COMU J Mar Sci Fish 2022 5 (1): 39-47
https://doi.org/10.46384/jmsf.1054288

e-ISSN: 2651-5326

COMU Journal of Marine Sciences and Fisheries

Journal Home-Page: http://jmsf.dergi.comu.edu.tr Online Submission: http://dergipark.org.tr/jmsf

RESEARCH ARTICLE

Growth, Mortality and Exploitation Rate of Round Sardinella (*Sardinella aurita*, Valenciennes, 1847) in the New Calabar River, Niger Delta, Nigeria

Henry Dienye[1]*, Olaniyi Olopade[2], Chijioke Ichendu[3]

[1]Department of Fisheries, Faculty of Agriculture, University of Port Harcourt Choba Nigeria.P.M.B.5323 https://orcid.org/0000-0001-6254-9179
[2]Department of Fisheries, Faculty of Agriculture, University of Port Harcourt Choba Nigeria.P.M.B.5323 https://orcid.org/0000-0002-9550-2956
[3]Department of Fisheries, Faculty of Agriculture, University of Port Harcourt Choba Nigeria.P.M.B.5323 https://orcid.org/0000-0001-6232-317X

Received: 06.01.2022 /Accepted: 02.06.2022 / Published online: 20.07.2022

Key words:

Growth
Mortality
Clupeidae
Africa

Abstract: This study assessed the growth, mortality and exploitation rate of *Sardinella aurita* in the New Calabar River. A total of 513 specimens of *S. aurita* were collected from artisanal fishers and assessed between March 2020 and February 2021.For statistical analysis, FiSAT II software was used. At asymptotic length (L_∞) = 21.73 cm, growth rate (K) = 0.95 yr^{-1}, longevity (*T*max) = 2.68 yrs., theoretical age at birth (t_0) = -0.48 yrs., and growth performance index (Φ′) = 2.65. Length at first capture (Lc_{50} = 15.06 cm) was lower than length at first maturity (Lm_{50} = 21.12 cm). Mortality parameters revealed a total mortality rate (Z) = 3.03 yr^{-1}, a natural mortality rate (M) = 1.42 yr^{-1}, and a fishing mortality rate (F) = 1.61 yr^{-1}. This indicates that *S. aurita* in the study area has a fast growth rate, small attained size, delayed sexual maturation, and high natural mortality. The exploitation rate (E) was 0.53. *S. aurita* was found to be experiencing optimum exploitation. Therefore, to prevent overfishing, sustainable fisheries measures should be adopted, and these include monitoring of fishing efforts and implementation and enforcement of increased mesh size to sustain the fishery of *S. aurita* in the New Calabar river.

Anahtar kelimeler:

Büyüme
Mortalite
Clupeidae
Afrika

New Calabar Nehri’nde (Nijer Deltası, Nijerya) Yuvarlak Sardalyanın (*Sardinella aurita*, Valenciennes, 1847) Büyüme, Ölüm Oranı ve Sömürülme Oranı

Öz: Bu çalışma, New Calabar Nehri'ndeki *Sardinella aurita* türünün büyüme, ölüm oranı ve yararlanma oranını değerlendirdi. Mart 2020 ile Şubat 2021 arasında ticari balıkçılardan toplam 513 *S. aurita* örneği toplandı ve değerlendirildi. İstatistiksel analiz için FiSAT II yazılımı kullanıldı. Asimptotik uzunluk (L_∞) = 21,73 cm, büyüme katsayısı (K) = 0,95 yıl-1, maksimum ömür (Tmax) = 2,68 yıl, teorik doğum öncesi yaş (t_0) = -0,48 yıl ve büyüme performans indeksi (Φ ′) = 2.65 olarak belirlendi. İlk yakalanma boyu (Lc50 = 15.06 cm), ilk eşeysel olgunluk boyundan (Lm50 = 21.12 cm) daha düşüktü. Ölüm parametreleri olan toplam ölüm oranı (Z) = 3.03 yıl-1, doğal ölüm oranı (M) = 1.42 yıl-1, balıkçılık ölüm oranı (F) = 1.61 yıl-1 olarak gerçekleşti. Bu, çalışma alanında *S. aurita* türünün hızlı bir büyüme oranına, küçük boyuta, geç cinsel olgunlağa ve yüksek doğal ölüm oranına sahip olduğunu gösterir. Yararlanma oranı (E) 0,53 idi. *S. aurita* türünün optimum şekilde yararlanıldığı bulundu. Bu nedenle, aşırı avlanmayı önlemek için sürdürülebilir balıkçılık önlemleri benimsenmelidir ve bunlar arasında balıkçılık çabalarının izlenmesi ve New Calabar Nehri’nde *S. aurita* balıkçılığını sürdürülebilir kılmak için artan ağ gözü boyutunun uygulanması ve uygulatılması yer almaktadır.

Introduction

The round Sardinella, *Sardinella aurita* (Pisces, Clupeidae), is a marine pelagic fish that is widely distributed throughout the tropical and subtropical seas of the world, including the entire Mediterranean and the Black Sea (Froese and Pauly 2003). It is a key species inhabiting the ecosystem of the northwest African upwelling region (Bard and Koranteg 1995). *S. aurita* (commonly referred to as sardines and indigenously referred to as Songu) is a ray-finned fish. It belongs to the family Clupeidae. The body is elongated and sub-circular, the belly is rounded. (Riede, 2004). *S. aurita* is a pelagic coastal species that prefers clear saline waters with temperatures below 24 °C (Bianchi et al., 1999). It is a typical schooling and migratory species, rising to the surface at night and scattering inshore and near the surface to the shelf's edge and down to 350 meters, or possibly deeper (Whitehead, 1985).

*Corresponding author: henry.dienye@uniport.edu.ng

How to cite this article: Dienye, H., Olopade, O., & Ichendu, C. (2022). Growth, mortality and exploitation rate of Round sardinella (*Sardinella aurita*, Valenciennes, 1847) in the New Calabar River, Niger Delta, Nigeria. COMU J. Mar. Sci. Fish, 5(1): 39-47. doi: 10.46384/jmsf.1054288

S. aurita is a warm-water species that approaches the coast and shoals at the surface during the upwelling season, but retreats below the thermocline in the hot season, down to depths of 200 to 300 meters. It eats mostly zooplankton, particularly copepods and mysid larvae, but sometimes phytoplankton, especially by juveniles. (Whitehead, 1981). It can breed at any time of year, but only at certain times of the year; the breeding pattern is enormously complex, with two main spawning seasons in some areas. Juveniles stay in nursery areas, but when they reach maturity, they join adults in colder offshore waters. (Whitehead, 1985).

The distribution of *S. aurita* extends to the Atlantic Ocean and the West African coast, particularly in the three West African upwelling areas stretching from Mauritania to Guinea, Côte d'Ivoire to Ghana, and Gabon to Angola. (Cury and Fontana, 1988).

Fish and fishing contribute significantly to food and nutrition security in many countries. Nevertheless, fish stocks are declining in many parts of the world. This will have a significant impact on the seafood industry's contribution to achieving the United Nations Sustainable Development Goals. As a result, it is critical to focus on the long-term management of fish stocks. (Tsikliras, 2008). Fish population characteristics are critical inputs in the evaluation and management of fish populations. With world fish populations now being poorly managed, resulting in overexploitation and decline, there is a need for data on critical criteria to assist in guaranteeing proper fisheries management. (Arra et al., 2018). Various research on the sex ratio, growth, mortality, and exploitation of *S. aurita* has been conducted, but none has been conducted in the New Calabar River in Choba. This study is, therefore, essential to provide information to fill the gap in the study area and complement the existing data on management of the species.

Material and Methods

Description of study area

In Choba, Rivers State, Nigeria, the New Calabar River is located between longitude 06°53 53086' E and latitude 04°53 19.020' N. The entire river course is located in the coastal area of the Niger Delta, between longitude 7°60' E and latitude 5°45' N, and drains into the Atlantic Ocean. The yearly rainfall in the New Calabar River region ranges from 2000 to 3000 mm (Abowei, 2000). The New Calabar River is one of the most important water resources in the Niger Delta region of Southern Nigeria; it is located near Port Harcourt, the rapidly rising oil city in Rivers State. Effluent discharge from industries located along the river's banks pollutes the water. Surface run-off from soil erosion, lumberic operations, forestry operations, dredging operations, and domestic sewage inputs are also potential large scale pollution sources (Dienye and Woke, 2015).

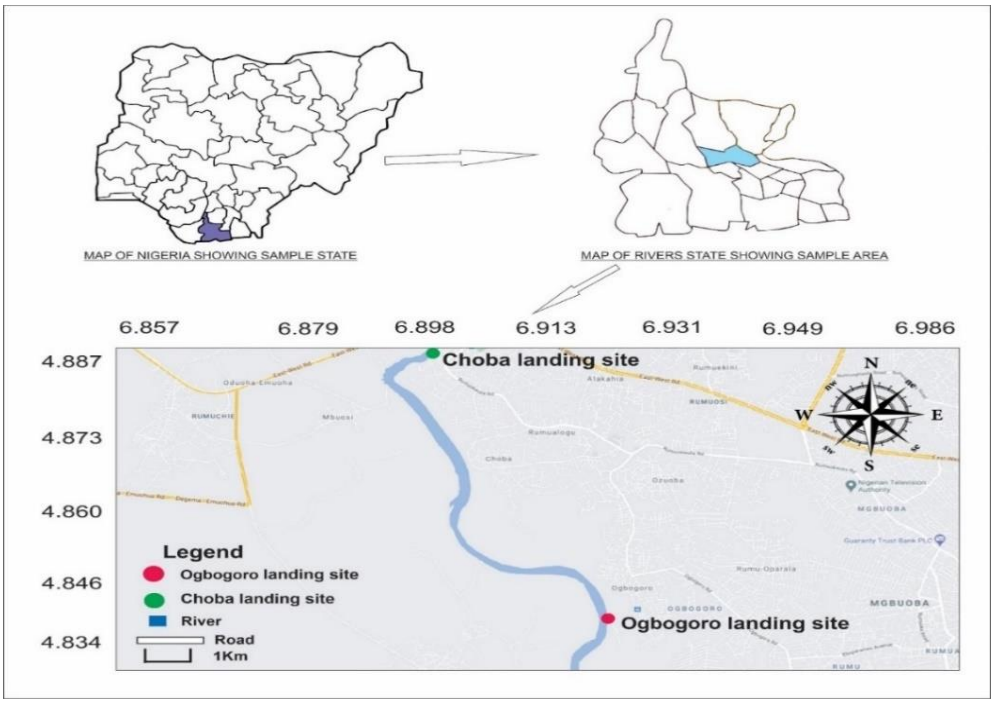

Figure 1. Map of the study area

Data collection

S. aurita was sampled monthly for a period of twelve (12) months, from two stations using cast nets of mesh sizes (1.5–2.5 mm) by the local artisanal fishermen. A total of 513 species were captured. Species identification was carried out using identification keys (Paugy, 2003; Adesulu and Sydenham, 2007).

Sampling stations were chosen due to the high level of fishing activity in these areas (Station One: Choba, Station Two: Rumuoparali). Sampled specimens were preserved on ice for further analysis. The body weights (BW) of the samples were measured to the nearest 0.01 grams with an electronic weighing scale, while the total length (TL), of sampled species was measured to the nearest 0.1 cm with a calibrated 30 cm measuring board.

Length-weight relationship

The length–weight relationships were calculated using the equation:

$W(t)=aL_t{}^{b}$

Where: a is a coefficient relative to body form; b is an exponent indicating isometric growth when equal to 3.0, positive allometry when>3 and negative allometry minorant when<3.

The monthly length frequencies of each sample were grouped into classes of 1 cminterval and were laid out sequentially over one year to estimate the growth (Froese 2006).

Sex-ratio

The sex ratio was determined generally for each sampled station and according to individual size. The sex ratio is the proportion of male or female individuals utilising the gravid gonads in comparison to the overall number (e.g., testis and ovary). The sex ratio was expressed as a percentage of males to females, using the formula by Kartas and Quignard, (1984):

SR=Fx100x(1/(M+F)) (F=female and M=male).

Growth parameters

The parameters for the Von Bertalanffy Growth Function (VBGF) including growth rate (K), asymptotic length ($L\infty$) and the growth performance index (Φ') were estimated using the ELEFAN Simulating Annealing (ELEFAN_SA). Estimation of longevity (Tmax) for the species followed the formula:

$Tmax = 3/K + t_0$ (Anato,1999)

The growth performance index was calculated using the formula:

phi prime test (Φ') $=2\log L_\infty + \log K$ Munro, and Pauly, (1984).

The theoretical age at length zero (t_o) followed the equation:

$Log_{10}(-t_0)=-0.3922-0.2752\log_{10}L_\infty-1.038\log_{10}K$ (Aleev,1952)

Where: Growth rate (K), asymptotic length ($L\infty$) and the growth performance index (ϕ) of the Von Bertanlaffy Growth Function (VBGF) was estimated.

Length at first capture (Lc50)

The ascending left part of the length converted catch curve was used in estimating the probability of length at first capture (Lc50) in addition to the length at both 75 and 95 percent capture, which correlates with the cumulative probability at 75% and 95%, respectively (Pauly,1983).

Length at first maturity (Lm50)

The length at first maturity (Lm50) as:

$Lm50=0.8979\times Log_{10}(L_\infty)–0.0782$ (Arra et al., 2020)

Mortality parameters

The length-converted catch curve was used to calculate the total mortality coefficient (Z). The natural mortality rate (M) was calculated using Pauly's (1980) empirical equation and a mean surface temperature (T) of 25.7°C:

$Log_{10}M = - 0.0066 - 0.279\ 1og_{10} L_\infty + 0.6543 \log_{10} K + 0.4634 \log_{10}T$

Total fishing mortality (F) was estimated as:

F = Z - M (Gulland, 1971).

Exploitation rates (Emax, E0.1 and E0.5)

The knife-edge option was used to determine Emax (exploitation rate at maximum yield), Rate of exploitation (E) is the ratio of fishing mortality (F) and total mortality (Z) (Pauly, 1984), and is written as follows:

E = F/Z

Gulland (1971) states that the optimal exploitation for a fish stock occurs when fishing mortality (F) is proportional to the natural mortality:

F optimum = M

Thus, E ranges from 0 to 1. It is optimum at 0.5, under-exploited when it is less than 0.5, and over-exploited when the estimate is above 0.5.

Data analysis

The length frequency data was combined into groups of 1 cm intervals. The FiSAT II (FAO-ICLARM Stock Assessment Tools) program was then used to analyze the data (Gayanilo et al., 2005). The Yield software tool was used to graph the length at each age (Branch et al., 2000).

Results

The length-weight relationship of this study revealed that *S. aurita* had an exponent "b" value of 3.210, which shows a positive allometric growth (Figure 2). The value of the correlation coefficient (r^2) estimated for the species was 0.86971. The size groups of the sex ratio for *S. aurita* in the study area is shown in Table 1. The lengths of sampled fish ranged between 4.1 cm – 24 cm. Of 513 sampled fish, 262 were male and 251 were female, based on a one-centimetre interval corresponding to 51% males and 49% females of the total catch.

The exploitation structure of *S. aurita* in the study area is shown in Figure 3. Maximum exploitation was observed in the range of 8.1–12 cm size group for both the male, pooled and female samples, followed by 12.1 – 16 cm, and the minimum group percentage exploitation was recorded for size group 20.1 – 24 cm.

Figure 4 shows the reconstructed length-frequency distribution superimposed with the growth curves and the length curve for *S. aurita*. Figure 5 shows the length curve for *S. aurita* where the ration of M/K is 1.50.

The estimated growth parameters for *S. aurita* using the ELEFAN II program discovered the best fit for asymptotic length (L_∞) = 21.73 cm, growth rate (K) = 0.95 yr^{-1}, age at birth (t_0) = -0.48 yr^{-1}, longevity (t_{max}) = 9.09 yr^{-1} and the growth performance index (φ'= 2.65) (Table 2).

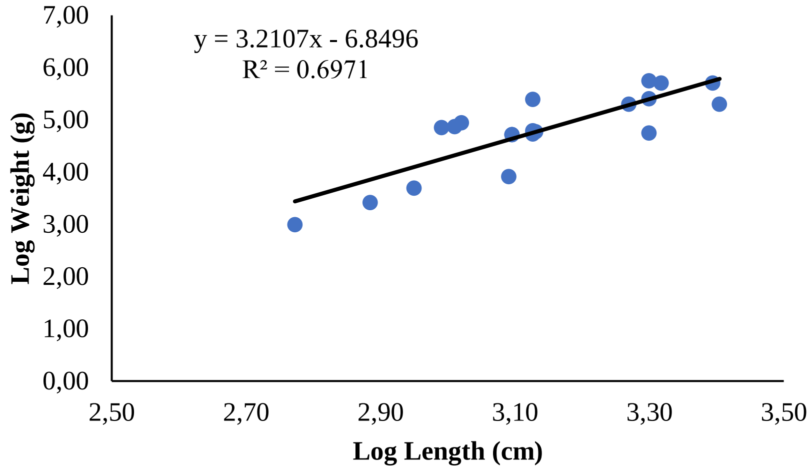

Figure 2. Length-weight relationship of *S. aurita* during the study period

Table 1. Length groups (Sex ratio) of *S. aurita* from New Calabar River

Length groups (cm)	Pooled	No of fish Male	Female	Sex ratio (Male: Female)
4.1 – 8	47	25	22	1:0.88
8.1 – 12	304	174	130	1:0.75
12.1 – 16	157	62	95	1:1.53
16.1 – 20	4	1	3	1:3
20.1 – 24	1	0	1	0:1
Total	513	262	251	51:49

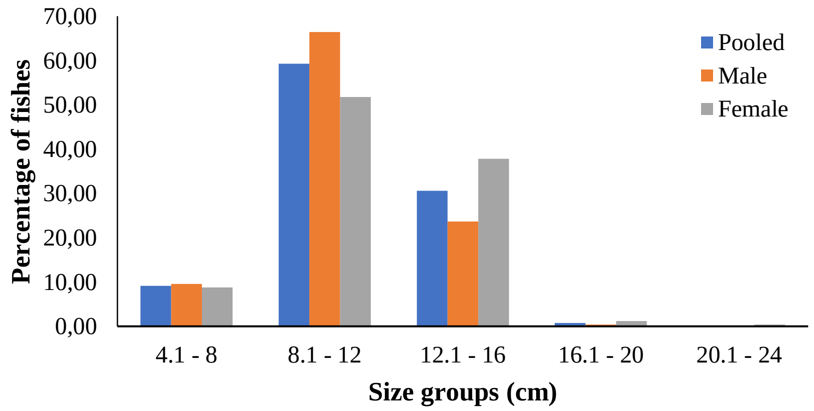

Figure 3. Exploitation structure of *Sardinella aurita* from New Calabar River

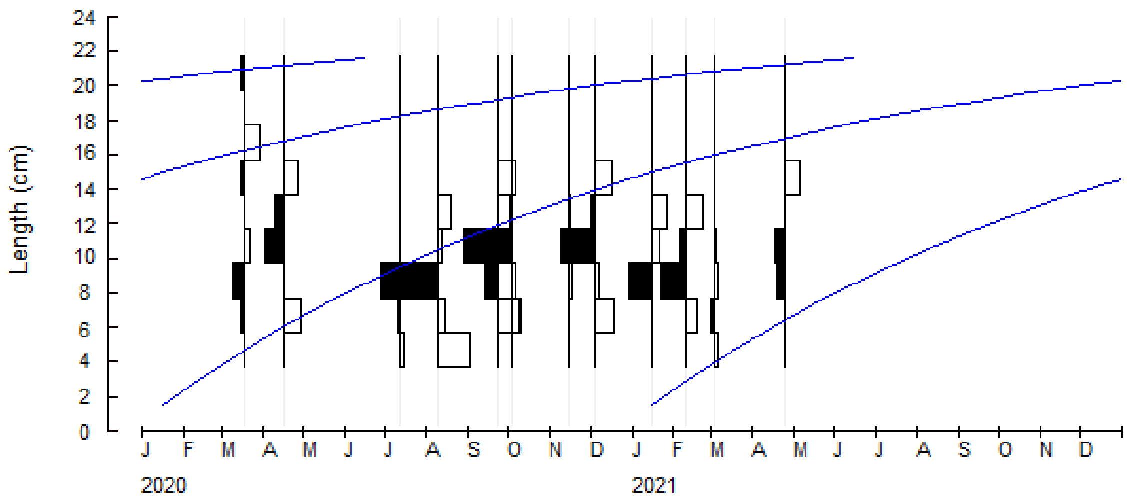

Figure 4. Reconstructed monthly length-frequency distribution

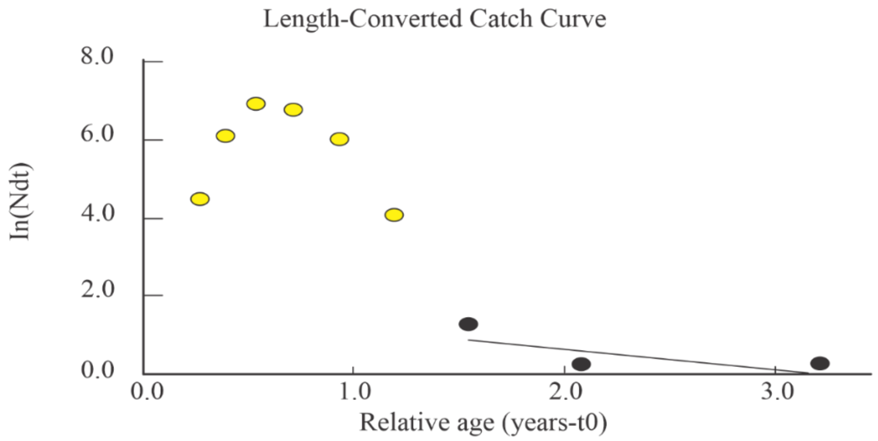

Figure 5. Length-converted catch curve for *S. aurita* in the New Calabar River

Table 2. Some growth parameters of *S. aurita* from New Calabar River

Indicators	Unit	Value
Growth rate (K)	yr^{-1}	0.95
Asymptotic length (L_∞)	cm TL	21.73
Age at birth (t_0)	years	-0.48
Longevity (t_{max})	years	2.68
Growth performance index (phi-prime, φ’)		2.65

The probability of catching *S. aurita* gives a good indicator of the estimated true size of fish captured by certain gear in a given fishing location, as the length at initial capture (Lc50) was 15.06 cm and the length at first maturity (Lm50) was estimated at 21.12 cm. The estimated total mortality rate (z) was 3.03 yr^{-1} and natural mortality was 1.42 yr^{-1}, given a fishing mortality of 1.61 yr^{-1}. The current exploitation rate was estimated as E=0.53 and the M/K ratio found was 1.50 (Table 3).

Table 3. Exploitation rate and mortality of *S. aurita* from New Calabar River

Indicators	Unit	Value
Length at first maturity (Lm50)	cm TL	21.12
Natural mortality rate (M)	yr^{-1}	1.42
Total mortality rate (Z)	yr^{-1}	3.03
Fishing mortality rate (F)	yr^{-1}	1.61
Exploitation rate (E)		0.53
Length at first capture (Lc50)	cm TL	15.06
M/K		1.50
Number of data points (N)		513

Discussion

The value of the correlation coefficient (r^2) estimated for the species shows that the relationship between the length and weight of the fish was highly significant. The length-weight relationship value of the species however, falls within the acceptable range of 2.5 and 3.5, which is typical for tropical fish stocks (Froese, 2006). This is in agreement with the findings of Amina et al., (2016). The differences in sex growth and mortality are useful for an adequate knowledge of demographic structures. The ratio of sex changed significantly when the fish attained maturity, and there were variations in the sex-ratio dependent on the size of the reproductive unit. The sex-ratio favored males (51%) to females (49%), which is in line with the findings of Bensahla-Talet et al. (1988) and Lawson and Doseku (2013) in Majidun Creek, Lagos, Nigeria, but contradicts the findings of Baali et al. (2015), who recorded a higher percentage value for females (63.98%). Sex-ratio varies with respect to size ranges.

Maximum exploitation was observed in the 8.1–12 cm size group, with a higher number of males compared to females. The prevalence of males could also be explained by the migratory nature of this species. In migratory species, females frequently arrive at the spawning site later than males. Males predominate among the early migrants, followed by a numerical disparity between males and females, and a female majority in late migration (Diouf et al., 2010). This could be a factor in the dominance of males in this study as a result of predominance in early migration. Furthermore, differences at various sizes are associated with unequal rates of growth and mortality (Turner et al., 1983). The length at asymptotic (L_∞) (21.73 cm) and growth rates (K) of 0.95 yr^{-1} calculated in this study were relatively different from estimates by other researchers (Al-beak, 2016; Mehanna and Salem, 2011). Nabil et al. (2012) obtained L_∞= 28.37 cm, K= 0.23 year-1 and t_0= 0.98 year. In the Mediterranean Sea, Gaamour et al. (2001) obtained L_∞=31.32 cm; K=0.24 year-1 and t_0=0.87 year in the Tunisian coast. Differences between authors may be due to the number of examined individuals. Such variations in growth coefficients may be due to the estimation protocol, length classes obtained, the geographical locations and the level of fishing pressure (Amponsah et al., 2016a). Also, the variations in estimates of asymptotic lengths may, therefore, be as a result of the maximum observed length, sampling methods, computation methods used and the obtained length-frequency (Sparre and Venema, 1992). The estimated growth rate recorded in this study was higher than the 0.34 yr-1, indicating that *S. aurita* is a fast-growing fish species (Kienzle, 2005). The estimated fast growth rate of *S. aurita* in this study compared to the other related findings may be due to disparities in the ecological characteristics such as habitat, fish adaptive life pattern and location, environmental conditions as a result of regional differences, food abundance or size composition of the stock that directly affect growth rate. The estimation protocol, length classes obtained, geographical locations, and the level of fishing pressure could all be factors for variations in the growth coefficient (Amponsah et al., 2017), as indicated by its 12-year lifespan and a growth performance index outside the normal range of 2.65-3.32, which is reserved for fast-growing fish species (Baijot et al., 1997). *S. aurita's* poor development rate recorded by other researchers could be attributed to the lower nutritional value of the accessible feed (Montchowui et al., 2011).

In this study, the length at first capture (Lc_{50}) was recorded as 15.06 cm and the length at first maturity (Lm_{50}) was calculated as 21.12 cm. This study's estimated length at first catch (Lc_{50}) was lower than (Al-Beak's, 2016) estimates and within the range of values recorded by Amponsah et al. (2017). These findings could be attributed to artisanal fishermen's use of small mesh sizes. As a result, fishing gear with small mesh sizes should be prohibited as a management strategy. Furthermore, the relatively higher estimated Lm_{50}/L_∞ ratio indicated that *S. aurita* is a small-sized fished species in the New Calabar river. Environmental factors, long-term fishing pressure and a rapid response to natural selection are all possible causes for this observation. (Tsikliras and Anthonopoulou, 2006).

The index of growth performance (φ') is considered as a useful tool for comparing the growth curves of different populations of the same species and/or of different species belonging to the same family. In this study, the value of the growth performance index was φ'=2.65. This growth index is higher than those obtained by Gaamour et al. (2001) in the Tunisian coast (φ' =2.27), and by Salem et al. (2010) in the Mediterranean coast (φ'=2.27). Differences in growth parameters may be due to genetic structure, temperature, food availability and diseases (Tsikliras et al., 2005).

S. aurita juveniles become susceptible to capture six months after being recruited into the stock, according to the age at first capture (tc_{50}) method, because of the mesh size and type of fishing gear used. The calculated age at first capture (tc) was lower than that calculated by Al-beak (2016) and Mehanna and Salem (2011). Furthermore, the intensity of fishing over time may be a factor that tends to alter the species' length structure in order to prevent future collapse.

Beverton and Holt (1959) demonstrate that a fish's natural mortality coefficient (M) is proportional to its growth coefficient (K) and inversely proportional to its asymptotic length (L) and life span. The natural mortality was 1.42 yr^{-1} while the growth coefficient was 0.95. The M/K ratio in this study was 1.55, which was in agreement with the range of 1–2.5 proposed by Beverton and Holt (1959). Estimated total mortality (Z) at 3.03 yr^{-1} is likened to 2.46-7.07 by Pauly (1994) for several stocks in this study. Barry and Tegner (1989) documented that a M/K ratio < 1 indicates that the population is growth dominated, whereas a M/K ratio > 1 is an indication that the population is mortality dominated. However, when the M/K ratio = 1, then the growth and mortality of the population are in equilibrium. From the present study, the calculated M/K ratio was slightly greater than 1, suggesting that the stock is fishing mortality dominated. King and Etim (2004) highlighted that for a mortality dominated stock, an M/K ratio ≈ 2 denotes a lightly-exploited stock while values greater than 2 show heavy exploitation. With the estimated M/K ratio lower than 2, it shows that *S. aurita* stock in the study area is maximally exploited. The estimated M/K ratio (1.50) was well within the range of 1.5 – 2.5 for fishes, indicating the presence of a good environmental state (Abowei et al., 2009). The exploitation rate ranges from 0 to 1. It is optimum at 0.5, under-exploited when it is less than 0.5, and over-exploited when the estimate is above 0.5. The estimated exploitation rate (E) of 0.53 in this study is within the range of the maximum exploitation rate (E_{max}=0.53), and this shows that the fishery exploitation is at its peak (optimal), but that it may be subject to minor growth fishing pressure. The exploitation ratio found in this study indicates that *S. aurita* is at maximum exploitation and not over-fished (Pauly, 1994). This is predicated on the assumption that natural and fishing mortalities should be equal in an optimally exploited stock, or E=F/Z=0.5 (Gulland, 1971).

Conclusion

The estimated growth rate recorded in this study depicts that *S. aurita* is a fast-growing fish species, and growth overfishing was found to be present due to the harvesting of relatively small-sized species, and also has a high natural mortality to asymptotic length ratio (M/K > 1). The sex-ratio favors males with 51%, particularly for range (8.1–12 cm), with optimum exploitation structure observed within the same group. Additionally, the intersection of the required length at capture and the exploitation rate showed that the species was being exploited at its maximum rate. Therefore, to prevent growth overfishing, sustainable fisheries measures should be adopted, and these include monitoring of fishing efforts and implementation and enforcement of increased mesh size to sustain the fishery of *S. aurita* in the New Calabar river.

Acknowledgements

We thank the University of Port Harcourt, Faculty of Agriculture, Rivers State, Nigeria for providing access to the equipment and facilities during this study and to the fishermen who provided the fish samples.

Conflict of Interest

There are no conflicting interests declared by the authors.

Author Contributions

The study was conceived by authors HE and OA, HE prepared the first draft of the publication, and CD conducted the statistical analyses. The final manuscript was read and approved by all the writers.

Ethic Approval

The material used in the article was obtained from the local artisanal fishermen. Ethics committee approval is not required for this study.

References

Abowei, J.F.N. (2009). The Abundance Condition Factor and Length-Weight Relationship of some *Sardinella maderensis* (Jenyms, 1842) from Nkoro River, Niger Delta, Nigeria. *Advanced Journal of Food Science and Technology*, 1(1), 65-70.

Abowei, J. F. N. (2000). Aspect of the fisheries of the lower Nun River. [Ph.D. Thesis. University of Port Harcourt]. 238

Adesulu, E. A., & Sydenham, D. H. J. (2007). The freshwater and fisheries of Nigeria. Macmillan Nigeria Publishers Limited.

Al-beak, A.M. (2016). Fisheries management of round *Sardinella aurita* along North Sinai coast. *Journal of Coastal Life Medicine*, 4(7), 505-509.

Aleev, Y. G. (1952). Horse Mackerel of the Black Sea, VNIRO Press.

Amina, D., Mardja, T., Mourad, B., Rachid, A., & Borhane, D. (2016). Growth, age and reproduction of Sardinella aurita (Valenciennes, 1847) and Sardina pilchardus (Walbaum, 1792) in the Algerian eastern coasts. AACL Bioflux,, (9)5. http://www.bioflux.com.ro/aacl

Amponsah, S.K.K., Ofori-Danson, P.K., Nunoo, F.K.E., & Ameyaw, G.A. (2017). Population dynamics of

Sardinella aurita (Val., 1847) within Ghana's coastal waters. *Res. Agric. Livest. Fish.*, 4 (3), 215-226.

Anato, C. B. (1999) Les Sparidae des côtes béninoises: Milieu de vie, pêche, présentation des espèces et biologie de Dentex angolensis Poll et Maul, 1953. Thèse de Doctorat d'Etat es Sciences, Fac. Sci. 1060 Tunis, 277 p.

Arra, S., Sylla, S., Kouame, A. C., Zan-BI, T. T., & Ouattaraw, M. (2018). Reproductive biology of the African moonfish, *Selene dorsalis* (Gill, 1862) (Carangidae) in continental shelf of Côte d'Ivoire fishery (West Africa). *International Journal of Fisheries and Aquatic Studies*, 6(2), 358-363.

Baali, A., Yahyaoui, A., Amenzoui, K., Manchih, K., & Abderrazik, W., (2015) A preliminary study of reproduction, age and growth of *Sardinella aurita* (Valenciennes, 1847) in the southern of Atlantic Moroccan area. *AACL Bioflux,* 8(6), 960-974.

Baijot, E., Moreau, J., & Bouda, S. (Eds), (1997). Hydrological Aspects of Fisheries in Small Reservoirs in the Sahel Region. Technical Centre for Agricultural and Rural Cooperation, Wageningen, Netherlands: 79–109.

Bard, F. X., & Koranteg, K. A. (1995). Dynamics and use of Sardinella resources from upwelling off Ghana and Ivory Coast. Orstom, Paris.

Barry, J.P., & Tegner, M.J. (1989). Inferring demographic processes from size frequency distributions: simple models indicate specific patterns of growth and mortality. *US Fisheries Bull*., 88: 13-19.

Bensahla-Talet, A., Mortet, Y., & Tomasini, J.A. (1988). Relations masse-longueur, sex-ratio et reproduction (saison de ponte, fécondités) de *Sardinella aurita* (Val. 1847) des cotes Oranaises (Algerie), *Comm. Int. Mer Médit.* 31 V-II: 14.

Beverton, R.J.H, & Holt, S.J. (1959). On the dynamics of exploited fish populations. In Fishery investigations, Series II, 19. Her Majesty's Stationery Office, London, 533.

Bianchi, G., Carpenter, K.E., Roux, J.-P., Molloy, F.J., Boyer, D. & Boyer, H.J. (1999). FAO species identification guide for fishery purposes. Field guide to the living marine resources of Namibia. FAO, Rome.265.

Branch, T.A., Kirkwood, G.P., Nicholson, S.A., Lawlor, B J., & Zara, S.T. (2000). Yield Version 1.0, MRAG Ltd, London U.K.

Cury, P., & Fontana, A. (1988). Compétitionet 46nternatio démographiques 46 nternat de deuxespèces de *sardinelles* (*Sardinella aurita et Sardinella maderensis*) des côtesouest-africaines. *Aquatic Living Resources*, 1:165-180.

Dienye, H.E., & Woke, G.N. (2015). Physico-chemical Parameters of the Upper and Lower Reach of the New Calabar River Niger Delta. *Journal Fisheries & Livestock Production*, 3, 154. doi:10.4172/2332-2608. 1000154

Diouf, K., Samb, B., & Sylla, M. (2010). Contribution à la connaissance de la biologie des sardinelles (*Sardinella aurita* et *Sardinella maderensis*) du littoral sénégalais. Dans: Science et aménagement des petits pélagiques. Symposium sur la science et le défi de l'aménagement des pêcheries de petits pélagiques sur les stocks partagés en Afrique nord-occidentale. S. Garcia, M. Tandstad, Caramelo A. M.(eds), pp. 39–56, 11-14 mars 2008, Casablanca, Maroc. FAO Comptes rendus des pêches et de l'aquaculture, No. 18, Rome, FAO.

Froese, R. (2006). Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. *Journal of Applied Ichthyology*, 22, 241-253.

Froese, R., & Pauly, D. (2003). Fish base. World Wide Web electronic publication. Available at: www.fishbase.org, 10 September, 2003.

Formacion, S.P., Rongo, J.M., & Sambilay, V.C. (1991). Extreme value theory applied to the statistical distribution of the largest lengths of fish. *Asian Fisheries Science*, 4, 123-135.

Gaamour, A., Missaoui, H., & Ben Abdallah, L. (2001). Biological parameter of round sardinella (*Sardinella aurita*, Valenciennes, 1847) in the region of Cap Bon, (Canal Siculo-tunisien). GFCM. 26-30 March 2001. Kavala, Greece. pp 26-30

Gayanilo, F., Sparre, P., & Pauly, D. (2005). FAO-ICLARM Stock Assessment Tools II (FiSAT II). Revised. User's guide. Computerized Information Series (Fisheries). No. 8. Revised version. FAO, Rome, 168.

Gulland, J. (1971). The Fish Resources of the Oceans. FAO/Fishing News Books, Surrey, 255.

Jobling, M., (2002). Environmental factors and rates of development and growth. Handbook of fish biology and fisheries. P. J. B. Hart and J.D. Reynolds.

Kartas, F., & Quignard, J. P. (1984). Contribution à l'étude de l'allache (*Sardinella aurita* Val. 1847) des côtes de Libye, *Commission internationale de la Mer Méditerranée*. 23, 157-176.

Kienzle, M. (2005). Estimation of the population parameters of the Von Bertalanffy Growth Function for the main commercial species of the North Sea. Fisheries Research Services Internal Report. No. 05/05. Aberdeen, 34 .

King, R.P., & Etim, L. (2004). Reproduction, growth, mortality and yield of *T. mariae* (Boulenger, 1899) (Cichlidae) in Nigeria rainforest wetland stream. *J. of Applied Ichthyology*, 20(6), 502-510.

Lawson, E. O., & Doseku, P. A. (2013). Aspects of Biology in Round Sardinella, *Sardinella aurita* (Valenciennes, 1847) from Majidun Creek, Lagos, Nigeria. World

Journal of Fish and MarineSciences, 5(5), 575-581. doi: 10.5829/idosi.wjfms.2013.05.05.74144

Mehanna, S.F., & Salem, M., (2011). Population dynamics of round sardine *Sardinella aurita* in El-Arish waters, Southeastern Mediterranean, Egypt. *Indian Journal of Fundamental and Applied Life Sciences*, 1(4), 286-294.

Montchowui, E., Chikou, A., Ovidio, M., Laleye P. & Poncin, P. (2011). Population dynamics of Labeo senegalensis (Val, 1842) in the Oueme River, Benin. *Journal of Fisheries International*. Vol 6 (3);52 – 58.

Munro, J.L., & Pauly, D. (1983). A Simple Method for Comparing Growth of Fishes and Invertebrates. *ICLARM Fishbyte*, 1, 5-6.

Nabil, F.A.E.H., Attaia, A.O., & Mohsen, S.H. (2012). Stock Assessment and Potential management of Sardinella aurita Fisheries in the East Mediterranean sea (North Sinai coast). *Egyptian Journal Aquatic Biology and Fisheries,* 16 (2), 121-132.

Paugy, D. (2003). Alestidae. In D. Paugy, C. Lévêque & G. G. Teugels (Eds.), The fresh and brackish water fishes of West Africa Volume 1. Coll. faune et flore tropicales 40. Institut de recherche de développement, Paris, France, Muséum national d'histoire naturelle, Paris, France and Musée royal de l'Afrique Central, Tervuren, Belgium, 457.

Pauly, D. (1984). Some Simple Methods for Tropical Fish Stock. FAO Fish. Tech. Pap. (243): p. 52. Google Scholar

Pauly, D. (1980). On the Interrelations between Natural Mortality, Growth Parameters and Mean Environmental Temperature in 175 Fish Stocks. *ICES Journal of Marine Science*, 39, 175-192.
doi: 10.1093/icesjms/39.2.175

Pauly, D. (1983). Length converted catch curves. A powerful tool for fisheries research in tropics (Part-1), *ICLARM Fish byte*, 1, 9-13.

Pauly, D. (1994). On the Sex of the Fish and the Gender of Scientists Chapman and Hall, London.

Riede, K. (2004). Global register of migratory species - from global to regional scales. Final Report of the R and D-Project 808 05 081. Federal Agency for Nature Conservation, Bonn, Germany. 329 p.

Salem, M., EL-Aiatt, A.A., & Ameran, M. (2010). Age, growth, mortality and Exploitation rates of round Sardinella (*Sardinella aurita*) from the east Mediterranean Sea (north Sinai coast). *Research Journal Fisheries of Hydrobiology*, 5(1), 32-38.

Sparre, P. & Venema, S.C. (1992). Introduction to Tropical Fish Stock Assessment. Part 1. Manual, FAO Fisheries Technical Paper, 306. No. 1, Review 1, FAO, Rome, 376 p.

Tsikliras, A.C., & Antonopoulou, F. (2006). Reproductive biology of round sardinella (*Sardinella aurita*) in the north-eastern Mediterranean. *Sci. Mar.*, 70(2), 281-290.

Tsikliras, A.C., Koutrakis, E.T., & Stergiou, K.I. (2005). Age and growth of Sardinella (*Sardinella aurita*) of the northeastern Mediterranean. *Scientia Marina*, 69(2), 231-240.Crossref

Tsikliras, A.C. (2008). Climate-related geographic shit and sudden population increase of a small pelagic fish (*Sardinella aurita*) in the eastern Mediterranean Sea. *Marine Biology Research*, 4, 477 – 481.

Turner, S. C., Grimes, C. B., & Able, K. W. (1983). Growth, mortality, and age/size structure of the fisheries for the tilefish, *Lopholatilus chaemaelonticeps,* in the middle Atlantic- Southern New England region. *Fisheries Bulletin*, 81, 751-763.

Whitehead, P.J.P. (1981). Clupeidae. In Fischer W., Bianchi G. and Scott W.B. (eds.) FAO species identification sheets for fishery purposes. Eastern Central Atlantic; fishing areas 34, 47 (in part). Department of Fisheries and Oceans Canada and FAO. (2), 46.

Whitehead, P.J.P. (1985). FAO Species Catalogue. Clupeoid fishes of the world (suborder Clupeoidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. FAO Fish. Synopsis. 125 (7/1): 1-303. Rome: FAO.