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Length-based growth, mortality, and biological reference points of *Chrysichthys nigrodigitatus* (Lacepède, 1803) from the Yeji arm of Lake Volta, Ghana

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ABSTRACT

Individuals of *Chrysichthys nigrodigitatus* from Lake Volta, Ghana (West Africa), were examined between January and December 2020 for growth, mortality, and exploitation rate using total length measurement. Monthly length-frequency data were collected from 244 samples and analysed using the FiSAT II Tool. The estimated asymptotic total length (L_∞), the coefficient of growth (K), and the calculated growth performance index (phi) were 27.3 cm, 0.57, and 2.63 per year, respectively. The total mortality rate (Z), natural mortality rate (M), and fishing mortality rate (F) were 1.57, 0.92, and 0.66 per year, respectively. The exploitation rate (E = 0.42) was below the optimum level of 0.5, which indicates that the species is underexploited. Based on the Emsy (0.56) value, analyses show that the exploitation rate is below the sustainable limit, hence the need for continuous monitoring of fishing efforts to ensure that the limit reference point is not exceeded.

Keywords: Ghana, Inland fishes, Fisheries management, Population parameters, FiSAT II

Introduction

The silver catfish (*Chrysichthys nigrodigitatus*), which belongs to the Claroteidae family, occurs in most of Africa's major rivers, including Ghana (Ezenwa, 1981). The Family Claroteidae was carved from the traditional Bagridae to reflect a monophyletic group of African catfishes (Berra, 2001). They are highly valued food fish in most native African waters and are among the prevailing inland fish of commercial catches (Ikongbeh *et al.,* 2015). Because of the bottom-dwelling habit, this fish species is primarily harvested with a dragnet, hook and line, bottom-set gillnet, and bottom-set traps (Offem *et al.,* 2008).

Chrysichthys (Pisces: Siluriformes: Claroteidae) species consistently supports inland artisanal fisheries, both economically and in nutrition for communities along Lake Volta, Ghana (Ikongbeh *et al.,* 2015). The most commonly found species of Chrysichthys in Ghana include *C. walkeri, C. auratus, C. maurus, C. johnelsi,* and *C. nigrodigitatus* (Dankwa *et al.,* 1999), with *C. nigrodigitatus* as the most dominant species (Nelson, 2006). Fishermen residing in fishing villages along the lake Volta engage different types of fishing gear in the exploitation of *C. nigrodigitatus.* These gears include gillnets of various mesh sizes, cast nets, bamboo, traps, and hooks (Ajagbe *et al.,* 2021). Despite being present in most inland waters of Ghana, the stock of *C. nigrodigitatus* is profusely exhibiting a decline due to environmental degradation and overfishing (Adite *et al.,* 2017). This is evinced by the prominent appearance of smaller-sized individuals and juveniles of *C. nigrodigitatus* in the catches of fishermen, an indication of growth overfishing (Ofori-Danson *et al.,* 2002).

In Ghana, the only study (i.e., Ofori-Danson *et al.,* 2002) done on the population parameters of the species Lake Volta, Ghana, was carried out approximately two decades ago, which has dire implications for managing this valuable fish stock. Therefore, to update information on population parameters for this species, the study's main objective was to assess the growth, mortality, and exploitation rate of *C. nigrodigitatus* of Lake Volta, Ghana. Such scientific information will foster the implementation of proper management measures to sustain the assessed fish species in Lake Volta, Ghana.

Materials and Methods

Study Area

Four landing communities within Stratum VII of Lake Volta were selected, between longitude 0°10' and 1°05W and latitude 8°8' and 8°20'N and extending 60 km south and 50 km north of Yeji. These communities were Tonka, Vutideke, Brekente and Fante Akura, all landing sites within the Stratum VII of Lake Volta (Figure 1). Yeji is the capital of Pru District in the Brong-Ahafo region, with a population of 28.515 (GSS, 2014). Selection of these sampling inland fishing communities was based on two-stage stratified sampling criteria: geographical isolation and the level of fishing activities based on the number of fishing boats.

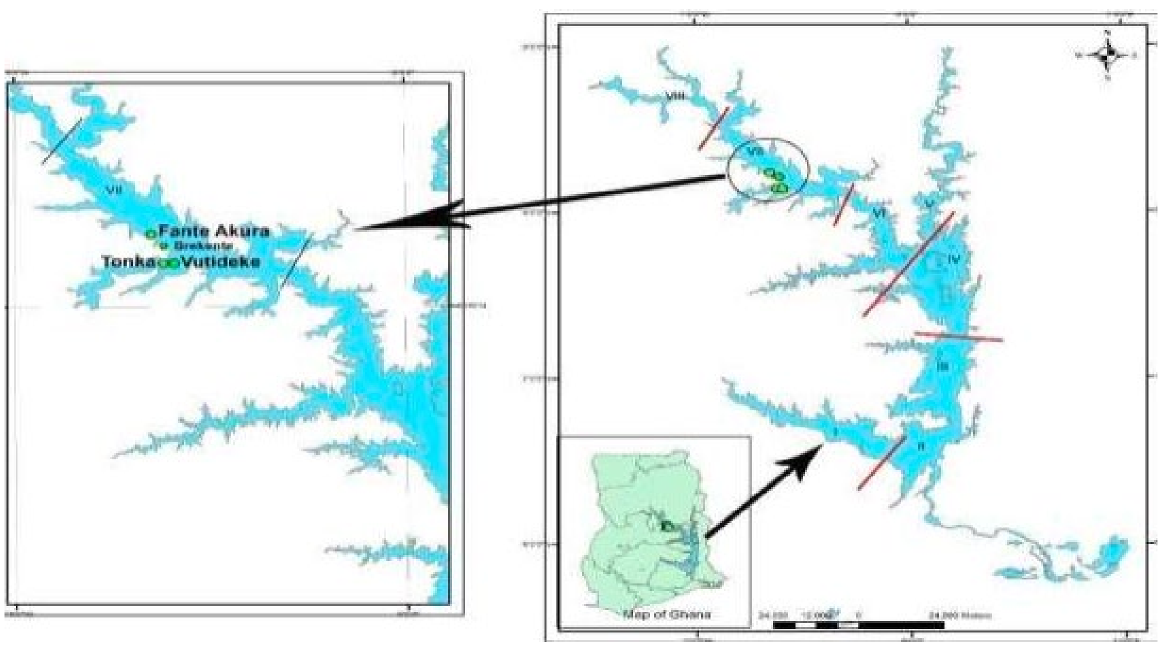

Figure 1. Map showing the fish landing sampling locations

Data Collection

Individuals of the assessed fish species were obtained from randomly selected fishermen who applied different fishing gear in their fishing activities. These fishing gears involved bamboo, traps, and set gillnets (mesh size = 0.25 and 0.5 inches diagonally stretched). Samples were obtained over twelve (12) months (i.e., January to December 2020), preserved on ice, and analysed in situ. The species were identified to the lowest taxonomic level using identification keys by Dankwa *et al.* (1999). Measurement of length was performed using a 100 cm graduated wooden measuring board. In all, 244 specimens of *C. nigrodigitatus* were obtained during the study period.

Growth Parameters

Parameters for which the fish growth is assumed to follow Von Bertalanffy Growth Function (VBGF), including growth rate (K) and asymptotic length ($L\infty$) were estimated.

Estimation of longevity (T_{max}) for the species was estimated:

$T_{max} = 3/K$ (Anato 1999).

The growth performance index was calculated using the formula:

$(\Phi') = 2\log L_\infty + \log K$ (Munro & Pauly, 1984).

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

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

Mortality Parameters

Total mortality (Z) was computed using a Linearized length converted catch curve (Sparre & Venema, 1992).

The natural mortality rate (M) was calculated using the procedure:

$M = 4.118K^{0.73}L\infty^{-0.333}$ (Then *et al.*, 2015).

Fishing mortality (F) was calculated as:

$F = Z - M$ (Qamar *et al.*, 2016).

The exploitation rate (E) was computed using:

$E = F/Z$ (Georgiev and Kolarov, 1962).

Length at First Capture (Lc_{50})

The ascending left part of the length converted catch curve was used in estimating the probability of length at first capture (Lc_{50}) in addition to the length at both 25 and 75 percent capture, which correlates with the cumulative probability at 25% and 75% respectively (Pauly, 1984).

Biological Reference Points

E_{msy}, which depicts the exploitation rate producing maximum yield, and $E_{0.5}$, implying the exploitation rate under which the population is reduced to half its virgin biomass, were computed using the knife edge selection options.

Data Analyses

The length frequency data were pooled into groups with 2 cm length intervals. Then, the data was analysed using the FiSAT II Tool (Gayanilo *et al.,* 2002).

Results and Discussion

Length Distribution Frequency

The mean length of *C. nigrodigitatus* was 13.8, with minimum and maximum lengths of 7 cm and 25.1 cm recorded in January 2020 and March 2020, respectively. The modal length of the assessed fish species was 10 cm to 12 cm (Table 1).

Growth Parameters

Figure 2 shows the restructured length frequency with superimposed growth curves. The asymptotic length ($L\infty$) was 27.3 cm. *C. nigrodigitatus* grew at a growth rate (K) of 0.57 per year with longevity (T_{max}) of 5.26 yr. The growth performance index (Φ') and age at length zero were estimated at 2.628 and -0.29, respectively. The VBGF for length at the time (t) was expressed as $L_t = 27.3 * (1-e^{-0.57\,(t+0.29)})$.

Mortality Parameters

From the length converted catch curve (Fig 3), the total mortality rate (Z) estimated was 1.57 per year. The natural mortality rate (M) was 0.92 per year, and the fishing mortality rate (F) was 0.66 per year. The exploitation rate (E) recorded for *C. nigrodigitatus* was 0.42.

Length at First Capture (Lc_{50})

The probability of capture was estimated as $L_{25} = 8.58$ cm, $L_{50} = 9.66$ cm and $L_{75} = 10.7$ cm. Therefore, the length at first capture (Lc_{50}) was 9.66 cm.

Biological Reference Points

From Fig 5, the indices for sustainable yield were 0.32 for optimum sustainable yield ($E_{0.5}$) and 0.56 for the maximum sustainable yield (E_{msy}).

Table 1. Length frequency distribution of *C. nigrodigitatus* from Stratum VII of Lake Volta, Ghana

Upper limit	2020												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
8	7	0	1	0	0	0	0	0	0	0	0	0	8
10	10	2	11	0	0	0	0	3	0	3	4	1	34
12	11	9	3	1	1	6	9	3	3	5	6	2	59
14	0	5	2	4	6	7	4	3	5	4	2	2	44
16	0	2	0	9	10	6	9	3	3	0	1	4	47
18	1	2	1	4	5	9	2	2	0	0	1	5	32
20	0	0	3	0	1	1	0	1	1	0	0	0	7
22	0	0	1	2	3	0	0	0	0	0	0	0	6
24	0	0	0	3	0	1	0	2	0	0	0	0	6
26	0	0	1	0	0	0	0	0	0	0	0	0	1
Total	**24**	**20**	**23**	**23**	**26**	**30**	**24**	**17**	**12**	**12**	**14**	**14**	**244**

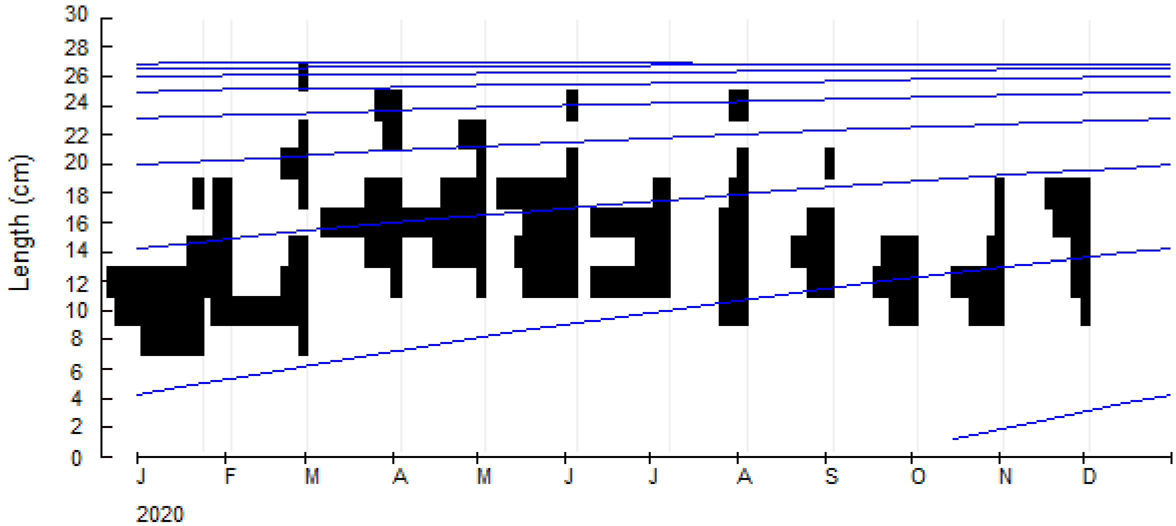

Figure 2. Reconstructed length frequency distribution superimposed with the growth curve

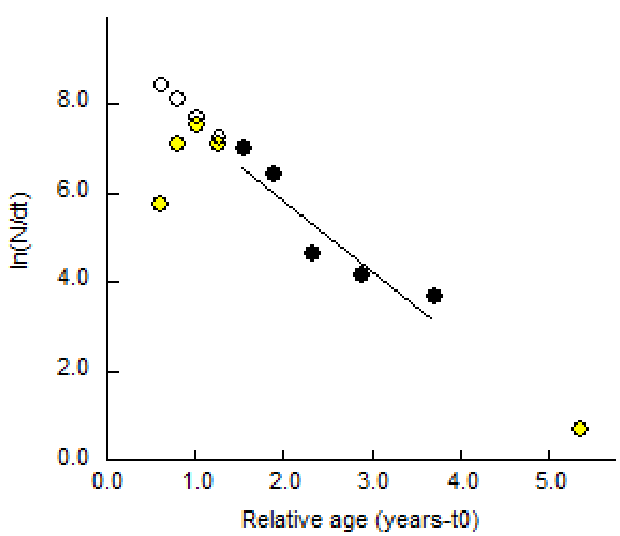

Figure 3. Linearized length-converted catch curve for estimation of instantaneous total mortality (Z)

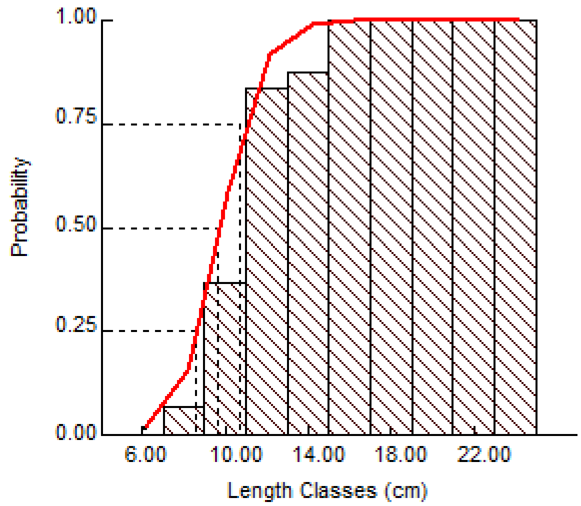

Figure 4. Probability of capture of *C. nigrodigitatus*

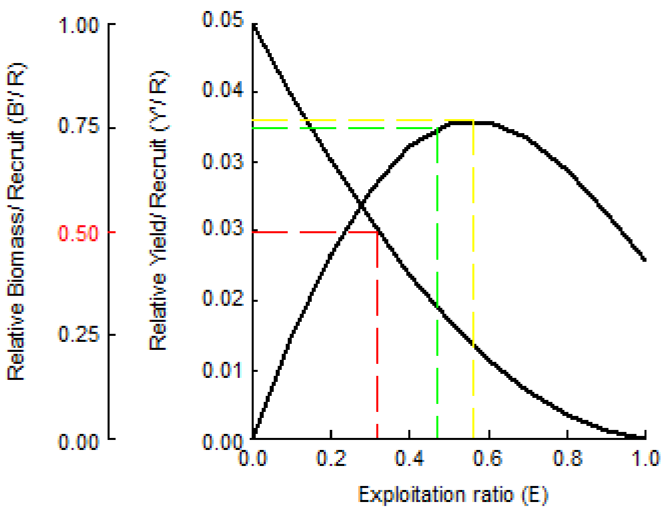

Figure 5. Yield per recruit analysis of *C. nigrodigitatus*

The study's maximum theoretical length (L∞) was 27.3 cm TL, which was lower than the estimated length recorded by Ofori-Danson *et al.* (2002). This suggests that small-sized individuals of this species from Lake Volta are facing high fishing pressure. Okogwu *et al.* (2010) assigned the observed difference in maximum theoretical length to the variability of the study environments and fishing pressure. The growth performance index from the present study (phi = 2.62) was outside the range (i.e. phi = 2.65 – 3.12) estimated by Baijot and Moreau (1997) for crucial African fish species showing slow growth. This fast growth exhibited by individuals of the species may be a coping strategy for high fishing pressure on Lake Volta, Ghana.

The size at first capture is a biological indicator and a vital parameter that indicates the health status of the resource (Kone *et al.,* 2022). The length at first capture from the study (i.e. 9.66 cm) was lower than the findings by Kone *et al.* (2022), Ajabge *et al.* (2021), and Udoidiong *et al.* (2016). In addition, the critical length at capture (Lc = 0.35) indicated that species are harvested at 35% of growth, higher than documented by Udoidiong *et al.* (2016), which, from a management perspective, is unhealthy for the sustenance of the stock. Furthermore, Lc < 0.5 signifies harvesting smaller individuals of the assessed fish species than adults. These findings from the study confirm the exploitation of more minor or juvenile individuals from Lake Volta. Such exploitation indicates growth overfishing, characterised by individuals having a lower chance of contributing significantly to the stock (Ofori-Danson *et al.,* 2002). The high abundance of juvenile individuals could be attributed to the excessive use of bamboo as fishing gear on the Lake. *Chrysichthys* sp. primarily views bamboo as spawning or breeding substrates; hence, there is a high possibility that fisherfolks who employ these fishing gears will harvest gravid individuals. Continuous indulgence in unsustainable fishing practices could impair the recruitment potential of the assessed fish species. This observation calls for mesh size regulation and a ban on the bamboo used for fishing this species, which will permit the escape of small-sized individuals.

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 (1.61) fell within the acceptable demarcated range, which shows the reliability of the estimates obtained for the present study. According to Cissé *et al.* (2021), the maximum level of exploitation of a resource is reached when fishing mortality (F) is equal to or higher than natural mortality (M). From the present study, the natural mortality rate (0.92 per year) was higher than the fishing mortality rate (0.66 per year), which is reflected in the low exploitation rate (E = 0.42). The relatively lower fishing mortality rate than the natural mortality rate from the current study points to an imbalanced stock position (Azim *et al.,* 2017), which is always expected in a natural system. Also, the low exploitation rate experienced by individuals of the species suggests that these individuals are underexploited (Gulland, 1971). Ofori-Danson *et al.* (2002) recorded a higher exploitation rate (E = 0.67) on *C. nigrodigitatus* from Lake Volta. Compared to the current study, the variation in exploitation rate may be due to fishermen exploiting other commercially important fishes at a higher rate than the assessed fish species.

From the biological reference point of view, the exploitation rate for the assessed species in the present study was lower than that at maximum sustainable yield (Emsy = 0.56). This indicates that the assessed fish species is far from over-exploitation. Given this underexploited level of fishing, continuous monitoring of fishing efforts is essential. Furthermore, the possible creation of inland protected area (IPA) and implementation of closed fishing seasons could be applied to safeguard the species from exceeding the limit reference point.

Conclusion

The study aimed to assess the growth, mortality, and biological reference points of *C. nigrodigitatus* from the stratum VII of Lake Volta, Ghana. From the study, *C. nigrodigitatus* recorded a growth rate of 0.57 per year, which signifies signs of fast growth. The exploitation rate (E = 0.42) was lower than the maximum sustainable yield exploitation rate (Emax = 0.56), which indicates that the species in Lake Volta, Ghana, is experiencing a low level form exploitation. In the wake of the low exploitation, there is a need to institutionalise specific management measures such as mesh size regulations, a ban on illegal fishing gears, closed fishing periods, and compliance to fisheries management measures.

Compliance with Ethical Standards

Conflict of interest: The author declares no actual, potential, or perceived conflict of interest for this article.

Ethics committee approval: -

Data availability: Data will be made available on request.

Funding disclosure: No funding provided.

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Disclosure: -

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