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SAMPLING STRATEGY AND MANAGEMENT RECOMMENDATIONS FOR SPANISH MACKEREL AND OTHER IMPORTANT FISH STOCKS IN DJIBOUTI

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ABSTRACT

Insufficient information can lead fisheries managers to make decisions without solid support of data or completeness of scientific understanding. This project investigated current data from the fisheries in Djibouti. Data from the Marine Biology Laboratory were analysed. Using length data collected since 2014, distribution of the size frequency for Spanish mackerel and other important fish species in Djibouti was established. Due to insufficiency of data, an estimation of Von Bertalanffy growth parameters was not possible. The length-weight relationship indicated a nonconformity of results with theoretical values and results drawn from the literature. The analysis of data from the fisheries department showed a high increase of landings per unit effort during the summer in Djibouti (March to September). A significant number of outputs from the fishing boats were also observed over the same period. The analysis of data recorded since 2011 by the Marine Biology Laboratory indicated a correlation between the distribution of catch and the chlorophyll a concentration from the satellite observations in the exclusive economic zone of Djibouti. A high number of biases were observed in the data from fishery in Djibouti, indicating that the data collection system in Djibouti requires revision. A sampling strategy was developed to contribute to the improved data collection system already in effect.

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1 DJIBOUTI AND ITS FISHERIES

1.1 Geography and population

The Republic of Djibouti is in the Horn of Africa. It is bordered by Eritrea in the North, Ethiopia in the West, and Somalia in the South. The Djiboutian waters are located at the intersection of Gulf of Aden and the Red Sea. The coastline is about 372 km and the Exclusive Economic Zone (EEZ) is about 2,563 km². Djibouti is a multi-ethnic nation, the estimated population was about 900,000 in 2015 (World population review, 2015). Between the years 1997 and 2007, the annual growth rate of the Djiboutian population was estimated at 2.3% and was one of the highest in the world (OMS, 2009). Continued population growth is accompanied by an increased need for food, especially animal protein.

1.2 Fisheries in Djibouti

The fisheries sector is underdeveloped in Djibouti. A fishery resource assessment conducted in 1996 through a collaboration of the Djiboutian and German governments indicated that the total exploitable potential of Djibouti's fishery resources are approximately 47,000 tonnes per year (Künzel *et al.*, 1996). At the present Djibouti is far from realizing this potential.

Artisanal fishing is the mainstay of the fisheries sector. Currently the active fleet in Djibouti has about 200 artisanal boats. According to FAO (2010), over 95% of the active fleet are canoes under 9 meters long, equipped with outboard engine of 40hp. Djibouti's population, faced with the recent rise in meat prices due to drought, consume more and more fish as animal protein of substitution. Although exploitation of the resource has developed significantly in recent years due to a high demand for seafood, the average production is still very low and does not exceed 3,000 tons per year, according to the annual investigations from Fisheries Department. During the last 3 decades the total catch by year has increased from 500t to 3000t (Figure 1).

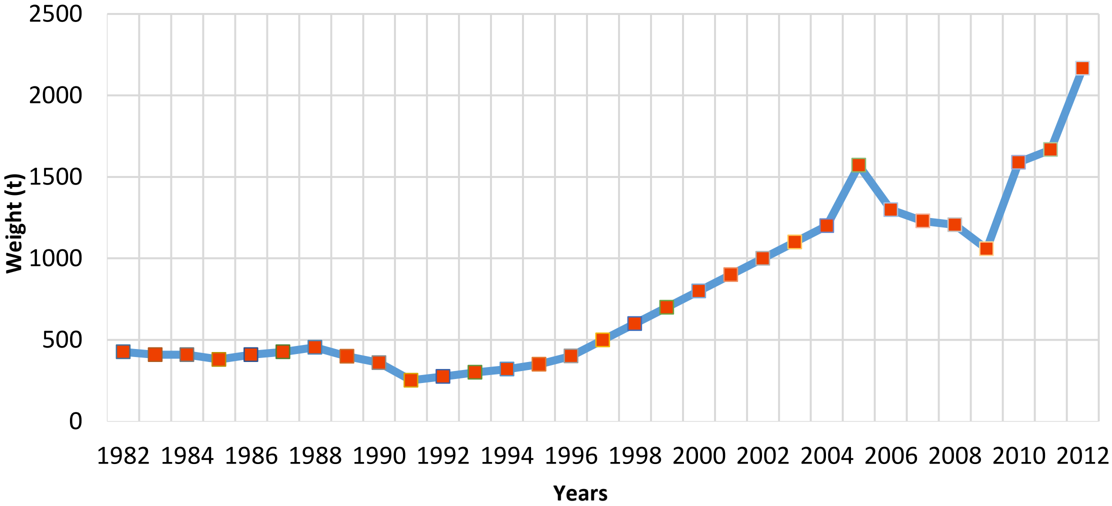

Figure 1: Total catch (tones) from 1982-2012 in Djibouti (FAO, FishStat)

Fisheries does not play an important role in consumption of animal products in Djibouti, where annual fish consumption is about 2 kg per year. The population is nomadic and uses livestock as a main source of protein. Currently fisheries contribution to GDP is negligible at less than 1%.

According to statistical surveys conducted by the Directorate of Fisheries, demersal fish represents 55% of the resource and 45% are pelagic. Among the most commonly fished and economically important species we find Spanish mackerel (*Scomberomorus commerson*) highly prized by local people, trevally (*Caranx sexfasciatus),* Mahi Mahi (*Coryphaena hippurus*) and great barracuda (*Sphyraena barracuda*). These are shown in Figure 2.

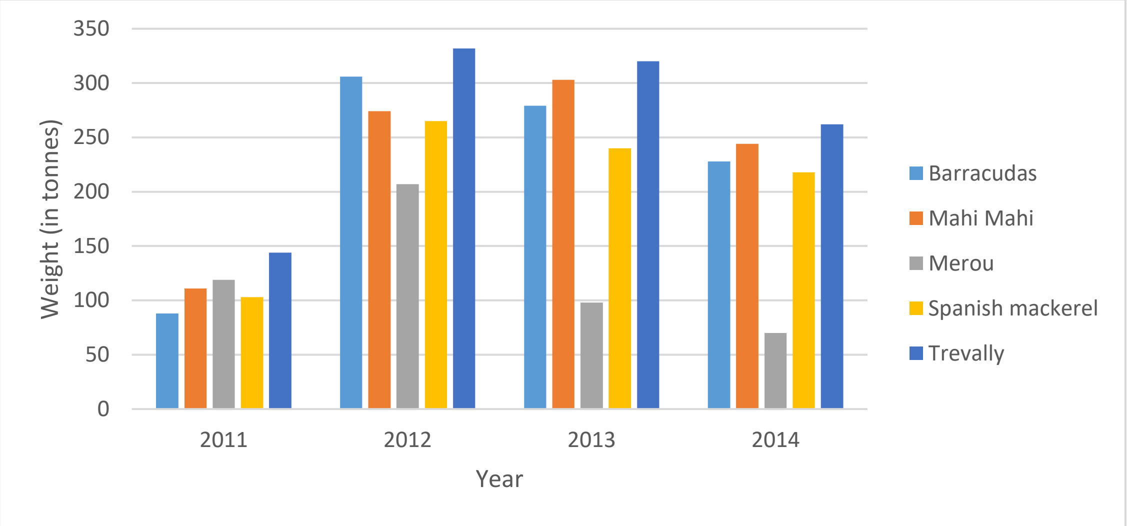

Figure 2: Catch of most important fish species in Djibouti 2011-2014 (Centre of Study and Research of Djibouti-data).

While the local population prefers livestock, Djiboutians do eat and enjoy the Spanish mackerel. This species is also recognised by the fisherman all over the world for its culinary qualities, good nutritional value and easy storage (Donati, 2005). In Djibouti, Spanish mackerel represents 16% of fish caught. Over the area of the Red Sea, Spanish mackerel is the most caught fish species, making up 8.5% of landed catch in the Red Sea (Shotton, 2005). In the Indian Ocean, Spanish mackerel displays signs of overexploitation (Anon, 2014). Economically this species has a high commercial value especially to the artisanal sector and needs to be monitored for proper management purposes. There is no recent information available on its distribution, abundance and the state of this resource in Djibouti, but the fish is highly migratory and overexploitation sign observed in neighbouring waters is a concern.

The management of the fisheries is done by various ministries. The roles and functions of each ministry is described in Figure 3.

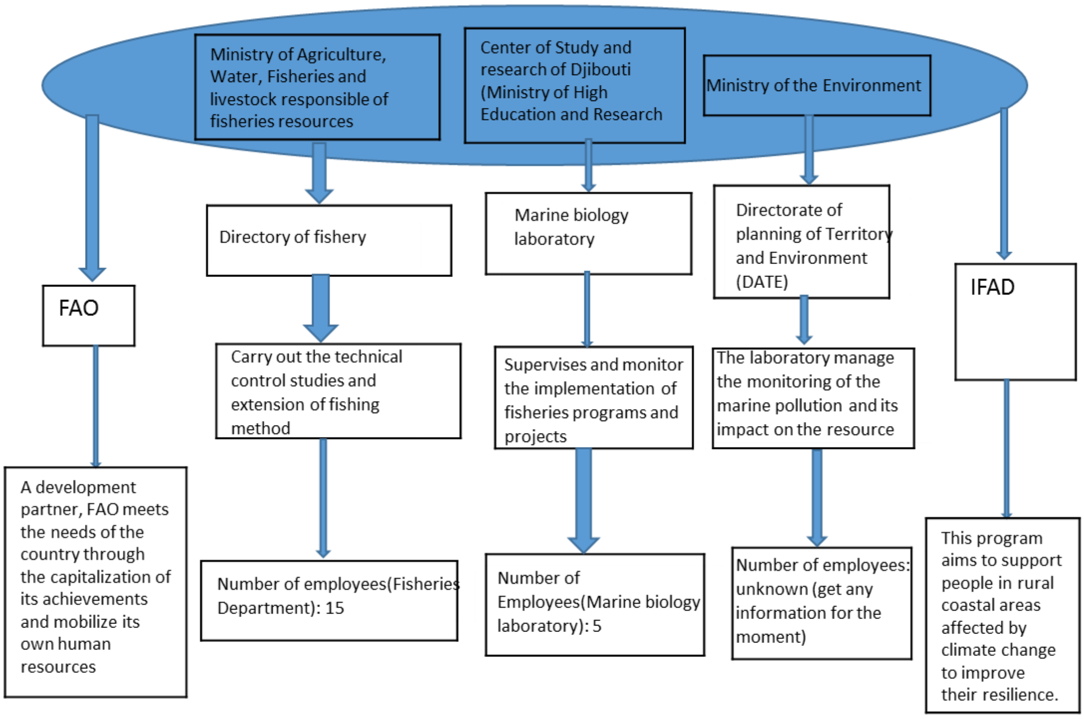

Figure 3: The central management of fisheries in and the roles of ministries in Djibouti

1.3 Red Sea ecosystem

The Red Sea (Figure 4) is an extension of the Indian Ocean, located between Africa and Asia. Entrance to the sea in the south is through the Gulf of Aden and the narrow Bab el Mandeb. According to FAO (2010) the Red Sea has an enclosed nature that creates unique fisheries situations and extensive demersal resources are primarily found on the wider continental shelves in this sea.

Figure 4: Map of the Red Sea and Gulf of Aden area

According to the regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA) the area of the Red Sea is considered rich in biodiversity with the presence of coral reefs and an important biomass of seagrass (PERSGA, 2002).
Species endemism in the Red Sea is extremely high. For example, approximately 6.3% of the coral species are endemic to the Red Sea (Gerges, 2002). Despite its richness characterized by a number of unique marine habitats, including seagrass beds, saltpans, mangroves, coral reefs and saltmarshes, few stock assessments of the state of fisheries resources in this area have been made (Shotton, 2005).

The coastal and marine environments and resources of the Red Sea and Gulf of Aden are globally significant and were in a generally healthy state (Gladstone, 1999), but over the last ten years localized destruction of coral reefs, seagrass and mangroves and declines in some fisheries have been observed (Gladstone, 2003). The main causes of these issues are the natural vulnerability of the Red Sea due to its semi-enclosed nature and pollution from the development and transport of petroleum. Around 60% of the world's oil is transported through the Arabian Sea and Gulf of Aden (Red Sea) (Gerges, 2002).

1.4 Development of fisheries in Djibouti

Djibouti is subjected to environmental conditions such as arid climate, low rainfall, high erosion, high temperature, and a drought accentuated by the effects of climate change. This has led in the degradation of thin vegetation cover and negative impacts on the living conditions of the rural population. Draught in the country has lead people to abandon traditional livestock farming. Recently, these has been an influx of people from rural areas to more urban centres, particularly along the coastal areas. With a view to end the fight against hunger, exploitation of fisheries resources, an effort long neglected, has become a necessity in Djibouti (CRB, 2011).

Currently, the fisheries sector in Djibouti is underdeveloped, but significant possibilities to increase and develop the fisheries sector were observed and some indicators such as the number of vessels and gear and the size of caught fish, point in that direction (ACPFISHII, 2013). However, lack of recent information on marine resources and the levels of exploitation remain the major obstacle for the development of the fisheries sector. Indeed, in the absence of this information the development of an appropriate management strategy to determine the volume and direction of investment is not plausible. The national priorities are to get information on the species available, their distributions, seasonal variations and their yields. The aim is to obtain more accurate assessments of the size of the stocks, it is also a necessity for the further needed development of the fishery. The objective is to ensure optimal resource exploitation and sustainability through the establishment of a system to ensure the monitoring and evaluation of exploited stocks. This will be accomplished mainly through the development of a protocol of research for stock assessment.

2 SCOPE OF THE STUDY

The overall objectives for this study were to:

- Analyse the data available for the Spanish mackerel and other important fish stocks in Djibouti
- Analyse spatial distribution of catches in Djibouti during 2011 – 2015
- Create a sampling plan for the fishery of Spanish mackerel and other important species

3 LITERATURE REVIEW

3.1 Spanish mackerel in the world

The Spanish mackerel (Figure 5**),** is distributed in the waters of the Indo Pacific from the Red Sea and South Africa to Southeast Asia, North to China and Japan and South to Australia (Figure 6). They are also fund in the eastern Mediterranean Sea. Within this geographical distribution, Spanish mackerel can be found from the edge of the continental shelf to shallow coastal waters. Adults are associated with coral reefs, rocky shoals and current lines on outer reef areas and offshore (Collette, 1983). This fish is most frequently caught in areas less than 100 meters deep.

Figure 5: The Spanish mackerel (*Scomberomorus commerson*)

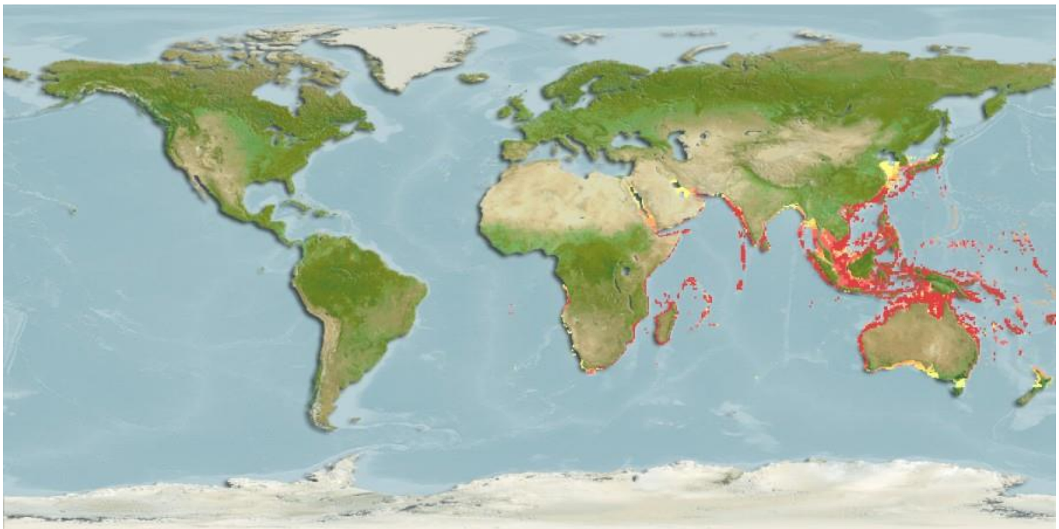

Figure 6: Distribution of Spanish mackerel in the world (Fishbase).

Spanish mackerel is a large, highly migratory fish and fast pelagic predator (Aspinall, 1996). The growth parameter estimates of *S. commerson* from the northern Indian Ocean are shown in Table 1.

Table 1: Growth parameters for *Scomberomorus commerson* from the Indian Ocean (Pillai, 1994).

Study area	Linf	K
Djibouti	135.7	0.21
Oman	200	0.27
Kenya	240	0.02

In Iran, the coefficient of allometry estimates for the length weight relationship for this species is close to 3 for males and females and is indicating isometric growth. The mean length at first maturity for females was 83.6 cm (Kaymaram *et al*. 2010).

Spawning is seasonal, but it is protracted in the warmer waters of the tropics, in general, spawning times for Spanish mackerel tend to be associated with higher water temperatures that promote optimal food availability for the rapid growth and development of the larvae (Donati, 2005). That agrees with the conclusion of Indian Ocean Tuna Commission who found that the spawning has been observed in east African waters, with peaks during late spring to summer (April-July) and autumn (September-November) coinciding with the two seasonal monsoons which generate high abundances of plankton and small pelagic fish. Spawning in the southern Arabian Gulf occurs in the spring and summer months between April and August (Anon, 2014). In Djibouti the fishing season is between April and September (Bouhlel, 1986).

3.1.1 Stock assessment on the Spanish mackerel

The information available on the fishery and biology of the Spanish mackerel are limited (Begg, 2006). The maximum sustainable yield of the entire Indian Ocean is estimated at 137,000 tons (Anon, 2014). The Indian Ocean Tuna commission indicates that the stock has been exploited at a rate close to 80% of its maximum sustainable yield in recent years and is close to fully exploited. Gulf of Oman Sea countries indicate that localised depletion may be occurring from an analysis done in 2013, and overfishing is occurring in this area, though the degree of connectivity with other stocks remains unknown. Considerable uncertainties remain about the structure of the stock for Spanish mackerel in the Indian Ocean. In the Indian Ocean according to the observation from the FAO a continued increase of annual caught of Spanish mackerel has been observed during the last decades and suggested an increase of fishing pressure on the entire Indian Ocean stocks (Anon, 2014).

In Djibouti a study on the stock assessment of the Spanish mackerel was carried out in 1984. The results indicated that the fishing effort on the targeted on Spanish mackerel in Djibouti had reached levels which may adversely affect the yield from the stock (Bouhlel, 1986). Currently there is no recent information on the state of the resources and their level of exploitation that would corroborate with this hypothesis. Some indicators as a low production about 3,000 tonnes by year, moderate fishing pressure (expressed in number of active vessels), the use of selective fishing gear (mostly lines and longlines) and fish catches of large sizes of target species, suggest these resources are not yet fully exploited and that there is a margin of potential development for the fishery (ACPFISHII, 2013).

However, there is a need to focus on research to improve the indicators, studying stock structure and explore the stock assessment approaches for data-poor fisheries in Djibouti.

3.2 Sampling strategy

3.2.1 An overview of sample strategy

The structure of data collection programmes differs between various fisheries. Within a country there is typically a mixture of different types of fisheries. These may include industrial, commercial on a small scale, artisanal, subsistence and recreational. The importance and properties of those activities can be quite different, and opportunities to provide data from each sector.

How different variables are collected must be adapted to the fishery structure (Danida, 1999). A sampling strategy will be more relevant than the sample population will be representative of the target population (Lasserd, 2004).

Sampling exists to pull information from a fraction of a large group or population in order to draw conclusions about the entire population. The object of sampling is to provide a sample to represent the population as closely as possible replicate the main features of the study population (Forest, 1999). It must lead to maximum precision with minimal effort and cost. (Lasserd, 2004). If the sample is not representative, it gives a biased value of the estimator. The first required information to establish a strategy for data collection are information regarding infrastructure and personnel:

- Existing ports and landing sites, their locations, their distribution and accessibility.
- The number of fishing units and information on their composition (fishing gear, number of fisherman, type of fishing boats) and their geographical distribution in relation to home ports and landing sites.
- Fishing activity and conditions of landing (seasonal, or daily).

4 MATERIAL AND METHODS

4.1 Data collection

The data used for the analysis, the exploitation, and for the realization of this project come from the Fisheries Department and the Marine Biology Laboratory under the Center of Study and Research of Djibouti.

The republic of Djibouti owns five ports of fish landing and the port of Djibouti in the capital is the main landing site. In 2011, 87% of the landings were made there. The sampling program in Djibouti covered mainly the artisanal fishing/landing. There are two trawlers in Djibouti, but they operate only in Somaliland waters. Trawling in Djiboutian waters is prohibited. The limited sampling that does occur does not cover these activities. Investigations are conducted daily, excluding Friday, by 3 or 4 investigators.

The information on the catch in Djibouti port is collected by the field agent then it is sent to the Centre of Study and Research of Djibouti and The Fisheries Department for records and future analysis.

Data from the Marine Biology Laboratory come from the collection which began in 2011. A daily sampling was conducted and focused on a set of 17 species. This sampling was conducted in various landing ports of Djibouti. This data is divided into two phases. The first phase was conducted between 2011 and 2013 and has measurements of 6,101 individuals.

During this period for each fish landing, the catch areas were recorded. Then the fish were separated into different species and for each individual fish their individual weights were measured and recorded. These data were then listed in a table showing the entry date (year, month, and day), the area, the name of the species and the weight in kilograms or grams. These data are not consistent and because the weight of fish was saved simultaneously in grams and kilograms and it is difficult to achieve accurate results.

The harvest of the second phase of the data was conducted between 2014 and 2015 and focused on a set of 1,272 individuals. During this time the sampling protocol remained the same but consistent weight in kilos for each species and their lengths (in cm). But here also, these data look suspicious (Results after analyses).

Data were collected by the Fisheries Department in 2015 and focused on a set of 11 fish species. The sampling protocol and the data collection is the same. The data were collected by field agents and then were registered on an Excel chart showing the date (years, month, and day), the port of landing, the type of boat, number of fishermen per boat, the fishing area, the name of the species, the price in kilos for each species and the total weight of each species landed. This investigation is supposed to be done daily to estimate:

- Daily production
- Daily production for the seven main species
- Catch by gear
- Monthly and annual production
- Total gains landed by species

Different denotations in the database have been used and combined to describe the type of vessel, landing ports and the method used in the fisheries. For landing ports we have:

- D: Landing port in Djibouti.
- O: Landing port in Obock.

Category of fishing Boats

- Category A: canoe with 3 persons maximum.
- Category B: canoe with 4 to 5 persons maximum.

The types of fishing techniques practiced by these boats.

- L: Angling
- F: Nets

The landings per unit effort (LPUE) were estimated based on daily landings as no information exist on the duration of the fishing trips. The effort is therefore only measure of sampling intensity. LPUE was analyzed and compared to different fishing tools and species.

4.2 Data Analysis

The statistics software R was used to analyse the data. Some analyses were also carried out using FiSAT II.

4.3 Length based Methods in fisheries.

The study of fish growth and the phenomena associated with it, such as maturation, migration, food availability is the backbone of fisheries biology (Pauly, 1985). The knowledge on the type of fish growth of a stock is essential for the estimation of stock status.

The growth of a fish stock is expressed by means of the von Bertalanffy growth equation, the simplest version is:

$$Lt = L\infty\ (1\text{-}e\text{-}K\ (t\text{-}t0))$$

Where L∞ is the mean length the fish would reach if they were to grow to a very old age and K is a growth coefficient. The t0 variable is the age the fish would have had length zero if it had always grown according to the equation (t0 is generally a negative value) and where Lt is the length at age t. The growth parameters can be estimated using three methods:

- Tagging: recapture data on, or direct observation of the growth of individual fish.
- Periodic markings: either annual or daily, on skeletal parts such as scales, otoliths, or other bones
- Size-frequency data: most commonly length-frequency data

It is generally less expensive and more convenient to analyse size frequency than studying skeletal parts and it requires less material investment which makes the method more appealing to a developing country with low capacity and resources. During the last few years concerning the methodologies appropriate to stock assessment in developing countries, FAO has advocated the use of length-based methodologies (Pauly & Morgan, 1987).

4.3.1 Length frequencies distribution.

Analysis of size frequencies of can enable better understanding of population dynamics (Graham, 2005).

Length frequency data have the advantage of being relatively cheap, straightforward, and quick to collect from landing sites and markets. Information on age structure of the population, growth rate, maximum size, the probability of capture relative to size of a fishing gear (e.g. gear selectivity), and natural mortality (e.g. predation) and fishing, can all be estimated from these data (Graham, 2005).

The distribution of size frequency was established for the most important fish species in Djibouti using R. The asymptotic length ($L\infty$) and growth coefficient (K) was estimated using FiSAT II. For each species the sizes frequency for each month has been used. The length frequencies were decomposed into normally distributed cohorts using Assess/Modal progression analysis according to Bhattacharya's method. The results (msd file) were used to connect the mean length of each cohort using Assess Modal progression analysis and linking of mean. An estimation of von Bertalanffy growth parameters was made through the analysis of growth increment data using the Gulland and Holt Plot routine in FiSAT.

Due to insufficient data for reliable growth parameters (Asymptomatic length and growth coefficient) found in the literature have been applied to all species.

Using asymptomatic lengths ($L\infty$) found in the literature, the size at first maturity for all species have been estimated through the application of the following empirical formula (Froese, 1999).

$$Log\ Lm = 0.8979 \times Log\ L\infty - 0.0782$$

For the grouper (*Epinephelus marginatus*) due to unavailable information in the literature on the asymptotic length ($L\infty$). The maximum size for this species found in the literature was used to estimate the asymptomatic length ($L\infty$) by applying the following formula (Froese, 1999).

$$Log\ L\infty = 0.044 + 0.9841 * Log\ (Lmax)$$

The length corresponding to optimum time (age group with maximum egg production) was estimated from the following empirical formula (Froese, 1999).

$$Log\ Lopt = 1.0421 * Log\ L\infty - 0.2742$$

4.4 Length weight relationship

Information on length-weight relationship is of great importance in studies of fisheries biology and on the evaluation of fish stocks. This relationship is relevant to the calculation of the average weight of fish at a certain length class which can be used to calculate growth (length and weight based). It can also describe morphological comparison between populations of the same species or between species living in similar or different conditions of food, density or climate (Benedicto, 1997).

Length weight relationship was estimated. The relation linking the length at weight is represented by the function:

$$WT = aLT^b$$

Where; WT: Total weight, LT: total length, a: constant and b: the coefficient of allometry

The value b is compared statistically to 3.

- If $b<3$ allometric with an unfavorable growth
- If $b=3$ isometric growth
- If $b>3$ allometric with a favorable growth

The results obtained were then compared to the results from other locations in the world, with preference given to those in similar regions.

4.5 Catch distribution

The distribution of catches in the exclusive economic zone of Djibouti waters for the last four years were represented on a map. The climatology observations of chlorophyll a concentrations during the period 2011-2014 were visualized.

The results of catch distribution were compared with the satellite observations of chlorophyll a concentration during similar period.

4.6 Sampling strategy

A sampling strategy was designed which considers socio-economic realities. The sampling plan was designed to allow acquisition of a representative sample of the target population.

Ideally, the type of information which should be collected to inform policy makers includes biological, economic, and socio-economic data. However, the present study is focused on developing a sampling strategy which collects reliable information relating to fishing and biology, including information on catches of fish and structure in size of the population. It is also important to determine methods to carry out collection with what means and what frequencies. The existing data sets and ongoing routing sampling were considered. A part of the existing data has been analyzed and was used in the formation of the new sampling strategy.

5 RESULTS

5.1 Length-frequency distributions

The data sampled by the Marine Biological Laboratory between 2014 and 2015 were used to establish a distribution of the size frequency for Spanish mackerel and other important fish species in Djibouti. The frequency of individual fish length is plotted, and distinct peaks were identified (Figure 7).

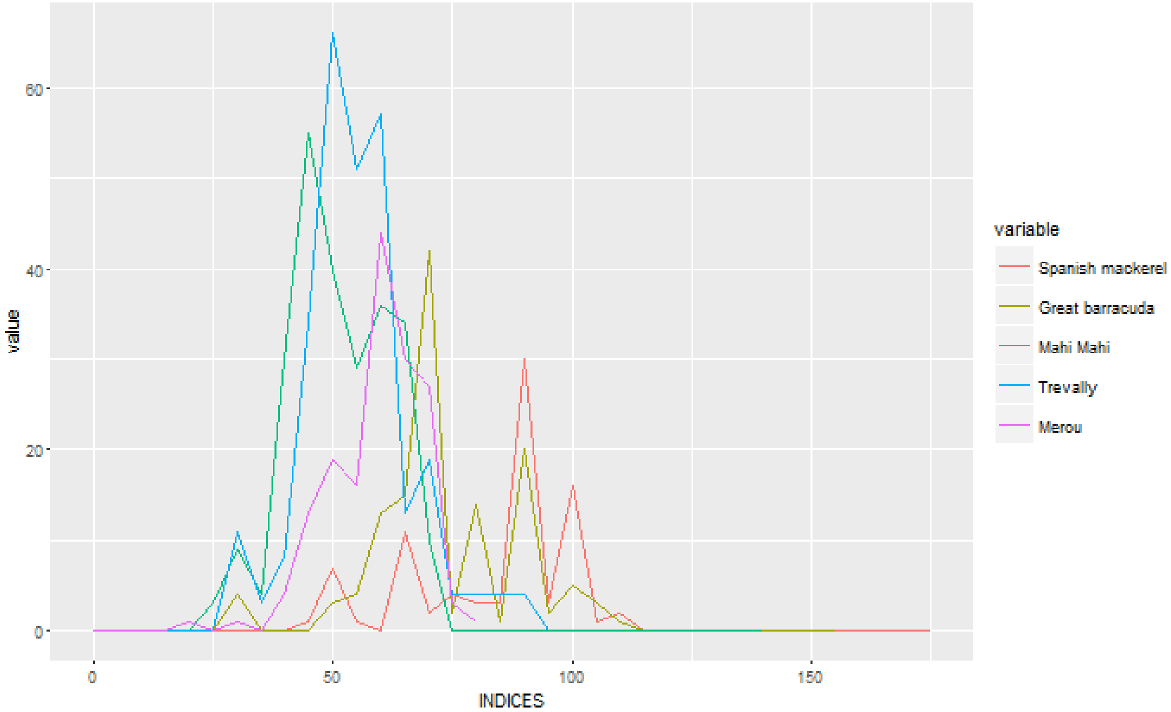

Figure 7: Length distribution for the most important fish species in Djibouti during 2014 - 2015.

A set of 1,212 individual fish were sampled in 2014-2015 for the species concerned.
The minimum size of Spanish mackerel is 45 centimetres and its maximum size is 110 centimetres. For all species the data show an abundance of size classes of between 45cm and 85cm.

The results were analysed in FiSAT by applying the methods of Gulland and Holt Plot to analyse the growth increment data. As shown in the results obtained in the comparative Figure 8, after application of this method to data from Marine Research Institute in Iceland (left) and those from the Marine Biology Laboratory (right) and reflecting the degree of insufficiency of data from Djibouti.

The frequencies of the data used from the Marine Biology Laboratory are insufficient to provide an estimation of the growth parameters for Spanish mackerel.

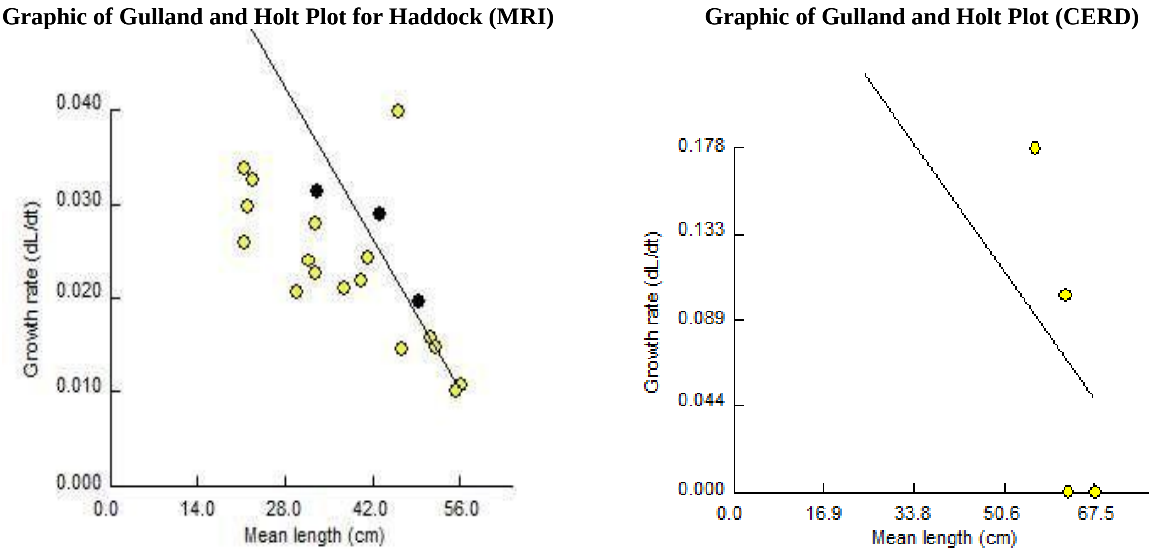

Figure 8: Comparison of graphics of Gulland and Holt Plot applied on the data from Iceland and Djibouti.

Due to insufficient data to allow obtaining reliable growth parameters, growth parameters found in the literature (Table 2) have been applied to all of these species.

Table 2: The values of growth parameters found in the literature.

common_name	latin_name	L∞ (cm)	country	references	K	Country	references
Spanish mackerel	*Scomberomorus commerson*	135.7	Djibouti	Bouhlel(1985)	0.21	Iran	Fishbase
Trevally	*Caranx sexfasciatus*	80	Papuaa	Fishbase	0.24	South Africa	Fishbase
Great barracuda	*Sphyraena barracuda*	134	South Africa	Fishbase	0.24	USA	Fishbase
Mahi Mahi	*Coryphaena hippurus*	106	India	Benjamin(2012)	0.4	India	Fishbase
Merou	*Variola louti*	83	USA	Grandcourt(2005)	0.48	Aisia Pacific Region	Fishbase

The size at first maturity, which corresponds to the size where half of individuals in the population are considered mature, and the optimum size, which is the age group with maximum egg production, were estimated for all these species as shown in Figure 9.

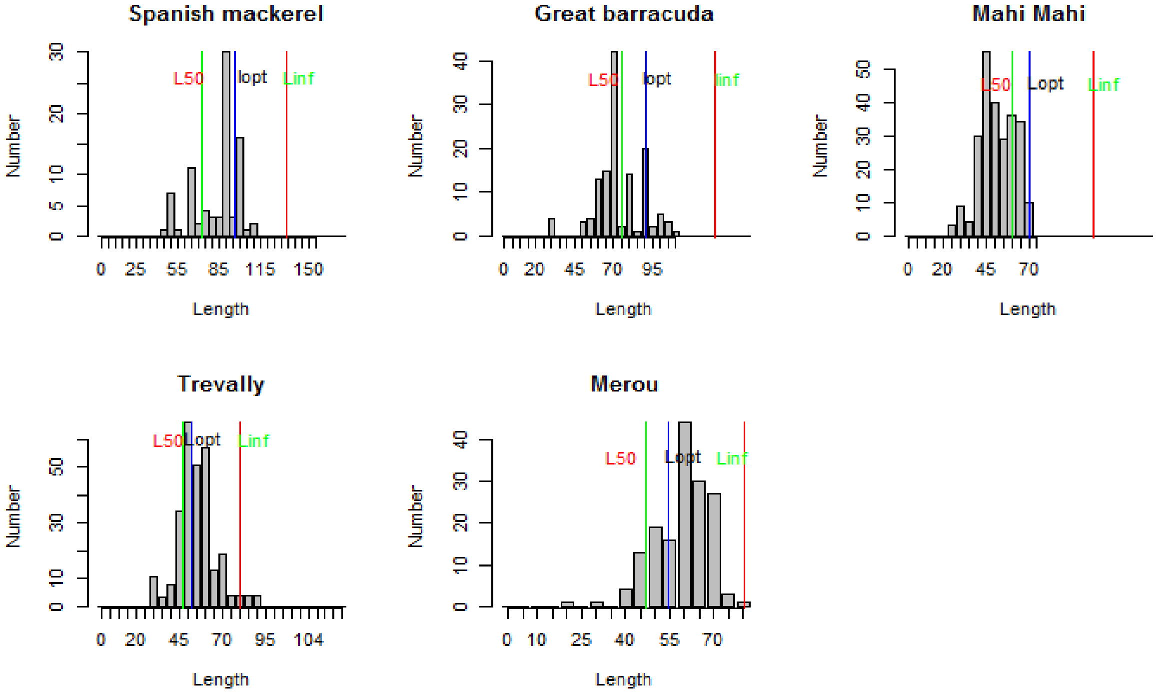

Figure 9: Distribution of size frequencies for the most caught fish species in Djibouti with indications of asymptomatic length and sizes of first maturity estimated using empirical equations.

For all species, it seems the capture sizes are larger than the size at first maturity. This reflects that the capture precedes the maturation. However, it would require more accurate and more complete analysis to confirm these results.

5.2 Length Weight relationship

The relationship linking the length to the weight has been defined for a set of five species, from the national fisheries of Djibouti. Using data collected by the Marine Biology Laboratory (CERD) as shown in Figure 10. The results were then compared to values found in the literature, which is indicated by the blue color in the figure.

The results for the coefficients of allometric b (Table 3) for all species seem strange and do not conform to the theoretical value of the coefficient of allometry b which is normally around 3 (Gulland, 1983). As indicated in Table 4, the results obtained for the allometric coefficient b are not consistent for all species. This fact results from the importance of incorrect data and a high level of bias in the data collected.

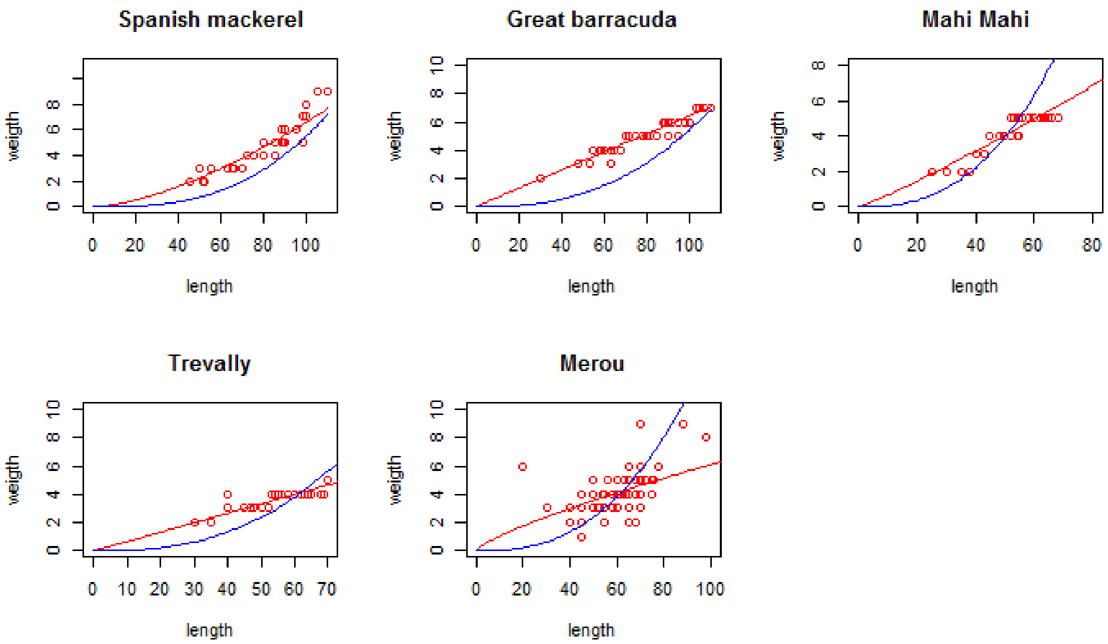

Figure 10: Length-weight relationship for the most important fish species in Djibouti. Values estimated from existing literature are blue.

Table 3: Comparison between different allometric coefficient values obtained for the present study and those reported in the literature.

latin_name	a	b	Présente étude	a	b	Pays	References
Scomberomorus commerson	0.00005	1.551	Djibouti	0.011	2.85	Djibouti	Bouhlel (1986)
Caranx sexfasciatus	0.268	0.988	Djibouti	0.248	2.573	South Africa	fishbase
Sphyraena barracuda	0.00319	1.128	Djibouti	0.05	2.513	Yemen	fishbase
Coryphaena hippurus	0.0278	1.101	Djibouti	0.0447	2.602	South Africa	fishbase
Pristipomoides filamentosus	0.026	0.969	Djibouti	0.012	3.081	New Caledonia	fishbase

5.3 Catch distribution

These data come from investigation conducted by the Marine Biology Laboratory (CERD) between 2011 and 2015. The proportions of catch during this period for the all fishing areas, of the exclusive economic zone of Djibouti had been represented on maps as shown in Figures 11 and 12.

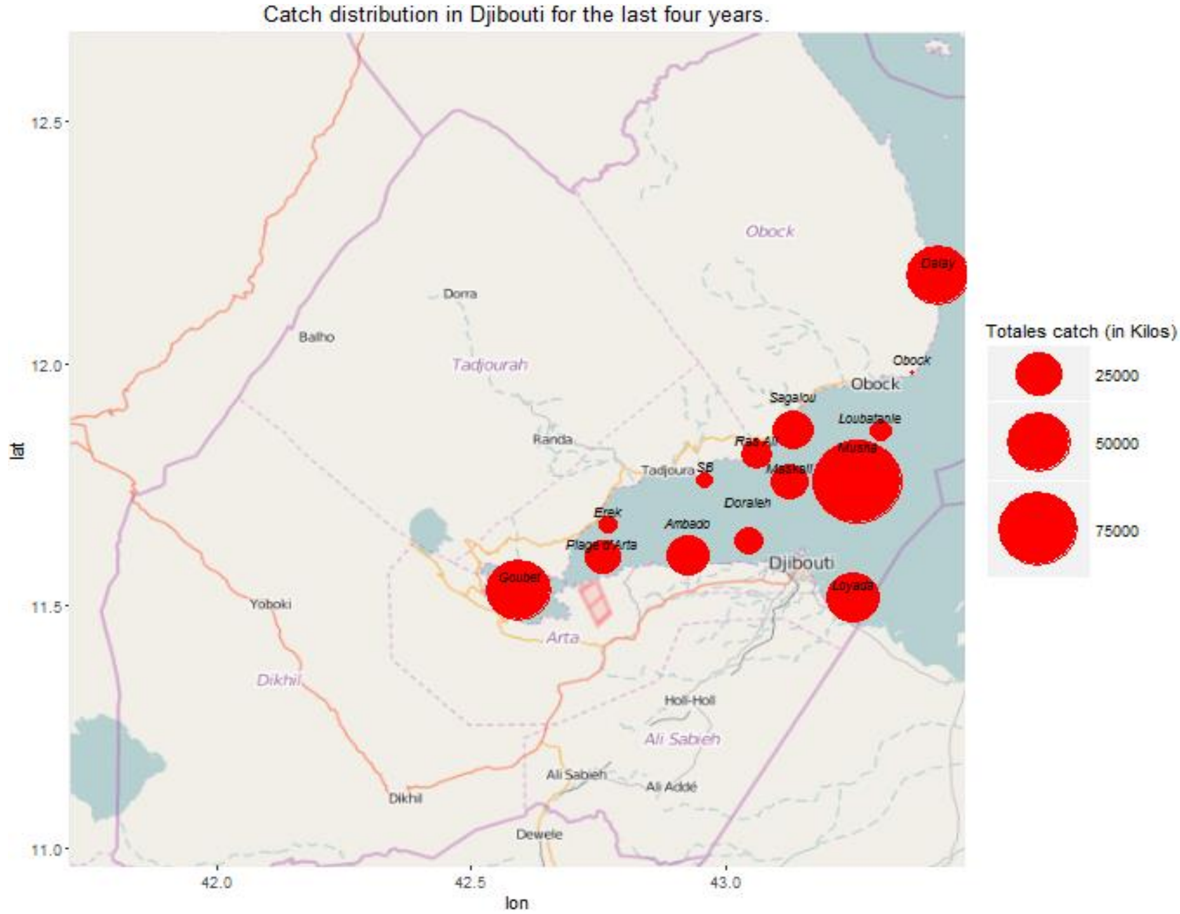

Figure 11: Distributions of catches in Djibouti 2011-2014

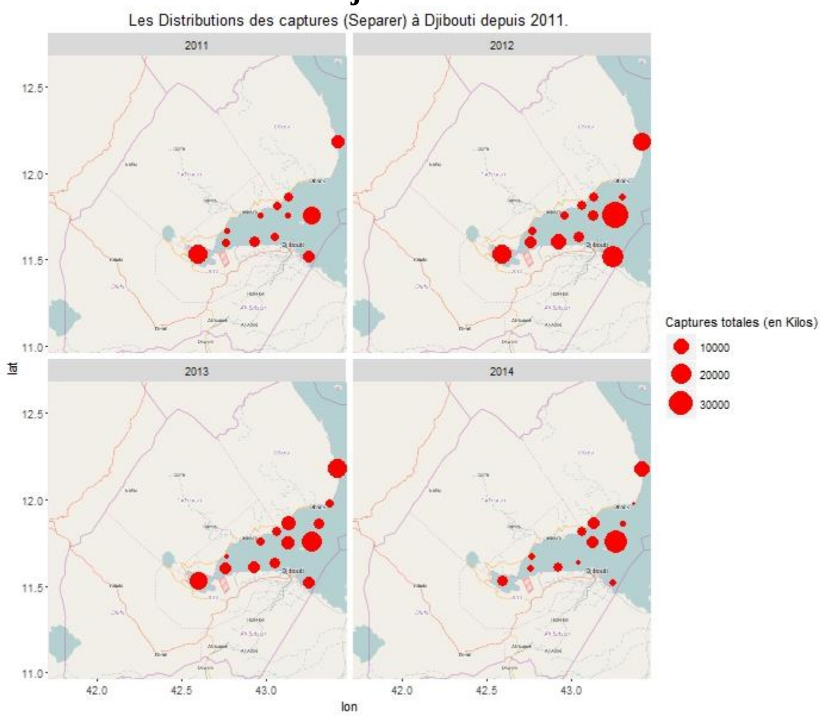

Figure 12: Distribution of catch in Djibouti for 2011-2014

We assumed that the concentration of fisheries activity in these areas is due to an abundance of fish resources and that this high fish concentration can be explained by an abundance of food available in the regions with of high fishing activities (Musha Loyada, Goubet). In the South at

Loyada the high concentration of catches could be explained by the physical phenomena that occur there.

Indeed, an upwelling is observed during summer in the south of the Red Sea and in Somali waters and this phenomenon leads to a high abundance of fish in these regions (Bonfil, 2004). To verify the probable existence of a relationship between the concentration of catch and the availability of nutrients. Satellite observations of the concentrations of chlorophyll a in the East African region over the same period have been visualized (Figure 13).

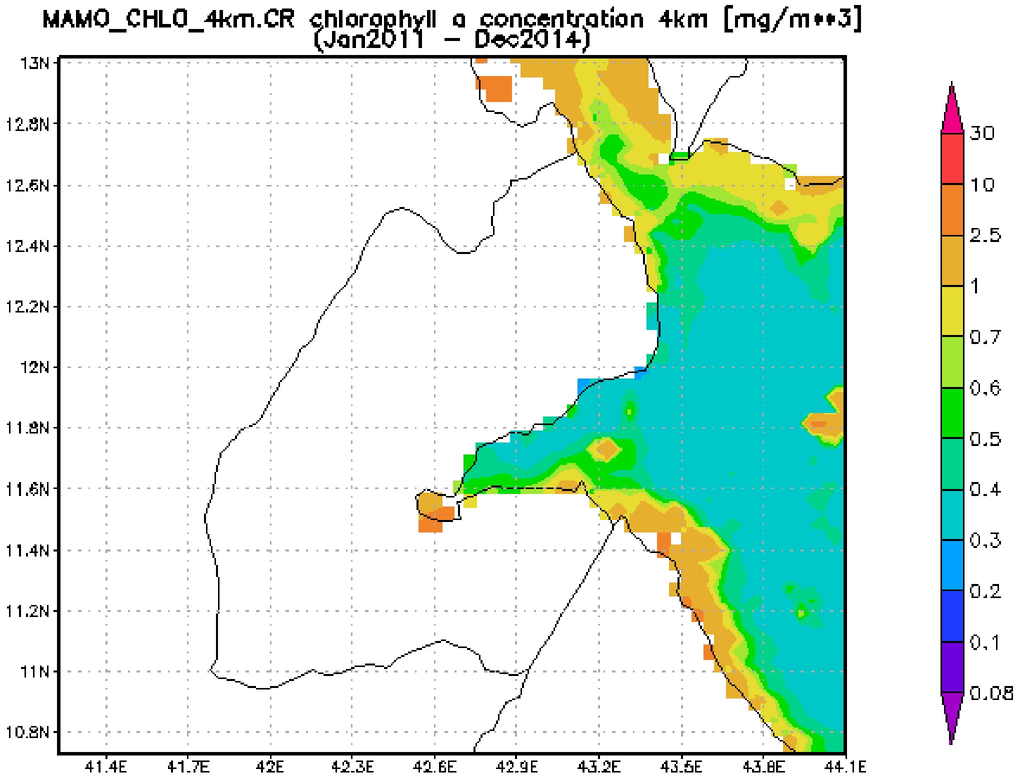

Figure 13: Concentration of chlorophyll a in the East African region between 2011 and 2014

The satellite observations of concentrations of chlorophyll a in the East African region are remarkably consistent with the observed distributions of catches in the exclusive economic zone of Djibouti.

Indeed, concentrations of chlorophyll a greater than 1 mg / m^3 are observed in the fisheries area Musha, Loyada. During the same period 2011-2014, concentrations was above 2.5 mg / m^3 in the region of Goubet. The regions with the highest concentrations of chlorophyll a correspond to regions with the highest proportions of catches during the same period.

5.4 Landing per unit effort

In this part, an estimation of landings per unit effort was made. Artisanal fishing gear and methods of fishing practiced were classified and related to their respective landings. The ratio between the catch and the number of outputs (days at sea) were expressed in landing per unit of effort. A monthly evolution of landing per unit effort was established for the year 2015 (Figure 14).

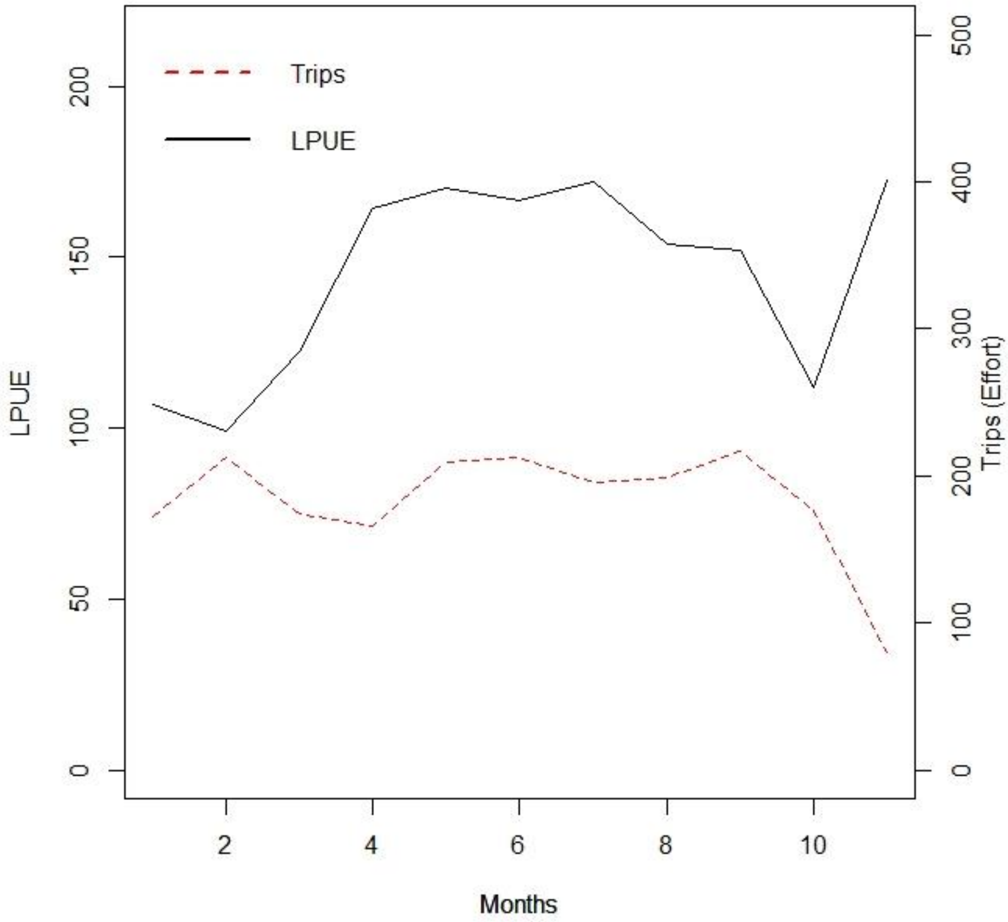

Figure 14: Evolution of the Lpue after month and trips (effort) in 2015.

As defined above, the artisanal fisheries gears are classified into two categories defined by the total number of fishermen that can be shipped (Class A and B). The techniques of fishing used by these are either angling (L) or net fishing (F).

The landings per unit effort expresses the average yield of fishing for an output of all fishing gear. This notion does not integrate the fishing time, the fishing power measured by the number of fishermen, the number of hooks line or net. Likewise, the information on the discards and other fish losses in the sea are not included in these results.

The results show the evolution of landings per unit of effort (LPUE) using data from the fisheries department for the year 2015. The estimated LPUE were increased initially between the months from March to September, reaching a maximum value of 170 kg per landing, before declining, from October to reach a value of 112kg per landings (Table 4). Less data was available in November.

Table 4: Evolution of the total catch and the landing by unit effort in Djibouti in 2015.

Month	Total catch	Trips effort	LPUE
1	18378	172	106.8488
2	21123.5	213	99.17136
3	21263	174	122.2011
4	27302	166	164.4699
5	35555.5	209	170.122
6	35335.5	212	166.6769
7	33704	196	171.9592
8	30585	199	153.6935
9	32930	217	151.7512
10	19672.8	176	111.7773
11	13794	80	172.425

For each region (North-South), the results have provided an overview of the landing per unit effort of different types of vessels (A and B) for different fishing techniques (L and F) (Figure 15).

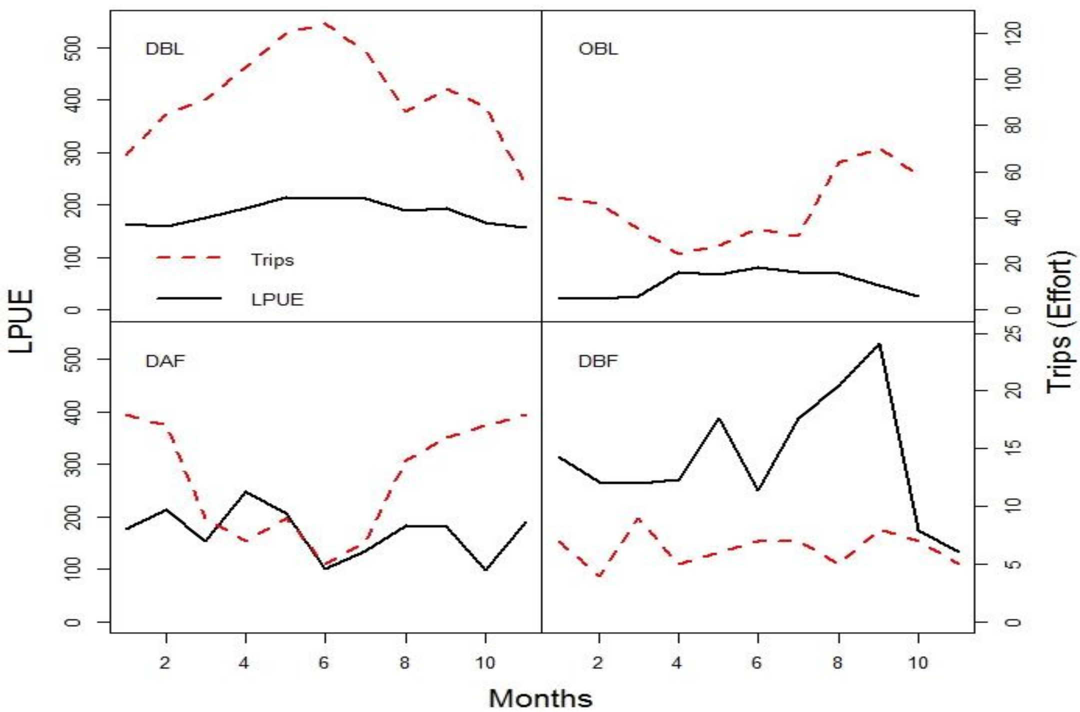

Figure 15: Landing per unit effort for the most important gear type and the techniques of fishing associated in Djibouti

In the South and North (Obock), the fishing gear of category B using the line as a technique of fishing (DBL and OBL), were associated and their landings per unit effort were estimated. The results obtained show high values of landings per unit effort, however, a peak is observed during the summer to reach maximum values of over 200 kg per trips for Djibouti (DBL). Similar summer peak was observed in Obock, but at much lower values of LPUE or around 75 kg per trip.

In the south (Djibouti), the numbers of fishing trip for 2015 was in average around 80 trips per month. These values increase from 60 in January and reach 120 trips during the summer. The increase in observed values of landings per unit effort appears not to be proportional to the increase of the number of outputs which increases at a faster rate.

In the Southern region of Djibouti, the landings per unit effort for both fishing vessels (A and B) deploying net were estimated. For boats from category A (DAF), a fewer trips were recorded during the summer (March - September). The landings per unit effort fluctuated and reached its maximum value in the month of April, with an approximate value of 250 kg per trip.

For boats from category B using net (DBF) the records trips were constant all over the year. However, the landing per unit effort was highest during the summer, with over 500 kg per trip in September.

The mean landings per unit effort for different types of boat associated to their fishing methods were estimated (Table 5). Highest landings per unit effort were observed for large boat category B, using nets in the region of Djibouti (DBF), with about 311 kg per trips.

Interestingly the smaller DAL boats (using line), had the higher LPUE of 280 kg per trip, compared to larger DBL boats that fished on average 185 kg per trip.

Table 5: The mean of Landings per unit effort for different types of boat associated to their fishing methods.

Type of boats	Total catch	LPUE
DAF	23804.5	171.5501
DAL	8402.5	280.6833
DBF	22164	311.6549
DBL	195006.3	185.5366
OAF	3026	76.4885
OAL	853	75.08333
OBF	15340	60.20284
OBL	21047	50.65589

The evolution of LPUE of Spanish mackerel and trevally were observed in the DBL fisheries (Figure 16). The results indicate an increase of landings per unit effort in the summer respectively between March and August for Spanish mackerel and between May and September for the trevally. For both, the maximum values of the landing per unit effort reached is about 60 kilos per trip.

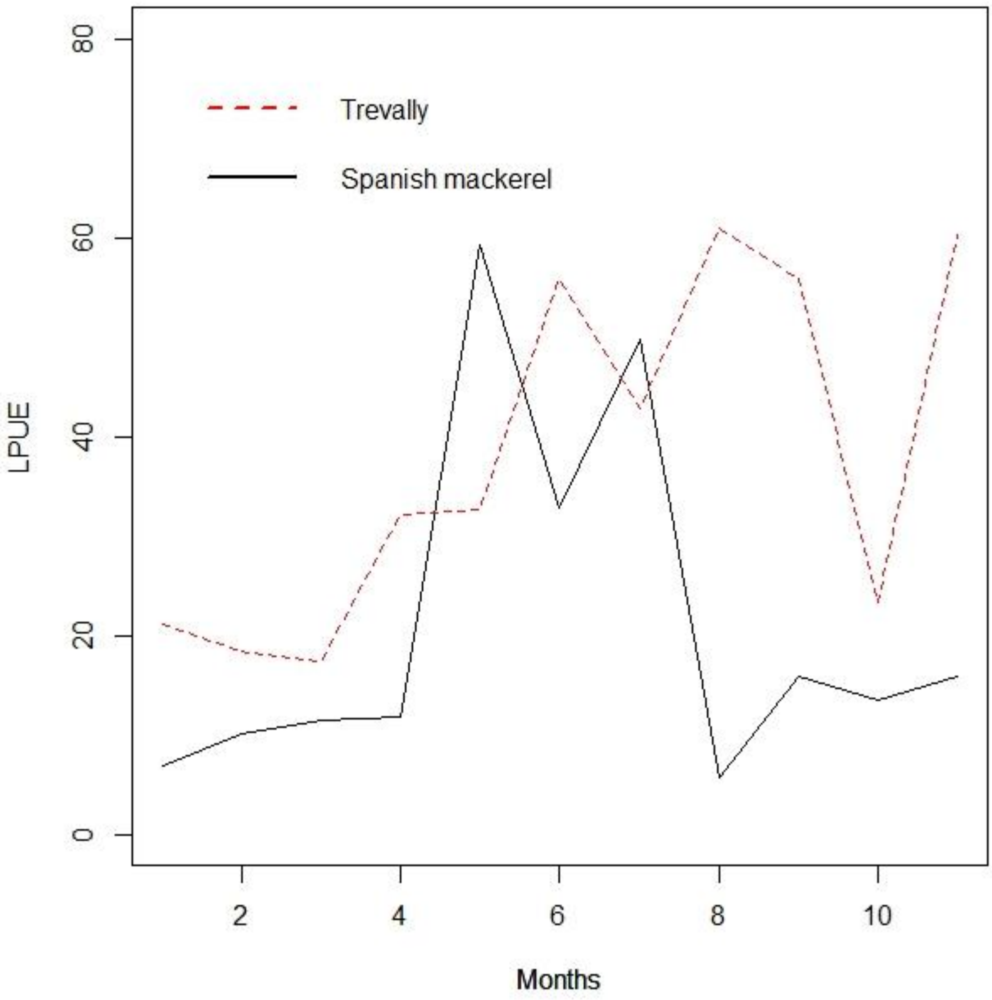

Figure 16: The landing per unit effort of Spanish mackerel and Trevally in port of Djibouti caught with line on larger boats (DBL)

5.5 Sampling strategy

5.5.1 Existing ports and landings sites

In the Republic of Djibouti, there are only four landing sites: Port of Djibouti city, Obock, Tadjourah and Loyada (Figure 17).

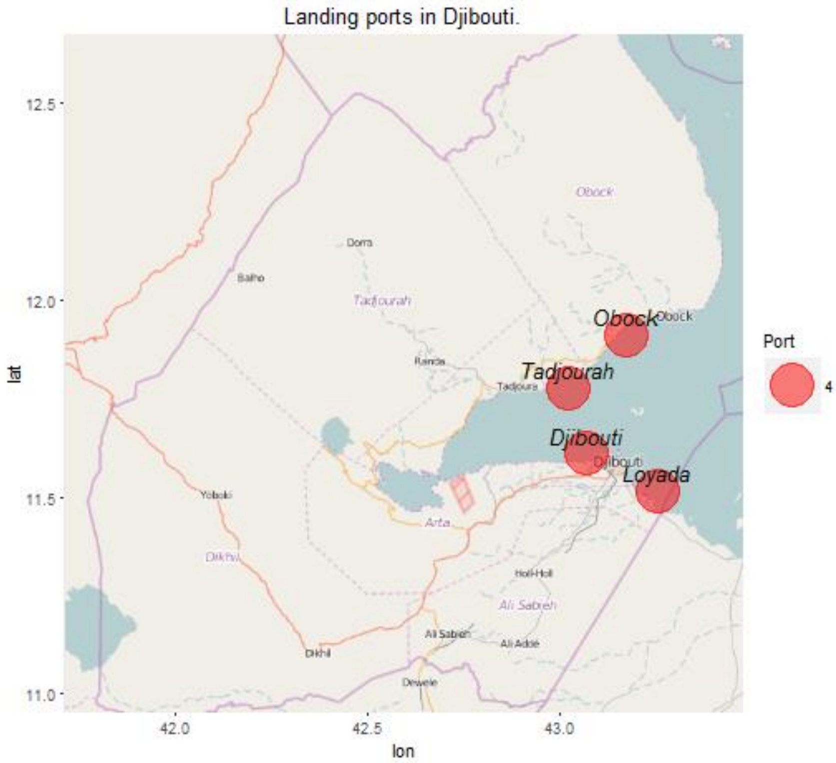

Figure 17: Landings ports in Djibouti

Compared to the other two, the ports of Djibouti city and Obock are more active. The port of fishing of Djibouti city hosts total landings of nearly 80%. Landings in Tadjourah and Loyada are virtually nil and ships based in these ports land mainly in Djibouti City.

5.5.2 Fleet

The fisheries sector in Djibouti provides about 2,000 jobs (direct and indirect) and the number of professional fishermen is estimated at around 600. The entire fleet is made up of small-scale fishing units. Currently the number of boats is estimated at 200. We can distinguish three groups of vessels characterized by their length.

Category A: with a length equal at 6 meters.
Category B: with a length less than 12 meters.
Category C: with a length large than 16 meters (which operate only in Somaliland waters).

5.5.3 Landing data

The conduct of investigations was described in the materials and methods part. Specifically, the sampling concerns the artisanal fisheries. The data collected concern the sampled landings (about 4 to 5 per day and per landing site).

The frequency with which it is appropriate to measure variables and collect data depends on their rates of change and their cost. The majority of data on landings, a summary of the effort during the trip, the fishing grounds, the prices, the costs of the output, and other operational data collection should be collected each day earlier in the morning at moment where most of the fishermen landed. Taking into account the moderate numbers of daily landings or roughly 60-70 according to the data on landings and the total estimated catch of around 300 tonnes, today it seems that 10 – 12 landings are sampled per day and this sampling should be enough to obtain a representative sample.

Currently, for the Department of Fisheries, the time, the landings ports, the types of boats, the technique of fishing used, the number of fisherman, the fishing area and the names of the species are the collected data for each sample. The data collected are grouped into an Excel file as follows:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Year	Months	Day	Landings ports	Type of boats	Techniques of fishing	Number of fisherman	Fisheries ares	Especes	Antak	Barracuda	Trevally	Mahi Mahi	Merou	Langouste	Shark	Sakla	Spanish	Tuna	Others
2																				
3																				
4																				

For the Center of Study and Research the time, the fishing areas, the name of the species, the weight of each individual fish and its length are collected and grouped into an Excel file as follows:

Years	Month	Day	Area	Species	Length	Weight
2014	10	1	Miri bis	Thazard	100	7

The sampling conducted by both institutions each have their advantages and disadvantages. By way of comparison, the investigations carried out by the Fisheries Department cover more elements and provides partial information on the effort. However, the data provided do not include the duration of outputs and the individual boat number, which is a problem if the catch per unit effort wishes to be estimated.

For the Centre for Study and Research of Djibouti (CERD), the collected data are limited, however, they provide information relating to the biology (the measures on sizes of fish). Furthermore, sampling conducted by the CERD covers a range of 18 fisheries areas and 17 species while only two fishing areas and a set of 11 species are covered by the investigations carried out by the Fisheries Department.

To appreciate the state of the resources, their exploitation potential, to prepare options and offer advice to fisheries managers, reliable data is needed. The extent to which this work can be done properly requires a close cooperation between both institutions in order to join efforts. This work begins by a mutualisation of the information collected. In this context the Centre for Study and Research in Djibouti would initiate the collection of fishing effort data and the department of fisheries would note more fisheries areas in its documentation.

The fishing areas on which investigations must carry should be predefined.

The analysis of data on the distributions of catches since 2011 revealed the existence of 18 fishing areas of which nine areas include more than 90% of fishing activities. Those areas are highlighted in Table 6.

Table 6: Proportion of catches by area since 2011, recorded by the CERD.

Area	Total catch	Proportion of catch	
Musha	98580.5	26.79%	89.82%
Goubet	51460	13.98%	
Dalay	48302	13.13%	
Loyada	34134	9.28%	
Mabla	25778.5	7.01%	
Ambado	22136	6.02%	
Sagalou	19138.5	5.20%	
Maskali	16749.3	4.55%	
Plage d'Arta	14266.5	3.88%	
Ras Ali	10723.5	2.91%	
Doraleh	10135	2.75%	
Loubatanle	5462	1.48%	
Erek	4409.5	1.20%	
SB	3973	1.08%	
Obock	1710	0.46%	
Heron	849	0.23%	
Ouramous	185	0.05%	

Among those 9 most important fishing areas, some may be considered as one single region due to extreme geographical proximity. Thus, the areas of Arta and Ambado can be considered as a single area as well as Musha and Maskali.

Considering this asumption, the investigations should cover seven main fishing areas. These regions would be associated with their respective GPS coordinates during the treatment of data. The sample collected concerning the exploited resources should provide information on:

- The date of sampling
- Total weight of sampled landings
- Total weight of sampled landing by species
- scientific names of families and species sampled
- The fisheries areas where sampled landings were caught

However, before starting the collection of data it would be a necessity to conduct a census of the total landings made:

- The total number of landed boats
- Types of vessels, their category, etc.
- Number of men on board

This total inventory would be made possible by the low number of daily landings (around 60-70).

A partial data collection on fishing effort was initiated by the Department of Fisheries, including number of outputs / month / category of boat. However, the lack of data on time, such as fishing hours, does not allow to estimate the catch per unit effort for different species groups distinguished in the landings.

The fisherman is a component of the fishing effort, and elements such as fishing time, the length of gill nets or the number of hooks (longlines or handlines), must be collected to get a better estimate of the catch per unit effort. These data on the fishing effort must be grouped as follows:

- Fishing areas
- Fishing season
- Boat number
- Number of trips / month / boat category
- Number of fishing hours / gear / output / boat category

Information related to the nominal fishing effort can be collected as follows:

Boats	Characteristics	Capacity	Activity	Nominal effort
Gillnets	Length Mesh	Numbers of nets. Length	Fishing time	Length of nets* hours surface of nets* hours
Longlines	Length Number of hooks	Number of longlines Number of hooks	Fishing time	Number of longline* hours Number of hooks* hours

5.5.4 Biologic data

Biology data, especially data related to size of fish and size frequency, of the main species caught along the Djiboutian waters are needed to study the dynamics of the fish stocks. This part describes the procedures developed to collect data from the main landing sites in Djibouti. Currently all the data relating to individual sizes of fish are collected by the Marine Biology Laboratory. However, the information concerning gonad weight, their sex and their sexual maturity stages are not collected. These investigations are in theory made every day (except Friday) and started in 2014. However, the analysis of the collected data on the sizes have not led to efficient results and a significant number of biases were observed. On the basis of the results obtained from the analysis of landings data and the procedures implemented in other countries recommendations were made on how to collect reliable data (Badts, 2012).

For the measurement of fish species, different measurements can be made: total length (TL), fork length (FL), standard length (SL). The default measure in Djibouti is the total length (TL), measured from the most forward point of the head, mouth closed, to the tip of the tail, the tail being flattened. The animal must be placed flat on its right side. All size measurements should be made, to the nearest centimetre, using an ichtyometer.

The samples could be taken directly from the canoes on the beach or in the packing areas at the fish trading centre.

For a sampling when the number of individual fish in a batch is too important for it to be fully measured, it is necessary to measure a variable number of individuals until the modes emerge (the mode is the most represented value of any variable in a population). The number of individuals of fish, to be measured depends of the extent of the size range of the species present in the sample. According to Gulland for each month from each stratum (a stratification by gear and area) a sample of two or three hundred fish should be enough to identify one or two modes. (Gulland, 1992).

The length measurements were recommended for the most important species.

To get a better representation of the stratum, the fisheries in Djibouti was stratified by gear type and by areas. A set of three fishing region and 2 types of boats were considered.

The selected fishing region (Figure 18), were defined depending on the width and depth of continental shelf and include the main fishing areas (defined above) in Djibouti.

Figure 18: Fishing regions (Darar, 2008)

The boats of category B, which deploys line were selected (DBL), and the others were grouped and considered as one single unit called others. The DBL boat represent over 67% of landings (Table 7).

Table 7: Proportion of catch per gear type in 2015.

Type of boats	Total catch	Proportion of catch
DBL	195006.3	67.33%
DAF	23804.5	8.22%
DBF	22164	7.65%
OBL	21047	7.27%
OBF	15340	5.30%
DAL	8402.5	2.90%
OAF	3026	1.04%
OAL	853	0.29%

This stratification has provided a set of 6 stratum.

By using the recommendations from Northwest Atlantic fisheries Organization which states that per month at least one sample (of around 200 fish) should be taken from any stratum of a fishery (Gulland, 1992) and taking into account, the six stratums identified in the fisheries in Djibouti. In average, the lengths measured should include 250 individuals of fish per stratum and per month. For each species a set of 1,500 individuals should be measured monthly, some species might be better represented, and some strata might be to scarce, but this procedure, would provide useful data,

The selection of individuals of fish to be measured must be by way of random drawing. In considering two precautions:

- For very important catches, individuals must be draw from different places in the pile (for example to avoid the risk of higher concentration of individuals of large fish
- When the measurement concern only one part of the individual fish contained in a box a fraction of the box is measured. In particular, the extraction of isolated individuals from a lot introduces a risk of bias.

At the time of sampling, in addition to information on the size of individual fish sampled, the following information should be recorded for each sample:

- Date
- Fishing areas
- The identification of boat
- Gear type
- Fishing hours
- Number of hooks
- Number of nets

Weight measurements should be taken in conjunction with detailed biological information that should be the focus of fisheries surveys or special sampling plan. In future it would be advisable to conduct dissections operations to collect information relating to:

- Gonads
- Weight of viscera
- Gutted weight
- Extraction of otoliths

6 DISCUSSION

6.1 Length frequency distribution

Length frequency data have the advantage of being relatively cheap, straightforward, and quick to collect from landing sites and markets. Information on age structure of the population and growth parameters can be estimated using length frequency data.

However, the data collected by the Marine Biology Laboratory cannot be fully utilised to determine these biological parameters, for two reasons. Firstly, the Marine Biology Laboratory began collecting biological data such as the length of the fish recently in 2014, this leads to an inadequacy of the data available to allow its optimal interpretation. The second reason is that inconsistencies were found in the data. For example, the length measurement for each individual fish was measured in centimetres in some cases and in meters in other instances.

This makes it difficult to make all the data homogeneous for better use. Obtaining reliable results does not require a laborious work and can be achieved in the near future with minimum rigor.

6.2 Length-weight relationship

Length-weight relationships allow scientists to compare populations and assess the living conditions of fish. The analysis of data collected by the Marine Biology Laboratory did not allow to produce an efficient result, the abundance of spurious data being the main reason. However, according to Bouhlel (1986), the growth of Spanish mackerel in Djiboutian waters was allometric, reflecting a faster gain in weight, than linear growth. In the Yemeni waters the growth seems to show an allometric with an unfavorable growth. In order to obtain credible results in the future, it will be wise to collect data with a minimum of rigor to reduce the incidence of spurious data. For this, the biologist in charge of the data analysis should be on the ground and take care of the production of information.

6.3 Catch distribution

The results obtained for the catch distribution in Djibouti seem to show a correlation between the distributions of catches and nutrient availability, specifically chlorophyll a. However, due to the lack of sufficient data on fishing effort (the means used: size of the fleet, vessel size, time spent at sea, distance travelled), the conclusions on the relationship between resource abundance and nutrient concentrations is inconclusive.

A preliminary assessment of stock exploitation requires data on fishing effort. It would therefore be desirable that the fishing effort data are collected for a better understanding of stock status and the various factors (nutrients, temperature, etc) influencing growth. It is necessity to collect better information on fishing effort to allow a preliminary assessment of the stock status was also one highlighted in the recommendations of the ACP FISH II Programme in its final report on "supporting administration fishing for the assessment of fishery resources in the Republic of Djibouti” (ACPFISH II, 2013).

6.4 Landings per unit effort

The analysis of landings per unit effort reported a combined increase of the values of landings per unit of effort and numbers of boats fishing in the summer. For the Spanish mackerel, two peak landings per unit effort were observed during the summer season.

These peaks may correspond to a resource abundance during this period or passages of migratory individuals towards Somali waters characterized by a large upwelling in this period, considering the highly migratory nature of the Spanish mackerel.

However, this measure underestimates the actual effort, the different elements collected are insufficient to provide a better estimation of effort. The data collected to estimate the landings per unit effort reflect a local exploitation for only two regions (Obock and Djibouti). These data are well below the real numbers of fisheries areas in Djibouti and do not cover the main fishing areas. The data collected on fishing effort at present do not take into account: number and type of gear (nets and hooks) and time spend at sea.

6.5 Sampling strategy

The collection and treatment of data on the fisheries are the basis for a system of monitoring, control and surveillance of fisheries, which aims to ensure the optimal use of resources and sustainable exploitation of the fishery. The frequency with which landing data is collected in Djibouti is good. With few and simple modifications, the information gathered, and the quality of the data can be improved substantially. The results obtained have enabled the establishment of a sampling strategy adapted to the local context and have accounted for the different components and characteristics of the fishery in Djibouti. Hopefully, this sampling strategy will lead to more reliable data collection which will allow the leaders of the fishing sector to have the necessary tools for decision making, in favour of a sustainable development of the fisheries sector.

7 CONCLUSION

The present project investigated application of a length-based method on data from the fisheries in Djibouti. However, the data were insufficient. There was a joint increase of landings per unit effort and the number of outputs from fishing boats during the summer in Djibouti (March to September). The geographic distributions of catches in the exclusive economic zone of Djibouti (EEZ) since 2011 showed correspondence with the distributions of chlorophyll a concentration according to satellite observations.

Following the analysis of the data collected by the Department of Fisheries and the Marine Biology Laboratory, it was observed that the data collection system established in Djibouti since 2010 requires improvement. A sampling strategy was developed with the aim to contribute to the improvement of the established data collection system.

In the future, obtaining reliable data is needed to achieve results which could inform management decisions for an optimal and sustainable development of the fisheries sector.

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ANNEXES

Monitoring of fishing efforts from the artisanal fisheries
Daily Sampling
Marine Biology Laboratory

Name of the investigator:___________ landing port: Date:__/__/20

Sample id	Nº1	Nº2	Nº3	Nº4	Nº5	Nº6	Nº6	Nº7	Nº8	Nº9	Nº10
Boat-id											
Category of boat											
Number of fisherman											
Fishing hours											
Fishing techniques											
Nets											
Longline											
Length of nets											
Number of longline											
SPECIES	Weight (kg)	Weight (kg)	Weight (kg)	Weight (kg)	Weight (kg)	Weight (kg)	Weight (kg)	Weight (kg)	Weight (kg)	Weight (kg)	Weight (kg)
Spanish mackerel											
Trevally											
Great Barracuda											
Dorado											
Merou											
Antak											
Shark											
Tuna											
Gray mulet											
Shrimp											
Others											

Collecting of length measurement from the artisanal fisheries
Daily Sampling
Marine Biology Laboratory

Name of the investigator: ________ Landing port: _____ Sample-id:
Date:__/__/20

Boat-id: _____ Fishing areas:

Species	Weight (Kg)	Length measured	Total counted
Spanish mackerel			
Trevally			
Great Barracuda			
Dorado			
Merou			
Antak			
Shark			
Tuna			
Gray mulet			
Shrimp			
Others			

Species: Spanish mackerel Sample-id: ______ Fishing area:

0		65	
1		66	
2		67	
3		68	
4		69	
5		70	
6		71	
7		72	
8		73	
9		74	
10		75	
11		76	
12		77	
13		78	
14		79	
15		80	
16		81	
17		82	
18		83	
19		84	
20		85	
21		86	
22		87	
23		88	
24		89	
25		90	
26		91	
27		92	
28		93	
29		94	
30		95	
31		96	
32		97	
33		98	
34		99	
35		100	
36		101	
37		102	
38		103	
39		104	
40		105	
41		106	
42		107	
43		108	
44		109	
45		110	
46		111	
47		112	
48		113	
49		114	
50		115	
51		116	
52		117	
53		118	
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57		122	
58		123	
59		124	
60		125	
61		126	
62		127	
63		128	
64		129	

Species: Trevally Sample-id: _______ Fishing area: _____

0		65	
1		66	
2		67	
3		68	
4		69	
5		70	
6		71	
7		72	
8		73	
9		74	
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36		101	
37		102	
38		103	
39		104	
40		105	
41		106	
42		107	
43		108	
44		109	
45		110	
46		111	
47		112	
48		113	
49		114	
50		115	
51		116	
52		117	
53		118	
54		119	
55		120	
56		121	
57		122	
58		123	
59		124	
60		125	
61		126	
62		127	
63		128	
64		129	