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Some Population Parameters of the *Sardinella maderensis* (Lowe, 1838) in the Sombreiro River of Niger Delta, Nigeria

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Research Article

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Abstract

A study was conducted to estimate the growth and stock characteristics of the *Sardinella maderensis* (Lowe, 1838) from Sombreiro River of Niger Delta, Nigeria. Results obtained revealed that mean total length and the mean weight of *S. maderensis* ranged between 4.1cm to 18.5 cm and 5g to 55.5g respectively. The b value of the length-weight relationship was 2.58 thus**,** the species could be categorized as displaying allometric negative growth and condition factor was very high, it ranged from 3.04 to 4.43. The estimated von Bertalanffy growth parameters (VBGP) of L∞, growth coefficient (k) and age at zero length (t_0) were 23.31cm, 0.54 and -0.03/year respectively. The species showed year round recruitment patterns having two peak periods during April and July. The total mortality (Z) was 2.74 year-¹., the natural mortality rate (M) and fishing mortality (F) were 1.32 and 1.42 respectively. The estimated fishing mortality (Z-M=F) stood at 0.518. The length-based index of growth performance (Ø'– phi prime) for *S. maderensis* was estimated at 2.46. The length at first capture L_{50} was 27.31 cm. The exploitation rate (E_{max}) was 0.421 whereas ($E_{0.1}$) was observed to be 0.355 indicating that that the level of exploitation is already high and to obtain the maximum sustainable yield, the present level of fishing effort should be reduced through appropriate fishing regulation techniques..

Keywords: Length- weight relationship, condition factor, population parameters, *Sardinella maderensis*, Sombreiro River, Nigeria

Sombreiro Nehri'ndeki (Nijer Deltası, Nijerya) *Sardinella maderensis*'in (Lowe, 1838) Bazı Popülasyon Parametreleri

Özet

Bu çalışma, Nijerya'daki Nijer Deltası'nın Sombreiro Nehri'ndeki *Sardinella maderensis* (Lowe, 1838), populasyonlarının bazı büyüme ve stok özelliklerini belirlemek için yapılmıştır. Elde edilen sonuçlar, *S. maderensis*'in ortalama toplam uzunluk ve ortalama ağırlığının sırasıyla 4,1 cm ile 18,5 cm ile 5 g ile 55,5 g arasında olduğunu göstermiştir. Uzunluk-ağırlık ilişkisinin b değeri 2,58 olarak tespit edilmiştir, bu nedenle türler, allometrik negatif büyüme gösteriyor şeklinde kategorize edilebilir. Bu türün durum faktörü 3,04 ile 4,43 arasında çok yüksek olarak belirlenmiştir. Tahmini L∞, von Bertalanffy büyüme parametreleri (VBGP), büyüme katsayısı (k) ve sıfır uzunluktaki yaş (t0) sırasıyla 23,31cm, 0.54 ve -0.03 / yıl olarak belirlenmiştir. Türler, Nisan ve Temmuz aylarında iki tepe periyodu olmak üzere yıl boyunca dağılım göstermektedir. Toplam mortalite (Z) 2.74 yıl, doğal ölüm oranı (M) ve balıkçılık ölümleri (F) sırasıyla 1,32 ve 1,42 olarak bulunmuştur. Tahmini balık ölümü (Z-M = F) 0,518 seviyesinde gerçekleşmiştir. *S. maderensis* için uzunluk temelli büyüme performansı endeksi (Ø'– phi prime) 2.46 olarak hesaplanmıştır. İlk yakalama L50'deki uzunluk 7,19 cm olarak bulunmuştur. E_{max} (0,421) ve $E_{0.1}$ (0,355) değerleri türden maksimum verim alınabilmesi için uygun balıkçılık düzenlemeleri ile mevcut avlanma baskısının azaltılması gerektiğini göstermektedir.

Anahtar kelimeler: Uzunluk-ağırlık ilişkisi, durum faktörü, populasyon parametreleri, *Sardinella maderensis*, Sombreiro Nehri, Nijerya

INTRODUCTION

Clupeids are chiefly marine coastal and schooling fishes; some freshwater and anadromous (Gaudant, 1991) widely distributed in the tropical and subtropical region (Riede, 2004) including the entire Mediterranean and the Black sea (Froese and Pauly, 2017). These are small, silvery fishes with fusiform, or strong compressed body. Three genera consisting of six species have been identified in Nigerian freshwaters Adesulu and Sydenham (2007). *Sardinella maderensis* belonging to family clupidae. *S. maderensis* resembles *Sardinella aurita*, but pelvic fin with 1 unbranched and 7 branched rays and no black spot on hind part of gill cover, but a faint gold or black area just behind gill opening (Tous et al., 2015). The species has maturity mean length of 13.4 cm and common length 25 cm (Whitehead, 1985).

The population of the *S. maderensis* is declining due to overfishing, with the average size of fish in the catch reducing and as a result, the International Union for Conservation of Nature has rated its conservation status as "vulnerable (Tous et al., 2015). The fish species is considered as one of the most important fishery resources in marine and brackish water in Nigeria because of its abundance in the landings. In Nigeria, *S. maderensis* accounts for 15,115 tonnes of fish production by species in 2015 (NBS, 2017). In spite of its economic importance, there is paucity of information on population parameters and biology of *S. maderensis* in Nigerian water bodies.

An approach towards conservation and management of the population of this particular fish species demands the generation of information on the stock or population structure. Stock assessment generally aims to estimate the current stock size and its potential for increased in size (de Graaf, 2015). Generally the size of the total stock of a race, species, (or) group of species vary from year to year and from one region of the world to the other. These fluctuations in abundance are caused by natural factors and also by man’s activity. The estimation of stock abundance is important in determining the effects of fishing and environmental disturbances as well as in estimating parameters such as length-weight relationships, recruitment variability, mortality and stock status. These information are required for consideration of management measures of the species in the future. As there is currently no knowledge of *S. maderensis* stock structure in the Sombreiro River. Therefore, this study was carried out to estimate population parameters, yield per recruit, biomass and MSY on *S. maderensis* in order to formulate management and conservation policies.

MATERIALS and METHODS

Sombreiro River system (between latitude 6^0 30^1 and 7^0 0^1 E, and longitude $4^0 12^1$ N and 60^0 17^1 N) is located in Rivers State in the Niger Delta region of Nigeria (Figure 1). It has its source from the Niger River, runs downwards into the Southern tip of the Niger Delta basin and empties into the Atlantic Ocean (Ezekiel et al., 2011). The middle reach of the Sombreiro River is brackish and appears turbid during the raining season. The extent of brackish in this river is between 117-132 km^2 Ssentongo et al. (1983) and Nduaguba (1983). Two distinct seasons is usually observed in a year. They include the rainy and dry season. The maximum temperature is between 26-28^{O}C and mean annual rainfall is 362.5 mm. The climate presents two distinct seasons; a rainy season (April - October) and a dry season, (November - March).

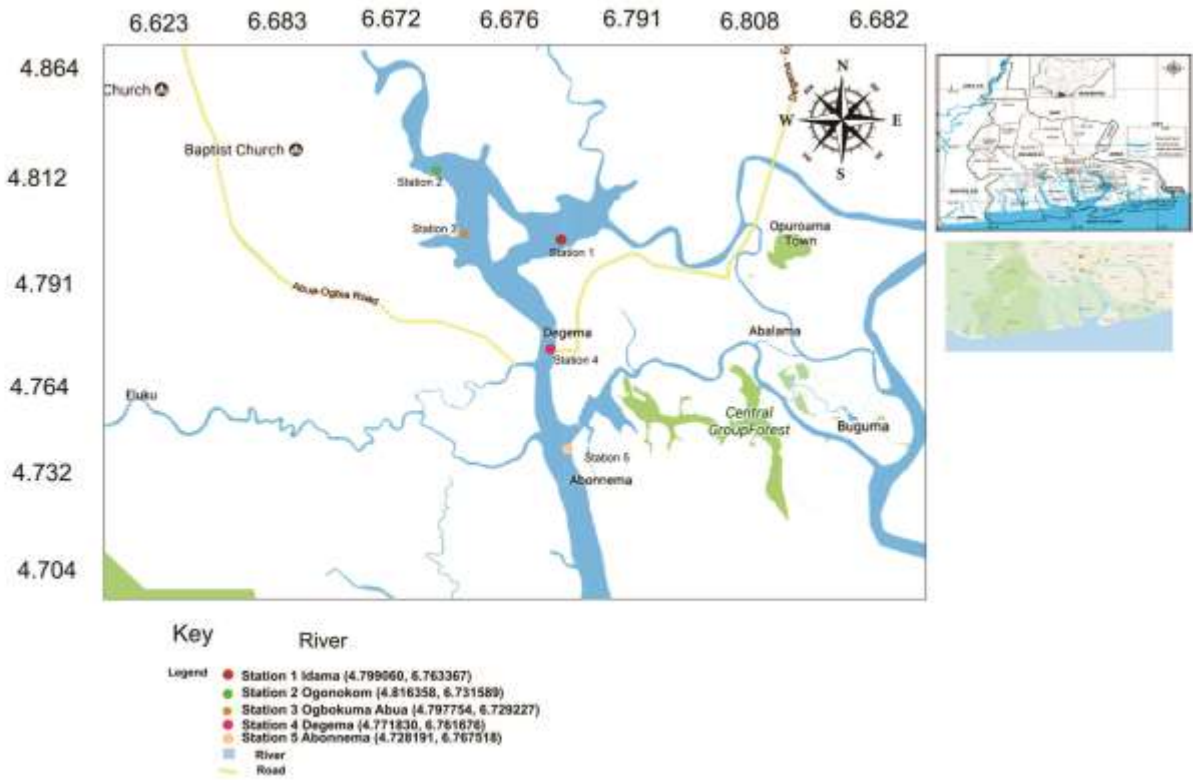

Figure 1. Map of Sombreiro River showing the study area

A total of 531 *S. maderensis* were collected monthly the period from January to December 2017 at five different stations (Degema, Ogonokomi, Ogbokuma Abua, and Abonnema) within the Sombreiro River.

These sites were chosen because they are the fishing and landing grounds of fishermen. Fishes were identified to species level based on Schneider (1990). Samples were transported to the laboratory for further evaluation. Total Length (TL) and Standard Length (SL) were measured to the nearest 0.01 cm using digital slide calipers and graduated plastic measuring board and total Body Weight (BW) was weighed by an electronic balance with 0.01 g accuracy for each individual.

The length/weight relationship of the fish was described by the equation: $W= aL^b$, where W= weight in grams, L= total length in centimetres, and a and b are regression constants. This can be expressed in logarithmic form as Log W= log a + b (log L) suggested by Le Cren (1951). Length and weight data were used to calculate the Fulton condition factor, 'k' from the equation: $k= 100\ W/L^3$, where W = weight in grams, and L = length in centimetres.

The growth parameters were estimated by fitting length frequency data into the von Bertalanffy growth function (VBGF) was used to describe the fish growth; $L_t = L_\infty (1\text{-exp}(-k(t\text{-}t0)))$

where Lt was the predicted length in the cm at age t, L∞ is the asymptotic length, K is the growth coefficient and t0 was the hypothetical age at which length of the fish is equal to zero (usually negative), (Haddon, 2011) which can be estimated from the empirical equation of Pauly (1983) as:

$\log 10\ (-t_0) = -0.3922-0.275 \log 10\ L_\infty - 1.038 \log 10\ K$

The total mortality coefficient (Z) was estimated by using Beverton and Holt's (1956) equation Z = K ((L∞ - L-) / (L∞ – L')) where Z is the instantaneous total mortality coefficient, L- is the mean length and L' is the length for which all fish of that length and longer are under full exploitation. Natural mortality coefficient (M) was calculated by using Pauly empirical formula (1980): Log M = -0.0066 – 0.279 Log L∞ + 0.6543 Log K + 0.4634 Log T; where T is the annual mean temperature. The fishing mortality coefficient (F) was computed as F = Z – M.

The recruitment pattern of the stock was determined by backward projection on the length axis of the set of available length frequency data as described in FiSAT II (Pauly and Caddy, 1985).

Growth performance index (Ø') was calculated by the equation given by Pauly and Munro (1984): 10 log 2 log k L Ø' ∞= +

Probability of capture against mid-length a resultant curve was used to compute the length at first capture (Lc_{50}). Length at first maturity (Lm_{50}) was estimated as: $Lm_{50} = (2 * L\infty)/ 3$ (Hoggarth et al., 2006)

Relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) were estimated using the model of Beverton and Holt (1959) as modified by Pauly and Soriano (1986) and incorporated in the FiSAT software.

RESULTS

Length-weight relationship and condition factor

As indicated in Table (1), the mean total length and mean weight of *S. maderensis* ranged between 4.1cm to 18.5 cm and 5g to 55.5g respectively. The weight of the fish strongly correlated with the total length (TL) with r^2 value of 0.89. The b value of the length-weight relationship was 2.58 thus**,** species could be categorized as displaying allometric negative growth. The value of (K) of the under study species was very high, it ranged from 0.52 to 7.82 and with mean value of 4.43 ± 0.07 (Table 1).

Table 1. Length-weight relationship and condition factor of *S. maderensis* from Sombreiro River

Species	N	Total weight (g)		Total length (cm)		a	B	r^2	K	
		Mean±SE	Range	Mean±SE	Range				Mean±SE	Range
S. maderensis	531	24.27±0.40	5 - 55	8.29±0.08	4.1 - 18.5	-2.25	2.58	0.89	4.43±0.07	0.52-7.82

Growth parameters

Parameters of von Bertalanffy's equations were estimated as shown in Table 2. Asymptotic length stood at 23.31cm, growth coefficient (k) was estimated at 0.54 and age at zero length (t_0) stood at -0.03 year-¹ in the restructured form of the length-frequency data is presented as output of ELEFAN I in Figure 4.

Table 2. Growth parameters of *S. maderensis* from Sombreiro River

Von Bertalanffy's Growth parameters	ELEFAN-I
Asymptotic length (cm)	23.21
Growth coefficient (k)	0.54
Age at zero length (t_0) (yr)	-0.03
Growth Performance index (Φ)	2.46

Mortality parameters and exploitation ratio

The mortality parameters and exploitation ratio are shown in Table 3.Total mortality (Z) was found to be 2.74 year-¹. Fishing mortality was computed as 1.42 year-¹ and Natural mortality was 1.32 at an annual average sea surface temperature of 29.7° Figure 4. The estimated fishing mortality (Z-M=F) stood at 0.518.

Table 3. Mortality parameters and exploitation ratio of *S. maderensis* from Sombreiro River

Fishing mortality (F)	1.42
Natural mortality(M)	1.32
Total mortality (Z)	**2.74**
Exploitation ratio (E = F/Z)	0.518

The length-based index of growth performance (Ø' – phi prime) for *S. maderensis* was estimated at 2.46 (Table1 and Figure 2).

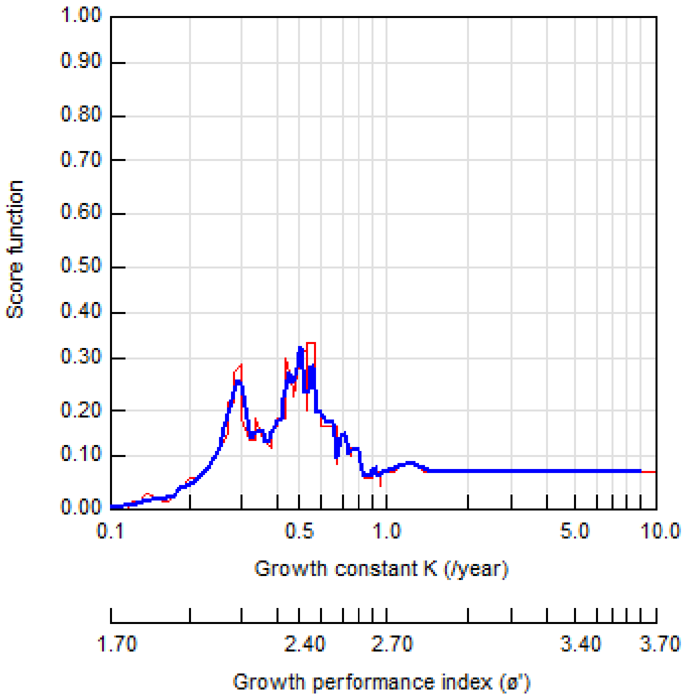

Figure 2. Growth Performance index of *S. maderensis* from Sombreiro River

Recruitment patterns

The recruitment patterns for *S. maderensis* is shown in Figure 3. Spawning capable individuals were recorded throughout the entire fishing period and the species showed year round recruitment patterns having two peak periods which occur in two nearly equal pulses. The minor peak during April and major peak during July.

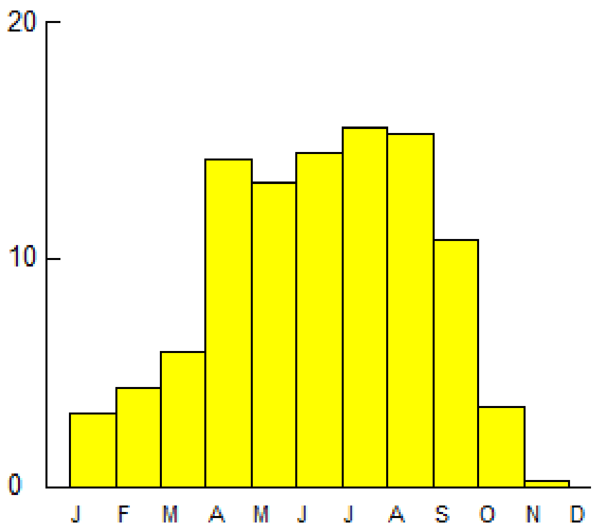

Figure 3. Recruitment patterns of *S, maderensis* from Sombreiro River

Figure 4 below showed the restructured length frequency with superimposed growth curves with bimodal population structure, indicating probably the existence of six cohorts within the population.

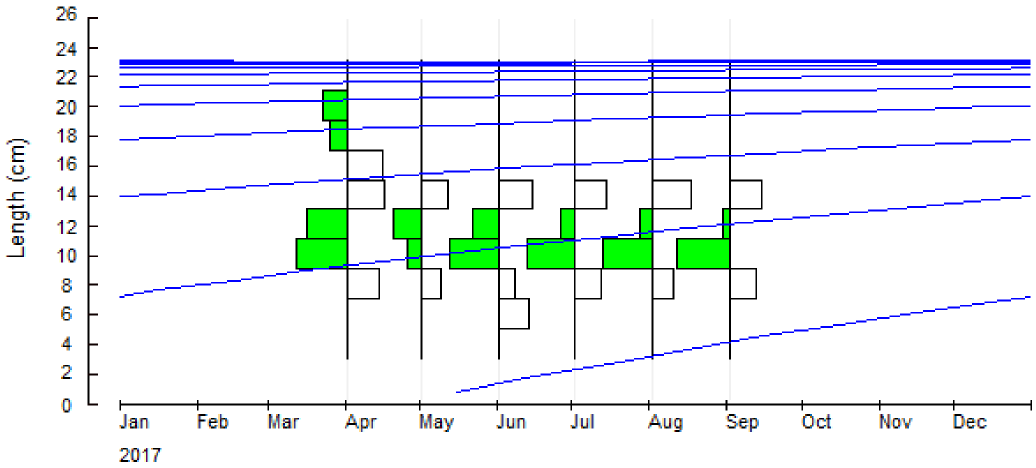

Figure 4. Length frequency distribution data and growth curve parameters using ELEFAN for *S. maderensis* from Sombreiro River

Figure 5 revealed the length at first capture L_{50} was 27.31cm, L_{25} estimated at 14.88cm and the length at which 75% fish are retained in the gear was estimated as 39.75cm.

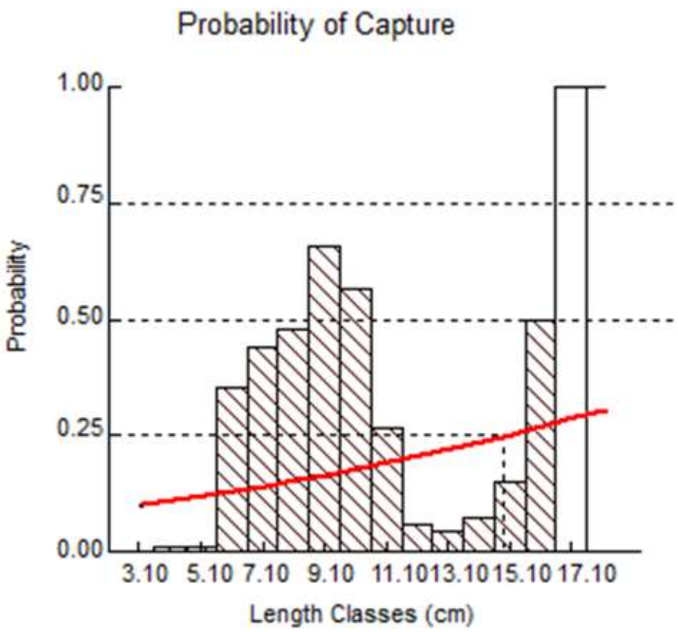

Figure 5. The probability capture curve showing the L_{25}, L_{50} and L_{75} of length converted catch curve

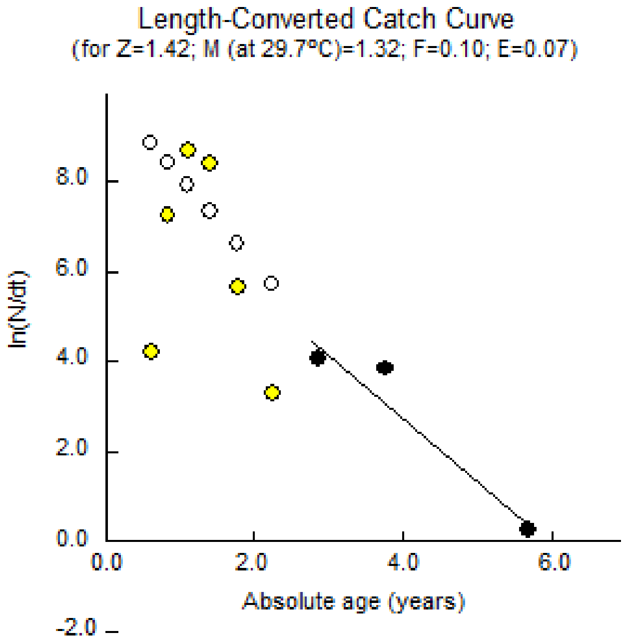

Figure 6. Length converted catch curve of *S. maderensis* using VBGF growth parameters

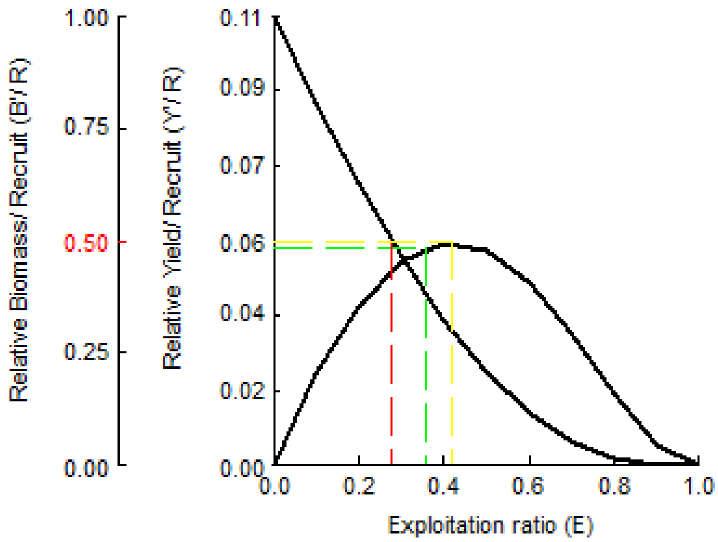

Figure 7. Relative yield per recruit and biomass per recruit curves of *S. maderensis* in Sombreiro River

Stock status of using Beverten and Holt's relative Y/R analysis

The relative yield-per-recruit (Y/R) and relative biomass-per-recruit (B/R) analysis by the knife-edge selection method. The exploitation rate (Emax) that gives maximum relative yield-per-recruit was 0.421. The exploitation rate at which marginal increase occurred in the relative yield-per-yield was 10% of its value at E = 0, whereas ($E_{0.1}$) was observed to be 0.355 (Figure 7). The exploitation rate ($E_{0.5}$) which corresponds to 50% of the virgin (that is., the unexploited stock) relative biomass-per-recruit was estimated to be 0.278.

DISCUSSION

Estimation of the population size of a fish stock for the purpose of its rational exploitation often requires knowledge of these relationships (Le Cren, 1951). Values of the exponent 'b' provide information on fish growth. The values of length-weight regression coefficient "b" in this study was 2.58 negative allometric growth pattern (b>3) meaning that the weight increase is made faster than the growth in length. This value is within the expected range of 2–4 reported by Tesch (1971), and 2.5 < b < 3.5 by Froese (2006). However, the negative allometric growth pattern obtained in this study for *S. maderensis* was in contrary with the positive allometric growth reported for this species in Nkoro River (Niger-Delta) (Abowei, 2009). The value of 'b' may be due to feeding, sex, state of maturity, metabolic activity and genetic nature (Wootton, 1990). The length-weight relationship provides means for finding out the condition factor which indicates the "Wellbeing of the fish". The condition factor was very high in this fish species, the values ranged from 3.04 - 4.43. This could be attributed to the length range of the sampled specimens. Salam et al. (2005) pointed out that 'K' remained constant with increasing in length and weight of fish.

In this study the values of asymptotic length ($L\infty$) and growth coefficient (k) were calculated as 23.31cm, and 0.54 respectively. The results are in agreement with Beverton and Holt (1959) who pointed out that the two parameters of growth, asymptotic length and growth coefficient are inversely proportionally to each other. It implies that fishes with high $L\infty$ should be with lower K values and those with lower $L\infty$ with higher K values. The estimated growth rate 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 (Kienzle, 2005). On the other hand, the $L\infty$ value (23.31cm) in this study was smaller than 37.5cm reported by Marcus (1989) from coastal waters around Lagos, Nigeria, on the same species. The difference may be due to the ecological differences, feeding variability and most importantly fishing pressure.

Age at zero length (t_0) stood at -0.03 year^{-1}. Amponsah et al. (2018) reported the age at birth (t_0) for the same fish species at -0.284 year^{-1} from coastal waters of Ghana. It has been reported that there must be some differences between growth characteristics among localities as a result of diversity and availability of dietary items, hydrographical and climatic conditions (Bartulovic et al., 2004).

In this study the value of growth performance index of *S. maderensis* was found to be 2.46. The result is lower than values reported for the same species by Amponsah et al., (2018) in coastal waters of Ghana and by Marcus (1989) in coastal waters around Lagos, Nigeria. The difference in values could be due to poor state of water quality in the study area as a result oil pollution and other human activities in and around the Sombreiro River. The value recorded in the current study was lower than recommended value for fishes in Africa. Baijot and Moreau (1997) estimated that the ϕ' mean value for some important fishes in Africa have a range of 2.65 - 3.32, which they considered as low. According to Kalhoro et al. (2015) the higher value of growth performance index indicates that fish can grow faster and larger.

Total mortality (Z) was found to be 2.74 year^{-1}, fishing mortality was computed as 1.42 year^{-1} and natural mortality stood at 1.32. The total mortality (Z) was slightly higher than the Hashem and Faltas (1982) estimated Z by 2.399 for *S. maderensis* in El-Mex. The high estimated Z in this study may indicate more pressure on the species that may be resulted from increasing in one, or both the components (M and F') of Z. Sardine is vulnerable to a wide variety of predators, including many recreationally and commercially important fish species such as *Scomber japonicus* (Rizkalla and Faltas, 1997). The fishing mortality was slightly higher than the natural mortality and exploitation rate estimated (E) at 0.52 showed that that the level of exploitation is already high and species may not be in a sustainable condition. The exploitation rate in this study was almost the same with 0.5 optimally exploited stock which shows that the stock of this species may be under the pressure and not in a safe condition. Coefficient of exploitation higher than 0.5 along with higher fishing mortality compared to natural mortality show the stock is under overfishing pressure (King, 2007).

The species showed year round recruitment patterns having two peak periods. The minor peak during April and major peak during July. Pauly (1982) reported that double recruitment pulses per year for tropical fish species and for short-lived species. Recruitment has been described as a year-round phenomenon for tropical fish and shrimps species (Weber, 1976). The results obtained by Diouf et al. (2010) show a continuous reproduction for *S. maderensis* throughout the year.

In this work, the length at first capture L_{50} and L_{25} were 27.31cm and 14.88cm respectively. The length at which 75% fish are retained in the gear was estimated as 39.75 cm.. The values in the current study were higher than those recorded in the coastal waters of Ghana for *S. maderensis* L_{25}%, L_{50}% and L_{75}% were 4.40 cm, 5.30 cm and 6.12 cm respectively by (Amponsah et al., 2018) In Senegal, the work performed by Boely (1980) and (Levenez 1993) showed that the L_{50} in this area was 20 cm.

The present level of exploitation rate (E = 0.36) was close to the maximum allowable limit based on the yield-per-recruit calculation (E_{max}= 0.42) indicating that that the level of exploitation is already high.

CONCLUSION

The results reveal that the level of exploitation is already high for this species and to obtain the maximum sustainable yield, the present level of fishing effort should be reduced. The present results can serve as baseline data for species with no previous information regarding stock assessment and for comparisons in future studies of Nigerian inland water fishery.

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