Int. J. Aquat. Biol. (2022) 10(4): 303-309
ISSN: 2322-5270; P-ISSN: 2383-0956
Journal homepage: www.ij-aquaticbiology.com

Original Article

Stock assessment of the African moony, *Monodactylus sebae* (Cuvier, 1829) in the New Calabar, Nigeria

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Abstract: The population biology and stock assessment of African moony, *Monodactylus sebae* was studied 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_∞ = 36.54 cm) and growth curvature (K = 0.61yr^{-1}). The estimated theoretical age at birth (t_0) and longevity for the assessed fish species were 0.55 years and 2.91 years, respectively. The total mortality (*Z*), natural mortality (*M*), and fishing mortality (F), 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 8.56 cm. 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 major peak in May with 19.9% recruits. E_{max} was 0.36, while E_{50} was 0.23 indicating that the current exploitation rate was below the maximum sustainable yield, showing that this stock was underexploited.

Article history:
Received 14 June 2022
Accepted 8 August 2022
Available online 25 August 2022

Keywords:
Growth
Mortality
Asymptotic length
Maximum sustainable yield

Introduction

Fish populations are subject to natural control processes that continually modify and adjust the structure and abundance of the 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 determining whether the stocks are subject to overfishing or overfished and developing 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 the knowledge of the growth, mortality, recruitment, and other fundamental parameters of their populations (Olopade et al., 2019).

The 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 can live in 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. African moony, *Monodactylus sebae* is a member of the family and the only species identified so far in Nigerian fresh water (Adesulu and Sydenham,

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DOI: https://doi.org/10.22034/ijab.v10i4.1695

Figure 1. Map of New Calabar River, Nigeria.

2007). Even though it is marine species that 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). It 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 its acceptance as a food fish in both fresh and dried conditions. According to the IUCN (2021), 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 *M. 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 *M. sebae* in the New Calabar River, Nigeria.

Materials and Methods

The New Calabar River, Nigeria is a partially mixed estuary system that lies between latitude 4º25′N and longitude 7º16′E (Olopade et al., 2019) (Fig. 1). The entire river course is situated in the coastal area of the Niger delta and empties into the Atlantic Ocean.

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) (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 and Holt, 1966). The total mortality rate (*Z*) was estimated by the 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*) were 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 (1986) and incorporated into 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 using the expression: Length at first maturity (Lm50) = 2 * L_∞ /3 (Hoggarth et al., 2006).

One-year recruitment pattern was obtained by projecting the length frequency data backward onto the time axis as described in the FiSAT routine. Biological reference points: Emsy which depicts the exploitation rate producing a maximum yield of a cohort and E0.5 implying the 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). 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

Length-frequency: 390 specimens were collected for this study and the size-frequency distribution (Fig. 2) shows a 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 12.8 cm TL size group was numerically dominant, followed by 10.8 cm, and constituted 53.86% of the total population.

Estimation of growth parameters and growth performance index: Figure 3 shows the growth curve of *M. sebae*. The asymptotic length ($L\infty$) and growth rate (K) of *M. sebae* were 36.54 cm TL and 0.61 year^{-1}, respectively (Table 1). The growth performance index or phi prime (φ′) was 2.91 (Fig. 4), and the estimated theoretical age at birth (t_0) and longevity for the assessed fish species were 0.55 and 2.91, respectively (Table 1).

The length-converted catch curve to estimate the annual total mortality rate (Z) is shown in Figure 5. 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

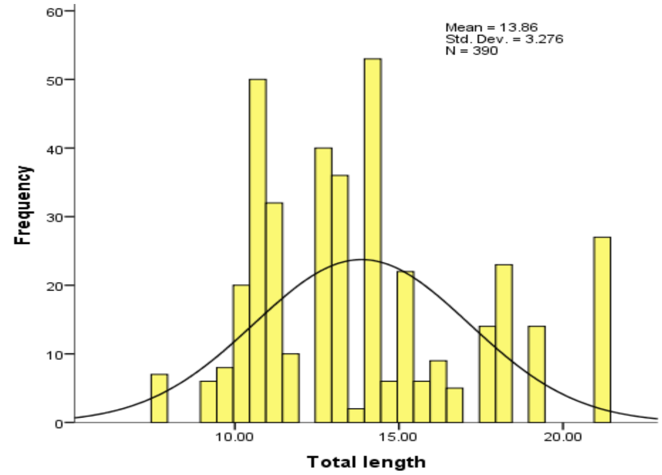

Figure 2. Length-frequency distribution of *Monodactylus sebae* from the New Calabar River, Nigeria.

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 (t_0)	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	24.36

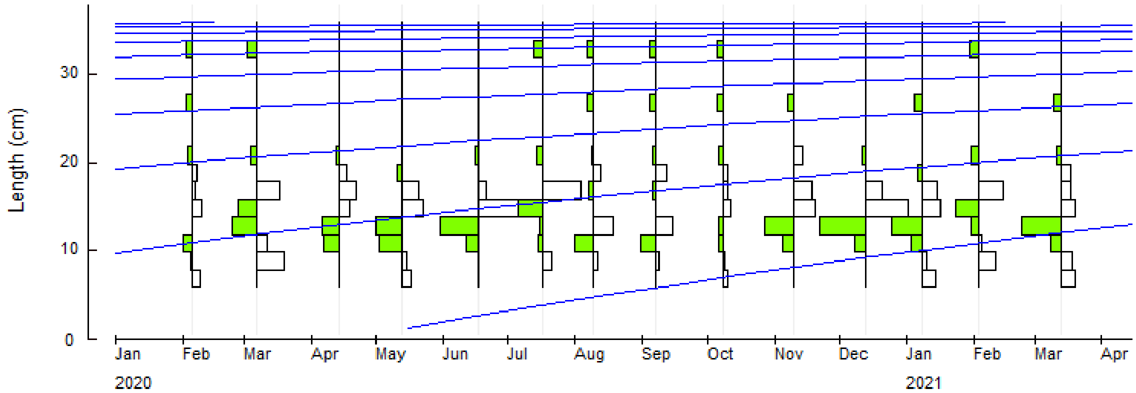

Figure 3. Growth curve of *Monodactylus sebae* in the New Calabar River, Nigeria.

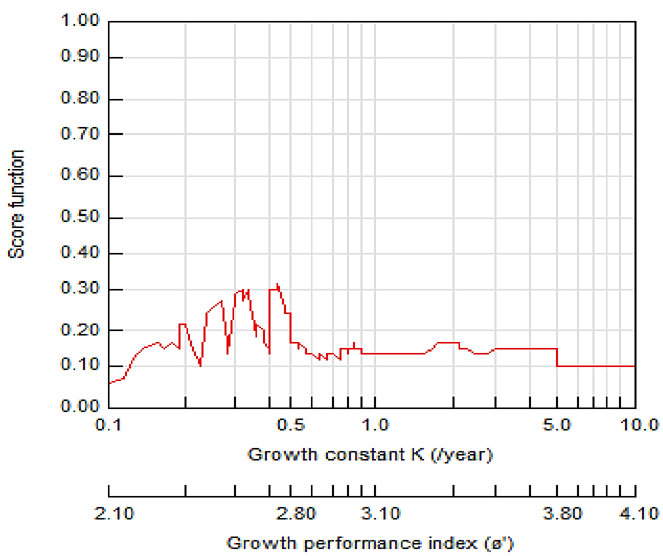

Figure 4. Growth performance index (K- Scan routines) of *Monodactylus sebae* in the New Calabar River, Nigeria.

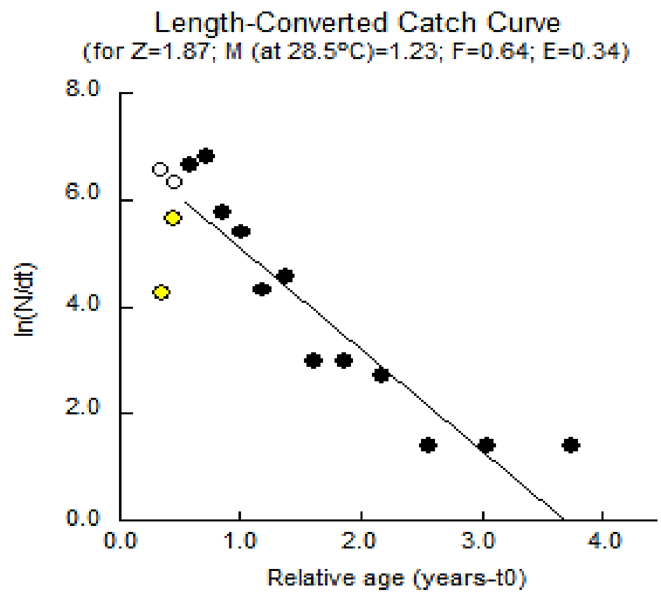

Figure 5. Length converted catch curves of *Monodactylus sebae* in the New Calabar River, Nigeria (The goodness-of-fit was at Rn= 0.344).

and was 0.64 $year^{-1}$ (Table 1). The current exploitation rate ($E_{current}$) was computed as F/Z= 0.34 and the M/K ratio found was 2.02 (Table1).

Length at first capture (L_{50}): The logistic of the probability of the capture routine of *M. sebae* is presented in Figure 6. The length at which 50% of the stock biomass is vulnerable to capture estimated at L_{50} = 8.56 cm. The L_{25} was calculated as 7.06cm while L_{75} was found to be 10.20 cm. The length at first maturity (Lm50) was estimated at 24.36 cm. 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).

Recruitment pattern: 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.

Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) analyses: The Beverton-Holt relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) estimated using the selective Ogive procedure of FiSAT for the species is given in the exploitation rate which maximizes yield per recruit produced values of E_{max} was 0.36 while E_{50} was 0.23 (Fig. 8).

Length-structured virtual population analysis: Figure 9 shows that natural mortality is the only cause of loss in *M. sebae* at lengths from 6.8 to 9.8 cm. This species is caught by fishing gear in sizes from 6.8 cm, with the highest quantities in lengths

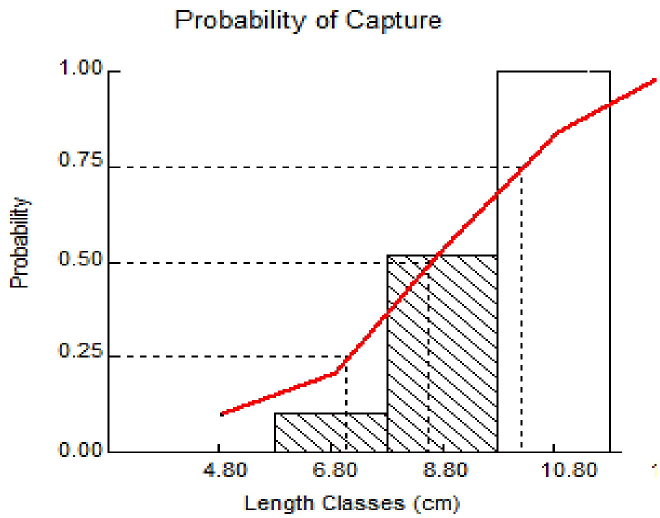

Figure 6. Length at first capture L50 for *Monodactylus sebae* in the New Calabar River, Nigeria.

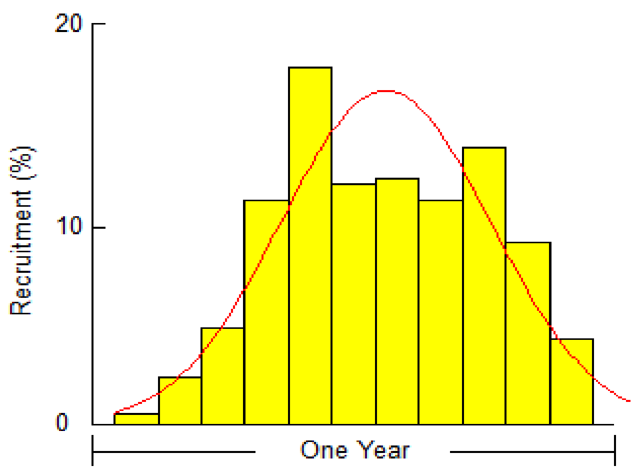

Figure 7. Recruitment pattern of *Monodactylus sebae* in the New Calabar River, Nigeria.

from 10.8 to 12.8 cm. The fishing mortality was at its lowest 22.8 and 30.8 cm. The smallest length groups have lower catches (harvesting rates) than the largest ones (Table 1), 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.

Discussion

Length frequency distribution showed that small-size fish were the most abundant in the catches. The 12.8 cm TL size group was numerically dominant,

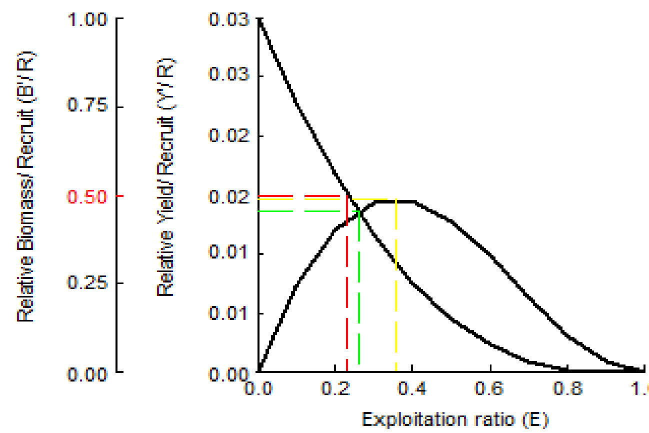

Figure 8. Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) analyses of *Monodactylus sebae* in the New Calabar River,

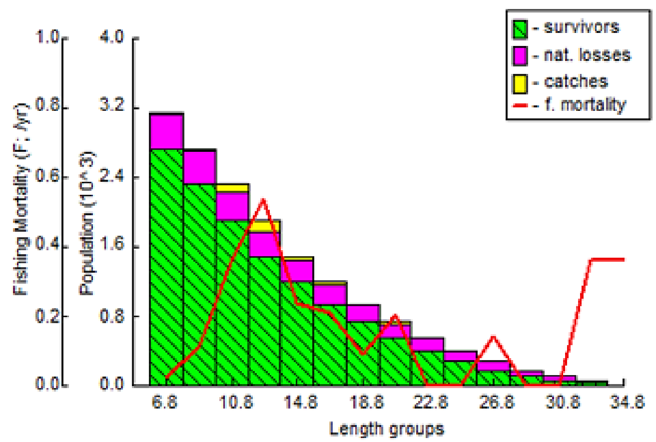

Figure 9. Length-structured virtual population analysis of *Monodactylus sebae* in the New Calabar River, Nigeria.

followed by 10.8 cm, and constituted 53.86% of the total population. The growth parameters in this study were as follows: asymptotic length (L_∞) = 36.54 cm, growth curvature (K) = 0.61 per year, growth performance index = 2.91, and t_0 (per year) = -0.55. The growth rate (k) of 0.61 year^{-1} 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. The natural mortality of fish becomes much higher in an unexploited population than in an exploited one. However, since 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 1.12-2.5 for most fishes. The *M*/*K* ratio in this study was 2.02 which was within the normal range. The 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 is clear that the stock is currently underexploited.

In this study, the length at first maturity (Lm50 = 24.36 cm) was higher than the length at which the species become vulnerable to the fishing gears (Lc50 = 8.56 cm) indicating that this species is harvested before they mature, a characteristic feature of growth overfishing (Fröese, 2004). Furthermore, the critical length at capture which is the 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 and 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, one major peak was recorded as continuous recruitment began from May to October. This result was in line with Pauly (1982) that observed a double recruitment pulse per year for tropical fish species and for short-lived species The recruitment pattern is related to the spawning time (Fiorentino et al., 2008). The present study agrees with the 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 for fisheries (Sparre and 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 VPA, the 12.8 cm length group was more vulnerable to fishing and more harvested. This implies that more individuals are caught before they reach 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 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 and some important information on the population biology and the stock assessment of *M. sebae* in the New Calabar River, Nigeria. The study revealed that the *M. sebae* stock was underexploited, and more individuals were caught before they are 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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