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Exploitation Rate and Spawning Behaviour of *Sardinella maderensis* (*Lowe,*1838) in the Artisanal landings of the Montserrado County Fishing District, Liberia, West Africa

Sellu Mawundu[1] and Stephenson Zeantoe[1, 2]

[1]Department of Aquaculture and Fisheries Management, School of Natural Resources Management, Njala University, PMB, Freetown, Sierra Leone

[2]Bong County Technical College, Gboveh Hill, Gbarnga City, PMB, Liberia

Abstract

The artisanal fishery sector plays a key role in the livelihoods of the coastal communities of Montserrado County of Liberia, accounting for roughly 89% of job creation. *S. maderensis,* commonly known as "Madeiran sardinella" or "Flat herring" or locally called in Liberia as "Flat bonny" is being the most commercially harvested fish stock in the artisanal fishery of Liberia. There is little or no information on the exploitation status of this fish stock in the artisanal fishery of Liberia. Field sampling was conducted at three fish landing sites for a period of six months. On each sampling occasion, the total length (TL) of each fish sample was measured on a measuring board to the nearest 0.01cm. This was followed by taking fish samples and preserving them in a duraplast coolman for laboratory analysis for monthly gonadosomatic index and maturity stage classification. In the Laboratory, each sample was dissected with a scalpel by cutting the ventral part of the sample to display the gonads. The gonads were removed and weighed on an electronic balance to the nearest 0.1g, followed by the removal of the visceral and the weighing of the fresh weight of the fish sample on the same electronic balance to the nearest 0.1g. Data was recorded in an excel spread sheet which was later transferred to the FiSAT II Computer software for analysis of growth and mortality parameters. Results from the study suggest a Phi-prime value of 2.41 (a test value) that shows the degree of conformity of growth parameter estimates of this study to other studies of the same species in other locations and does not reveal significant variation. Results on monthly gonadosomatic index and maturity stage classification suggest the onset of the raining seasons (May-July) as the likelihood period for spawning of *S. maderensis*. The exploitation rate suggests the stock is still under exploited. It is recommended for an increasing fishing effort for sustainable harvesting of this stock and the use of the period between May-July as the timing for

a closed season as a fishery regulatory policy to allow the adults spawn before been harvested to avoid recruitment overfishing.

Keywords: Spawning behaviour, *Sardinella maderensis,* exploitation rate, West Africa, fish, artisanal landings

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Correspondence: smawundu@njala.edu.sl

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Introduction

Fish is central to the livelihoods of artisanal coastal and inland fishing communities, providing a significant proportion of the national protein supply in Liberia (Tous, *et al.,* 2015). The artisanal fishery sector of Liberia accounts for approximately 89% of job creation within the coastal communities with women and children involved in processing and marketing (Gushchin & Corten, 2015). The Liberian fishery sector, is generally subdivided into three components; the Industrial sector, artisanal and inland sector and the aquaculture sector. The industrial sector is owned by foreign investors and is being primarily export oriented, while, the artisanal and inland sector is dominated by small scale and less mechanized local fisherfolks providing fish for the domestic market (Jueseah et al., 2020). *Sardinella maderensis* commonly known as "Madeiran sardinella" or "flat herring" or called locally in Liberia as "flat bonny" is among the commercially exploited fish stock in the artisanal sector of the Liberian fishery. It is primarily found in the east Atlantic Ocean and the Mediterranean Sea (Whitehead *et al.,* 1988), where it is targeted primarily by artisanal fisherfolks, forming a significant part of their livelihoods (Fricke *et al.,* 2020).

Generally, inadequate fishery statistics data, and the absence of analytical assessment of commercially harvested fish stocks in the artisanal fishery sector of Liberia, cripple management interventions gearing towards sustainable management (Jueseah *et al.,* 2020). The increasing number of fisherfolks entering the fishery annually as a result of youth unemployment is mounting pressure on the fish stocks in the coastal waters of Liberia resulting to illegal, unreported and unregulated (IUU) fishing (Boyer *et al.,* 2017). As *Sardinella maderensis* remain an important commercial fish stock in the artisanal fishery of Liberia, sustainable management requires an understanding of

the population dynamics and spawning characteristics of this fish species (Wehye, 2017). Weak governance and lack of enforcement of management policies and regulation are adding to the unsustain management of this fishery (Leal *et al.,* 2015).

It is on this note this study sought to estimate population growth and mortality parameters with focus on estimating the exploitation rate of this fish stock in the artisanal fishery of Liberia, to enhance the existing management interventions. This study further delved into generating information relevant to the spawning characteristics of this fish stock to help contribute to the development of management regulation on close seasons.

Materials and Methods

Study area

The study was conducted at three fish landing sites (Popo beach, West Point beach and King Gray beach) in Montserrado County of Liberia. The landing sites have the following geographical coordinates; Popo beach (6.3729ºN, 10.7973ºW); West Point beach (6.3273ºN, 10.8064ºW) and King Gray beach (6.2499ºN,10.6999ºW). West Point beach is the largest fish landing site lying between the St. Paul and the Mesurrado rivers jutting out into the Atlantic Ocean. These Landing sites (Figure 1) were chosen base on representative sampling as most of the fishing activities are centered on these landing sites.

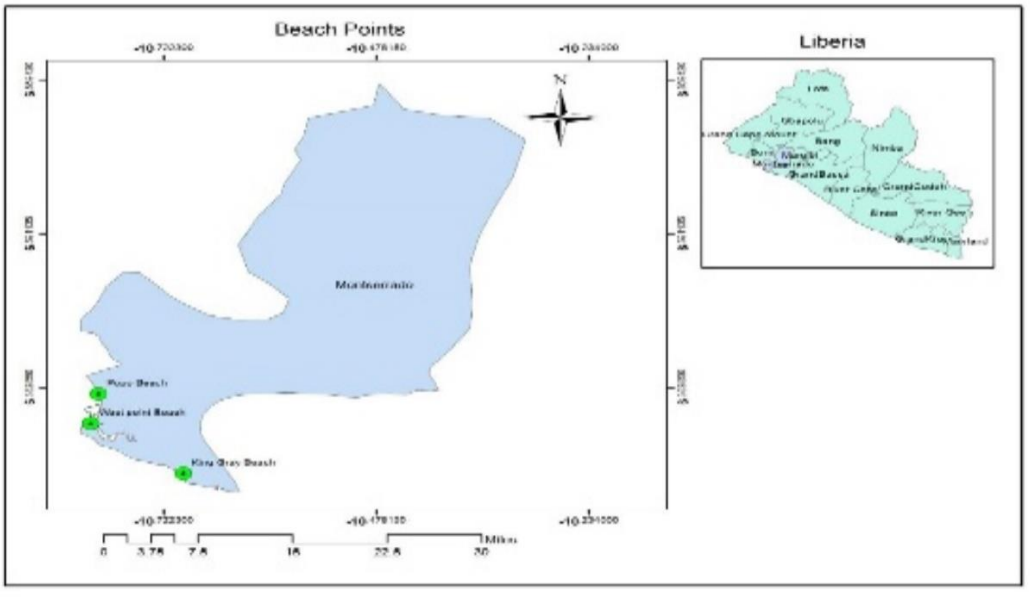


Figure 1: Map of study area showing landing sites for field sampling in Montserrado County Fishing District, Liberia

Field sampling

Sampling was conducted monthly from March to August, 2024 concurrently at the three landing sites. On each sampling occasion, fish samples of *S. maderensis* were randomly selected from the commercial landings. Each fish sample was measured for total length on a measuring board to the nearest 0.1cm, followed by weighing the sample on an electronic balance to the nearest 0.1g (Figure 2). Data was then recorded into an excel spreadsheet for subsequent analysis.



Figure 2: Length frequency measurement for total length (TL) of *S. maderensis* at the fish landing sites.

Laboratory analysis

Fish specimen were placed into a duraplast cool-man with ice cubes to preserve the specimen and transported to the USAID animal science laboratory, Cuttington University, Liberia for analysis of gonad maturity stage and gonadosomatic indices. In the Laboratory, each specimen was dissected with a disposable scalpel and gonads carefully removed with a forcep and weighed using the Adventurer pro (AV40101), a sensitive electronic scale to the nearest 0.01g (Figure 3). After weighing the gonads, the fish visceral were removed followed by weighing the fresh weight of fish sample to the nearest 0.01g. The gonads were further examined for maturity stage classification based on the following criteria: immature, maturing I, maturing II, mature, ripe/running and spent depending on colour, texture and egg visibility.



Figure 3: Specimen dissection & removal of Viscera, weighing of gonads at the USAID Animal Science Lab, CU

Data analysis

Analysis of length frequency data

The FAO-ICLARM Fish Stock Assessment Tools II (FiSAT II), a computer software developed at the International Center for Living Aquatic Resources Management (ICLARM) was used to analyze the length frequency data to estimate growth and mortality parameters. The Electronic Length Frequency Analysis (ELEFAN I)

routine in the FiSAT II was used to estimate the growth parameters (K & L∞) where K, is the growth curvature and L∞, the asymptotic length. The growth curvature K indicates the rate at which the fish species attain its asymptotic length, while the asymptotic length (L∞) is the maximum length the fish can grow to otherwise known as $L_{infinity}$. The linearized length-converted catch curve routine in the FiSAT II computer software was used to estimate the total mortality (Z), while natural mortality (M) otherwise known as mortality due to natural causes such as (predation, diseases, aging, cannibalism, pollution, parasitism, competition, etc.) was estimated using the Pauly's empirical equation. Fishing mortality (F), mortality due to fishing activities such as (fishing gear, fishing conditions, discarded fish, etc) was estimated as the difference between total mortality (Z) and natural mortality (M) as F = Z - M. The Exploitation rate (E) was estimated by considering the reciprocal of the total mortality (Z) and fishing mortality (F) as E = F/Z.

Analysis of gonadosomatic index

The gonadosomatic index (GSI), a measure of the relative gonad mass upon fresh fish weight was estimated by the formula below;

$$GSI = GW/BW * 100$$

Where;
GSI, is the Gonadosomatic index
GW, is the Gonad Weight
BW, is the fresh fish body weight

Results

Growth parameters (L∞ and K) of *Sardinella maderensis*

The result of growth parameters estimates (L∞ & K) of *Sardinella maderensis* from the artisanal landings of Montserrado County, Liberia using the non-parametric scoring of VBGF in the ELEFAN I routine is 26.78cm & 0.36 respectively Figure 4.

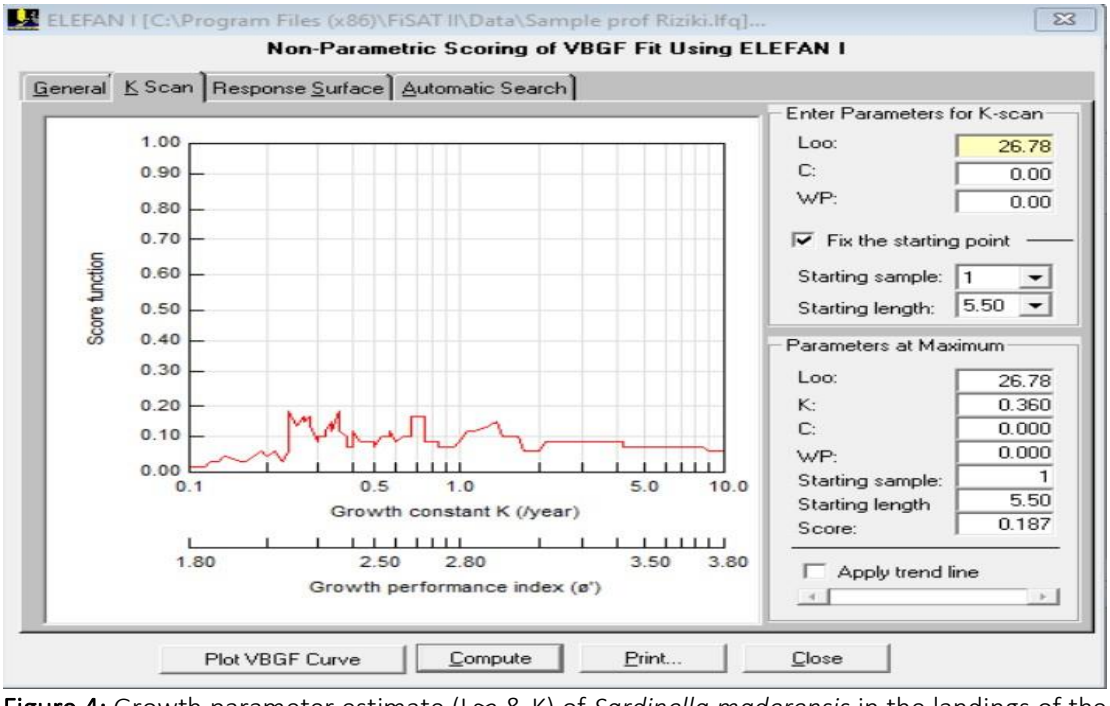


Figure 4: Growth parameter estimate (L∞ & K) of *Sardinella maderensis* in the landings of the artisanal fishery of Montserrado County, Liberia using the non-parametric scoring of VBGF in the ELEFAN I routine.

Phi-prime value

The phi-prime value for the growth parameter estimates of *S. maderensis* in the landings of the artisanal fishery of Montserrado County, Liberia is 2.412, Figure 5.

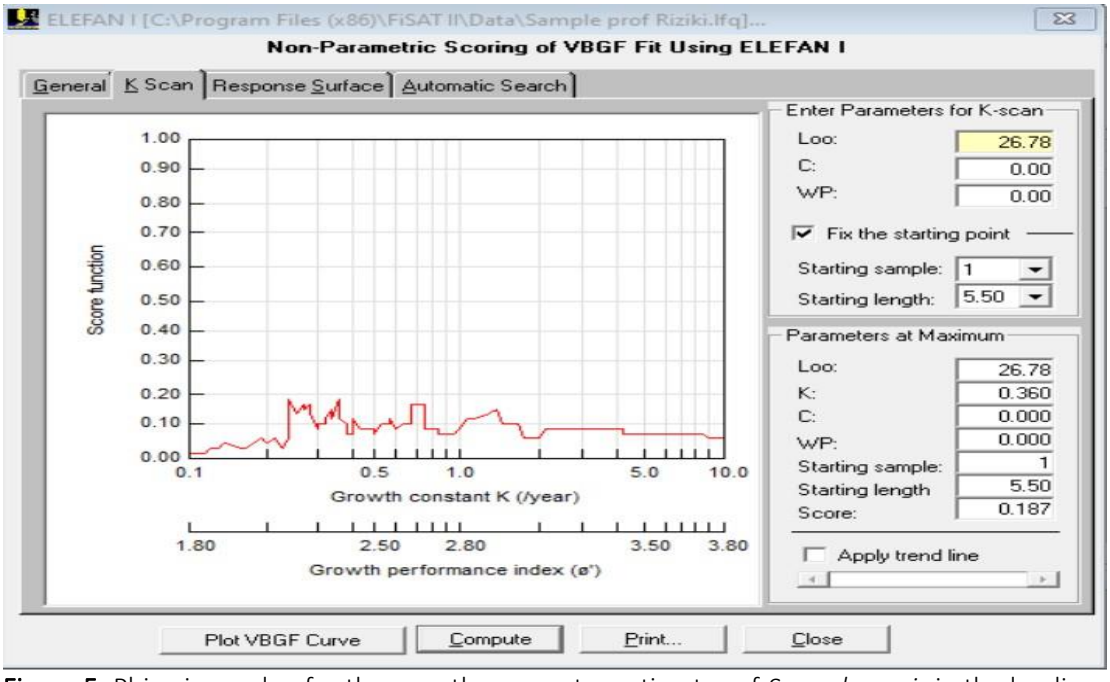


Figure 5: Phi-prime value for the growth parameter estimates of *S. maderensis* in the landings of the artisanal fishery of Montserrado County, Liberia.

Mortality parameters

Total Mortality (Z)

The result for total mortality (Z) parameter estimate using linearized length-converted catch curve for *S. maderensis* is 1.33y^{-1} Figure 6.

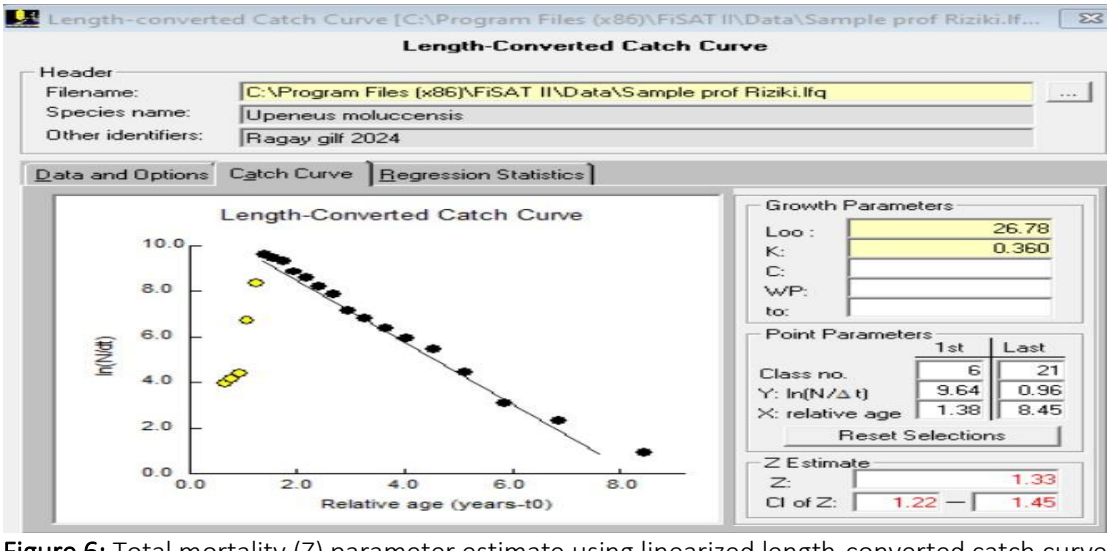


Figure 6: Total mortality (Z) parameter estimate using linearized length-converted catch curve of *S. maderensis* in the artisanal landings of Montserrado county, Liberia.

Natural mortality (M)

The natural mortality (M) parameter estimate using the Pauly's empirical equation for *S. maderensis* in the artisanal fishery of Montserrado County, Liberia is 0.88y^{-1} Figure 7.

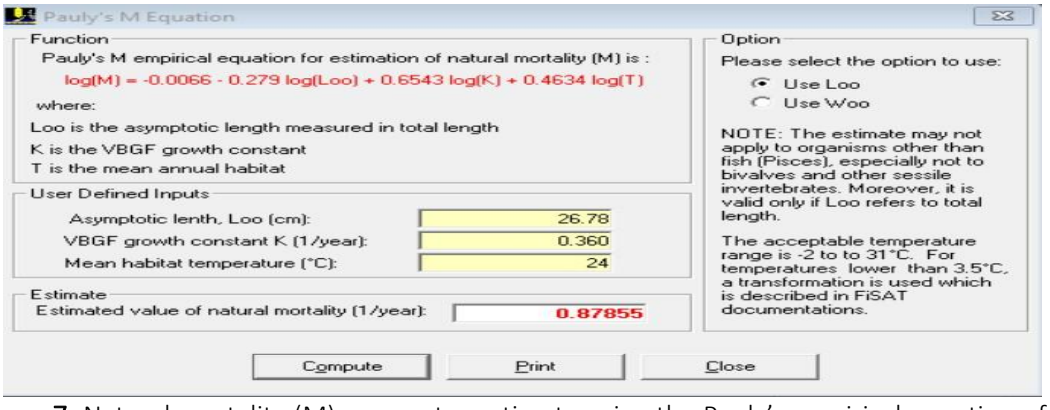


Figure 7: Natural mortality (M) parameter estimate using the Pauly's empirical equation of *S. maderensis* in the landings of the artisanal fishery of Montserrado County, Liberia

Fishing mortality

Fishing mortality (F) is estimated by taking the difference between total mortality (Z) and natural mortality (M), thus given Z as 1.33y^{-1} and M as 0.88y^{-1}, the estimated fishing mortality for this study is given as 1.33y^{-1} - 0.88y^{-1} = 0.45y^{-1}.

Exploitation rate (E)

The exploitation rate (E) was estimated by taken the reciprocal of fishing mortality (F) upon total mortality (Z). Thus, the exploitation rate (E) = 0.45/1.33 = 0.34y^{-1}.

Gonadosomatic index

The monthly variation of gonadosomatic index for *Sardinella maderensis* (flat herring) in the artisanal landings of Montserrado County, Liberia is shown Figure 8.

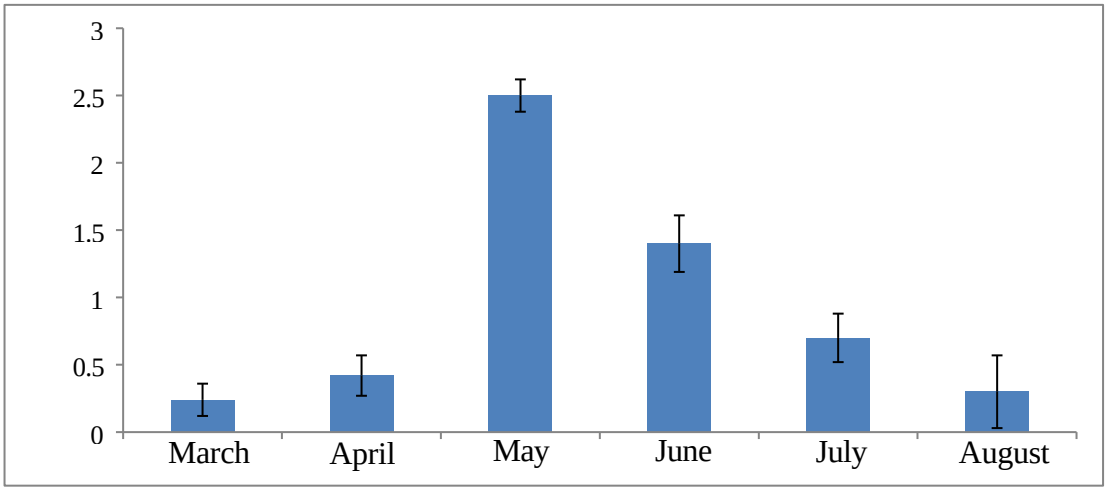


Figure 8: Monthly variation of gonadosomatic indices for *S. maderensis* in the artisanal landings of Montserrado County, Liberia

Maturity stage

The monthly variation of maturity stage classification for *S. maderensis* in the landings of the artisanal fishery in Montserrado County, Liberia is shown in Figure 9.

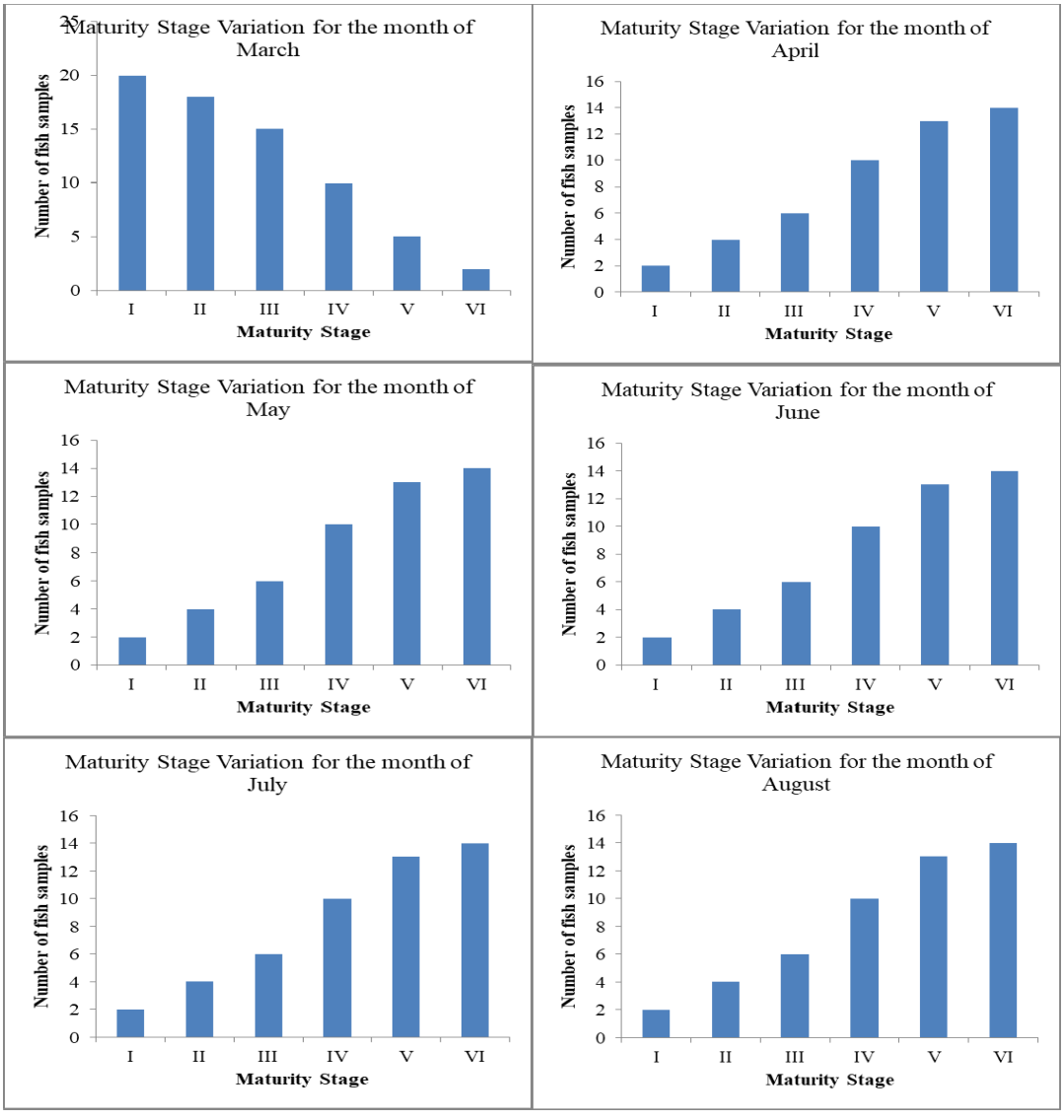


Figure 9: Monthly variation of maturity stage for *S. maderensis* in the artisanal landings of Montserrado County, Liberia.

Discussion

Growth parameters (L∞ and K) of *Sardinella maderensis*

The growth parameter estimates of this study were L∞ of 26.78cm and K of 0.36 year^{-1} in the landings of the artisanal fishery of Montserrado County, Liberia. Samb (1988), reported L∞ value of 37.5cm and growth curvature (K) of 0.30 year^{-1} off the coast of Senegal, while Showers (1996), reported L∞ value of 29.6cm and K of 0.30 year^{-1} in the artisanal landings of the western area fishing district, Freetown, Sierra Leone. Gheno & Le Guen (1968), reported L∞ value of 24.9 cm and growth

curvature (K) of 0.99 year^{-1} in the open waters of DRC. According to Djama & Younbi-Tienctheu., (1989), L∞ of 37.5cm and K of 0.34 year^{-1} in the open waters of Nigeria where observed. A study conducted by Beverton and Holt (1956) on growth and mortality estimates of *S. maderensis*, reported L∞ of 27.25 cm and K of 1.26 year^{-1} for length frequency data in coastal waters of Cameroon. Wehye (2017) observed L∞ of 44.63 cm and K of 0.38 year^{-1} *S. maderensis* in the Liberian artisanal fishery.

However, on comparative analysis of Phi-prime values, a parameter that have been shown to be remarkably the same between different populations of the same species as long as similar units and definitions are applied do not show much variation from Phi-prime values in fish base (Table 1). Comparing the Phi-prime value of this study (2.41) a test value to show the degree of conformity of growth parameter estimates of this study to other studies of the same species do not reveals significant variation from Phi-prime values of other studies (2.29 in Tunisia to 2.87 in Senegal (Table 1).

Table 1: Comparative analysis for Phi-prime (ø) values of *S. maderensis* in fishbase.org and this study

Loo (cm)	Length Type	K (1/y)	t0 (years)	M (1/y)	Temp° C	Lm	Ø'	Country	Locality	Questionable	Captive
24.9	TL	0.990			26.6		2.79	Congo	Pointe Noire	No	No
25.5	TL	0.298	-1.15		19.0	16.5	2.29	Tunisia		No	No
26.78	TL	0.360		0.88	24		2.41	Liberia	Montserrado	No	No
28.4	TL	0.499		0.70			2.60	Congo	Congo, Pointe- Noire	No	No
29.1	TL	0.830			26.6		2.85	Cameroon		No	No
29.4	TL	0.480		1.12	28.6		2.62	Nigeria	Lagos Lagoon	No	No
29.6	FL	0.300			26.6		2.42	Sierra Leone		No	No
32.5	TL	0.590			26.6		2.79	Cameroon	Lobe Estuary	No	No
35.0	TL	0.608			20.0		2.87	Senegal		No	No
37.5	FL	0.300			20.0		2.63	Senegal		No	No
37.5		0.340			22.0		2.68	Nigeria	Entered as 'Niger', but probably Nigeria.	No	No

Source: *fishbase.org*

Mortality and exploitation rate

The instantaneous total mortality coefficient (Z) in this study was estimated as 1.33 year^{-1} using the catch curve routine in FiSAT II software. Beverton and Holt (1956), reported an instantaneous rate of total mortality (Z) estimate using the Shepherd (1987) Length Composition Analysis (SLCA) in the Electronic Length Frequency Analysis (ELEFAN 1) routine as 1.22 year^{-1} off the coast of Kribi, Cameroon. According to Wheye (2017), the instantaneous rate of total mortality of *S. maderensis* in the Liberian coastal waters was estimated as 1.24 year^{-1} using the catch curve in FiSAT II software. Pauly *et al.* (2000) reported a natural mortality (M) estimate for *S. maderensis* at a mean water temperature of

28^0C as 0.46 year^{-1}. Fischer *et al.* (1981), reported on the instantaneous rate of natural mortality (M) of *S. maderensis* as 0.74 year^{-1} while Wehye (2017) estimated the natural mortality (M) of 0.81 year^{-1}. This study estimated the natural mortality (M) as 0.88 year^{-1} using the Pauly's empirical equation which does not show significant variation in natural mortality estimates of other studies. Fischer *et al.* (1981), reported fishing mortality (F) of *S. maderensis* as 0.10 year^{-1}, Wehye (2017) estimated a fishing mortality (F) of 0.43 year^{-1}. This study estimated fishing mortality (F), by taking the difference between total mortality (Z) and natural mortality (M), as 0.45 year^{-1}. The estimated F value show significant variation from the study of Fischer et al., (1981) in Kribi, Cameroun but similar to the one reported by Wehye *et al*. (2017) in the coastal waters of Liberia. Bintoro *et al.* (2019), reported an exploitation rate (E) estimate of 0.79 on the biology and population dynamics of *S. maderensis* in Bali Strait Waters, Indonesia, implying an over exploited state of the stock. Fischer *et al.* (1981), reported an exploitation rate (E) of 0.12 in Kribi, Cameroon, implying an under exploited stock, while Wehye (2017), reported an exploitation rate (E) and maximum exploitation rate (E_{max}) of 0.34 and 0.36 respectively, implying an under exploited state of *S. maderensis* in the coastal waters of Liberia. Comparing the above results with result of this study with an exploitation rate (E) estimate of 0.34 imply *S. maderensis* in the commercial landings of the artisanal fishery of Montserrado County, Liberia is under-exploited.

Gonadosomatic index and maturity stage

The monthly gonadosomatic index (GSI) in this study suggest highest peak values of 2.5 and 1.5 for the months of May and June respectively. Meaning the likelihood period for spawning is during the months of May and June which coincide with the onset of the rainy season when nutrient input in to the coastal waters as a result of erosion from the main land is high enough to prompt the increase in primary production that enhances gonad development and maturation. The monthly maturity stages of *S. maderensis* (flat herring) are ripe in the months of May and June, suggesting an additional likelihood period of spawning.

Conclusions

Based on the result of growth, mortality and exploitation status of *S. maderensis* in the artisanal landings of the Montserrado County in Liberia, the stock is under exploited. Monthly gonadosomatic indices and maturity stage suggest the likely spawning period to be at the onset of the raining seasons (May/June) when erosion from the main land has drained nutrients in the coastal waters prompting plankton blooming.

Recommendations

From the conclusions above, it is recommended that fishing effort be increase in the artisanal fishery by issuing more license to fishing crafts to ensure sustainable harvest of *S. maderensis* in the coastal waters of Montserrado County, Liberia. It is also recommended that for fisheries regulation on closed season, the months of June and July should be considered for closed season period as the spawning season for *S. maderensis* is likely to take place during these periods base on the findings of this study.

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