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Growth, Mortality and Exploitation of *Sardinella maderensis* (Lowe, 1838) in the Liberian coastal waters

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Abstract

This study examined some aspects of population dynamics of 1776 specimen of *S. maderensis* (Lowe, 1988) from Liberian coastal waters, from April 2013 to September 2013 (total of six months) using the FiSAT II for analysis. From the results, the growth was assumed to follow the von Bertalanffy growth function with asymptotic length (L_∞) and the growth coefficient (K) estimated at 44.63 cm total length and 0.38 $year^{-1}$ respectively. The growth performance index, longevity and the theoretical age at birth (t_0) were estimated as 2.88, 7.51 years and -0.387 $year^{-1}$ respectively. The length at first capture (L_{c50}=13.99 cm) was lower than the length at first maturity (L_{m50}=29.75 cm), an indication that most of the harvested stock were juveniles. Instantaneous rate of total mortality, natural mortality and fishing mortality were estimated as 1.24 $year^{-1}$, 0.81 $year^{-1}$ and 0.43 $year^{-1}$ respectively. The current exploitation rate (E) and maximum exploitation rate (E_{max}) were calculated as 0.34 and 0.36 respectively. Results from the study indicated that the exploitation of *S. maderensis* is at the maximum sustainable yield coupled with the presence of growth overfishing and intense fishing pressure. Therefore, urgent management actions including increasing fishing gears mesh size and regulating fishing effort is needed to protect the *S. maderensis* stock.

Keywords: Liberia; *Sardinella maderensis*; Growth; Mortality; Exploitation rate

Introduction

Sardinella maderensis also known as flat 'sardinella' forms part of the commercially important fish species of Liberia which prefers areas of lower salinities close to the mouth of river. Though *S. maderensis* appears throughout the year in Ivory Coast coastal waters with a strong reduction from May to July due to the transition from warm season to cold season, adults *S. maderensis* are more sedentary [1,2]. *S. maderensis* fishery is of great importance to fishing households within most coastal communities in Liberia, both economically and food security wise. As a result, *S. maderensis* fishery like other commercially important fish species in Liberia is currently subjected to intense fishing pressure. Intensive fishing pressure on marine biodiversity by location and depth has led to decline of marine capture fisheries [3,4].

In Liberia, factors such as poor fisheries data collection, limited resources, conflicts and illegal, unregulated and unreported (IUU) do not only make it difficult to estimate the status of almost all of the marine biodiversity but also presents a great challenge to fisheries managers [5,6]. However, Togba [7] reported that *Sardinella, Barracudas*, Croakers, Sharks and *Ilisha africana* constituted 83% and 59.06% of local fish supply in 2004 and 2005 respectively; indicating that there has been a declined in fish catches.

Furthermore, the paucity of information on population parameters and biology pertaining to commercially important fish species within Liberian coastal waters cripples any management interventions geared towards sustainable fisheries in Liberia. It is against this backdrop that the present study sought to estimate some population parameters of *S. maderensis* residing in Liberian coastal waters to enhance already existing management interventions.

Materials and Methods

Study area

The coastline of Liberia is 579 kilometres in length and consist of nine (9) coastal counties with an exclusive economic zone (EEZ) that extends 200 nautical miles off-shore, characterised by relatively warm waters with low nutrient content.

Figure 1: Map showing the study area.

The study focussed on eight counties namely Grand Cape Mount, Montserrado, Grand Bassa, River Cess, Sinoe, Maryland and GrandKru (Figure 1). A two-stage sampling strategy was applied in the selection of the study areas, namely the intense level of fishing activity and geographical location. The main source of livelihood for majority of inhabitants within the study areas was fishing and its related activities. However, a few are engaged in alternative source of livelihoods.

Data collection

The length frequency data was collected by Fisheries Enumerators of the Bureau of National Fisheries (BNF) from artisanal fishers from selected landing sites in eight (8) of the nine coastal counties for six months from April, 2013 to September, 2013 (6 months). Data was collected from fishers who operated mostly with multifilament fishing gears with morphometric measurement recorded on-site. For instance, total length was measured to the nearest 0.1 cm using the 100 cm measuring board while the weight was weighed using electric weighing scale. Identification of specimen was done to the species level using identification keys by Fischer et al. [8,9]. In all, a total of 1,776 specimens of *S. maderensis* were sampled.

Growth parameters

The growth rate (K), asymptotic length (L∞) and the growth performance index (Φ) of the fish was assumed to follow Von Bertanlaffy Growth Function (VBGF). These growth parameters were obtained using the VBGF fitted in FISAT II [10]. According to VBGF as expressed below, individual fishes grow on average towards the asymptotic length at an instantaneous growth rate (K) with length at time (t) following the expression: $L_t = L\infty\left(1\text{-}e^{-K(t\text{-}to)}\right)$ [11]. The theoretical age at birth (to) was calculated using the empirical formula: $\log10\left(-t_0\right) = -0.3922 - 0.275 * \log10L\infty\text{-}1.038*\log10K$ [11]. The longevity (tmax) was estimated as: tmax=3/K + to Pauly [12]. The growth performance index was calculated from the below expressed equation: $(\Phi) = 2\log L\infty + \log K$ [13].

Mortality parameters

The total instantaneous mortality rate (Z) was estimated using length converted catch curve method as implemented in FiSAT II. Natural mortality rate (M) was estimated using Pauly's empirical relationship, using a mean surface temperature (T) of 25.5°C:

Log M = -0.0066 - 0.279 1og L∞ + 0.6543log K + 0.4634log T [14],

Where M is the instantaneous natural mortality, L∞ is the asymptotic length, T is the mean surface temperature and K refers to the growth rate coefficient of the VBGF. Fishing mortality (F) was calculated using the relationship: F=Z – M [15], where Z is the total mortality, F the fishing mortality and M is the natural mortality. The exploitation level (E) was obtained using the relationship: E=F/Z [15].

Length at first capture (L_{c50}) and maturity (L_{m50})

The ascending left arm of the length converted catch curve incorporated in FiSAT II tool was used to estimate the probability of length at first capture (Lc50) in addition to the length at both 25 and 75 captures which corresponded to the cumulative probability at 25% and 75% respectively. The probability of capture gives clear idea about the estimate of the real size of the fish in the fishing area that is being caught by specific gear. It is an important tool for fisheries managers in sustainably managing a target fishery, because it helps would be managers determining the minimum mesh size of a fishing fleet. The length at first maturity was estimated using the expression: Length at first maturity $(L_{m50}) = (2 * L\infty)/3$ [16].

Relative yield per recruit (Y'/R)

The relative biomass per recruit (B'/R) was estimated as B'/R=(Y'/R)/F. Emax which depicts exploitation rate producing maximum yield, $E_{0.1}$ highlighting exploitation rate at which the marginal increase of Y'/R is 10% of its virgin stock with $E_{0.5}$ implying exploitation rate under which the stock is reduced to half its virgin biomass were computed using the procedure incorporated using the Knife-edge option fitted in the FiSAT II Tool.

Data Analysis

The length frequency data were pooled into groups with 1cm length intervals. Then the data was analyzed using the FiSAT II (FAO-ICLARM Stock Assessment Tools) software [17].

Result

Length frequency distribution

The monthly pooled length frequency data from the 1776 specimen of *S. maderensis* were group into one-centimeter interval. Figure 2 shows the length frequency distribution for the assessed fish species. From Figure 2, midlength of 19.5 cm showed the highest frequency distribution, follow by length 22.5 cm. The highest length recorded throughout the study period was 42 cm.

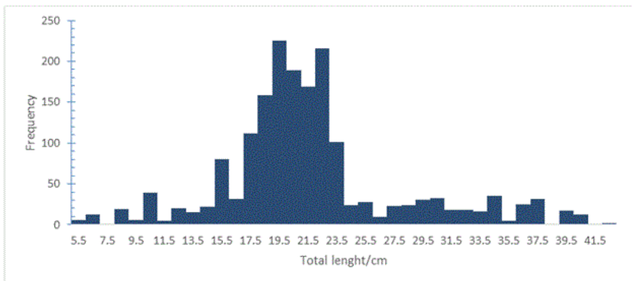

Figure 2: Length frequency distribution of *Sardinella maderensis* from the fisheries waters of Liberia.

Growth Parameters

The Length at infinitive (L∞) and growth constant (K) were estimated at 44.63 cm and 0.38 year-1 respectively with its longevity as 7.51 years. The growth performance index (Φ) and theoretical age at birth (t0) were estimated at 2.88 and -0.387 year respectively. Using the growth parameters (L∞, K and t0), the VBGF for length at time (t) was expressed as:

$L_t = 44.63\ (1\text{-}e^{-0.38\ (t\text{-}(-0.387)})$.

Figure 3 below showed the restructured length frequency with superimposed growth curves with bimodal population structure, indicating probably the existence of six cohorts within the population.

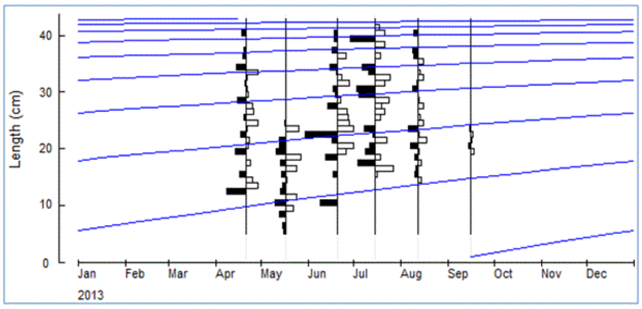

Figure 3: Restructured Length frequency distribution output from FiSAT II with superimposed growth curves (Dark bars=actual frequency bars & White bars=reconstructed bars).

Mortality coefficients and current exploitation rate

Figure 4 showed the calculated motilities from FiSAT II output of the length converted catch curve. The instantaneous total mortality coefficient (Z) was estimated as 1.24 $year^{-1}$. The natural mortality (M) and fishing mortality (F) were estimated to be 0.81 $year^{-1}$ and 0.43 $year^{-1}$ respectively. The current exploitation rate was estimated as E=0.34.

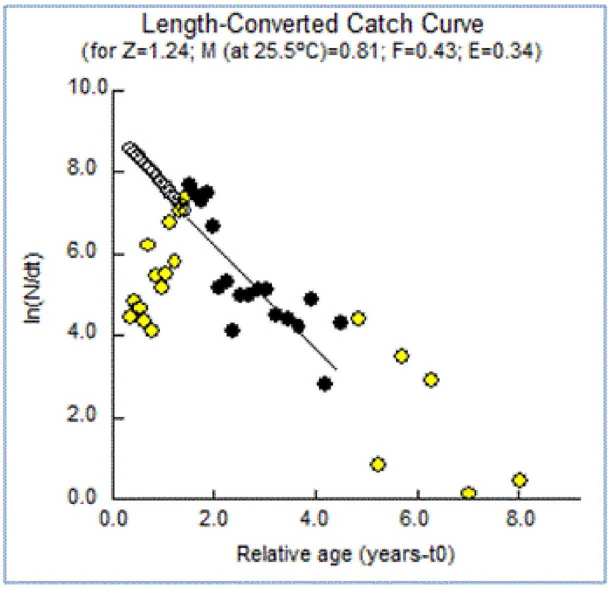

Figure 4: FISAT II output of linearized length-converted catch curve for *S. maderensis* (Yellow dots are dots used in calculation and White dots are dot not used in calculations).

Length at first capture (L_{c50}) and length at first maturity (L_{m50})

The probability of capture of *S. maderensis* at 25%, 50% and 75% which provides a clear indication of the estimated real size of fish in the fishing area that are being caught by specific gear were estimated as: L_{25}=12.41 cm, L_{50}=13.99 cm and L_{75}=15.58 cm (Figure 5). Therefore, the length at first capture (L_{c50}) was 13.99 cm. The length at first maturity (L_{m50}) was estimated at 29.75 cm.

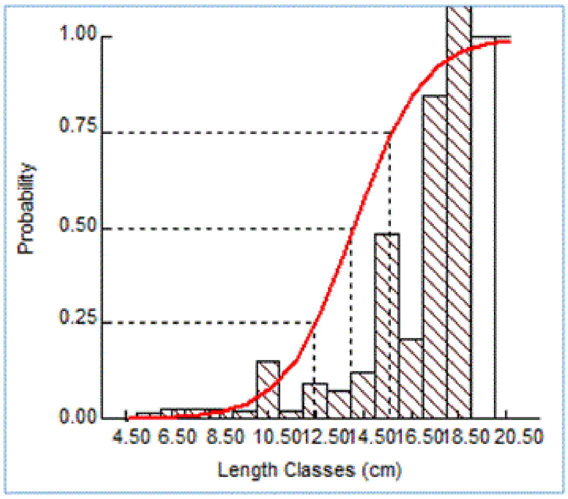

Figure 5: FiSAT II output of the probability of capture of *S. maderensis* in the fisheries waters of Liberia (0.2, 0.50 and 0.75 relates to 25%, 50% and 75% respectively).

Relative yield per recruit (Y'/R)

The Beverton and Holt relative yield per recruit model in figure 6 showed that the indices for sustainable yield were 0.236 for optimum sustainable yield ($E_{0.5}$), 0.363 for the maximum sustainable yield (E_{max}) and 0.254 for economic yield target ($E_{0.1}$).

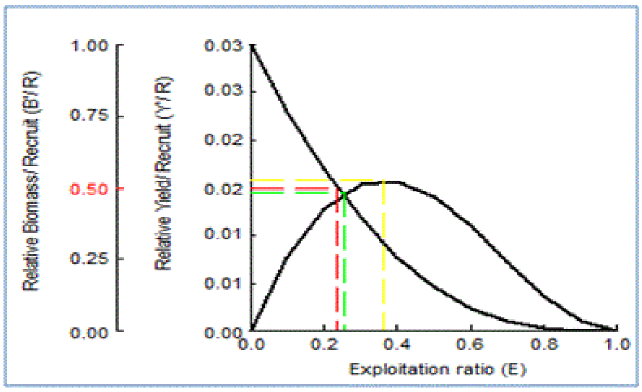

Figure 6: Beverton and Holt's relative yield per recruit and average biomass per recruit models, showing levels of yield indices for *S. maderensis* in the Coastal waters of Liberia (Red dashes=$E_{0.1}$, Green dashes=$E_{0.5}$ and Yellow dashes=E_{max}).

Discussion

Arguably, the present study appears to be the maiden work done on *S. maderensis* stock resident in Liberian coastal waters, therefore information gained will serve as a springboard for further research pertaining to this commercially important species. The asymptotic length in the present study is greater than results reported by other researchers (Table 1). This differences could be attached to factors such as the selectivity of the gears, the sampling methods and geographical locations. The estimated growth rate (K=0.38 $year^{-1}$) from this study was favourable with estimates by Gabche et al. [18,19]. However, it was relatively lower than estimates from studies done elsewhere (Table 1), possibly as a result of variation in geographical locations, the data analysis method used and the size classes obtained [20]. Further, the growth rate (K) of this study was within the range: 0.34 per year and 0.67 per year, suggesting that *S. maderensis* is an intermediate growing fish species, evinced by its lifespan of 7.51 years [21]. The growth performance index (=2.88) appeared to be in line with estimates from other studies (Table 1). This finding demonstrates that they are of similar taxonomic family. Further, the growth performance index indicates the important availability of food and other favorable environmental conditions [1].

TL∞	K	Φ	t0	Countries	Authors
44.63	0.38	2.88	-0.387	Liberia	Current study
33.6	0.65	2.86	0.24	Benin	Sossoukpe et al., 2016 [1]
27.24	0.48	1.76	-0.06	Cameroon	Gabche & Hockey, 1995 [2]
35	0.6	2.88		Senegal	Postel, 1955 [22]
37.5	0.34	2.68	-0.25	Nigeria	Marcus, 1989 [19]
32.5	0.59	2.79		Cameroon	Djama et al., 1989 [23]
24.93	0.98	2.79	0.024	Congo	Gheno & Le Guen, 1968 [24]

Table 1: Estimated growth parameters of *S. maderensis* of the fisheries waters of Liberia compared to those off other regions.

The length at first maturity (L_{m50}=29.75 cm) was relatively higher than the length at first capture (L_{50}=13.99 cm), signifying that the *S. maderensis* stock are harvested before they could reach the matured stage, a characteristic feature of growth overfishing [19]. Furthermore, the ratio $L_{c50}/L\infty$ from the study was estimated as 0.31, relatively lower than 0.5, which implied that the harvested catch is mostly made up of small sized *S. maderensis* [25]. This observation affirmed the earlier assertion that growth overfishing exists within the fishery of *S. maderensis* resident in Liberian coastal waters.

The natural mortality (M=0.81 $year^{-1}$) was greater than the fishing mortality (F=0.43 $year^{-1}$), contrary to estimates reported by Sossoukpe et al. [1] from Benin (M=1.30 $year^{-1}$; F=2.62 $year^{-1}$). This observation could be due to the fact that *S. maderensis* stock in Liberian coastal waters is more susceptible to natural mortality conditions than to fishing gears. The exploitation rate ($E_{current}$=0.34) from the present study was lower than 0.5, depicting that the *S. maderensis* stock is currently underexploited. Further, the current rate of exploitation (Ecurrent=0.34) of *S. maderensis* was slightly lower than maximum exploitation rate (E_{max}=0.36). Such observation indicates that the maximum sustainable yield for *S. maderensis* could be reached earlier than expected amidst continuous and intensive fishing as well as the use of the small mesh size fishing gears within the coastal waters of Liberia.

Conclusion

This study has shown that the stock of *S. maderensis* within the Liberian coastal waters is experiencing exploitation rate close to the maximum sustainable yield amidst the presence of heavy fishing pressure. Further, growth overfishing is currently present within the *S. maderensis* stock. Therefore, to ensure sustainable exploitation of *S. maderensis* stock, fishing effort should be regulated along with increase in mesh size.

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Conflict of Interest

No conflicts of interests

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