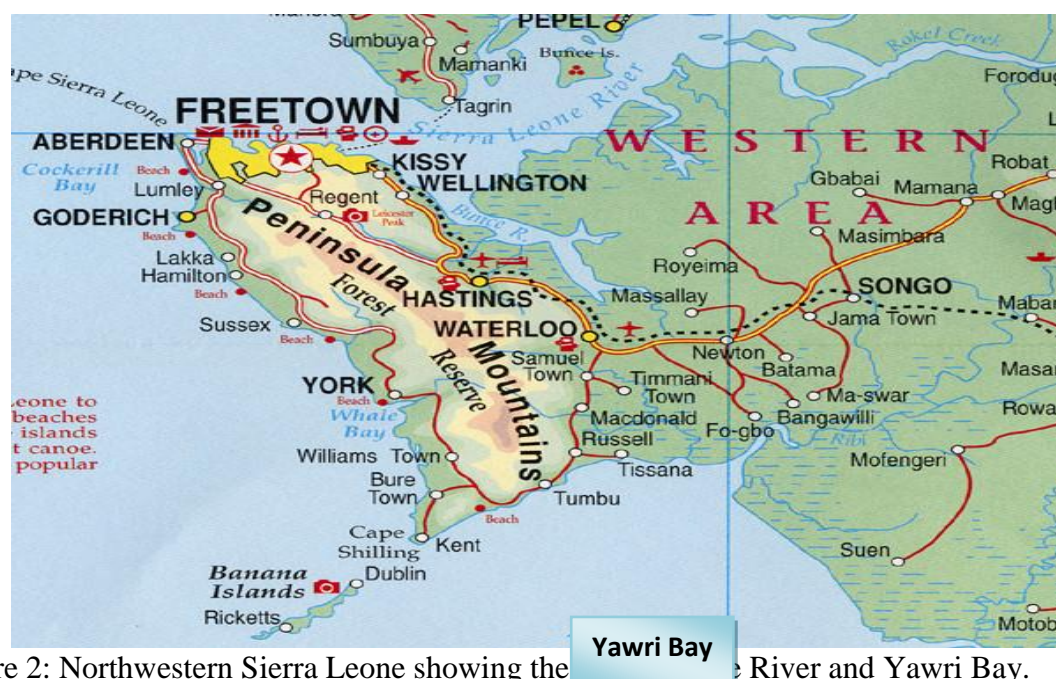


Figure 2: Northwestern Sierra Leone showing the Sierra Leone River and Yawri Bay.

Most of the artisanal fishing activities occur around the estuaries of the Sierra Leone River, and Yawri Bay in the Western area district (Figure 4). Over 100,000 metric tonnes of fish are produced yearly by the artisanal sector, thus contributing immensely to the enhancement of livelihood in coastal communities and mitigating the problem of malnutrition in remote rural communities throughout the country. The artisanal landings are dominated by the clupeids, mostly *E. fimbriata* (Bowdich, 1825), *S. maderensis* (Lowe, 1838) and *Ilisha africana* (Bloch, 1795) (Seisay 2006).



## 1.2 Project objectives

The management objectives of the Sierra Leone fisheries are; to improve national nutrition and food security, increase employment, raise socio-economic status of fishing communities, and generate revenue and foreign earnings (Jalloh 2009). To support these objectives information and data on the fisheries, which this study reviews, are important.

This study critically reviews the current fisheries statistics data collection system in the artisanal fishery sector of Sierra Leone and suggests improvements. The paper aims to:

- Analyse current data collection methods, analysis and presentation.
- Suggest improved methods of data collection and analysis.
- Discuss how to present and interpret data to stakeholders.

## 2 FISHERIES MANAGEMENT AND DATA COLLECTION FOR DEVELOPING COUNTRIES

Fisheries statistics are the primary means to measure the performance of a fishery within the social, economic, biological and environmental framework in which it is conducted (FAO 2002). Most commonly collected data include total catches and related fishing effort, the cost and revenue from fishing operations, employment and livelihood status, biological information on the fishery, and the distribution of these in time and space. The statistics are mainly used for management purposes. Managing fisheries solely through catch and effort restrictions does not work in small-scale artisanal fisheries due to practical constraints of enforcing catch and effort based management interventions (SEAFDEC 2005). Although at community level enforcing catch and effort based management intervention may work, the cost is high and often not related to monetary value of the resource. However, reliable data on the fisheries sector is essential for the formulation of fisheries policies and for fisheries management (Halls et al. 2005).

Management of fisheries resources rely on sufficient quality data and information. Thus, there is a general need to collect better data on the aquatic environment, the fish, and the fishers who form an essential part of the fisheries (Welcomme 2002). Regularly conducted fishery surveys are costly and will include field and office personnel costs, field operation costs and other overhead and maintenance costs related to office infrastructure and operations (FAO 2002). In a developing country like Sierra Leone, this may constitute a major constraint on effective fisheries statistics data collection. It is therefore important not to collect more data than is needed, and data collection should be tailored to the management objectives.

The type and amount of data collected depends on government intervention in the management of the fishery and the intended model used for the assessment of the fish stock. The maximum sustainable yield (MSY) concept provides a reference point that predicts the level of fishing effort that produces maximum sustainable yield from a stock. There are two approaches to this model, the first being a simple approach based on the analysis of catch against effort and requires time series data on both variables. The second method provides better estimates of MSY through complicated stock assessment procedures that require data on mortality, recruitment and growth for each species. The simple approach can only be done on a single species basis but is less useful in multi-species fisheries. However, it is less data demanding and could be useful for developing fisheries (Welcomme 2002).

Currently, data on artisanal fin-fish catch and effort production are collected in the Sierra Leone. However, the data are not being stored in a database for further processing by fisheries scientists who are interested in fisheries management and its development. The collected data are not being processed at local level and feedback is not provided to the local fishermen on

the status of the stocks they exploit. The current system of data collection, though well established in policy statement is not being maintained and critically reviewed. Furthermore, there is a need to improve the reporting of information on catch and effort data. Few if any assessment models have been applied to the artisanal fishery data due to lack of data consistency. The surplus production models of Schaefer and Fox have been mostly used to assess the maximum sustainable yield (MSY) of the industrial fisheries (Seisay 2008).

A shift towards co-management has prompted managers to review their roles and reconsider their data requirements. Though a lot of literature exists on fisheries statistics data to help guide co-managers to design and implement data collection programmes to meet their evolving needs, much of it lacks focus on designing systems specifically for co-managed fisheries (Halls et al. 2005). Probably, the only feasible way to manage artisanal fisheries is to transfer ownership of the resource to the resource users and allow them to manage it themselves. As long as the local fishers can limit access to the resources with good institutional support, and provide a reward for those who participate in the scheme (Halls et al. 2005), management objectives are likely to be realised.

## 2.1 The Fisheries Management System in Sierra Leone

Sættersdal (1984) defines fisheries management as to obtain the best possible utilization of fisheries resources for the benefit of the community. The concept of “best” implies having maximum yield, highest possible value of the catch, maximum profit, foreign currency and jobs. “Community” in this definition may be taken as the population of the world, region, country or people with common interest like fishermen, boat owners, consumers etc. Arnason (1993) considered fisheries management as the institutional framework under which the fishing activity operates. Social customs and traditions, the fisheries authorities, association of fishermen or other means may set this.

There are two main methods of fisheries management; biological fisheries management and economic fisheries management. Biological fisheries management takes the form of area closures, seasonal closures, gear restrictions, pollution restrictions and setting of total allowable catch. Catch assessment data are an important ingredient in the formulation of these measures. Such data are also important in economic fisheries management by providing information on sustainable rate of fishing mortality. Economic fisheries management aims at minimizing fishing effort, investment, taxes etc. to maximize the overall profit of the fisheries and the allocation of property rights (Arnason 2008).

The Fisheries Management and Development Act 1994 make provisions for the management, planning and development of the fisheries of Sierra Leone. The 1995 Fisheries Regulations that provide statutory guidance complimented this act. In 2003, the Ministry of Fisheries and Marine Resources of Sierra Leone, in consultation with stakeholders, developed the Fisheries Policy (Seisay 2006). All these fisheries management instruments are geared towards the implementation of biological control measures by area restriction, closed seasons, economic control measures, limiting the number of licenses issued, input control by gear restriction and mesh size regulation, and subsequent enforcement of fisheries regulation by imposing penalties for violation of the laws. These measures have not been successful in the artisanal sector, which still remains an open access fishery characterised by an illegal open seine net fishery in estuarine areas for juvenile *Sardinella spp* locally known as the mina fishery (Jalloh 2009).

Although the fisheries management and development Act of 1994 establishes a department for fisheries and marine resource management, the management and development of the artisanal fishery sector in Sierra Leone has been devolved to the local councils under the 2004 local government ACT. The 2004 local government ACT gave mandate to local councils for

licensing of artisanal fishing canoes (Kru canoe, Std 1-3 and 3-5) that fall within the artisanal fishing crafts according to the latest reclassification of fishing vessels, and the use of the economic rent to develop their communities in compliment to government support for local development (Jalloh 2009). It is hoped that the devolution of this responsibility will promote community based management of the resources at all levels. It also moves the responsibility of management of the small scale artisanal fisheries to the local councils. Under the same ACT the Std 5-10 and Ghana boat were classified as semi-industrial fishing crafts and management of these remain the responsibility of the central Government through the Ministry of Fisheries and Marine Resources (Jalloh 2009).

The conventional scientific approach to tropical fisheries management is seriously flawed in that it lacks a consideration of perhaps the most important component of managing fisheries, the human component (UNESCO 2004). In 2004 the artisanal fishermen in Sierra Leone formed two unions (SLAFU and SLAAFU) that work in collaboration with the Ministry to promote responsible fishing practices. The unions have been very instrumental in enforcing fishing gear regulations to mitigate the high incidence of juvenile exploitation.

The Institutional Support for Fisheries Management (ISFM) project funded by the EU emphasised the issue of community based management of the artisanal sector. After several stakeholder consultations, the following recommendations were agreed upon:

- Community based management was proposed including the local council, village head men, fishers' organisations, the Ministry of Fisheries extension staff, Sierra Leone Navy and Maritime Police.
- Banning of beach seines.
- Establishment of marine protected areas.
- Proposed minimum mesh size of 45 mm.

All these need stakeholder analysis with well-defined responsibilities and planning for implementation as policy instruments (ISFM 2009).

## **2.2 Fishery statistics data collection methods**

The scope of fishery statistics is quite wide and includes livelihood data, socio-cultural information and economic data in addition to catch and effort data. Obviously a decision has to be made about what is to be collected. This depends on what information is required and since this depends on policy and management decisions often taken at national level, the requirements and the statistical system will differ from country to country (SEAFDEC 2005). As an example, Dalzell (1992) reported that data collected by the Fisheries Training Centre in Vanuatu were records of fishing trips made by staff and students to Vanuatu's most important fishing grounds, and data collected during such trips were mostly catch composition and catch rates of the demersal stocks. Information on fish catches in Vanuatu comes from three sources; the annual catch record system for monitoring the dynamics of the fishery, daily record of each fishing trip in order to qualify for purchasing duty free fuel, and the record of catches from the Fisheries Training Centre during fishing trips made by staff and students. The data collected on the forms for daily record of each fishing trip was specified as total catch, duration of fishing trip, fish sales and expenses incurred for a particular fishing trip. A reward of 50 Vatu for completed daily trip forms formed an incentive for the fishermen (Dalzell 1992). Analysis of these data provided useful information on catch volumes, catch rates and average size of fish landed. Results further indicated that catch rates appeared to be inversely proportional to fishing effort suggesting that some form of surplus production model might be used as a management tool to estimate maximum sustainable yield and corresponding fishing effort.

Halls et al. (2005) provided guidelines for designing data collection and sharing information for co-managed fisheries. According to the guidelines, the information to help formulate and coordinate local management plans include fish species, catch weight or value, fishing gears, fishing seasons, socio-economic categories, numbers of fishers, fisheries legislation and management responsibilities. Information to implement management plans for enforcing rules and regulation and resolving conflicts include registration of fishing units and licensed fishers, while information to evaluate and improve local management plans include performance indicators such as abundance or catch rates of different species, income, fish consumption and occurrence of conflicts.

Basically, three types of fishery statistics are of interest for the development of management plans; A) Catch assessment data, which includes catch and effort, species composition, length frequency and other variables associated with stock assessment. B) Economic data on fish price, employment, processing, marketing and trade (import and export). C) Livelihood data on involvement, habitat use, importance of fishing related activities for livelihood and fish consumption (SEAFDEC 2005).

A) Catch statistics give useful information on fish harvest from year to year and show trends for individual species or species groups which can inform management measures. Data for catch assessment, which include catch and fishing effort is therefore essential to be able to assess any fisheries and should be among the first variables to be included in fisheries statistics.

B) Economic data on fisheries show the importance of the sector as compared to other sectors. The importance can be expressed in several units; monetary value of the total catch, exports, and job opportunities or livelihoods provided (SEAFDEC 2005). In the artisanal fisheries sector of Sierra Leone, these economic variables and indicators are not included in the data collection system. The Ministry of Fisheries and Marine Resources of Sierra Leone do not normally consider collection of economic data to be their responsibility and therefore it does not get the attention it deserves. Information on employment and marketing may well be considered to be the most useful economic variables, but are seldom included in routine data collection.

C) Livelihood data covers a wide range of variables and socio-economic or socio-cultural indicators which describe the fishery in terms of equitable benefits, social value of fisheries and the effect of policy and management not just in economic terms but in terms of involvement, distribution of fish consumption and income over age groups and gender (SEAFDEC 2005). The distribution of income out of fishing activities over different socio-cultural groups is an important indicator of equity. In terms of food security, it is important to know what groups are depending on fish and if there are alternatives in case of fish shortage.

Frame survey is a census where all landing sites are visited to record all boats and gears for each boat-gear combination. Collecting frame survey data has some severe shortcomings, thus a mix of counting and interviewing of key informants (fishermen, village head) is often the best approach. The result of a frame survey data comprise of; existing landing sites, number of motorised and non-motorised boats, number and type of gears, number of boat owners, number of fishermen and access route to landing sites (SEAFDEC 2005).

### **2.3 The present artisanal fishery statistics data collection methods in Sierra Leone**

A sample-based method is used in the artisanal fishery sector for data collection. Of the 641 identified fish landing sites, 24 are randomly selected for data collection on catch and effort (total catch, fishing time i.e. number of days at sea, type of boat and gear used, as well as propulsion). Species composition, area of operation and length frequency are also collected when donor projects are implemented. Sampling is conducted three times per week with

sampling days randomly selected. Enumerators are assigned to each proposed landing site for sampling with logbooks (Appendix 1) for data collection.

The enumerators are under the supervision of an extension officer stationed at each of the coastal districts of Sierra Leone. Sampling is done along the entire coast with the view of ensuring adequate representation of each coastal town and village. Monthly catch and effort data are computed using the ARTFISH software. The ARTFISH software computes monthly catch and effort estimates using data from sample-based surveys. A second module in the software makes integrated reports, graphics and statistical analyses.

The proportion of active boats is always noted. Catch and effort data are collected on regular basis, while biological data are irregularly collected. Biological data on length frequency is collected by measurement of total length to the nearest 0.1 cm on a stainless measuring board. The corresponding weight, sex, maturity stage, age and socio-economic data on fishing cost and revenue are not included in the data collection system (Seisay 2008).

### 3 THE BIOLOGY OF THE MOST IMPORTANT SPECIES

*E. fimbriata* (Figure 3) occurs in inshore waters and lagoons and are catadromous. They migrate up river for more than 300 km and feed by filtering phytoplankton chiefly diatoms. They breed throughout the year in waters of salinities 3.5- 38<sup>0</sup>/<sub>00</sub> and spawn in the sea, estuaries and rivers (Whitehead 1985). *S. maderensis* (Figure 3) form schools in coastal waters, preferring waters of 24°C and feed on a variety of small planktonic invertebrates, fish larvae and phytoplankton. Unlike *E. fimbriata*, *S. maderensis* are oceanodromous and breed during the warm seasons and their migration patterns are strongly correlated with seasonal upwelling (Whitehead 1985). According to Diouf (1996), *I. africana* is found along beaches and just off the shore, they also occur in lagoons and estuaries often penetrating into freshwater. They feed on plankton, benthic invertebrates and detritus. Table 2 gives a summary of life history characteristics of these three top pelagic species landed by the artisanal fisheries of Sierra Leone.

Table 2: Life history characteristics of top three pelagic species landed by artisanal fisheries of Sierra Leone.

Species	Life History Characteristics			Reference
	Growth rate (k)	Maximum attainable length (L-infinity)	Length at first maturity	
<i>E. fimbriata</i>	0.4	45 cm	17 cm	(King 1997)
<i>S. maderensis</i>	0.6	37 cm	13.4 cm	(Djama et al. 1989)
<i>I. africana</i>	1.0	30 cm	13.0 cm	(Vakily and Cham 2003)



Figure 3: *Ethmalosa fimbriata* (Bowdich, 1825) and *Sardinella maderensis* (Lowe, 1838).

Demersal species like *Pseudotolithus senegalensis* (Valenciennes, 1833) (Figure 4) *Arius latiscutatus* (Günther, 1864) and *Sphyraena barracuda* (Edward, 1771) (Figure 4) are also

exploited in artisanal gillnets, hook and line and beach seines and constitute a minor component of the total artisanal fishery production (Ndomahina 2002). *P. senegalensis* are found in coastal waters over muddy, sandy or rocky bottoms. Smaller individuals occur in shallow waters rarely entering the estuaries. They feed on shrimps, juvenile fish and crabs, and spawn from November to March (Chao and Trewavas 1990). *A. latiscutatus* occur in marine, brackish estuaries and sometimes entering freshwater and are often considered as aquaria fish (Bianchi et al. 1993). They feed on fish, benthic invertebrates, zooplankton and detritus (Diouf 1996). *S. barracuda* are found most predominantly at or near surface waters with juveniles occurring in mangroves, estuaries and shallow sheltered inner reefs and feed on fishes, cephalopods and sometime shrimps (Daget et al. 1986). Table 3 gives a summary of life history characteristics of this top three demersal species landed by the artisanal fisheries of Sierra Leone.

Table 3: Life history characteristics of top three demersal species landed by artisanal fisheries of Sierra Leone.

Species	Life History Characteristics			Reference
	Growth rate(k)	Maximum attainable length (L-infinity)	Length at first maturity	
<i>P. senegalensis</i>	0.4	114 cm	35 cm	(Poinsard and Troadec 1996)
<i>A. latiscutatus</i>	0.2	85 cm	28 cm	(Conand et al. 1995)
<i>S. barracuda</i>	0.1	200 cm	66 cm	(Pauly 1978)



Figure 4: *Pseudotolithus senegalensis* (Valenciennes, 1833) and *Sphyraena barracuda* (Edward, 1771).

#### 4 ANALYSIS OF SIERRA LEONE ARTISANAL FISHERIES STATISTICS DATA

The data analysed here comes from the fisheries of Sierra Leone annual report for 2008. The data were extracted from a tabular presentation to make the figures below. Though it is stated that data are being collected on catch, effort and price, no data exist in the annual report on the catch per unit of effort (CPUE) or the value of total catches. Data on length frequency for *E. fimbriata* were obtained from the logbooks (Appendix 1) at the statistics unit of the Ministry of Fisheries and Marine Resources of Sierra Leone. Those measurements were collected in 2009 as part of a donor project.

The greatest volume of fish (120,490 MT) was landed in 2006 and the minimum volume of fish (39,950 MT) was landed in 2001 (Figure 5). The total landings between 1991 and 2000 appear to be constant either due to bias or because no data were collected during the wartime. This is a reminder of how all data should be evaluated critically, even if an official institution

publishes them. From 2001 to 2004, there was a steady increase in total production, but the catch in 2005 and 2006 seems to be levelling off at about 120,000 MT.

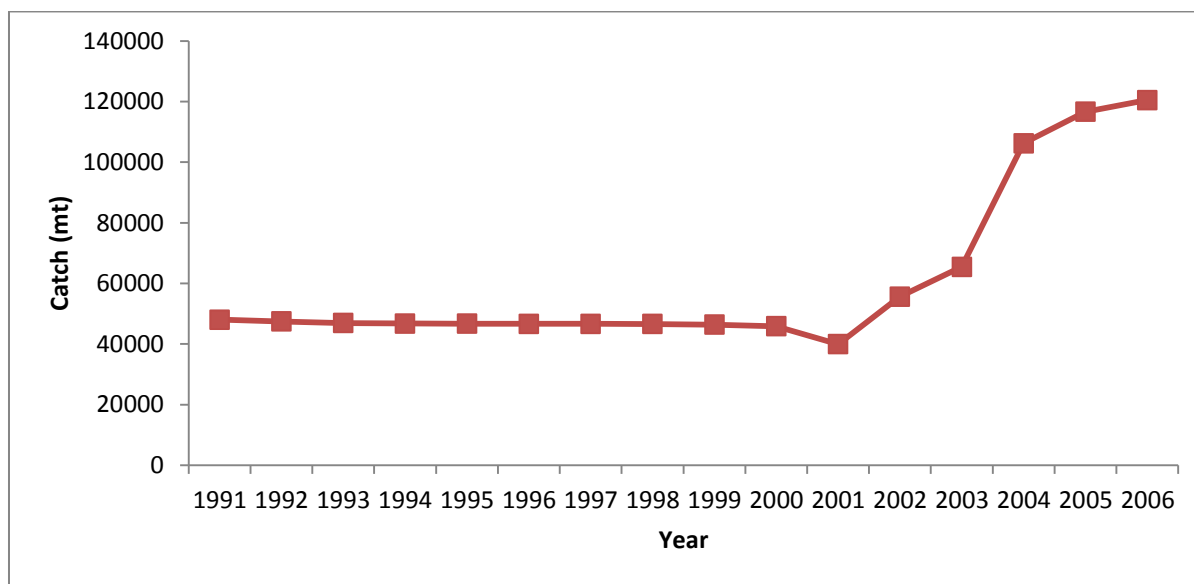


Figure 5: Total artisanal fishery production in Sierra Leone 1991-2006 based on information extracted from 2008 annual report (MFMR-SL 2008).

Figure 6 shows the total artisanal fishery production from 2002 to 2006 for the top eight species in the artisanal catch. *E. fimbriata* dominates the artisanal catch followed by *S. maderensis*, and *P. senegalensis*. Other species of relative importance includes *A. latiscutatus* and *I. africana*. Catches seem to be increasing steadily from 2002 to 2006 possibly due to increasing donor support toward artisanal fishery development.

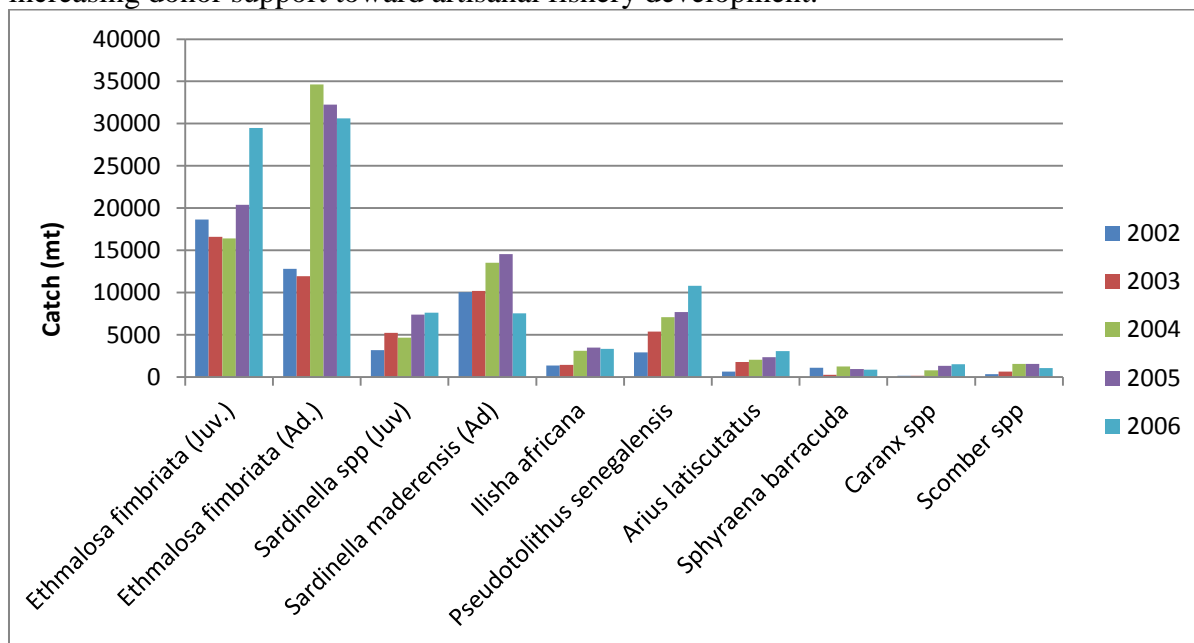


Figure 6: Total artisanal fishery production for the top eight species in the artisanal landings. For the most important two species, adults and juveniles are shown separately. The catch rate of juvenile *E. fimbriata* was lower in 2002 to 2004 (Figure 7), but increased steeply in 2005 and 2006 in spite of the support from the Artisanal Fisheries Development Project (AFDEP) providing legal fishing gear to artisanal fishermen. The increase in adult catches was even greater, and the catch during the last three years was almost three times as

high as the 2002 to 2003 catches. It is not certain that a species like *E. fimbriata* with a medium range lifespan can withstand such high fishing pressure on the juveniles for long. For *S. maderensis*, about twice as many tonnes of adult than juveniles were caught in 2002-2005, but the juveniles were probably higher in numbers. This high fishing pressure may not be sustainable for long either. The adult catch rates of *S. maderensis* decreased from 2005 to 2006.

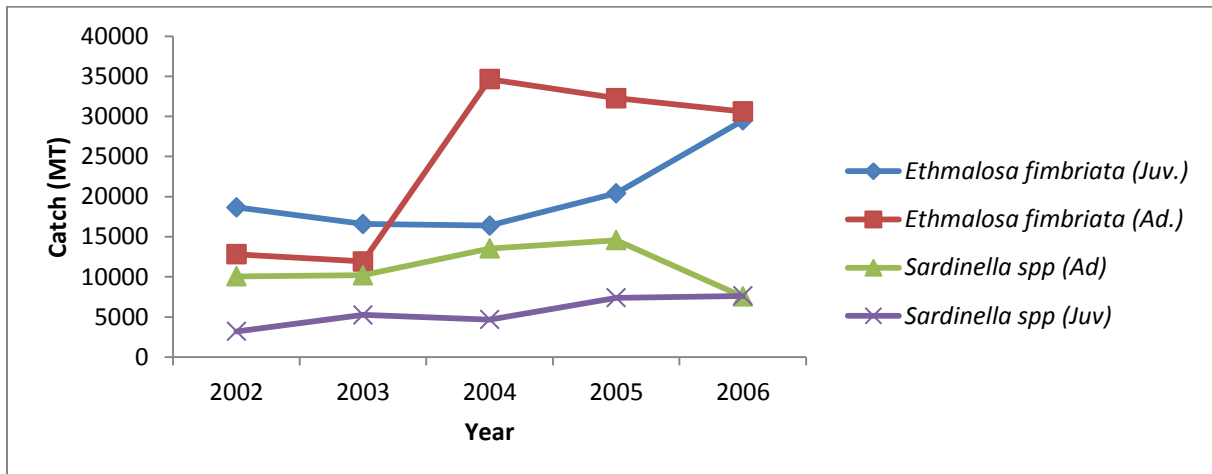


Figure 7: Comparative analysis of adult and juvenile *Ethmalosa fimbriata* and *Sardinella maderensis* in the artisanal landings, 2002-2006.

Figure 8 shows bi-monthly length frequency distributions of *E. fimbriata* in the year 2009. Initially the length frequency distributions show two contrasting peaks, suggesting two age groups (Figure 8). *E. fimbriata* is a species with a medium range lifespan, thus the two peaks combined with an extra peak for juveniles, which might have been excluded in January/February due to gear selectivity, may suggest three age groups. Plotting combined monthly data with the same scaling (Figure 8) shows a decrease in peaks from January to December suggesting downward fishing of the cohorts. The swift lowering of peaks between early and late in the year is quite worrying and deserves to be studied further. The sudden appearance of juveniles in May-June suggests a spawning period in the early or mid-dry season and these juveniles might also have accounted for an increase in catches from November to December (Figure 8). Whether the juvenile peaks suggested for the latter half of the year is two or just one cannot be substantiated as the broken lines are only drawn by eye.



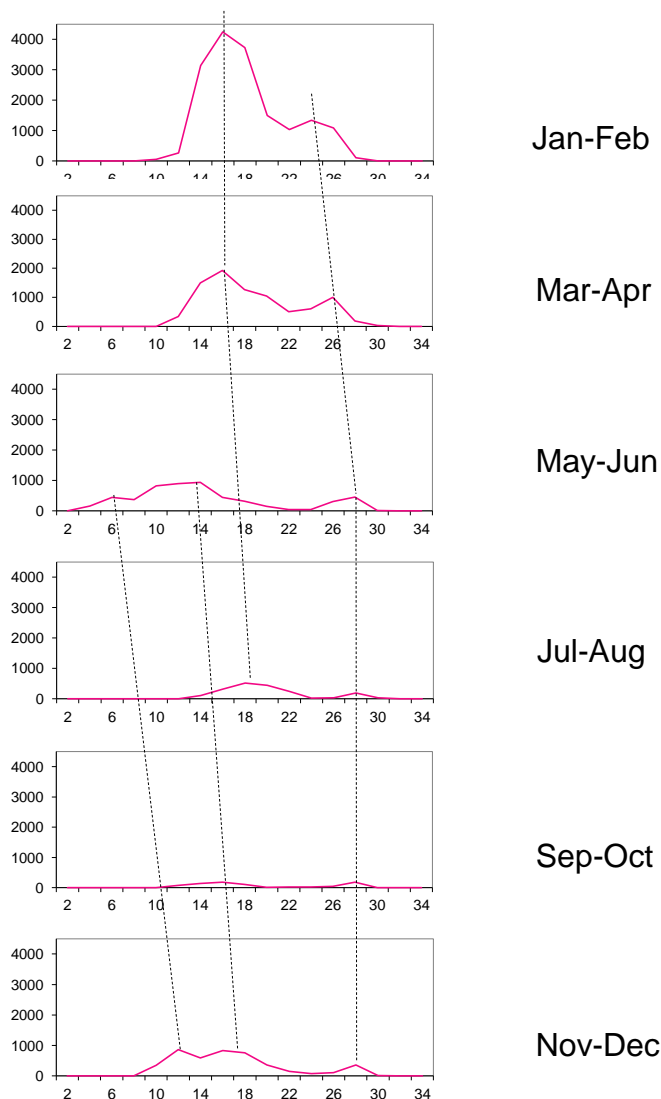


Figure 8: Bi-monthly length frequency distributions of *Ethmalosa fimbriata* from artisanal commercial catch at Tombo fish landing site, Western Area Fishing District, (January-December 2009). Broken lines are drawn by eye, to suggest possible age groups.

## 5 STRENGTHS AND WEAKNESSES OF THE PRESENT SYSTEM

The artisanal fishery of Sierra Leone is an open access fishery characterised by high diversity of fishing vessels and gears (Jalloh 2009). Data collection in such a complex fishery needs to be focused, decisive and well organised. In a bid to achieve this objective, policy statements have proposed the maintenance of an effective fisheries statistics data collection system. The government's approval of these policy statements in the 1994 Fisheries ACT of Sierra Leone was a positive move to strengthen the data collection system. However, the weakness has been the implementation strategy of the necessary measures to fully meet the requirements of the policy statement. It has thus been impossible to assess the exploitation status of commercially important species in the landings. Nevertheless, current catch and fishing effort data are assumed to provide reasonable information on the trends of exploitation.

Few if any assessment models have been applied to the artisanal fishery data due to lack of data coherence. The surplus production models of Schaefer and Fox have been mostly used to assess the MSY of the industrial fishery for shrimps and demersal stocks. It is thus a

weakness, failing to apply similar models to artisanal data, which contribute 80% of the total fish production. The same models could equally well be used for the assessment of the fish stocks being utilized by the semi-industrial boats (Std 5-10 and Ghana boats). The only additional requirement is that the length frequency of the most important fish species, need to be included in the data sampling program.

Biological data (length frequency), though rarely collected, appear to be trustworthy (Figure 6) when collected. Biological data collection has been devolved from the mainstream data collection system of the ministry to university students wishing to undertake research in fisheries. However, data collected by university students have not been included in the data storage of the ministry for subsequent use. Synchronising biological data collection with catch and fishing effort data collection followed by comparative analysis of independent results from the two forms of data collection makes stock assessment estimates more realistic. Collaboration between the university and the ministry is therefore necessary to further strengthen data collection.

The application of stock assessment models requires time series data. The inconsistency of biological data collection and sometimes catch and fishing effort data is a weakness that has to be addressed if any meaningful stock assessment is to be done in the future.

Lack of socio-economic data collection is also worth noting as a major weakness due to its importance in cost-benefit analysis and improvement in livelihood standards of the fishing communities.

## **6 SUGGESTED IMPROVED METHODS OF DATA COLLECTION**

Data collection has been working relatively well for the industrial fisheries but lacking in many aspects for the artisanal fisheries. With the present characteristics of the artisanal fisheries, data collection by enumerators may not be able to meet the need of data requirement for future stock assessment. With the devolution of artisanal fisheries management to local council government, a more co-managed data collection and sharing system should be explored for data acquisition to meet data requirements for stock assessment.

Halls et al. (2005) designed a participatory data collection system for co-managed fisheries as part of the process of formulating or reviewing management plans. According to the design, the first step is to identify the main stakeholders involved in the management of the resource and their responsibilities and capacities to help define their potential roles in the system. The next step is to define a management plan and set the objectives to achieve it. Once objectives are set, data that need to be collected can be identified, existing data that have been collected by different institutions reviewed, gaps identified, and the remaining data required by the stakeholders can be collected. Pathways and methods to share those data between stakeholders are agreed upon and ways of storing and managing data are identified. Finally, the system is implemented, evaluated and refined. The artisanal fisheries management system in Sierra Leone is already on the path of co-management, and depending on their management plans a combination with the Halls et al (2005) design may prove to be a sound basis for future data collection.

### **6.1 Frame survey data**

It is suggested here that, the “Harbour masters” (traditional leaders of fish landing sites) take responsibility for collecting frame survey data and assess boat activity and active fishing days on their landing site. “Harbour masters” may be involved in data collection because they are familiar with local fishers. This makes it easy for them to collect reliable frame survey data as

a component of an index of fishing effort estimation. As an incentive, “Harbour masters” can be rewarded with remuneration from the local council funds. A government representative may need to do random checks on the accuracy of these data.

## **6.2 Catch assessment data**

The current catch assessment data collection is the sole responsibility of enumerators. Some of the enumerators are currently on central government payroll whilst others are supported by donor projects only during project implementation in the form of allowances. This approach may lead to divided loyalty as those not on central government payroll may become less efficient and feel neglected. It is therefore suggested that the local government council put a mechanism in place to use part of the revenue generated from licenses to complement the efforts of the central government in the form of allowances for enumerators that are currently not on the central government payroll. This may improve data collection by making enumerators more committed to the quality of their work. It is further suggested that the boat owners become part of the data collection system by completing catch assessment record forms on fishing trip duration and estimated catch, both in terms of quantity and value, on a daily basis. As an incentive, they might be given a discount of e.g. 10% on license fee upon successful completion of the forms. The catch assessment record form to be filled by boat owners should be boat-gear specific (Appendix 1). The university should investigate how to convert each boat-gear type to a common standard.

## **6.3 Improved biological data collection**

The present catch data has some limitations for stock assessment use as it only provides estimates on total catch and only shows trends of exploitation over time. It does not however, provide information on the effect of fishing on individual cohorts. Biological data such as length frequency distribution may serve as a good indicator of fishing effects on cohorts even where the age cannot be determined (Figure 6). To improve data collection, it is suggested that length frequency data be incorporated into the regular data collection by enumerators at least for two of the most important species in the landings of the artisanal fisheries. This could be done once per week for different boat/gear type each week, which would enable sampling from the four most important boat/gear types every month with fish supply coming from selected boat-gear type at monthly intervals. The measured fish might even be an incentive for the enumerator and can be transformed into monetary value depending on the enumerator’s wish.

## **6.4 Assessment models**

With improved data collection as suggested above, the Schaefer and Fox models currently in use to analyse industrial fisheries data can also be applied to the semi-industrial fisheries (Std 5-10 and Ghana boat) data to estimate MSY with the corresponding fishing mortality (fMSY). With fMSY known, management decisions can be reviewed and appropriate steps put in place to enhance sustainability. It is worth noting that precautionary f-targets are expected to produce slightly lower yields but similar or greater economic yield. For the small scale artisanal fishing crafts (Kru canoe, Std 1-3 and Std 3-5), simple indicators like catch per unit of effort can be used to monitor changes in stock size (see Appendix 2). The sampling scheme

for the semi-industrial fisheries should be somewhat similar to that of the industrial fisheries, while the artisanal fisheries maintain a localised sampling approach. Length frequency data should be included in all three sampling programs

### **6.5 Experimental local fishing surveys**

Fishing survey data are good indicators to validate catch assessment data. Time series of survey data will provide an independent check on the CPUE indicator on the state of the fish stocks. Comparing independent results of local fishing survey data and catch assessment data can provide good information to evaluate exploitation status of stocks. It is thus suggested that fisheries institutions put mechanisms in place to at least annually or seasonally carryout standardized fishing surveys with artisanal fishermen to collect an independent catch and biological data for stock assessment in limited areas e.g. in Yawri Bay. The idea is to mobilize about 10 boats that will under guidance randomly sample a limited area by taking e.g. 3-5 fishing operations (stations) each. The whole exercise should be repeated at the exact same stations annually or seasonally, to compare locally the trends in total catch for different species.

## **7 DATA PRESENTATION AND INTERPRETATION TO STAKEHOLDERS**

Data on their own are of little importance and must be analysed to become information and information should be interpreted and fed into the management plan (Welcomme 2002). The process of data analysis and interpretation is as important as data collection. Information obtained from data analysis has to be presented in simple graphical formats that can be self-interpreted by stakeholders, even those facing difficulty with reading. Bar charts and line graphs should therefore be the main methods of data presentation. A decreasing trend in a bar chart or line graph can be interpreted as the stock size not coping with the fishing pressure. Ascending trends will be viewed as positive, and place confidence in the local resource users regarding sustainability of the resource.

The presentation and interpretation of the aforementioned information should be done during sessions with local community stakeholders. The approach could be through Participatory Rural Appraisal (PRA) or Rapid Rural Appraisal (RRA). In PRA, information is owned and shared by local people and professionals facilitate and assist rural people in the collection, presentation and analysis of information. This approach of data sharing will be of vital importance for artisanal fisheries management. This will be synchronised by the RRA approach where professionals collect, analyse and present information to local resource users. Currently information flow from fisheries authorities to local fishing communities is irregular. With implementation of the suggested data collection methods above, data collected should be shared between stakeholders on quarterly basis and reports forwarded to the fisheries authorities annually to see progress being made and to identify strengths and weakness of the system. Fisheries authorities will then discuss with local authorities and other stakeholders for further review of the system with new measures to strengthen the weaknesses and improve the strengths. It is worth informing local fishermen on the status of the stocks to realise their potentials for livelihood enhancement.

## 8 CONCLUSIONS

This paper analyses Sierra Leone artisanal fisheries statistics and suggests some new and improved methods of data collection, analysis, presentation and interpretation to feed management plans.

As stated, data collection should have focused objectives with respect to data use. The management policies and objectives should be well defined and intended models for assessment of fish stocks, taking into account data collection potentials, should be stated. Biological reference points and their variables to guide policies and support models should be selected, and data and information needed for the variables collected.

In resource poor societies like Sierra Leone, data collection should be limited to what can be collected with available resources while conserving the quality of data. Data accuracy should be favoured over precision, but to maintain the needed accuracy, cooperation between chiefdoms is suggested. Policies and models should not be complex and they should be consistent with data collection potentials.

Data collected must be analysed to become useful and information should be shared with local stakeholders to enable them to contribute in the implementation and monitoring phase of the management plan. Information is only valid when it is used. Fisheries related information collected by institutions such as the Institute of Marine Biology and Oceanography (IMBO), Fourah Bay College and Njala University should be used in the management process and put in a database system, which can be accessible to fisheries scientists and other interested parties.

The present data collection of Sierra Leone artisanal fisheries statistics has some focus regarding management objectives in the wider sense, but lack consistency or regularity. Because of the inconsistency problem, the ministry should team up with other institutions generating fisheries related information to address the problem. Since the management of the artisanal fisheries has been devolved to the local council government, the local authorities should take responsibility together with the central government by providing means to run the data collection program. The management approach should be a cooperative co-management (government and local fishing communities cooperate as equal partners in decision-making), and an appropriate legal framework must support its implementation.

With the application of the suggested data collection methods, a simple community based management instrument or guide for artisanal fisheries is suggested in Appendix 2.

The following is a abridged list of the present suggestions to sum up the main conclusions of the project. The list may need to be discussed by local stakeholders and polished further by their suggestions. In its final form however, the list could be used as a guide to facilitate the effective transition from central to communal management of the artisanal fisheries in Sierra Leone.

1. Well defined management objectives.
2. Data collection and analysis tailored to objectives and available resources.
3. Cooperation in data collection and analysis between adjacent communes.
4. "Harbour masters" included in the collection of data for Frame survey and boat activity.
5. Allowances for all enumerators.
6. Boat owners to complete daily forms on trip duration and estimated quantity and value of catch.
7. Weekly length measurements for the 2 most important fish species. Four different boat/gear groups sampled each month.
8. A simple computation method for Catch Per Unit of Effort (CPUE) used as an indicator on the state of fish stocks (Appendix 2).

9. Cooperation between central government and other relevant institutions (e.g. universities) on fisheries data collection and common data storage.
10. Length measurements added to the semi-industrial data collection, to enable Schaefer and Fox production models to be applied.
11. Simple graphical representation of results shared between stakeholders on quarterly basis and reports forwarded to the fisheries authorities annually.
12. Seasonal or annual experimental fishing survey as an independent check on the CPUE indicator.

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## APPENDIX 1: CATCH AND LENGTH COMPOSITION RECORD FORMS FOR ARTISANAL FISHERIES STATISTICS DATA COLLECTION

### MINISTRY OF FISHERIES AND MARINE RESOURCES-SIERRA LEONE

Catch and Length composition record forms for artisanal fisheries statistics data collection

Coastal District..... Landing site.....  
 Fishing Craft..... Fishing Gear.....  
 Date.....  
 Mesh Size(mm)..... Depth (m)..... Head Length (m).....  
 Fishing Area.....  
 Recorder.....  
 Species..... Total Catch.....(kg)  
 Total weight of Sample.....

Total Length (cm)	Number at Length (tally)	Total Length (cm)	Number at Length (tally)
1.5		32.5	
2.5		33.5	
3.5		34.5	
4.5		35.5	
5.5		36.5	
6.5		37.5	
7.5		38.5	
8.5		39.5	
9.5		40.5	
10.5		41.5	
11.5		42.5	
12.5		43.5	
13.5		44.5	
14.5		45.5	
15.5		46.5	
16.5		47.5	
17.5		48.5	
18.5		49.5	
19.5		50.5	
20.5		51.5	
21.5		52.5	
22.5		53.5	
23.5		54.5	
24.5		55.5	
25.5		56.5	
26.5		57.5	
27.5		58.5	
28.5		59.5	
29.5		60.5	
30.5		61.5	
31.5		62.5	

## **APPENDIX 2: A SIMPLE COMMUNITY BASED MANAGEMENT OF ARTISANAL FISHERIES**

By Konrad Thorisson

### **1. Introduction**

When the management of small-scale artisanal fisheries is devolved from central government to local councils, the added responsibility is usually accompanied by some limited means, e.g. from licence sales. The task of managing fisheries locally may however, be even more demanding than on the national scale, at least relatively. When fisheries data are collected on a national scale, only a small part of the landing sites may need to be sampled, to get a reliable estimate on the sought after parameters. For example in Sierra Leone, the present program of sampling the artisanal fisheries in 24 of the 641 landing sites may work well collectively for the whole country. Within each of the many small local chiefdoms however, there may be just one or even no landing site sampled, using this method. Obviously, this is totally inadequate and many more landing sites must now be sampled to get even a rough idea of how the fish stocks are doing. The local councils are thus left with the dilemma of assessing and managing the fish stocks with very limited means. There is no escape from sampling the catch regularly however, if the health of the fish stocks is to be monitored and managed properly. The only way to mitigate the problem is to sample economically and use simple indicators. The data collected by the communes have to be sent to the Ministry of Fisheries also. The use of stock assessment models combined with proper statistical methods can only be done by such a centralized body, that collects all fisheries data on the national scale.

The local communities may, and perhaps should cooperate in their efforts to sample data, process the data and even manage the artisanal fisheries. Even so, regularly conducted fishery surveys are costly, and need to be designed in an economical and efficient way. No authority can (nor needs to), census its fisheries completely, neither in space nor time. Therefore, the data surveys have to be sample based. The question is how many samples are needed, to estimate the wanted indicators with acceptable accuracy? And also, what is acceptable in terms of accuracy?

When data collection is based on taking samples, all of the parameters are estimated. For example you don't count all landed fish from every boat, at every landing site on every day of the year. Instead you take samples from a few boats, a couple of times per week, from several of the landing sites. Then you use these sample data to estimate e.g. the total catch for the whole area in question. Frame surveys are the only exception from the above rule, where all boats and gear are registered along with many other statistics. This is a huge task and even the central government can't afford to do a Frame survey more than once in every 2, 3, 4 or even 5 years.

Other parameters like total catch, fishing effort, catch per unit effort and value of the catch must be estimated by sampling. Samples for these estimates are taken at least weekly and they are usually estimated separately for each month of the year. The industrial fleet and the larger, semi-industrial boats remain the responsibility of the central government, which has the means to sample these fleets regularly and has qualified staff to do statistical tests and use Schaefer/Fox models for fish stock assessment. The local councils may not however, have the needed means to sample regularly and adequately the fisheries of the smaller artisanal boats. They may not either possess the required capacity for statistical analysis or using stock models, to assess the health of the fish stocks.

Clearly the long term goal in localizing management is to develop adequate local skills and to allocate sufficient funds for independent and self-sustained local management of the artisanal fisheries. Until these goals are met, a simpler and less expensive backup plan is needed. For now, all stock models and (almost all) statistical analysis will be left out, for economical and capacity reasons and mainly simple sample averages will be calculated. Cutting down on data sampling would still not be a good idea however. Both national and international interests demand statistically sound data and good data will also become more useful locally, when the long term goals of improved local skills and sufficient funds are met. The longer the monitoring series become, the more valuable and accurate they are as managing tools.

Statistical analysis requires time-series of data and if a sample-based fishery survey is to be sustainable, it must be able to survive through times of bad fisheries. The sample data need to be edited, checked and properly stored in an easily accessible format. To ensure continuity, the whole system should also have minimal dependence on external assistance.

The quality of the collected data decides the statistical reliability of the outcome. Therefore the data collectors and their supervisors must be mobile and thoroughly and regularly trained. They should be motivated not only financially, but also mentally by making them understand the purpose and utility of their work and let them participate in the structuring and implementation of surveys.

## 2. A sampling scheme

To achieve the desired 95% statistical accuracy in estimated parameters, the number of sampled boats should not be less than about 5 per working day (124-127 during a month). The samples should be taken randomly from 3-5 sampling sites, depending on the total number of landing sites in the commune. Randomness is vital in all sampling and when there is a choice between two boats, a coin should always be flipped to select which one to sample. The landing sites chosen should ideally represent all boat/gear types. This much sampling allows for some comparisons between gear types and boat types, especially when adjacent management units work together.

The much less desired 90% accuracy can be achieved by sampling only 32 boats per month. Changes in such a time series will have to be exceptionally big to be significant however, and there will be few if any possibilities to make meaningful comparisons.

The general data to collect are: Document identification number, Name of recorder, Date, Landing site, Boat type, Gear type (+ mesh size), propulsion, Duration of trip, Total landing (kg), Activity during previous 3 days

Species data: Landing by species (kg), Number of fish by species, Length frequency, Price by species

Remarks: Noteworthy or unusual things like: The measured catch was caught by two cooperating boats

## 3. The useful index Catch Per Unit of Effort (CPUE)

The total catch of fish species is of general interest to stakeholders e.g. for economic reasons. Changes between years in total catch are not a very useful indicator on the size of fish stocks however, as other changes such as increase/decrease in effort (e.g. number of boats) can have a greater effect. Catch-Per-Unit-Effort (CPUE) on the other hand, can be used as a simple index of stock abundance, where some relationship is assumed between that index and the stock size. Declines in CPUE may mean that the fish population cannot support the present level of harvesting. Increases in CPUE may mean that a fish stock is recovering and more fishing effort can be applied.

CPUE should always be calculated separately for each boat and gear type, but when there are acceptable similarities, types can be combined. CPUE by boat and gear categories, combined with data on fish size at capture, permit a large number of analyses relating to gear selectivity, indices of exploitation and monitoring of economic efficiency. To estimate CPUE the total Catch is divided by the number of units of Effort (e.g. boat-days), that were used to catch the fish

$$\text{CPUE} = \text{Catch} / \text{Effort}$$

**Catch:** The total catch of all boats of a certain boat/gear type, in an area, that were sampled during a month

**Effort:** The total number of effort units (e.g. boat-days) sampled in the area, during the month

The unit of effort here is the boat-day, and if all the boats sampled did only single day trips, the number of units is simply the total number of samples. If any of the sampled boats spent two days on a trip, that fishing trip counts as two boat-days in the total effort.

Example: Every sixth day of June, 10 boats were sampled totalling (5 x 10 =) 50 samples. 47 were single day fishing trips, but 3 trips lasted for two days. That means the total effort was not 50 boat days, but:

$$\text{Effort} = (47 \times 1 \text{ day}) + (3 \times 2 \text{ days}) = 47 + 6 = 53 \text{ boat-days}$$

Assuming the total landings from all the sampled boats was 530 kg, the average CPUE was:

$$\text{CPUE} = \text{total Catch} / \text{total effort}$$

$$\text{CPUE} = 530 \text{ kg} / 53 \text{ boat-days} = 10 \text{ kg/day}$$

#### 4. Statistical processing of the data

If lack of capacity prevents statistical tests and interpretation of the data, one possibility (at least a theoretical one), is to outsource the statistical part of the computation to some foreign aid donor for a few years, during local capacity building. The capacity to do some simple statistics may however, already be present and therefore an example is given in the Addendum below on how, in a simple way a valuable confidence interval can be added to the CPUE calculated above\*.

#### 5. The total catch for an area

To estimate the total catch for an area, the average catch of one boat-day from the sampled boats must be scaled up to the total effort of all the boats in the area. For simplicity, let's say

the average catch per unit of effort (CPUE) was 10 kg/day. Lets also say that the total number of boats in the area (from Frame survey), was 500 and that all the boats in the area were fishing every day of the month June. Then the scaling would be simply

Total Catch = CPUE x Effort

Total Catch = 10 kg/day x (500 boats x 30 fishing days)

Total Catch = 10 x 15000 = 150 000 kg

In reality, the total landings would never add up to 150 tonnes however. This figure could be called the “maximum attainable catch”, and is only achieved if all the boats are active all the time. Most Cristian fishers don’t fish on Sundays however, and most Moslim fishers don’t fish on Fridays. Fishermen may get sick or have some pressing errands to attend to. Then there is bad weather, that can hold back all the boats for a day or two during the month. Lastly, some of the boats that were counted in the Frame suvey may be broken or temporarily without petrol, but there may also be new boats that were added after the Frame survey was conducted. Hopefully the last two will cancel out. The important measure here is the total units of effort during the month, i.e. the number of active boat-days.

The total number of boats in the area, that are actually active is not easy to estimate. One way of doing that is to make the assessment of active days a part of the sampling questionnaire. Then every fisherman questioned is asked if his boat was active yesterday, the day before yesterday and the day before that. He will not be asked about today however, as only active boats are sampled anyway. The total of **active** boat-days devided by the total of all days sampled (= days asked about) will give the active proportion. The “maximum attainable catch” computed above, must then be multiplied by this number (say 0.719), to get an estimate of the actual catch. The example above could then look like this:

Catch = 10 kg/day x (500 x 30) \* 0.719 = 107 850 kg

As this is a point estimate, containing some uncertainty we would round up this figure and present the result as 108 tonnes. Note that the statistical method shown in the Addendum below is also useful here, to calculate a 95% confidence interval around this point estimate. In the same way, we make a sum of squares by adding all the individual “(catch minus average catch) squared”. It is more practical to separate the effort and the total catch into species, which can then be used to estimate trends and changes in individual stocks.

## 6. The Value of the catch

The total catch of each species (in kg), is multiplied by the price per kg to get the total value of the species. Adding the value of all species gives the total value of the whole catch.

## 7. Boat and gear selectivity

With the above suggested sampling scheme, some comparison between the average catch of boat types and gear types can be made, but if the length of each fish in some of the samples is registered also, more parameters can be estimated.

## 8. Management actions

If Catch Per Unit of Effort decreases over 3 quarters in a row or more, overfishing is likely to be occurring and the Council should act to end the overfishing. The purpose of the action is to rebuild the stock or stock complex in as short a time as possible. The most effective way at hand is to reduce the number of fishing licences released. When the CPUE returns to its previous level, the number of fishing licences can be increased again.

### Addendum

The mean CPUE ( $\bar{x}$ ) = 10 kg/day in the example above (section 3), was calculated in the simplest way possible, by adding all the catch measurements. In doing that, we reduced unnecessarily the information content of the data. A more informative way is to calculate the CPUE of each landing and take an average of all the individual CPUE's. We would still get the same average as above (10 kg/day) and this is still a simple point estimate. But, unless we use all the raw data to calculate a confidence interval around the average however, we have little idea on how good the point estimate is.

Using the catch of every sampled boat as a separate estimate of CPUE (remember to divide the catch of the two-days trips by 2), and assuming a normal distribution of our sample mean (which we call  $\bar{x}$ ), we get a 95 % confidence interval\* for the mean as

$$\bar{x} - 1.96 s/\sqrt{n} \text{ (lower limit)} \quad \text{and} \quad \bar{x} + 1.96 s/\sqrt{n} \text{ (upper limit)}$$

where  $s$  = standard deviation and  $n$  = number of samples

To calculate the standard deviation ( $s$ ), we subtract the already calculated mean CPUE ( $\bar{x}$ ), from every individual CPUE ( $x_n$ ), square the result and add them all together

$$\text{Sum of squares} = SS = (x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + \dots + (x_n - \bar{x})^2$$

Divide the sum of squares by  $n-1$

$$s^2 = SS / (n-1)$$

and the square root of the answer is the standard deviation

$$s = \sqrt{s^2}$$

\* If we repeat the calculation with new measurements a lot of times, we would each time get a slightly different mean, and our confidence interval would include the true mean 95 % of the time.