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Stock Assessment of The African Moony Fish (*Monodactylus Sebae*) (Cuvier, 1829) in The New Calabar, Nigeria

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Abstract

Some important information on the population biology and stock assessment of African moony fish (*Monodactylus sebae*) was scrutinized based on monthly length frequency data collected from New Calabar River, Nigeria from February 2020 to March 2021. The estimated von Bertalanffy growth parameters were growth performance index 2.91 per year, asymptotic length (L_∞) and growth curvature (K) were 36.54 cm and 0.61yr^{-1} respectively. The estimated theoretical age at birth (to) and longevity for the assessed fish species were 0.55 years and 2.91 years, respectively. The total mortality (Z), natural mortality (M), fishing mortality (F), for *M. sebae* were 1.87 year^{-1}, 1.23 year^{-1} and 0.64 0.64 year^{-1} respectively. The length at first capture (L_c) was 8.56cm. The exploitation rate (E) and maximum exploitation rate (E_{max}) were calculated as 0.34 and 0.36 respectively. The recruitment pattern occurs throughout the year, with only one recruitment peaks in May with 19.9 % recruits. Biological reference points: Emsy which depicts exploitation rate producing maximum yield of a cohort indicated that, the exploitation rate which maximizes yield per recruit produced values of E_{max} was 0.36 while E_{50} was 0.23 for *M. sebae* indicates that the current exploitation rate was below the maximum sustainable yield, indicating that this stock was underexploited.

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Keyword
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Asymptotic length;
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Introduction

Fish population are subject to natural control processes that continually modify and adjust the structure and abundance of population and their life cycle in response to a wide range of factors (Milner et al., 2003), apart from those caused by human activities such as overfishing and habitat alteration, as well as pollution and lately climate change. Stock assessment is the basis for understanding changing fishery patterns and issues such as habitat destruction, predation and optimal harvesting rates (Olopade et al., 2019). Regular stock assessment and reference points are required for monitoring and for determining whether the stocks are subject to overfishing or overfished and develop fishery management plans (Mohamed et al., 2021). Kebtieneh et al., (2016) stated that the basic purpose of stock assessment is to provide decision-makers with the information necessary to make rational choices on the optimum level of exploitation of aquatic living resources such as fish. Stock assessment forms the basis for calculations leading to knowledge of the growth, mortality, recruitment and other fundamental parameters of their populations (Olopade et al., 2019).

The fish family Monodactylidae contains six extant species in two genera, Monodactylus and Schuettea. Monodactylidae is found in the eastern tropical Atlantic Ocean along the African coast from Senegal to Angola and the Canary Islands (Desoutter 1990). Monodactylidae is primarily found in estuaries and coastal mangrove habitats, but is able to live in both freshwater and marine habitats (Schneider 1990). Reproduction takes place in marshes and lower courses of rivers, sometimes ascending over long distances into freshwater (Bauchot 2003). They are laterally compressed with an approximately diamond shape body with a long anal and dorsal fin extended distance that gives this fish a square like look African monny, *Monodactylus sebae* is a member of the family and the only species identified so far in Nigerian fresh water (Adesulu & Sydenham 2007). Even though, it is marine species which can survive in fresh water for some times. This species lacks the yellowish coloration in the caudal fin seen in other species of *Monodactylus* (Monks 2006). This species is economically important as it can be found in the aquarium trade, and lately, this fish has assumed importance in the Niger Delta region of Nigeria by virtue of its acceptance as a food fish in both fresh and dried conditions. According to the IUCN (2021) record, the fish is assessed as at least concern (LC). However, there is massive fishing pressure on this species in the New Calabar River and in other water bodies in the Niger Delta region. This could be attributed to the absence of commonly important fish species. In spite of the importance of the *Monodactylus sebae* in Nigeria there is no information on stock assessment in the country or elsewhere. The objective of the present study was to assess the growth parameters, mortality rates, probability of capture, recruitment pattern, yield per recruit, and virtual population analysis of *Monadactylus sebae* in the New Calabar River, Nigeria.

Materials and Methods

Time and place

The New Calabar River, Nigeria is a partially mixed estuary system that lies between latitude 4°25′N and longitude 7°16′E (Olopade et al. 2019) (Figure 1). The entire river course is situated in the coastal area of the Niger delta and empties into the Atlantic Ocean.

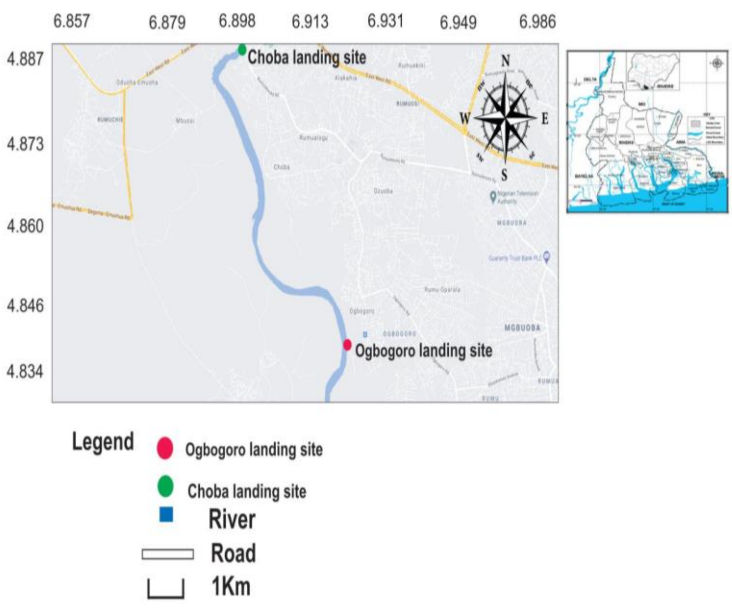

Figure. 1 Map of New Calabar River, Nigeria

Data Collection

Fish samples were collected from the New Calabar River at two fishing landing sites, namely Choba and Ogbogoro from the local fishermen using different gears. These samples were taken twice monthly, starting from the month of February 2020 to March 2021. The species were identified to the species level using the identification keys by Monks (2006). Fish specimens were immediately iced and transported to the laboratory to measure the weight (to the nearest 0.5 g) and length (to the nearest 1.0 cm) of each specimen.

Data Analysis

The length-frequency data for *M. sebae* were collected monthly from a number of different gears at all sites and then grouped into class intervals for analysis. The data were analyzed using FiSAT II (FAO-ICLARM Stock Assessment Tools) as explained in details by (Gayanilo et al. 2005).

The von Bertalanffy (Pauly 1980) growth parameters, asymptotic length L_∞ and annual growth coefficient K were computed by ELEFAN I (Electronic Length Frequency Analysis) method (Beverton & Holt 1966). The total mortality rate (*Z*) was estimated by length-converted catch curve (Pauly 1984). The natural mortality rate (*M)* was also calculated by using Pauly's empirical formula (Pauly 1980). The fishing mortality rates (*F*) was then calculated by the difference between (*Z*) and (*M*). The rate of exploitation (*E*) was calculated by the quotient between fishing and total mortality: $E= F/Z$ (Pauly 1984). Relative yield per recruit (*Y/R*) was estimated using the model of Beverton and Holt (Beverton and Holt 1966) as modified by Pauly and Soriano (Pauly and Soriano 1986) and incorporated in the FiSAT software. Lengths at first capture (Lc50) and first maturity (Lm50): The left ascending part of the length converted catch curve was used to estimate the probabilities of length at 50, 75, and 95 capture which correlates with the cumulative probability at 50, 75 and 95 percent, respectively (Pauly 1984). The length at first maturity (Lm50) was estimated. The length at first maturity was estimated using the expression: Length at first maturity (Lm50) = $2 * L_\infty/3$ (Hoggarth et al. 2006).

One year recruitment pattern was obtained by projecting the length frequency data backward on to the time axis as described in the FiSAT routine. Biological reference points: Emsy which depicts exploitation rate producing maximum yield of a cohort and E0.5 implying exploitation rate under which the population is reduced to half its virgin biomass were computed together with the corresponding fishing mortality rate (i.e. Fmsy and F0.5).Virtual Population Analysis – VPA The length-based Virtual Population Analysis (VPA) was performed on the pooled annual length frequencies from the fishery to estimate the mean number in the population and the overall fishing mortality by length group.

Results and Discussion

Results

Length-frequency analysis

A total of M.sebae specimens collected for this study was 390. The size frequency distribution of the M. sebae population (Figure 2) shows that it was of the unimodal type. They were grouped into twenty classes of total length frequency with the collected samples falling in the length range of 7.7 to 34 cm and with a mean of 13.53±2.94. The 12.8cm TL size group was numerically dominant, followed by 10.8 cm, and constituted 53.86% of the total population.

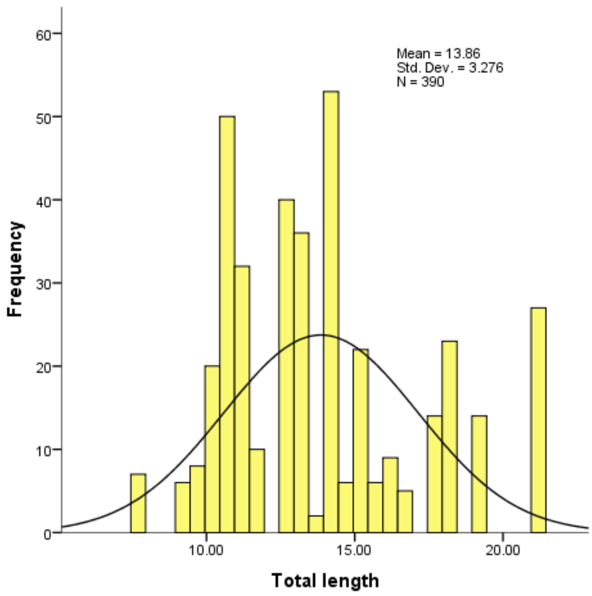

Figure 2. Graph of respondent's profile based on age

Estimation of growth parameters and growth performance index

Figure 3 shows the growth curve generated by ELEFAN I for *M. sebae*. The asymptotic length (L∞) and growth rate (K) were 36.54 cm TL and 0.61 year-1, respectively (Table 1).The growth performance index or phi prime (ϕ') for *M. sebae* recorded from New Calabar River was 2.91. The estimated theoretical age at birth (to) and longevity for the assessed fish species were 0.55 and 2.91 respectively (Table 1).

Table 1: Population Parameters of Monodactylus sebae in the New Calabar River, Nigeria

Indicators	Unit	Value
Growth rate (K)	year-1	0.61
Asymptotic length (L_∞)	cm TL	36.54
Age at birth (to)	Years	-0.55
Longevity (t_{max})	Years	4.37
Growth performance index(phi)		2.91
Natural mortality rate (M)	year-1	1.23
Total mortality rate (Z)	year-1	1.87
Fishing mortality rate (F)	year-1	0.64
Exploitation rate (E)		0.34
M/K		2.02
E-10		0.26
E-50		0.23
E-max		0.36
L_{25}	cm	7.06
L_{50}	cm	8.56

L_{75}	cm	10.20
Lm	cm	29.75

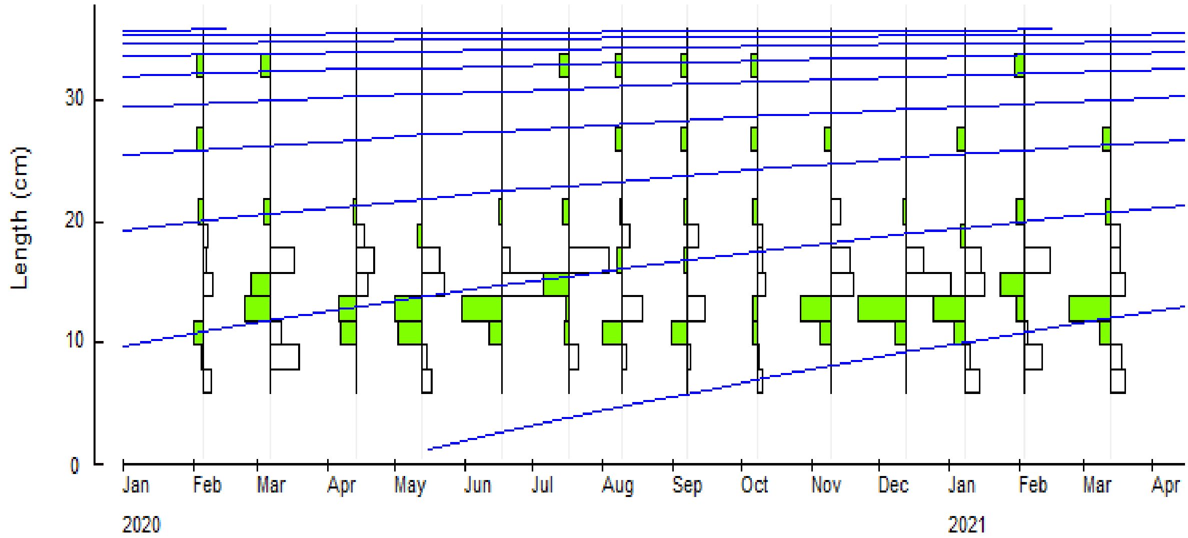

Figure 3 ELEFAN-1growth curve of M. sebae in the New Calabar River, Nigeria

The length-converted catch curve for *M. sebae* to estimate the annual total mortality rate (Z) is shown in Figure 4. The natural mortality (*M*/year)
as per Pauly's empirical formula was calculated as 1.23 year-1 and the total mortality (Z) as 1.87 year-1 while the fishing mortality (F) was taken by subtraction of M from Z and was 0.64 year-1 (Table 1). The current exploitation rate ($E_{current}$) computed as F/Z= 0.34 for *M.sebae* and the M/K ratio found was 2.02. (Table1).

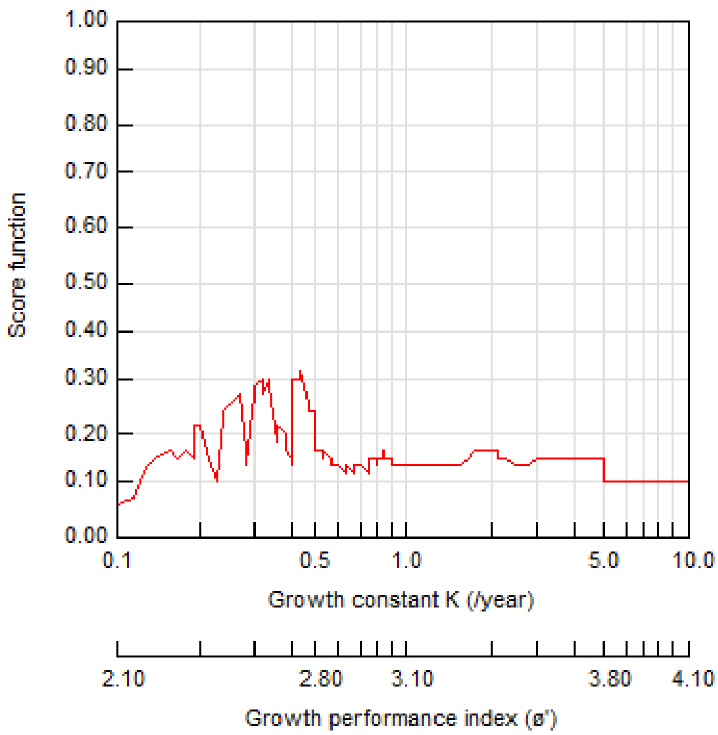

Figure 4 Growth performance index (K- Scan routines) of M. sebae in the New Calabar River, Nigeria The goodness-of-fit was at Rn= 0.344

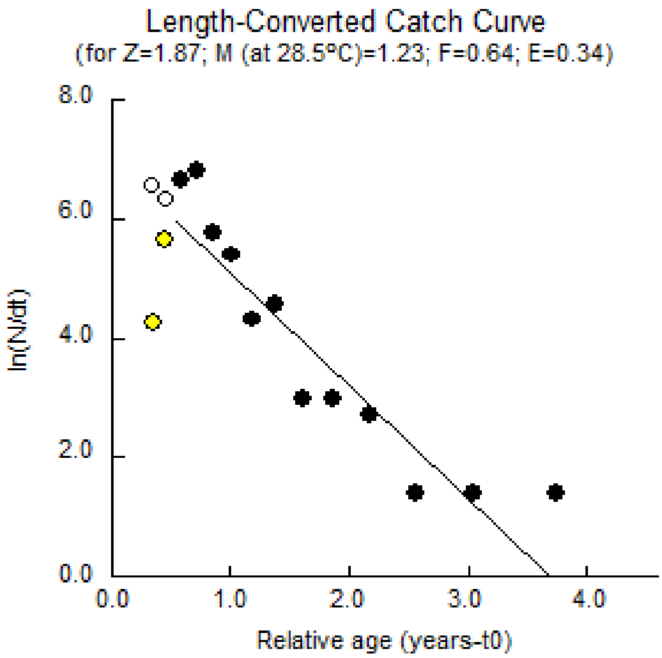

Figure 5 Length converted catch curves of M. sebae in the New Calabar River, Nigeria

Length at first capture L50 for M. sebae in the New Calabar River, Nigeria

The logistic of the probability of capture routine of *M. sebae* presented in Figure 5. The length at which 50% of the stock biomass is vulnerable to capture estimated at L_{50} = 8.56cm. The L_{25} was calculated as 7.06cm while L_{75} was found to be 10.20cm for *M. sebae.* The length at first maturity (Lm50) was estimated at 24.36 cm. In this study, the reproductive load ratio (L_{50}/ L_{∞}) (8.56/36.54) = 0.23 for *M. sebae* indicating the length at first capture is quite low for the population (Table 1).

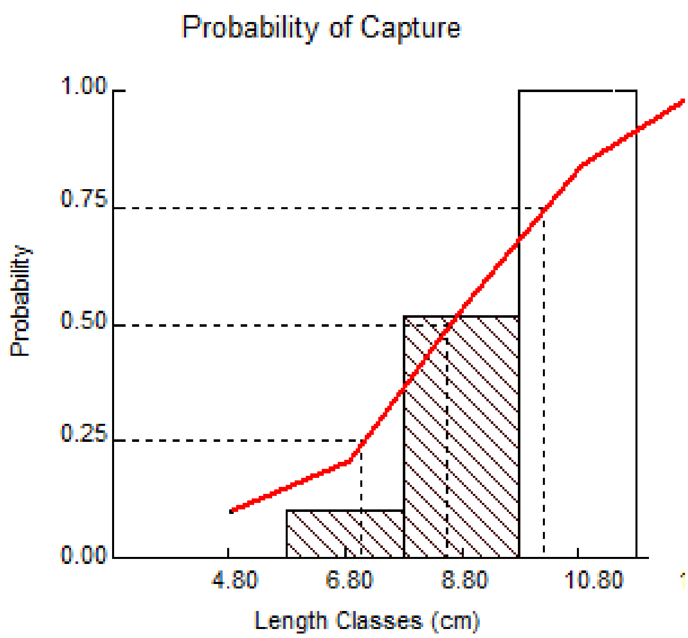

Figure 6 Length at first capture L50 for M. sebae in the New Calabar River, Nigeria

Recruitment pattern of M. sebae in the New Calabar River, Nigeria

As shown in Figure 7, the annual recruitment pattern of *M. sebae* indicated that recruitment occurred throughout the year with only one prominent peak in May with 19.9 % recruits, while the minor peak occurred in September with 16.6 % recruits.

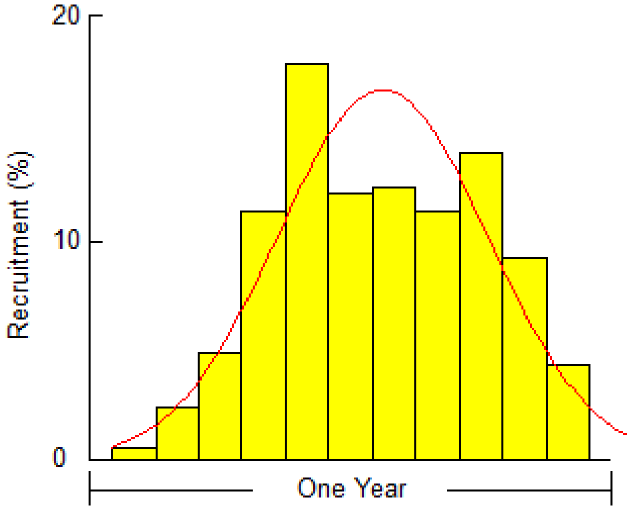

Figure 7 Recruitment pattern of M. sebae in the New Calabar River, Nigeria

Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) analyses of M.sebae in the New Calabar River, Nigeria

The Beverton-Holt relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) estimated using selective Ogive procedure of FiSAT for the species is given in the figure below. The analysis indicated that, the exploitation rate which maximizes yield per recruit produced values of E_{max} was 0.36 while E_{50} was 0.23 for *M. sebae* (Figure 5).

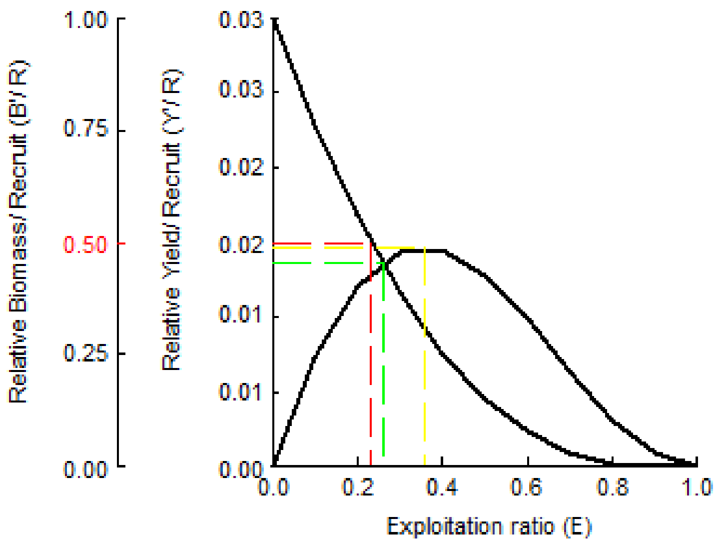

Figure 8 Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) analyses of M. sebae in the New Calabar River, Nigeria

Length-structured virtual population analysis of M. sebae in the New Calabar River, Nigeria

Figure 9 showed that natural mortality is the only cause of loss of *M. sebae* at lengths from 6.8 cm to 9.8 cm. *M. sebae* was caught by fishing gear in sizes from 6.8 cm, with the highest quantities in lengths from 10.8 cm to 12.8 cm. The fishing mortality were at lowest at 22.8 and 30.8 cm. The smallest length groups have lower catches (harvesting rates) than the largest ones (Table 2), indicating that the fishing mortality rate is size specific. Natural losses were highest among individuals within the length range of 6.8 to 9.8 cm and then decreased gradually to the length group of 30.8 cm.

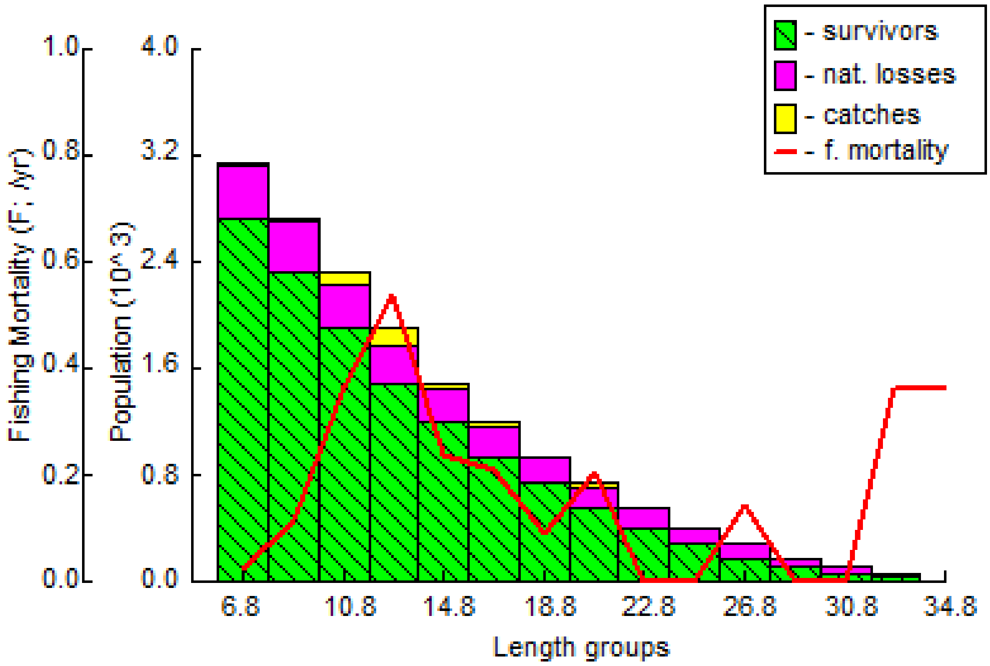

Figure 9: Length-structured virtual population analysis of M. sebae in the New Calabar River, Nigeria

Discussion

Length-frequency distributions observed in this study provide snapshots of the size structure of the species. Length frequency distribution showed that small size fish were the most abundant in the catches. The 12.8cm TL size group was numerically dominant, followed by 10.8 cm, and constituted 53.86% of the total population. The growth parameters in this study were estimated using the length frequency data in ELEFAN 1 software, revealing the following result: asymptotic length (L_∞) as 36.54cm, growth curvature (K) as 0.61 per year, growth performance index as 2.91, and t_0 (per year) as -0.55. The growth rate (k) of 0.61 year-1 from the current study signifies that *M. sebae* exhibited a fast growth rate, evinced by the low longevity of 4.37 years. The growth coefficient (K) of *M. sebae* was high (2.91). The greater of these values indicates that the fish growth rate to achieve the maximum size is faster.

The total mortality (*Z*), natural mortality (*M*/year), fishing mortality (*F*), and exploitation rate (*E*) of *M. sebae* were found to be 1.87, 1.23, 0.64, and 0.34 respectively. Natural mortality of fishes becomes much heavier in an unexploited population than in an exploited one. However, since value for natural mortality (1.23) exceeded fishing mortality (0.64), the stock is not over- exploited. According to (Macer 1977) the consistency of the estimated natural mortality rates (M) was ascertained using the M/K ratio, which has been reported to be within the range of 1.12 and 2.5 for most fishes. The M/K ratio in this study was 2.02 which was within the normal range. Exploitation rate allows for determining whether a stock is overfished or not based on the assumption that the optimal value of E is 0.5 (Gulland 1971; Pauly 1983). Based on the exploitation rate (E) of *M. sebae* in this study (0.34), it clear that the stock is currently underexploited.

In this study, the length at first maturity (Lm50=29.75 cm) was higher than the length at which this species become vulnerable to the fishing gears (Lc50 = 8.56cm) indicating that this species is harvested before they could reach the matured stage, a characteristic feature of growth overfishing (Fröese 2004). Furthermore, the critical length at capture which is ratio of L_{C50}/L_{∞} ($_{8.56}$/36.54= 0.23), indicated that it was lower than 0.5. This signals the harvesting of more juvenile fish species (Pauly & Soriano 1986). The presence of many small-sized fish species in the catches could be explained by the unselective use of small mesh sized fishing gears. Continuous exploitation of this at this level could result in growth overfishing and eventually lead to a possible collapse.

In *M.sebae* population, a two-peak recruitment pattern was observed and the peaks were during May and September. This result was in line with (Pauly 1982) observed a double recruitment pulse per year for tropical fish species and for short lived species. The recruitment pattern has concerned with the spawning time (Fiorentino et al. 2008). The present study agrees with spawning seasons reported for tropical fish species.

The yield per recruit model is an efficient approach for fish stock assessment, consisting in an important tool to the management of fisheries (Sparre & Venema 1997). The predicted E_{max} of the Selective Ogive procedure for *M. sebae* (0.36) was higher than the current exploitation rate *E* (0.34) showing that *M. sebae* was lower than both target reference points. This is a further implication that the stock of the species is underexploited. Virtual population analysis (VPA) data were utilised to make management decisions and provide more information about the status of fish stocks in terms of growth, recruitment, and overfishing (Chen et al. 2008). According to virtual population analysis (VPA), the 12.8 cm length group was more vulnerable to fishing and more harvested. This implies that more individuals are caught before they reached length at first sexual maturity. This situation is also described by (Fröese 2004) as growth overfishing; when fishes are caught before they can realize their full potential. If this condition continues without any efforts to regulate *M. sebae* stock, the fish species will be threatened in the long term. The protection of juveniles through fish size stipulation and mesh size limitation is probably a key factor for the sustainability of this species. This can be achieved by compliance with or enforcement of the mesh size (7.5 cm) recommended as the standard as the minimum mesh size for all inland water bodies in Nigeria by a joint effort between resource users and the governing authority.

Conclusion

The present study is the first effort to evaluate the growth parameters some important information on the population biology and the stock assessment of the species *M. sebae* from the New Calabar River, Nigeria. The study revealed that the *M. sebae* stock was underexploited, and more individuals are caught before they reached length at first sexual maturity. This study suggests that mesh size regulations will be required to protect *M.sebae* in the New Calabar River in Nigeria.

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