REVIEWING SAMPLING AND DATA ANALYSIS TECHNIQUES FOR ARTISANAL FISHERIES IN LIBERIA

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ABSTRACT

This study attempted to review the sampling and suitable data analysis techniques for marine artisanal fisheries in Liberia using the available data (2013, 2014 and subset of 2016, 2018 and 2019). Three key small pelagic species that compose most of the catch were studied. The process of data extraction and preparation was streamlined. Analysis of variance tests showed some spatial patterns in landed catch. Herring (*Sardinella spp.*), most commonly caught species, are mainly found in the Western Region of the coastal area. Atlantic bumper is landed mostly in the Western and West Eastern Regions, and Atlantic flying fish is the least caught species among the three and mainly found in the South Eastern Region and were absent from West Eastern Region and part of South Eastern Region of Liberia. A seasonal effect could be seen for Atlantic bumper. Two major types of canoes operate in the fishery. Fanti canoes are larger and catch more fish. The Kru canoes are much smaller in size and catch less. Most of the catch is landed by ring-nets. Fundamental sampling theory was applied to estimate total annual catch. Due to sparse data these estimates are not considered reliable and it is recommended to revise these once more data are available. A number of inconsistencies was noted both in the old and new data collection and storage system, and recommendations are provided to address these, which will help to strengthen the data collection and monitoring of artisanal fisheries in Liberia.

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1 INTRODUCTION

Liberia has plentiful aquatic resources, enjoying a coastline of about 570 kms and marine fishing ground of approximately 240,000 km². The country has numerous wetlands with diverse river systems entering the Atlantic Ocean (NaFAA, 2018). Liberia is adjacent to the Gulf of Guinea current and lies between 4°N and 9°N latitude and shares maritime borders with Ivory Coast in the East and Sierra Leone in the West, with Guinea lying along the northern border of Liberia (Service, Group, & POSEIDON, 2013). There are 9 coastal counties along the coast; on 12 January 2012, Liberia declared a 200 nautical miles (NM) Exclusive Economic Zone (EEZ) by Executive Order (Figure 1) (Service, Group, & POSEIDON, 2013).

Figure 1. Map of Liberia Showing the 9 Coastal Counties (Maps of the World, 2015)

The National Fisheries and Aquaculture Authority (NaFAA) is the only Government Agency responsible for all fishing and fishing related actives in Liberia. The authority is responsible for building its own capacity and managing its resources (NaFAA, 2018). In the past, the authority has been supported by international staff and experts and has had support from the World Bank, through the Liberian component of the World Bank funded project, the West Africa Regional Fisheries Project (WARFP) that started implementing its support in 2009. The artisanal sector provided employment to over 33,000 people in 2015 and contributed 10% to the GDP which was higher than other African countries, such as Senegal with 3%, Nigeria 4% and Ghana 3% respectively (Belhabib, Dyhia; Sumaila, U. Rashid; Pauly, Daniel, 2015). Fish

is best known to provide protein for the Liberian population and about 80% of Liberians depend on fish for food as the animal and livestock sector is still being revitalised (BNF, 2013). The fishery sector is divided into 3 sub-sectors;

- marine fisheries, which include the industrial, artisanal (small-scale) and recreational fisheries,
- inland fisheries, which include mainly subsistence fisheries,
- aquaculture.

There is not much information available on the Recreational and the Inland Fisheries of Liberia. The Government is seeking support to monitor these fisheries (NaFAA, 2018). This study will focus on the small-scale fisheries sector.

1.1 Problem Statement

Research has shown small-scale fisheries in Liberia is exploited throughout the year by fishermen deploying various fleets using multi-gears to target multi-species and consequently showing signs of over-exploitation (Belhabib, et al., 2013). The marine fishery in Liberia has struggled with huge amounts of illegal, unreported and unregulated catches in the absence of monitoring during the civil conflicts. This has had a strong negative impact on fisheries and food security. In more recent years, effort has been made to revive the small-scale fisheries sector, and a sampling programme has been in place to collect artisanal catch and effort data since 2013. However, discrepancies exist in the data, because the data collectors were not properly trained and lacked proper expertise to collect data in a consistent manner. A Microsoft Access database has been developed by WARFP; unfortunately, due to administrative issues, not all sampled data have been entered into the database.

In August 2018, the sampling program was transformed from being paper based to a Computer Assisted Personal Interviewing (CAPI) system, using the OPEN ARTFISH (Open Approaches Rules and Techniques for Fisheries statistical monitoring) application from the Food and Agriculture Organisation (FAO), with support from WARFP. The software application is built to estimate the total catch and value by species for small scale fisheries (FAO, 2016). The backend database is built in Microsoft Access. The tablets needed for data collection are provided by WARFP. This system has possibly led to improvements in data collection.

However, challenges are still to be faced due to the poor quality of the existing data, and capacity is still lacking in analysing the available catch and effort data. Over the years, the Research and Statistics Department of NaFAA has faced challenges with exporting data for statistical analysis. The data have so far been exported into Excel for analysis, which has limited capacity to deal with large amounts of data. Additionally, queries and aggregate functions used to extract and summarise data in Access can use a lot of storage space making the performance of the database slower.

It is therefore important to streamline the process of retrieving large amounts of data from the database and establish methodologies to visualise and statistically analyse the available data to get more insight into the status of these resources. It is also of interest to discover whether improvements in the sampled data can be seen with the new data collection programme.

1.2 Research Objectives

The work carried out in the project is divided into four main parts with specific objectives outlined below:

1. To develop scripts in R to connect to the Microsoft Databases to retrieve data.
2. Carry out a descriptive and statistical analysis of the landed catch and effort data for the three main species from years 2013, 2014 and 2016 to examine any spatial and temporal differences.
3. Estimate total catch and effort for the three main species for year 2013, 2014 and 2016.
4. To study any improvements in the data collection system by summarising the available 2018 data collected using the OPEN ARTFISH database by FAO.

2 ARTISANAL FISHERIES (SMALL-SCALE)

2.1 Fishing gears and canoes used by Artisanal Fishers

The small-scale fisheries are largely operated by three ethnic groups:

I. Kru that are comprised of indigenous tribes of Liberia and have been fishing since the establishment of the country; mainly using small dug-out canoes (around 7m)

with paddles or sails and a crew of 1-3 persons using multi gears (hooks, long-lines and gill nets) targeting all species, and comprising about 75% of the canoes in the small-scale sector.

II. Fanti (Ewe) from Ghana mostly using large plank canoes (about 12-15 m) with 8–40 horse power *(hp*) and a crew of 15; this group of fishermen and their families arrived in Liberia in the 1920s (Belhabib, et al., 2013). These types of canoes use both passive and active gears varying according to the fishing season. The passive gears mainly used by this canoe type is gill nets, set gill nets and trap lines and are used during both the dry and rainy seasons (BNF, 2013). Active gears like ring nets are used during the dry season to target mainly the *Sardinella spp.*

III. The Popoh ethnic group from Benin and the Ivory *C*oast are fishermen who have been mainly involved in beach seine but are now diverting either by using the paddle canoes or canoes with outboard engines because of the 2010 Fisheries Regulations; these categorised beach seine as illegal fishing practices because of the mesh sizes of the nets. Now this group of fishermen target all species, similar to the Kru (BNF, 2013).

Apart from the classification of the canoe type used by ethnic groups given above, there are also standard canoes that are used by all three ethnic groups that are medium-sized (10m long) with a crew of 3–5 men using 8-15 horse power and same fishing gear types as the Fanti canoes.

At a workshop held in Liberia on the 20th – 25th of November 2017, by the Fishery Committee for the West Central Gulf of Guinea (FCWC), FAO, and the then BNF entitled, 'Regional Workshop on Routine Data Collection', it was decided that all small-scale canoes be placed in the following categories:

i. Kru dug-out canoe (less than 6 m long and with a moulded depth of about 60 cm, and 1–3 men).
ii. Ghana-type canoe using 15-40 horse power (either dug-out or planked) with a length of about 12m and a crew of 12 persons or more, classified as Fanti canoe.
iii. The standard canoe (medium-sized 10m long) with a crew of 3–5 men using 8-15 horse power to be also classified as Fanti canoe.

2.2 Small Pelagic Species in Liberia

Small pelagic species have been fished over the years by the small-scale fishermen, supplying food for the Liberian population (BNF, 2013). In 2013, MRAG was contracted through the support from WARFP to identify key stocks harvested within the Marine fisheries sector in the country. Using the sampled data, this study estimated total landed catch by the two main canoe types for the artisanal sector in the years 2013 and 2014, for all species combined. The total catch estimated for year 2013 was 341,830.4 kg (with Fanti canoes landing 79% of the catch), and for year 2014 was 1,457,722.4 kg (with 89% of catch landed by Fanti canoes) (Appendix 1a). The big difference in the estimated landed catch between the years was attributed to increased sampling.

The report indicated that small pelagic species are targeted by the small-scale fisheries using multi gears namely floating nets, ring nets, gill nets, and set nets (MRAG Ltd, 2014). The small scale fisheries is typically composed of approximately 120 different species (BNF, 2013) however, three main small pelagic species were emphasis by the MARG report for management purposes because these species compose majority of the catch, Herring (*Sardinella sp.*), Atlantic Bumper (*Chloroscombrus chrysurus*), and Atlantic flying fish *(Cheilopogon melanurus*). Pelagic species such as herring and Atlantic flying fish are mainly targeted by the Fanti fishermen (MRAG Ltd, 2014). This study will focus on these three-key species.

2.2.1 Herring (Sardinella spp.)

The Herring (Figure 2) are mainly targeted by the Fanti canoes using ring nets and gillnets. This species is harvested in greater abundance during the summer (October-April) than in the rainy season (MRAG Ltd, 2014). Herring are distributed in Liberia over a broad area and reported in both inshore and the offshore waters where the species is vulnerable to a variety of gear types which are found in the Southern Eastern Central Atlantic (CECAF) region from Guinea to Angola (MRAG Ltd, 2014).

Figure 2. Herring (*Sardinella spp*.) (Fishbase)

2.2.2 Atlantic Bumper (Chloroscombrus chrysurus)

The Atlantic bumper (Figure 3) is mainly targeted by the Kru canoes using gillnets and floating nets and has been historically taken in high quantities (MRAG Ltd, 2014). The report also emphasised the importance of the Atlantic bumper to neighboring countries forming an important component of their catch. Even though CECAF currently does not assess the status, MRAG recommended management should not only be done on national level but also on a regional level.

Figure 3. Atlantic bumper (*Chloroscombrus chrysurus*) (Fishbase)

2.2.3 Atlantic flying fish (Cheilopogon melanurus)

The Atlantic flying fish (Figure 4) is an important seasonal fish (March - September) vulnerable to the fishing gears of both the Kru canoes and the Fanti canoes (MRAG Ltd, 2014).

Figure 4. Atlantic flying fish (*Cheilopogon melanurus*) (Fishbase)

3 THE LIBERIAN ARTISANAL DATA SAMPLING PROGRAM

3.1 Former sampling programme

Small-scale data collection sampling started as a six-month pilot project in 2013 from April to September considering four coastal counties (Grand Bassa, Grand Capemount, Margibi, Montserrado). Within the selected counties, one to four fish landing sites were selected, based on, the number of canoes at the fish landing site, the size of the fish landing site, and accessibility to fish landing sites. Within each landing site, seven canoes of each canoe type, Kru and Fanti were selected using stratified random sampling method (MRAG Ltd, 2014). The sampling was done from Mondays through Saturdays and data were collected using paper-based questionnaires. The data were reported at the end of every month at the Fisheries Head Office and entered into a Microsoft Access Database. Fishery dependent data collection method was used with data collectors assigned at each fishing site and they were not rotational. In 2014, an additional four coastal counties were added (Grand Kru, Maryland, River Cess, and Sinoe) and the sampling was conducted from January through December. In 2016, the last remaining county (Bomi) was added, thus, covering all the nine coastal counties, and a total sample of 20 fish landing sites out of the 111 fish landing sites (Figure 5). The selection of fish landing sites

for sampling was consistent over the years. In 2015, the sampling program was not performed due to lack of funding and the data collection programme continued in 2017 from January – December but these data have not been entered into the database.

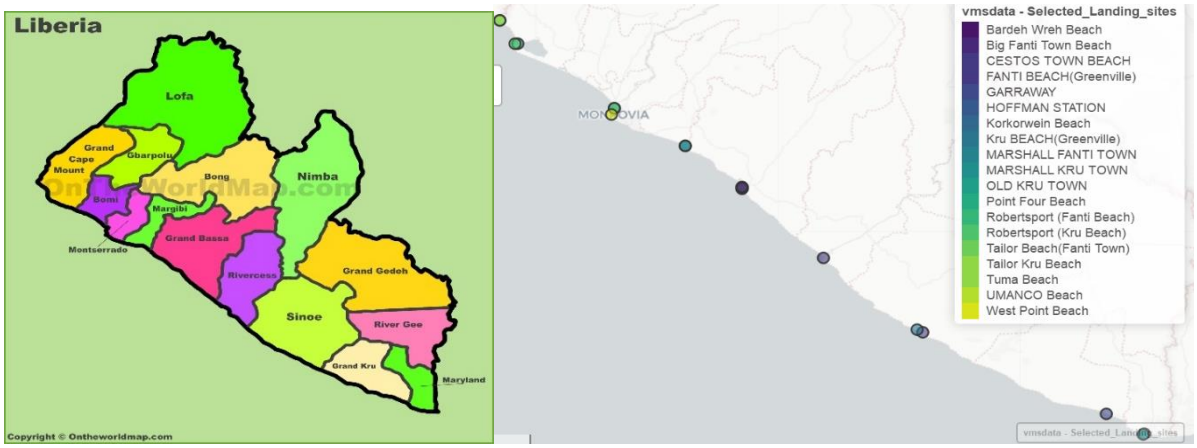

Figure 5. Selected fish landing sites by MRAG sampling programme.

Catch samples were recorded in volumetric units (bucket, tub, bag, hand), as aggregated individuals (bunch), or as the bigger number of individual fishes caught and measured by piece (MRAG Ltd, 2014). The reason for this was the unavailability of accurate scales, familiarity with using these methods to describe catches, and the speed with which sampling could be undertaken given the rates of deterioration of catches and the short time availability to sample fish (MRAG Ltd, 2014). Effort data in the database comprised of the number of canoes of each type fishing, the number of days fished, the time spent at sea, and the trip duration per day. The gear type was also considered in terms of what type of gear target for which species. The first canoe frame survey was done in 2010 in the nine coastal counties (Figure 6). This was updated in 2012 and 2016 adding new canoes entering the fisheries and identifying all decommissioned canoes. In 2010, a canoe registration database was developed in Microsoft Access; the database comprises of two main sections, the canoe (boat) owner and the canoe (boat) characteristics (NaFAA, 2018).

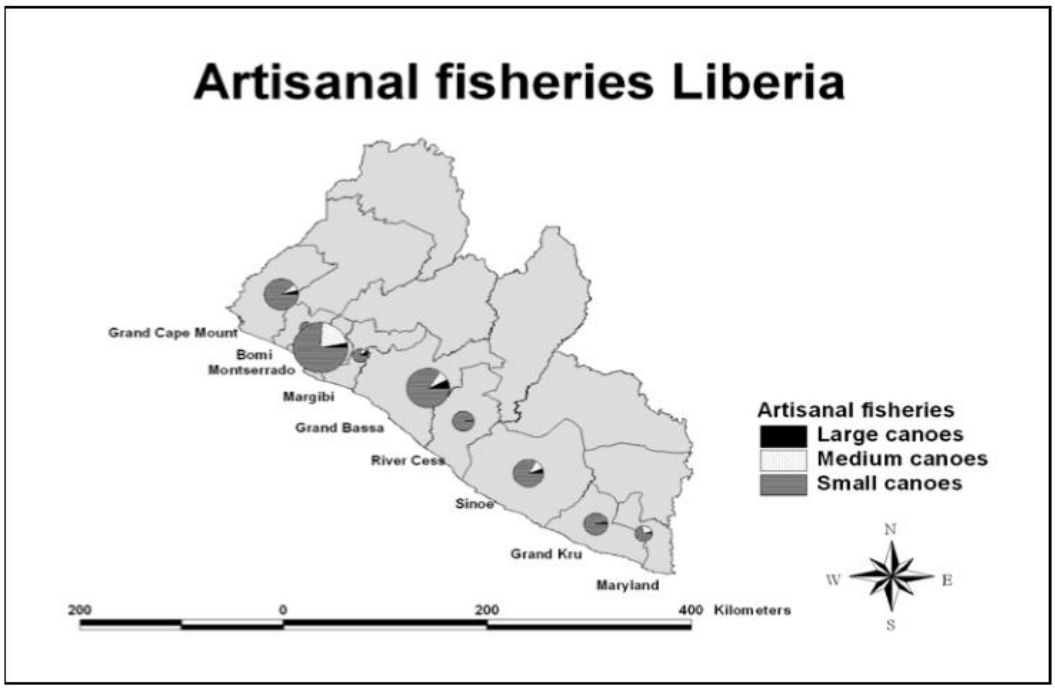

Figure 6. Distribution of artisanal fishing canoes in the 9 coastal counties of Liberia. A pie chart is given for each county. The size of the chart shows number of fishers with a bigger circle indicting more fishers. The composition of the canoes is shown within the pie chart (Belhabib, et al., 2013)**.**

3.2 New sampling programme (Open ArtFish)

The current data collection programme is being transformed from paper-based method of collecting data to electronic data collection using the Open ArtFish software application designed by FAO. This data collection system comes in the form of an App on a tablet which has pre-loaded standard questionnaires that the data collectors use at the landing site and should help in reducing sampling errors (World Bank, 2016). This system was implemented in August 2018. Together with this, more data collectors have now been assigned to each site. At some landing sites, the data collectors enter information in notebooks and later enter the data into the App. All the data can be uploaded onto the server and copies are stored on Google Cloud. The data can be downloaded and saved into the backend Open ArtFish database. This system can ensure that data are uploaded daily rather than monthly which was the case with the former collection programme. The entire catch is weighed at the landing site in a standard catch unit, bowl, and a total landed catch estimate is calculated automatically within the database for each canoe by trip and species.

4 METHODOLOGY

This study sought to utilise the available data within the artisanal catch and effort database and the frame survey database of NaFAA.

4.1 Extracting data

Data were extracted using the R package called RODBC to implement the Microsoft Open Database Connectivity (ODBC) (Moore, 2015). The tidyverse package was used to connect tables by applying the inner_ join command and transforming the data extracted from the access databases (Wickham, 2017) . The R script used is seen in (Appendix 1a).

4.2 Available data (2013, 2014, 2016)

The following variables were extracted from the database for analysis: year, county, landing site, number of units, average weight, trip Duration, canoe type and gear type. All herring species were recoded and considered as one group of herring because of inaccuracies in species identification where species were sometimes misclassified. When the catch was landed a few catch units of each type (i.e. bag, bucket, tub, hand, bunch, piece depicted as catch unit description in the database) was weighed, and an average weight was calculated for that catch unit description per species. These were entered into the database as average weight. There were discrepancies and missing values in the average weight field in the database. These were corrected, and the values used for each catch unit description per species is outlined in (Table 1) below. Also recorded were the number of units landed. The landed catch per sample was then calculated by multiplying the average weight by the number of units landed.

The data frame with year, month, day, species, county, landing site, canoe type, gear type, trip duration and catch were used for analysis.

From the frame survey data, the following fields were extracted: year, county, landing site, canoe type, and number of canoes. In addition, a table was extracted for the gear types being used at each landing site.

Even though the sampling programme was followed, and the planned counties and months were sampled, not all data were entered into the database, giving only a subset of months and counties that could be studied. The average weight estimate per catch unit description is not available for all species therefore, a total landed catch per year cannot be estimated. The approach of using a length-weight relationship to estimate weight cannot be applied as done in the MRAG report because length data are not available for samples in 2016. It should be noted that a separate conversion factor study was carried out by MRAG Report to estimate these missing weights. Therefore, only three key small pelagic species were chosen for analyses including herring, Atlantic flying fish and Atlantic bumper.

Table 1. Average measurement unit in kg by catch unit description for the three main species.

Catch Unit Description	**Herring**	**Atlantic flying fish**	**Atlantic bumper**
Bag	20	25.5	26.2
Bucket	11.1	16	10.1
Tub	17	26.0	26.0
Bunch	1.8	4.0	6.0
Hand	1.2	0.5	0.6
Piece	0.1	0.01	0.02

4.3 Sampling statistics

The data were summarised to take a closer look at the sampling performed over the three years 2013, 2014, and 2016 within the nine coastal counties of Libera for the three main species.

4.4 Analysis of variance (ANOVA) and Tukey Test

The landed catch weight was examined visually using boxplots. Boxplots graphically signify the distribution of data and depict the degree of dispersion and skewness within groups in the dataset. It also gives a visual representation of differences in data distribution between groups. Further, the statistical differences in mean landed catch weight for the three species among different groups were tested using ANOVA. ANOVA allows us to study the differences among groups in our dataset (Taylor, 2018), to test whether the mean is significantly different among groups. In this study, ANOVA was used to assess any significant differences in sampled catch

by species among years, months, counties, landing sites, canoe types and gear types. The Tukey test, where applicable, was used to determine where the differences lay within the group.

4.5 Catch Estimation

An attempt is made to estimate the total landed catch for the three main species for years 2013, 2014 and 2016. The catch landings data and the frame survey data were used for this. The equations 1-6 in MRAG Report were reviewed and applied in this study to estimate the total landed catch (MRAG Ltd, 2014). This task was considered useful because more data from 2014 were entered into the Artisanal database after MRAG finalised the 2013-2014 sampling programme report. Also, additional data are available from 2016 which have not been analysed before.

The catch of species *s*, in month, m, year, *y*, in county, c landed by vessel type *v* is given by:

$$C_{s,m,y,c,v} = \sum_j C_{j,m,y,c,v} \frac{F_{m,y,c,v}}{\sum_j f_{j,m,y,c,v}}$$

Where:

- $C_{s,m,y,c,v}$ is the catch of species, *s* in catch sample *j*, in month, *m* year *y*, county, *c* by canoe type *v*.
- $F_{m,y,c,v}$ is the total number of days spent fishing.
- $\sum_j f_{j,m,y,c,v}$ is the number of days sampled.

The catch in the sample is multiplied by a raising factor to account for all the days spent fishing.

$F_{m,y,c,v}$ the total canoe fishing days in month *m*, year *y*, and county *c* for canoe type *v* was calculated:

$$F_{m,y,c,v} = B_{y,c,v} \,.\, BAC_{m,y,c,v} \,.\, Days_{m,y}$$

Where:

- $B_{y_{Cv}}$ is the total number of canoes of type v, in county, c, in the frame survey for year y.

- $BAC_{m,y,c,v}$ the canoe activities coefficient, equivalent to the probability that a canoe will fish on a given day of the month. A global value of 0.46 was used from the MRAG Report. Further details on how this value is calculated can be seen in MRAG report.
- $Days_{m,y}$ is the number of days in month, *m* and year *y* spent fishing. If fishermen take a break on Sundays of every week, this estimate becomes 26.083 ((365-52)/12).

The total catch from all sampled counties (SC) was calculated by summing up the estimated catch over counties:

$$C_{s,m,y,v}^{SC} = \sum_{c} C_{s,m,y,v,c}$$

Under the assumption that un-sampled counties remain unsampled, total catch was calculated by:

$$C_{s,m,y,v}^{AC} = C_{s,m,y,v}^{SC} \cdot \frac{B_{m,y,v}}{B_{j,m,y,v}}$$

Where:

- $B_{m,y,v}$ the total number of boats/ canoes of type v in all counties,
- $B_{j,m,y,v}$ the total number of boats / canoes in the sampled counties.

The total annual catch of species s, in year y for the entire fishery is then obtained by summing the catch over months and vessel types:

$$C_{s,y} = \sum_{m} \sum_{y} C_{s,m,y,v}$$

The annual catch per unit of effort (CPUE), for species, s, in year y by vessel type v is given by:

$$\frac{CPUE_{s_{yv}} = \Sigma_m \Sigma_c C_{s,m,y,c,v}}{\Sigma_m \Sigma_c f_{m,y,c,v}}$$

The R statistical software was used for all analyses.

4.6 Data 2018 and 2019

The Open ArtFish database which is now the current database being used by the Research and Statistics Department (RSD) of NaFAA includes the following sections: catch and effort data, the social economic data of fishermen, and the length frequency data. A part of the catch and effort data were made available for 2018 and 2019 for analysis. Part of the data for August, September and October were extracted from the Open Artfish database. Some data for December 2018 and January 2019 were downloaded from the google server in Liberia and shared for analysis. The data on the server could not be accessed directly. The following fields were used for analysis; date, county, landing site, canoe type, gear, species and catch to take a closer look at the sampling frequency and review the way all data are entered in the new database for statistical analysis.

5 RESULTS

5.1 Sampling statistics

In Table 2 below the sampling frequency by counties and years sampled for the three key species are outlined (X in the table represents no sampling done in that year for a county; NA indicates sampling was done in the year, but data have not been entered; 0 shows sampling was done, but no fish were present in the sample). The total number of samples are higher in 2013 and 2014 because all data were entered in the database whereas for 2016 all data have not been entered. Additionally, in 2014 the total number of samples are much higher than 2013 because the sampling in 2013 only targeted four counties while 2014 sampling was done in seven counties. Atlantic bumper is not observed in the catch landed in Grand Bassa, River Cess and Sinoe and very few were observed in Margibi county in 2013 (6) and Maryland county in 2014 (9) (highlighted in blue in Table 2). Atlantic flying fish were not observed in River Cess and Sinoe (highlighted in green in Table 2). Herring is the most frequently observed species and is present in a high number of samples in Grand Bassa, Grand Capemount, Montserrado, Rivercess, and Sinoe (highlighted in grey in Table 2).

Table 2. Number of landed samples across years and counties for the three key species caught in the Liberia artisanal fisheries.

			Year sampled by species		
No.	**County Description**	**3-key Species**	**2013**	**2014**	**2016**
1	Bomi (BMC)	Herring	X	X	NA
	Bomi	Atlantic flying fish	X	X	NA
	Bomi	Atlantic bumper	X	X	NA
2	Grand Bassa (GBC)	Herring	978	1239	420
	Grand Bassa	Atlantic flying fish	3	81	NA
	Grand Bassa	Atlantic bumper	0	0	NA
3	Grand Capemount (GCC)	Herring	645	1947	198
	Grand Capemount	Atlantic flying fish	171	153	NA
	Grand Capemount	Atlantic bumper	90	1005	NA
4	Grand Kru (GKC)	Herring	X	306	54
	Grand Kru	Atlantic flying fish	X	18	NA
	Grand Kru	Atlantic bumper	X	30	12
5	Margibi (MGC)	Herring	417	582	NA
	Margibi	Atlantic flying fish	33	123	126
	Margibi	Atlantic bumper	6	0	NA
	Maryland (MLC)	Herring	X	615	303
6	Maryland	Atlantic flying fish	X	93	NA
	Maryland	Atlantic bumper	X	9	NA
7	Montserrado (MNC)	Herring	849	2571	99
	Montserrado	Atlantic flying fish	147	48	3
	Montserrado	Atlantic bumper	33	177	21
8	Rivercess (RCC)	Herring	X	1176	NA
	Rivercess	Atlantic flying fish	X	0	NA
	Rivercess	Atlantic bumper	X	0	NA
9	Sinoe (SNC)	Herring	X	1350	NA
	Sinoe	Atlantic flying fish	X	0	NA
	Sinoe	Atlantic bumper	X	174	NA
	Total		**3372**	**11697**	**1236**

The Table 3 depicts the number of samples by months and years sampled for the three key species. In 2013, the sampling programme only ran for six months (April- September), whereas in 2014 all months were sampled (January- December). In 2016, all data have not been entered into the database, even though the sampling programme lasted for twelve months. Months March, April, and July in 2013 and 2014 indicate active fishing months as the data shows high frequency in the sampling scheme.

Table 3. Number of landed samples across months and years for the three main species combined.

	Year		
Month	**2013**	**2014**	**2016**
January	X	9	NA
February	X	9	NA
March	X	2376	3
April	804	2364	522
May	285	1371	384
June	429	1251	327
July	567	2394	NA
August	771	1881	NA
September	516	27	NA
November	X	6	NA
December	X	9	NA
Total samples	**3372**	**11697**	**1236**

A mean catch by year, month, county, canoe type, and species can be seen in Table 12, in Appendix 1a.

It can be observed that a higher number of samples come from Fanti canoes than the Kru canoes across years even though more Kru canoes are in operation (Table 4). The mean landed catch is also higher.

Table 4. Number of samples by canoe type and year. With the total number of canoes in operation and mean catch (kg) displayed within brackets.

	Number of Samples / (Number of canoes) by year		
Canoe Type	**2013**	**2014**	**2016**
Kru canoes (1)	732 (1603) (25.0)	1029 (1603) (22.8)	174 (1895) (39.2)
Fanti canoes (2)	2640 (306) (568)	10668 (306) (238)	1062 (528) (103)

Herring is mostly caught in gears 1, 2, and 5. Atlantic flying fish is mostly caught by gear 1, whereas Atlantic bumper is landed mostly by gear 5. Gear 9 doesn't catch much of any of the three main species (Table 5).

Table 5. Number of landed samples and mean catch (kg) by gear type and species (mean catch is displayed in brackets) and canoe type.

		Number of samples (Average weight of sample (kg))		
Gear Type	Canoe Type	Herring	Atlantic flying fish	Atlantic bumper
Setnet (1)	Kru	531(30.74)	375(18.94)	78(23.03)
	Fanti	4833(303.94)	219(24.66)	270(73.69)
Gill nets (2)	Kru	531(17.66)	45(7.67)	99(0.72)
	Fanti	3258(66.65)	108(26.99)	261(83.14)
Hook& line (3)	Kru	93(23.72)	12(16.02)	15(1.27)
	Fanti	9(42.93)	6(0.14)	NA
Ring nets (5)	Kru	27(300.94)	126(23.63)	3(0.22)
	Fanti	4458(446.78)	24(18.13	912(456.93)
Long lines (9)	Fanti	9(17)	NA	3(26)

5.2 Catch comparisons

The distribution of landed catch for the three species across years 2013, 2014 and 2016 and the median catch can be seen in Figure 7. An analysis of variance showed there is no significant difference in mean landed catch for herring across years (Df=2, F=1.3866, P =0.2522). The mean landed catch for Atlantic flying fish showed significant difference across years (Df =2, F= 29.926, P = 2.582e-13). A tukey test shows 2016 is different from 2013, and difference is also caused by 2013. A large interquartile range indicates the amount of landed catch is highly variable. The mean landed catch was significantly different across years for Atlantic bumper (Df = 2, F = 532.2, P = 2.2e-16). The year 2013 was different from 2016 and 2014 (Figure 7).

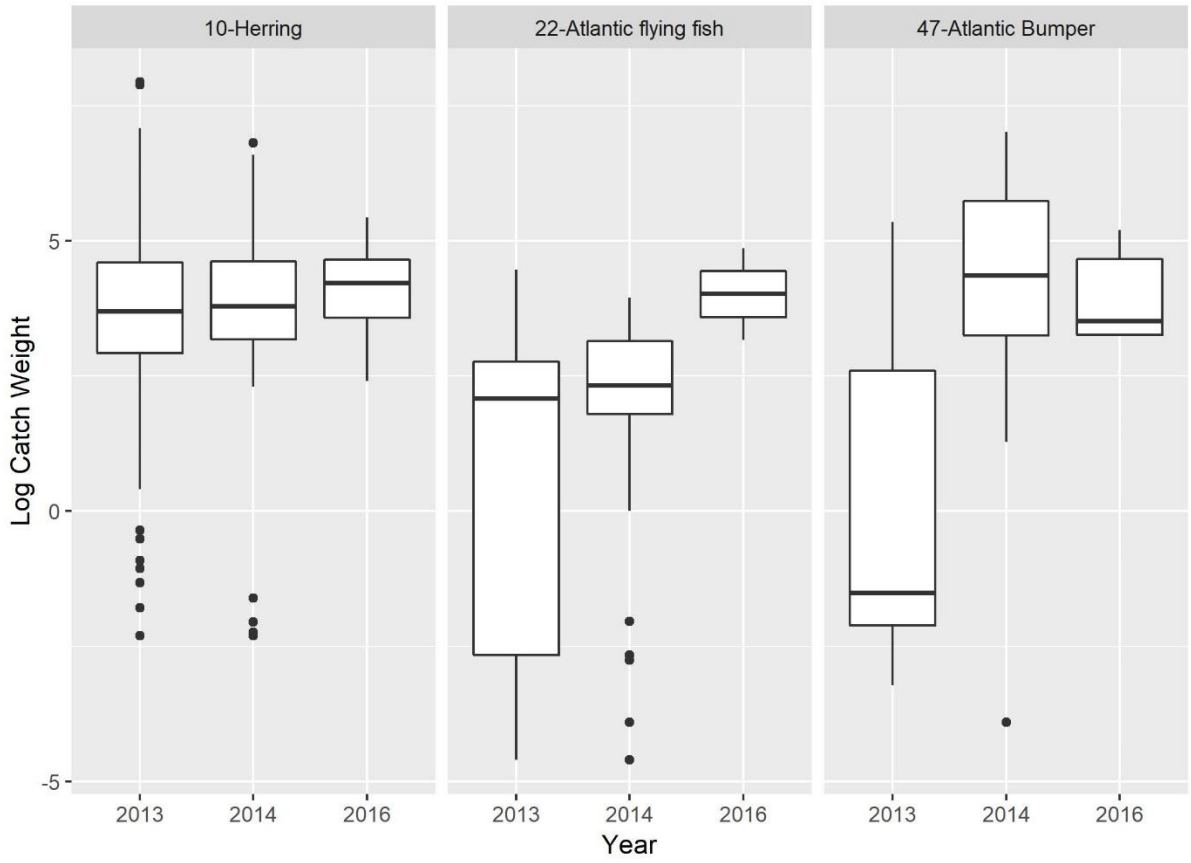

Figure 7. Boxplot depicting the variation in catch weight (log) with median, upper and lower quartiles, and outliers for the three main species across years.

The landed catch for herring across months showed significant difference (Df=10, F =145.05, P=2.2e-16; Figure 8). A tukey test showed month 12 (December) was different from the rest. Atlantic flying also showed significant difference across months (Df= 6, F= 84.199, P= 2.2e-16; Figure 8). A tukey showed months that have low catch (8, 9, 5 & 6) differ from months that have high catch (3, 4, 7). There was a significant difference in landed catch weight for Atlantic bumper fish across months (Df=7, F=90.54, P= 2.2e-16). Months 8 & 9 were different from the rest of the months.

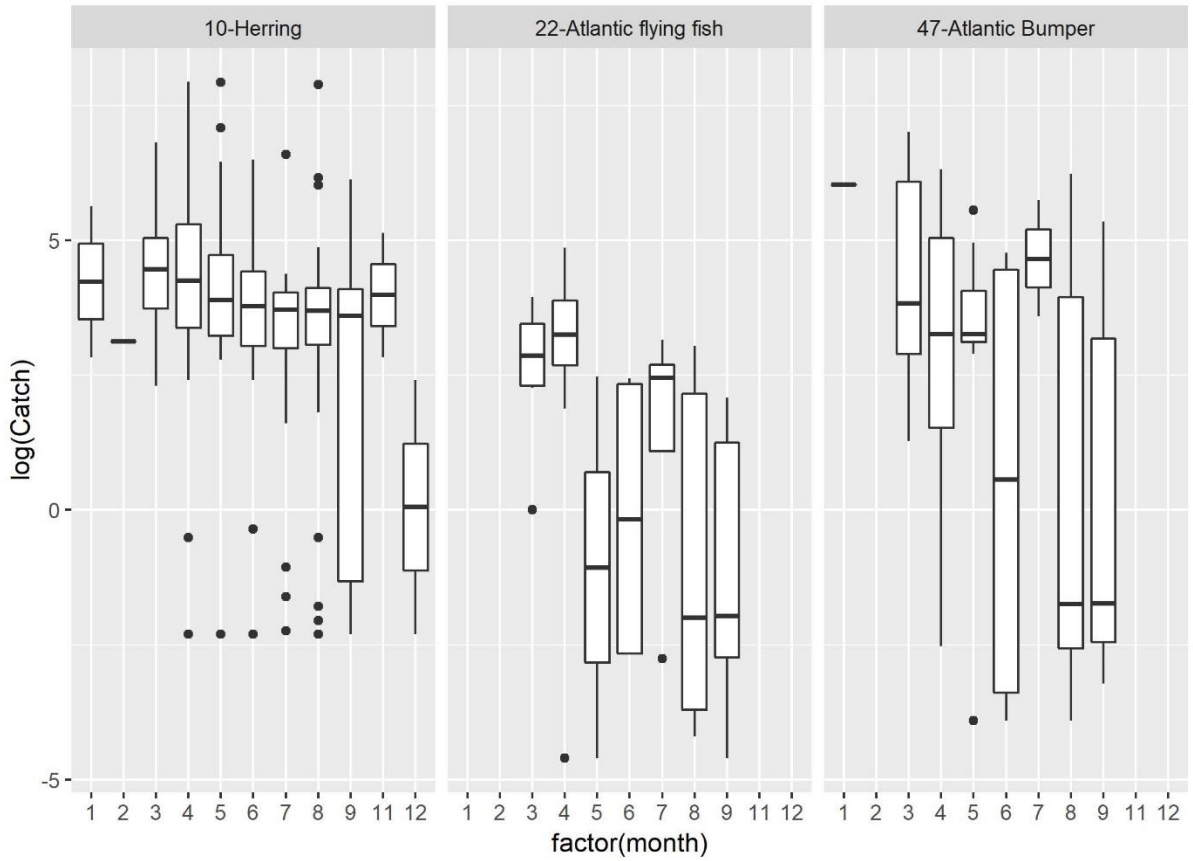

Figure 8. Boxplot depicting the variation in catch weight (log) with median, upper and lower quartiles, and outliers for the three main species across months.

Herring showed significant differences in mean landed catch weight across counties (Df =7, F=226.2, P = 2.2e-16; Figure 9). Montserrado was different from other counties. There is significant difference in landed catch weight across counties for Atlantic Flying fish also (Df= 4, F=42.704, P=2.2e-16; Figure 9). Montserrado and Grand Capemount were different from the rest of the counties and different from each other. The flying fish is not found in SNC (Sinoe), River Cess (RCC) and GBC (Grand Bassa). Atlantic bumper is significantly different among counties (Df=6, F=13.591, P = 4.174e-15; Figure 9). MGC (Margibi) is different from GCC (Grand Capemount) and SNC (Sinoe).

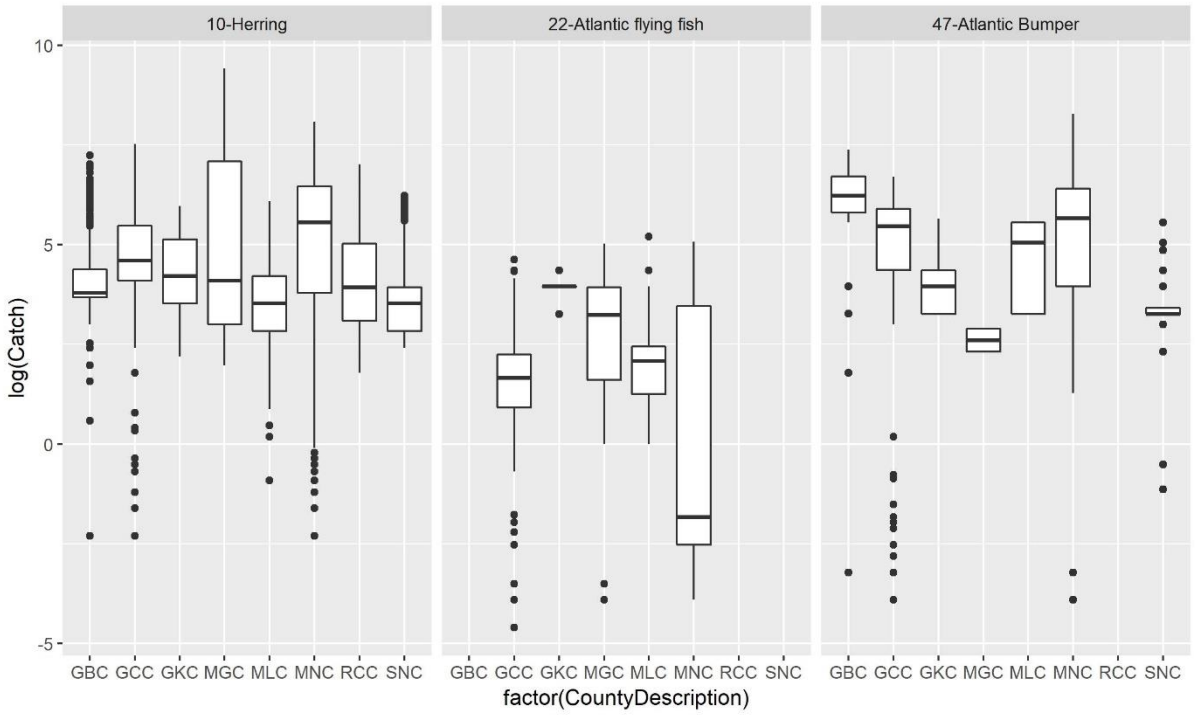

Figure 9. Boxplot depicting the variation in catch weight (log) with median, upper and lower quartiles, and outliers for the three main species across counties.

The amount of herring caught by different gear types is significantly different (Df=3, F=1206.6, P=2.2e-16; Figure 10). Ring nets (5) catch the most herring and hook and line (3) catch the lowest. The mean landed catch of Atlantic flying fish showed significant difference across fishing gear types also (Df=3, F=40.953, P=2.2e-16; Figure 10), Hook and line (3) and long line (9) do not catch Atlantic flying fish. The Atlantic bumper showed significant difference across fishing gears in landed catch weight with (Df=4, F=304.3, P=2.2e-16; Figure 10). Hook and line (3) are different from all the gears, they catch the least.

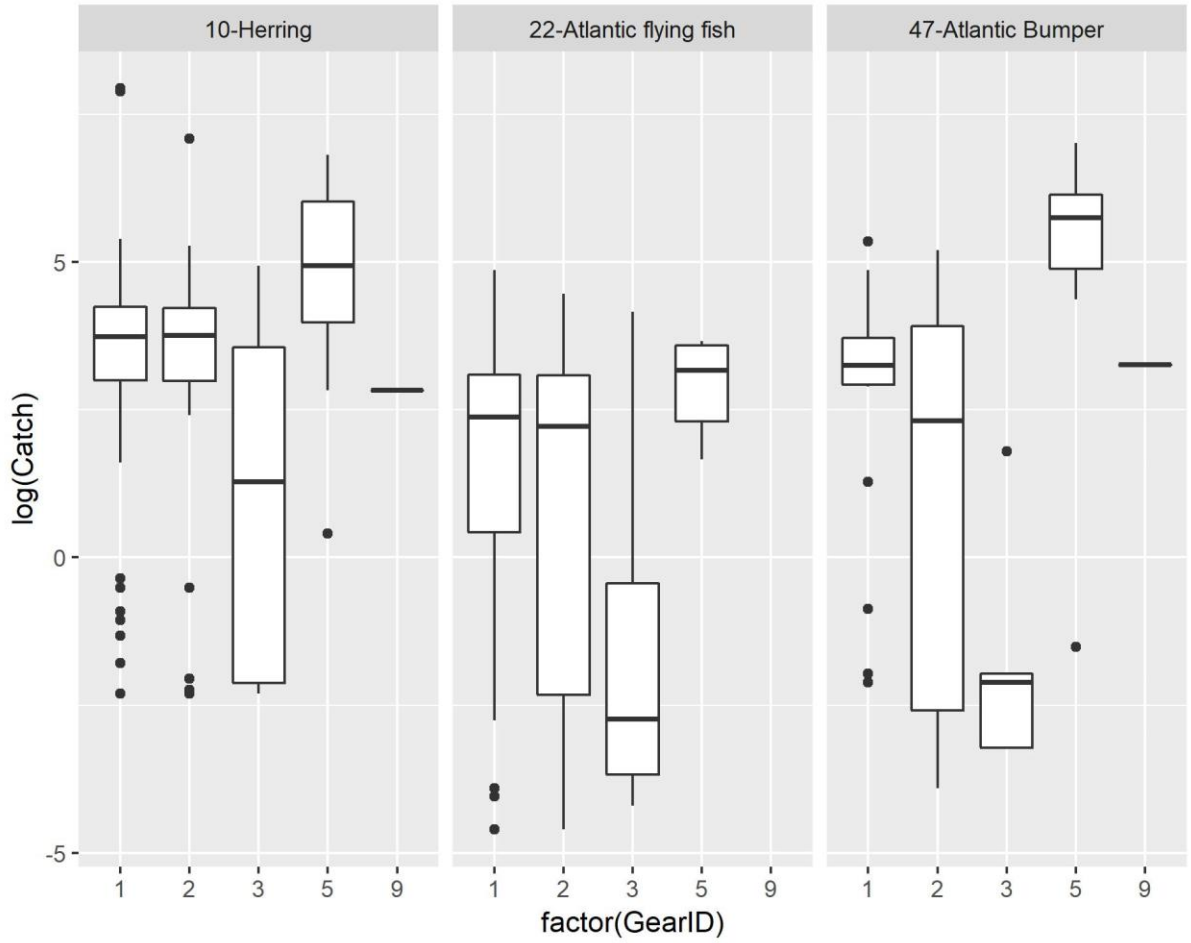

Figure 10. Boxplot showing the median sampled catch weight (log) for the three-key species across fishing gear types with upper and lower quartiles and outliers (1 = setnet, 2 = gillnet, 3 = hook and line, 5 = ring net and 9 = trap line).

Herring is significantly different across canoes types where 1 represents Kru canoes and 2 symbolises Fanti canoes (Df=1, F=3618.6, P=2.2e-16; Figure 11). Atlantic flying fish showed no significant difference among canoe types (Df=1, F= 20.488, P= 6.763e-06). Whereas, Atlantic bumper showed significant difference among canoes types (Df= 1, F=1878.1, P=2.2e-16). In general, the Fanti canoes land more catch than the Kru canoes.

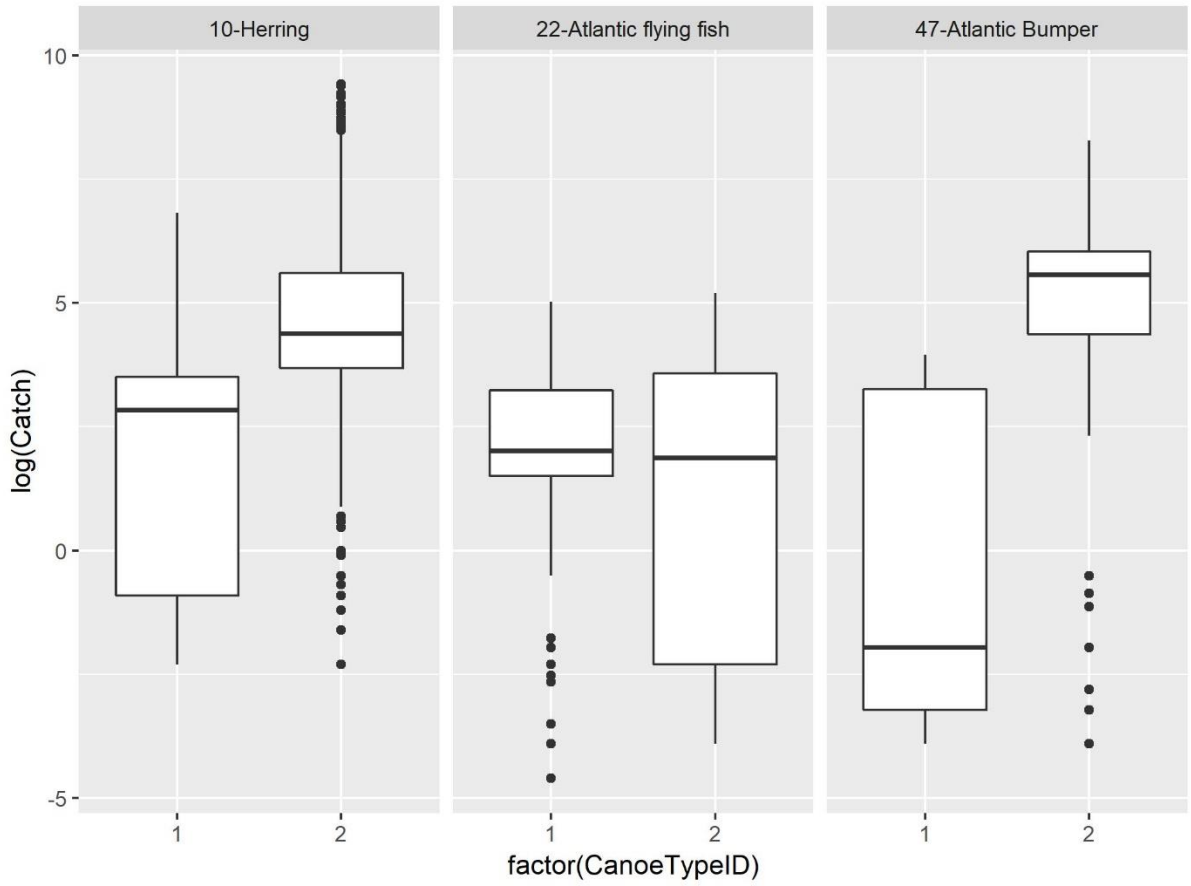

Figure11. Boxplot showing the median catch weight (log) for the three key species across Fanti and Kru canoes type with upper and lower quartiles and outliers.

There was a significant difference across sampled landing sites for herring (df=13, F=569.21, P= 2.2e-16). The following landing sites were different, Robertsport Fanti and Tailor Kru in Grand Capemount county. Atlantic flying fish is significantly different in landed catch weight among selected landing sites also (Df=8, F=23.557, P=2.2e-16). The differences are seen within the following landing sites, Point Four in Montserrado and Tailor Kru in Grand Capemount, Atlantic bumper was significantly different among selected landing sites (df=10, F=461.93, P=2.2e-16). The boxplot for landing sites is not legible because of the high number of landing sites, therefore the plot is not included in this report.

5.3 Catch Estimation

The total catch estimates in tons are shown in Table 4 for year 2013, 2014 and 2016 by species and canoe types. The estimated catch for herring is much higher by Kru canoes in 2014 compared to 2013 but lower for Fanti canoes. In 2014, the Fanti canoe type has high total catch estimate for Atlantic bumper, and 2016 shows high catch rate for Atlantic flying by Fanti canoe type. A more detailed estimate of raised catch by year, month, county, species, and canoe type together with the estimated total fishing days, and the total number of boats operating in the fishery is given in Table 12 in Appendix 1a.

Table 6. Total catch estimates in tonnes across years by canoe types for the three main species targeted by the Liberia artisanal fisheries.

Species name	Canoe type	2013	2014	2016
Herring	Kru canoe	564.89	2432.36	375.22
Herring	Fanti canoe	1177.44	636.59	267.41
Atlantic flying fish	Kru canoe	131.08	183.63	4.25
Atlantic flying fish	Fanti canoe	33.66	157.46	273.64
Atlantic bumper	Kru canoe	162.26	117.50	98.21
Atlantic bumper	Fanti canoe	83.67	1281.69	417.73

The Catch per Unit Effort (CPUE) for each year by species and canoe type is shown in (Table 7). In 2014, the CPUE for Kru canoes fishing herring increased and the CPUE for Fanti canoes decreased. In the same year, CPUE for Fanti canoes increased for Atlantic bumper. The available data for 2016 indicates the CPUE for Kru canoes fishing herring decreased while the Fanti canoes fishing Atlantic flying fish increased.

Table 7. Total Catch per Unit Effort (CPUE) ton per days for canoe type by year and species.

Species name	Canoe type	2013	2014	2016
Herring	Kru	8.9	27.9	23.8
Herring	Fanti	43.9	13.8	11.2
Atlantic flying fish	Kru	2.07	2.11	0.27
Atlantic flying fish	Fanti	1.25	3.41	11.4
Atlantic bumper	Kru	2.56	1.35	6.24
Atlantic bumper	Fanti	3.12	27.8	17.4

5.4 Data 2018 and 2019

5.4.1 Discrepancies in the data

County names are not standardised between the Open ARTFISH database and the data collection app. For example, the following variation in names is used for the same county, Capemount county, Grand Capemount, Grand Cape Mount. Similar issues were seen with names of canoes, which were spelled Fante sometimes instead of Fanti.

Atlantic flying fish were not observed in the 2018 and 2019 data. It is unclear whether the species was not observed in the catch landings for the months analysed or a new FAO code is being used in the new data collection system. This species is therefore not included in the 2018 and 2019 data summary.

Canoe and Gear types are joined together in the new database. Therefore, these fields had to be separated during analysis in R.

5.4.2 Sampling frequency

The number of samples by months, year and counties for the available data show that not all counties were sampled, or the data have not been either uploaded onto the server or downloaded into the database (Table 6). For example, Grand Kru county and month of November are missing samples (Table 6). Only part of the data was available for the months of December and January also as outlined in (Table 8) even though these data were downloaded from the server (Table 9).

Table 8. Number of samples from the Open Artfish data collection programme, for all species across counties and months available for 2018 and January 2019.

County	year	Jan.	Aug.	Sept.	Oct.	Dec.
Bomi	2018	NA	NA	420	NA	12
Bomi	2019	31	X	X	X	X
Grand Capemount	2018	NA	1584	1842	48	133
Grand Capemount	2019	252	X	X	X	X
Grand Bassa	2018	NA	1698	NA	NA	247
Grand Bassa	2019	234	X	X	X	X
Margibi	2018	NA	12	300	NA	44
Margibi	2019	65	X	X	X	X
Maryland	2018	NA	NA	NA	NA	47
Maryland	2019	160	X	X	X	X
Montserrado	2018	NA	108	510	NA	225
Montserrado	2019	498	X	X	X	X
River Cess	2018	NA	606	6	NA	63
River Cess	2019	79	X	X	X	X
Sinoe	2018	NA	NA	6	NA	10
Sinoe	2019	35	X	X	X	X

Table 9. Available data in days sampled for each month 2018 and 2019

day	Jan 2019	Dec.2018
1	7	NA
2	40	NA
3	31	NA
3	31	NA
4	NA	NA
4	80	NA
5	NA	NA
5	80	NA
6	NA	NA
7	NA	NA
7	140	NA
8	NA	NA
8	112	NA
9	NA	NA
9	187	NA
10	NA	NA
10	99	NA
11	NA	NA
11	76	NA
12	NA	NA
12	67	NA
13	NA	22
14	NA	10
14	91	NA
15	NA	49
15	107	NA
16	NA	NA
16	152	NA
17	NA	135
17	85	NA
18	NA	54
19	NA	91
20	NA	81
21	NA	41
22	NA	33
23	NA	NA
24	NA	45
25	NA	NA
26	NA	13
27	NA	37
28	NA	55
29	NA	58
30	NA	NA
31	NA	57

From the latest data, it can be seen the Fanti canoes are still landing more fish than Kru canoes (Table 10).

Table 10. Number of samples and mean catch weight by canoe type for part of year 2018 and 2019 from the Open Artfish programme.

Canoe Type	Year 2018	Year 2019
Fanti	242 (129.71)	215 (172.53)
Kru	16 (144.38)	33 (186)

6 DISCUSSION

6.1 Patterns in landed catch data

This study sought to explore the available data in 2013, 2014, 2016 and 2018 where visual, descriptive, and statistic illustrations are used to study differences in landed catch weights between years, fishing regions, canoes types and gear types, but it should be noted that the data are incomplete for 2016 because they were not entered into the database and sampling coverage for 2013 was smaller than other years. The data were used more to develop and practice analysis techniques that can be applied to a complete dataset once that becomes available.

Some general patterns could be identified in the fishery. The coastal area is broadly classified into western, southern eastern, and west eastern regions. Herring is landed more in the Western Region (Grand Capemount, and Montserrado counties) and the West Eastern Region (Margibi county). The Atlantic flying fish is a seasonal species and mostly caught from March – September. The landed weight was high in Grand Kru at Garraway landing site in the South Eastern Region and are also present in considerable amounts in Marshall Fanti Landing site in Margibi located in the West Eastern Region. It is also recorded in Montserrado with a high variability. Atlantic Flying fish were not seen in River Cess, Sinoe and Grand Bassa counties.

Atlantic Bumper is landed mainly in Montserrado and Grand Capemount counties at Point Four Landing site in the Western Region and Grand Bassa at Korkorwein Landing site in the West

Eastern Region. It is a seasonal species, and this can be seen in the data where they are observed more during the rainy season (March – September) than the dry season.

The Fanti canoes which are much larger with greater horsepower, and more crew, catch more fish than Kru canoes. Fanti canoes use ring nets and large gillnets and fish in the offshore waters. Even though the Kru canoes are more in numbers and mainly fish in the inshore waters, the Fanti canoes land more catch overall (Table 4). This study estimated the total catch for herring at 3068.95 tons in 2014. FAO reported the global catch production for herring in 2014 was 177, 329 tons (FishStat, FAO, 2014) .

A high catch estimate for herring was obtained for Kru canoes in 2014 in comparison with Fanti canoes (Table 6). This could be an effect of a sampling bias. For example, in River Cess, only three samples represent the catch of Herring in April, and these samples show high landed catch weight (Table 12, in Appendix 1a). These samples might be not representative of true landings and increase the estimate when a raising factor is applied. The high catch estimates in turn cause the CPUE estimates to increase also. It is emphasised, that these estimates are not reliable because of sparse data and need to be revised once more data are available. Also, the Kru canoes tend to land samples which are highly variable in catch, therefore more samples are needed to capture this variability in the system and get a better representation. It is also acknowledged that with very few samples in some groups (e.g. in some months and counties), the normal distribution assumption of the data is sometimes not met for analysis of variance tests. A closer look can be taken at the outlying measurements to check the integrity of the data (Figure 9). In the future, with increased sampling frequency and a more complete dataset, this can be taken into account.

The small-scale fishery is changing greatly. In the past the Kru canoes fished mostly demersal species using longline and hook and line and Fanti canoes were the ones fishing small pelagic. The ring nets are mostly used by the Fanti canoes using 40 horsepower engine (hp) NaFAA (2018), targeting mostly herring and Atlantic bumper. This gear which composed most of the landed catch for herring and Atlantic bumper are used seasonally by these canoes but use gillnets and set gillnets fishing in the rest of the season. The Kru canoes use the same gear throughout the year accept for those few Kru canoes that are using ring nets and do likewise by changing their ring nets during fishing season.

6.2 Reviewing of the former sampling programme

The data collection system which ran from 2013, 2014 and 2016 has almost all the required fields to analyse catch per unit effort (CPUE) and the data were collected within the nine coastal counties. A database was developed in Microsoft Access to store all catch and effort data and data collectors were willing to carry on their duties in collecting the data despite the delinquency in their allowances. The data can be imported in R statistical software for further analysis. Despite the training held for data collectors, the following errors and inconsistencies were identified during the process of extracting, transforming and analysing the data.

- Sardinella species were misreported due to limited knowledge of species identification by data collectors. Two different species of *Sardinella* are usually observed, herring *(Sardinella aurita)* and herring *(Sardinella mederensis)*. This study considers all species as one group because they are commonly misclassified.
- The weight of species was noted in various volumetric units described as catch units, which caused inconsistency in data reporting. Average weight per catch unit descriptions were not standardised.
- Data collectors miscalculated the actual time fishermen spent at sea which made it difficult to calculate CPUE using the time field in the database rather, the duration of fishing day is considered for the CPUE calculation.
- Inadequacy in manpower has long delayed the data entry process.
- Inconsistencies were noted in the frame survey data where three landing sites were miscoded causing a misreporting in total number of landing sites to 114 instead of 111 in year 2016. Misreported sites include Kpanbee (709) coded incorrectly as 710, Chapia (712) coded incorrectly as 713, and Banan (715) coded incorrectly as 716. Ad hoc manner of data collection and storage could have resulted in discrepancies in in raw data over the years, which can cause unreliable results in catch estimates.

6.3 Implementation of Open Artfish data collection and storage system

The Open Artfish sampling programme has been designed to speed up the data reporting system and reduce inaccuracies by using standard data collection forms pre-loaded on hand-held devices. It is clear the new data collection system is still in its infancy and being slowly

implemented. Some data collectors still lack tablets and use the old method to take measurements and use the App in the office at a later time for electronic storage of data thus, causing a delay in reporting. Hence, the data that were shared to be used in this study still show missing entries. Data are still incomplete therefore the benefits of the new sampling programme are not reflected in this analysis. It is a new platform for Liberian fisheries therefore, the access to the data are restricted to the data administrator, and the data are not yet open access. Further, it is unclear whether all the data collectors are diligent in uploading their data onto the server daily and whether the data are being downloaded on a timely basis to be stored in the database. The benefits of the new data collection system are fully acknowledged though:

- Manual data collection and entry will not be a feature in the future which will reduce human generated error.
- The catch is now weighed at the landing site and noted in standard units.
- The values of the landed catch are also estimated.
- Access to data will much faster in the future when the programme has been fully implemented.

7 RECOMMENDATIONS

1. There should be a quality check on all data before and after going into the database.
2. All raw data from 2016, 2017 and 2018 should be imported in the database.
3. More training for data collectors is recommended for species identification and for adhering to certain data collection protocols.
4. Training for database entry staff is recommended.
5. Customisation and adaptation of the Open Artfish data collection programme should be closely followed to ensure consistency and effectiveness and to minimise human error.
6. The new database should keep all fields separate for easier analysis of data. Currently, the gear and canoe fields are merged into one.
7. Names and spellings should be kept consistent among platforms.
8. Sampling design should be closely followed, and the sampling frequency should be maintained for reliable measurements of sample-based catch estimates, which is a common practise in small-scale artisanal fisheries with multi-species utilising multi-gears.

9. Once the raw data are available for the past years, the sample-based catch estimation technique should be applied to all species to get an estimate of total catch.
10. Repeat analysis for the complete dataset to look at patterns in the fishery.
11. The sampling programme should focus more on the biological aspects of the species (the current data collection focuses on catch and effort data). For instance, more effort needs to be expanded into collecting good data for length-frequency analysis. The current length measurements are not recorded with acceptable accuracy.
12. The fisheries management should continue to fully support the small-scale data collection programme for good management of the fisheries.

8 CONCLUSION

From the available dataset for the artisanal fisheries in Liberia, some exploratory and statistical data analysis techniques were used to study the patterns in the landed catch. Artisanal fisheries in Liberia catches close to 70 different types of fish, however the three main species that comprise most of the catch were studied. Herring (*Sardinella spp*.) is the most commonly caught species and they are mainly found in the Western Region of the coastal area. Atlantic bumper is landed mostly in the Western and Western Eastern Regions, and Atlantic flying fish is the least caught species among the three and mainly found in the South Eastern Region and in the West Eastern Region but were absent in Grand Bassa and River Cess in the West Eastern Region and Sinoe in the South Eastern Region. The fisheries are changing with more canoes and gill nets being deployed in the fisheries. The Fanti canoes are less in number, but fish more frequently use larger gears (ring nets) landing more catch. The Kru canoes operate in higher numbers but landed catch in smaller amounts. The study attempted to streamline the data extraction and analysis routine. Various inconsistencies were also observed in the stored data and recommendations are provided to rectify these. The total catch estimates need revision once more data are available. A closer look at the Open Artfish data collection and storage shows that some inconsistencies need to be addressed and it is recommended that the adaptation and customisation of this data collection programme should be followed carefully.

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APPENDICES

10 APPENDIX 1A

Catch in Kg showing the catch by Fanti and Kru canoes separated by year (Marine Resource Assessments Group (MRAG Ltd), 2014).

Table 11. Total catch estimates by canoes type for all species in kg

Year	Canoe Type	Catch (kg)	%
2013	Fanti	271,554.8	**79%**
2013	Kru	70,275.6	**21%**
	Total	341,830.4	
2014	Fanti	1,457,722.4	**89%**
2014	Kru	181,197.9	**11%**
	Total	1,638,920.3	

Table 12. A mean catch by year, month, county, canoe type, day sampled, number of boats, Total fishing days and raised catch.

Month	Year	County Description	Canoe type	Mean Catch	Days Sampled	Boats	Total fishing days	Raised Catch
1	2014	Grand Capemount	Fanti	280	3	39	466.44	43534.4
1	2014	Maryland	Fanti	17	3	21	251.16	1423.24
2	2014	Sinoe	Fanti	22.67	9	16	191.36	481.94
3	2014	Grand Bassa	Fanti	311	225	70	837.2	1157.20
3	2014	Grand Capemount	Fanti	242.72	762	39	466.44	148.58
3	2014	Grand Kru	Fanti	94.97	87	7	83.72	91.39
3	2014	Maryland	Kru	14	9	172	2057.12	3199.96
3	2014	Maryland	Fanti	40.30	42	21	251.16	240.99
3	2014	Montserrado	Kru	129.77	9	254	3037.84	43801.15
3	2014	Montserrado	Fanti	840.44	333	127	1518.92	3833.49
3	2014	River Cess	Fanti	150.23	141	9	107.64	114.69
3	2014	Sinoe	Kru	20.00	15	246	2942.16	3922.88
3	2014	Sinoe	Fanti	49.25	24	16	191.36	392.69
3	2016	Montserrado	Fanti	80.00	3	249	2978.04	79414.40
4	2013	Grand Bassa	Fanti	55.21	114	70	837.2	405.44
4	2013	Grand Capemount	Kru	50.78	15	127	1518.92	5142.05
4	2013	Grand Capemount	Fanti	578.41	345	39	466.44	782.01
4	2013	Margibi	Fanti	2801.44	15	11	131.56	24570.50
4	2013	Montserrado	Kru	20.31	48	254	3037.84	1285.54
4	2013	Montserrado	Fanti	47.15	39	127	1518.92	1836.49
4	2014	Grand Bassa	Kru	0.1	3	367	4389.32	146.31
4	2014	Grand Bassa	Fanti	168.92	183	70	837.2	772.78
4	2014	Grand Capemount	Kru	0.1	3	127	1518.92	50.63
4	2014	Grand Capemount	Fanti	241.48	366	39	466.44	307.74
4	2014	Grand Kru	Kru	30.09	42	246	2942.16	2107.55
4	2014	Grand Kru	Fanti	138.59	177	7	83.72	65.55
4	2014	Margibi	Fanti	25.79	72	11	131.56	47.13

4	2014	Maryland	Fanti	22.125	12	21	251.16	463.08
4	2014	Montserrado	Fanti	520.18	504	127	1518.92	1567.69
4	2014	River Cess	Kru	220	3	138	1650.48	121035.20
4	2014	River Cess	Fanti	219.09	366	9	107.64	64.433
4	2014	Sinoe	Fanti	182.91	162	16	191.36	216.06
4	2016	Grand Capemount	Fanti	200.30	198	47	562.12	568.66
4	2016	Grand Kru	Fanti	194.56	27	13	155.48	1120.35
4	2016	Maryland	Kru	105.4	15	210	2511.60	17648.18
4	2016	Maryland	Fanti	69.23	66	57	681.72	715.05
4	2016	Montserrado	Fanti	37.69	78	249	2978.04	1439.09
5	2013	Grand Bassa	Fanti	119.33	12	70	837.20	8324.91
5	2013	Grand Capemount	Kru	16.65	6	127	1518.92	4215.00
5	2013	Grand Capemount	Fanti	220	3	39	466.44	34205.60
5	2013	Margibi	Fanti	2769.33	225	11	131.56	1619.25997
5	2013	Montserrado	Kru	16.3	33	254	3037.84	1500.51
5	2014	Grand Bassa	Fanti	60.50	321	70	837.2	157.79
5	2014	Grand Capemount	Kru	0.1	48	127	1518.92	3.16
5	2014	Grand Capemount	Fanti	60	3	39	466.44	9328.80
5	2014	Margibi	Fanti	38	30	11	131.56	166.64
5	2014	Montserrado	Fanti	634.29	273	127	1518.92	3529.04
5	2014	Sinoe	Kru	35.69	105	246	2942.16	1000.17
5	2014	Sinoe	Fanti	35.12	456	16	191.36	14.74
5	2016	Grand Bassa	Fanti	99.95	213	120	1435.2	673.50
5	2016	Grand Kru	Fanti	73.67	27	13	155.48	424.21
5	2016	Maryland	Fanti	64	102	57	681.72	427.75
5	2016	Montserrado	Fanti	19.83	18	249	2978.04	3281.36
6	2013	Grand Bassa	Fanti	43.55	231	70	837.2	157.82
6	2013	Grand Capemount	Kru	20.35	18	127	1518.92	1717.22
6	2013	Grand Capemount	Fanti	109.03	93	39	466.44	546.85
6	2013	Montserrado	Kru	31.41	60	254	3037.84	1590.31
6	2013	Montserrado	Fanti	33.53	21	127	1518.92	2425.11

6	2014	Grand Bassa	Fanti	43.58	153	70	837.2	238.48
6	2014	Grand Capemount	Kru	0.1	48	127	1518.92	3.16
6	2014	Grand Capemount	Fanti	55	180	39	466.44	142.52
6	2014	Maryland	Kru	11.1	6	172	2057.12	3805.67
6	2014	Maryland	Fanti	51.54	54	21	251.16	239.74
6	2014	Montserrado	Kru	78.85	6	254	3037.84	39922.28
6	2014	Montserrado	Fanti	341.13	222	127	1518.92	2333.99
6	2014	River Cess	Fanti	24.51	279	9	107.64	9.45516
6	2014	Sinoe	Kru	17	3	246	2942.16	16672.24
6	2014	Sinoe	Fanti	26.32	162	16	191.36	31.09
6	2016	Grand Bassa	Kru	91.43	21	453	5417.88	23588.05
6	2016	Grand Bassa	Fanti	87.33	186	120	1435.20	673.84
6	2016	Maryland	Kru	31.05	6	210	2511.60	12997.53
6	2016	Maryland	Fanti	60.88	114	57	681.72	364.04
7	2013	Grand Bassa	Kru	33.3	3	367	4389.32	48721.45
7	2013	Grand Bassa	Fanti	39.90	207	70	837.20	161.36
7	2013	Grand Capemount	Fanti	79.05	63	39	466.44	585.25
7	2013	Montserrado	Kru	17.69	123	254	3037.84	436.97
7	2013	Montserrado	Fanti	39.1075	120	127	1518.92	495.01
7	2014	Grand Bassa	Fanti	41.16	207	70	837.20	166.46
7	2014	Grand Capemount	Kru	0.11	93	127	1518.92	1.79
7	2014	Grand Capemount	Fanti	65.3125	192	39	466.44	158.67
7	2014	Margibi	Fanti	49.35	321	11	131.56	20.22
7	2014	Maryland	Kru	18.99	69	172	2057.12	566.19
7	2014	Maryland	Fanti	50.77	219	21	251.16	58.23
7	2014	Montserrado	Kru	42	30	254	3037.84	4252.98
7	2014	Montserrado	Fanti	598.27	681	127	1518.92	1334.39
7	2014	River Cess	Kru	30.07	9	138	1650.48	5513.83
7	2014	River Cess	Fanti	41.42	171	9	107.64	26.07
7	2014	Sinoe	Fanti	56.38	180	16	191.36	59.94

8	2013	Grand Bassa	Fanti	47.45	153	70	837.2	259.63
8	2013	Grand Capemount	Kru	18.6	69	127	1518.92	409.45
8	2013	Grand Capemount	Fanti	77	9	39	466.44	3990.65
8	2013	Margibi	Fanti	2681.36	177	11	131.56	1992.99
8	2013	Montserrado	Kru	15.57	78	254	3037.84	606.37
8	2013	Montserrado	Fanti	162.62	171	127	1518.92	1444.45
8	2014	Grand Bassa	Fanti	35.92	147	70	837.20	204.55
8	2014	Grand Capemount	Kru	0.125	24	127	1518.92	7.91
8	2014	Grand Capemount	Fanti	74	210	39	466.44	164.36
8	2014	Margibi	Fanti	42.26	159	11	131.56	34.97
8	2014	Maryland	Kru	32.4	54	172	2057.12	1234.27
8	2014	Maryland	Fanti	47.62	123	21	251.16	97.24
8	2014	Montserrado	Kru	77.94	39	254	3037.84	6070.89
8	2014	Montserrado	Fanti	315.73	474	127	1518.92	1011.76
8	2014	River Cess	Kru	27.87	9	138	1650.48	5110.38
8	2014	River Cess	Fanti	68.66	198	9	107.64	37.33
8	2014	Sinoe	Fanti	35.86	234	16	191.36	29.32
9	2013	Grand Bassa	Fanti	70.23	258	70	837.2	227.90
9	2013	Grand Capemount	Kru	15.425	12	127	1518.92	1952.45
9	2013	Grand Capemount	Fanti	36.65	12	39	466.44	1424.59
9	2013	Montserrado	Kru	232.03	30	254	3037.84	23495.67
9	2013	Montserrado	Fanti	376.03	126	127	1518.92	4532.97
9	2014	Grand Capemount	Kru	0.1	9	127	1518.92	16.88
9	2014	Maryland	Fanti	122.4	15	21	251.16	2049.47
11	2014	Maryland	Fanti	93.5	6	21	251.16	3913.91
12	2014	Grand Capemount	Kru	0.1	6	127	1518.92	25.32
12	2014	Maryland	Kru	11.1	3	172	2057.12	7611.34
3	2014	Grand Capemount	Kru	12.04	60	127	1518.92	304.77
3	2014	Grand Capemount	Fanti	1	6	39	466.44	77.74
3	2014	Grand Kru	Fanti	52	18	7	83.72	241.86

3	2014	Maryland	Kru	13.375	12	172	2057.12	2292.83
3	2014	Maryland	Fanti	23	24	21	251.16	240.70
3	2014	Montserrado	Fanti	36	3	127	1518.92	18227.04
4	2013	Grand Capemount	Kru	16.15	90	127	1518.92	272.62
4	2013	Grand Capemount	Fanti	16.74	33	39	466.44	236.57
4	2013	Margibi	Fanti	28	6	11	131.56	613.95
4	2013	Montserrado	Kru	16	3	254	3037.84	16201.81
4	2013	Montserrado	Fanti	86.46	39	127	1518.92	3367.39
4	2014	Grand Capemount	Kru	7.67	9	127	1518.92	1293.89
4	2014	Grand Capemount	Fanti	52	3	39	466.44	8084.96
4	2014	Margibi	Kru	35.42	108	21	251.16	82.36
4	2014	Margibi	Fanti	39	6	11	131.56	855.14
4	2014	Maryland	Kru	6.57	21	172	2057.12	643.72
4	2014	Maryland	Fanti	22.25	36	21	251.16	155.23
4	2014	Montserrado	Fanti	9.5	6	127	1518.92	2404.96
4	2016	Margibi	Kru	23.63	126	71	849.16	159.26
4	2016	Montserrado	Fanti	130	3	249	2978.04	129048.40
5	2014	Grand Capemount	Kru	10.83	36	127	1518.92	457.12
6	2013	Montserrado	Kru	0.07	3	254	3037.84	70.88
6	2014	Grand Capemount	Kru	11.5	9	127	1518.92	1940.84
6	2014	Montserrado	Fanti	1.49	21	127	1518.92	107.67
7	2013	Montserrado	Kru	10.7	9	254	3037.84	3611.65
7	2013	Montserrado	Fanti	12.65	42	127	1518.92	457.41
7	2014	Grand Capemount	Kru	23.5	12	127	1518.92	2974.55
7	2014	Montserrado	Fanti	0.06	9	127	1518.92	10.69
8	2013	Grand Capemount	Kru	0.02	21	127	1518.92	1.34
8	2013	Margibi	Fanti	15.89	27	11	131.56	77.42
8	2013	Montserrado	Kru	0.135	6	254	3037.84	68.35
8	2013	Montserrado	Fanti	7.75	33	127	1518.92	356.63
8	2014	Grand Capemount	Kru	21	15	127	1518.92	2126.49

8	2014	Margibi	Fanti	8.02	9	11	131.56	117.19
8	2014	Montserrado	Fanti	0.06	9	127	1518.92	9.56
9	2013	Grand Capemount	Kru	1.33	15	127	1518.92	134.68
9	2013	Grand Capemount	Fanti	0.14	12	39	466.44	5.44
9	2013	Montserrado	Fanti	8.05	12	127	1518.92	1018.94
9	2014	Grand Capemount	Kru	5.5	3	127	1518.92	2784.69
1	2014	Grand Capemount	Fanti	419.2	3	39	466.44	65177.22
3	2014	Grand Bassa	Kru	6	3	367	4389.32	8778.64
3	2014	Grand Bassa	Fanti	778.48	60	70	837.2	10862.39
3	2014	Grand Capemount	Fanti	357.6722581	465	39	466.44	358.78
3	2014	Grand Kru	Fanti	26	3	7	83.72	725.57
3	2014	Montserrado	Kru	22	6	254	3037.84	11138.75
3	2014	Montserrado	Fanti	1111.79	69	127	1518.92	24474.23
4	2013	Grand Capemount	Kru	0.14	33	127	1518.92	6.28
4	2013	Grand Capemount	Fanti	0.165	12	39	466.44	6.41
4	2013	Margibi	Fanti	10.1	3	11	131.56	442.92
4	2013	Montserrado	Kru	10.1	6	254	3037.84	5113.70
4	2013	Montserrado	Fanti	20.2	3	127	1518.92	10227.39
4	2014	Grand Bassa	Fanti	261.67	18	70	837.2	12170.41
4	2014	Grand Capemount	Fanti	414.76	177	39	466.44	1093.00
4	2014	Grand Kru	Fanti	43.33	27	7	83.72	134.37
4	2014	Maryland	Fanti	147.33	9	21	251.16	4111.58
4	2014	Montserrado	Fanti	551.84	48	127	1518.92	17462.44
4	2014	Sinoe	Fanti	130	3	16	191.36	8292.27
4	2016	Grand Kru	Fanti	182	6	13	155.48	4716.23
4	2016	Montserrado	Fanti	26.2	3	249	2978.04	26008.22
5	2013	Grand Capemount	Kru	20.2	3	127	1518.92	10227.39
5	2013	Margibi	Fanti	18	3	11	131.56	789.36
5	2014	Grand Capemount	Kru	0.02	18	127	1518.92	1.69
5	2014	Montserrado	Fanti	78.62	6	127	1518.92	19902.92

5	2014	Sinoe	Kru	25.39	57	246	2942.16	1310.52
5	2014	Sinoe	Fanti	64.03	18	16	191.36	680.75
5	2016	Grand Kru	Fanti	143	6	13	155.48	3705.61
5	2016	Montserrado	Kru	26	6	372	4449.12	19279.52
5	2016	Montserrado	Fanti	39	12	249	2978.04	9678.63
6	2013	Grand Bassa	Kru	0.04	3	367	4389.32	58.52
6	2014	Grand Capemount	Kru	0.02	9	127	1518.92	3.38
6	2014	Grand Capemount	Fanti	76.91	93	39	466.44	385.74
6	2014	Montserrado	Fanti	117.9	6	127	1518.92	29846.78
7	2014	Grand Capemount	Fanti	105.41	129	39	466.44	381.14
7	2014	Montserrado	Fanti	314.4	18	127	1518.92	26530.47
7	2014	Sinoe	Fanti	36.16	54	16	191.36	128.15
8	2013	Grand Capemount	Kru	0.22	27	127	1518.92	12.50
8	2014	Grand Capemount	Kru	0.02	3	127	1518.92	10.13
8	2014	Grand Capemount	Fanti	102.62	108	39	466.44	443.19
8	2014	Montserrado	Kru	0.02	3	254	3037.84	20.25
8	2014	Montserrado	Fanti	509.03	21	127	1518.92	36817.79
8	2014	Sinoe	Fanti	41.47	42	16	191.36	188.95
9	2013	Grand Capemount	Kru	0.116	15	127	1518.92	11.75
9	2013	Montserrado	Kru	0.04	3	254	3037.84	40.50
9	2013	Montserrado	Fanti	141.69	21	127	1518.92	10248.27

11 APPENDIX 1B

R package and Script for extracting data from Access database

```
#install.packages("RODBC")
#install.packages('dbplyr')
#install.packages('odbc')
#install.packages("tidyverse")
library(tidyverse)
library(dbplyr)
library(dplyr)
library(RODBC)
library(odbc)
getwd()
connect_to_access_dbi <- function(db_file_path)
  {
  require(DBI)
  # make sure that the file exists before attempting to connect
  if (!file.exists(db_file_path)) {
    stop("DB file does not exist at ", db_file_path)
  }
  # Assemble connection strings
  dbq_string <- paste0("DBQ=", db_file_path)
  driver_string <- "Driver={Microsoft Access Driver (*.mdb, *.accdb)};"
  db_connect_string <- paste0(driver_string, dbq_string)

  myconn <- dbConnect (odbc::odbc(),
                       . connection_string = db_connect_string)
  return(myconn)
}

conn <- connect_to access dbi("C:/Users/UNUFTP/Desktop/Testing2.accdb")

##Extracting data into a dataframe (table)
landingsdat2<-
  tbl(conn, 'Catch_Detail') %>%
  inner_join(tbl(conn, 'CE_Header')) %>%
  inner_join(tbl(conn, 'Effort_Detail') %>% rename(GearID=GearTypeID)) %>%
  inner_join(tbl(conn, 'LK_GearType')) %>%
  inner_join(tbl(conn, 'LK_County')) %>%
  inner_join(tbl(conn, 'LK_CatchUnit')) %>%
  inner_join(tbl(conn, 'LK_LandingSite')) %>%
  select(Date_CE, CountyID, CountyDescription, LandingSiteID, LandingSiteDescription,
SpeciesID, CatchUnitDescription, NumberUnits, PiecesPerUnit,
         AvergedWeight, TripDurationDays, TimeLeft, CrewNumber, CanoeID, CanoeTypeID,
TimeReturned,
         GearID) %>%

  collect(n=Inf)
```

Bureau of National Fisheries Artisanal Catch and Effort Data Form

Enumerator Name

Date

Counties	Town/ Area	Landing site

Canoe Details

Number of Crew

Canoe Registration

Motorized Yes/ No ——— hp

Canoe's Length ———

Fisher Association ☐ Fanti ☐ Kru ☐ Other (Specify in problem box)

Fishing location

Target Species

Date &Time left	Hour fished	Date & Time
_____/____/___ ___ ___AM/PM		___/___/__ ___ ___ __ AM/PM

Water depth at fishing location(fathoms):

Gear type	Gear Size (hooks/heads/length and depth)	Number of times used

Catch unit	Pieces per unit	Number of units	Length (cm)

Problem encountered whilst fishing

Figure 12. Artisanal Data Form Used in 2013, 2014 and 2016