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Assessment of Growth and Mortality Parameters of Four Commercial Fish Species from Lekki Lagoon Nigeria

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ABSTRACT

This study assessed the growth and mortality parameters of four commercial fish species (*Chrysichthys nigrodigitatus* (Lacepède, 1803), *Coptodon zillii* (Gervais, 1848), *Ethmalosa fimbriata* (Bowdich, 1825) and *Elops lacerta* (Valenciennes, 1847) from Lekki Lagoon, Nigeria. Fish specimens were collected monthly from five landing sites (Wharf, Agbalegiyo, Ebute-Oni, Ilumofin and Luboye). Specimens were collected using proportional sampling based on the level of fishing activities between January and December, 2022. Estimation of growth parameters was performed according to the growth equation: $L_t = L_\infty - (1- e^{-K(t-to)})$ by von Bertalanffy with the Length Frequency Data Analysis (LFDA) package. The length-converted catch curve model was adopted for the estimation of mortality parameters using FiSAT II software. Results showed that *C. nigrodigitatus* exhibited the highest growth rate (K = 1.30 yr^{-1}) and exploitation rate (E = 0.83) with an asymptotic length ($L\infty$) of 53.94 cm. However, *C. zillii* exhibits the lowest growth curvature (K = 0.44 yr^{-1}) with $L\infty$ = 39.15 cm and an exploitation rate of 0.42. *E. fimbriata* showed a rapid growth rate (K = 1.15 yr^{-1}) but low exploitation (E = 0.12), while *E. lacerta* exhibited moderate growth rate (K = 0.58 yr^{-1}) and low exploitation (E = 0.16). It is concluded that *C. nigrodigitatus* is overfished in the lagoon, which demands a closed season and small mesh size restriction to prevent recruitment overfishing. The low exploitation levels of *E. fimbriata* and *E. lacerta* means that these stocks are currently sustainable, but there is a need to monitor them to avoid future over-exploitation.

KEYWORDS: Fish, Sustainability, Population dynamics, Brackish water

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1. Introduction

Fish remains a common source of protein, especially in developing countries. The decline in fish stocks in tropical waters poses challenges of insufficient food availability and unemployment for the growing populations (Belhabib et al., 2019; Chan et al., 2021). It is reported that more than 50 % of coastal communities in the tropics rely on fish products as their major means of survival and source of protein (FAO, 2022). According to the 2021 report of the Federal Department of Fisheries and Aquaculture (FDFA), domestic fish production in Nigeria stands at about 1.1 m tonnes which is only 31% of the country's annual fish demand of 3.5 million tonnes. This wide gap between the quantity of fish produced and the amount demanded makes Nigeria a net importer of fish (Chan et al., 2021). Recent statistics by the Food and Agricultural Organization show that fish consumption in the African region is relatively low with an estimated 10.1 kg per capita per year in 2020 compared to the recommended global threshold of 20.2 kg per capita (FAO, 2022). One of the major reasons for this low production is attributed to the decline in wild stocks as a result of overfishing (Doumbouya et al., 2017). The catch trend of major fish stocks has declined as high as 20-30 % over the last two decades. This decline is reported to have occurred mostly in coastal waters dominated by artisanal and small-scale fisheries. Globally, about 35 % of fish stocks were reported as over-exploited in 2019 which is about a 10 % rise in the last 5 decades indicating a steady decrease in sustainable fish stocks as a result of over-exploitation and ineffective management policies (FAO, 2022).

Fish stock assessment remains a valuable tool for fisheries managers. It provides essential information on the growth indices of fish species and their mortality parameters which are crucial in making accurate decisions for sustainable management and conservation of these aquatic resources (Abdul et al., 2023). Furthermore, through fish stock assessment, responsible fishing practices that ensure sustainable utilization of aquatic resources are encouraged, thus improving the livelihood of fishing communities (Santo et al., 2022). Fish stock assessments therefore are the right tool for maintaining ecological stability and economic well-being. To proffer solutions to challenges like overfishing and pollution for the sustenance of coastal waters and their biodiversity, efforts from all stakeholders are required. Assessment of fish stocks can be carried out with length-frequency data (Pasisingi et al., 2021). Traditional methods for estimating fish growth rely on measuring both the length and age of fish species (Quinn and Deriso 1999;) which could be costly and tedious as a result of inconsistent early growth trends.

Lekki Lagoon is a habitat for various species including *Chrysichthys nigrodigitatus* (Lacepède, 1803), *Coptodon zillii* (Gervais, 1848), *Ethmalosa fimbriata* (Bowdich, 1825) and *Elops lacerta* (Valenciennes, 1847) and many other fishes, all exhibiting different growth patterns influenced by its unique environmental conditions of both fresh and marine water, making it brackish water (Emmanuel and Chukwu, 2010; Abdul, 2015; Akinsanya et al., 2021). Few studies by Abdul et al. (2012) and Abdul (2015) have provided information on the growth and mortality indices in the lagoon. Thus, there is insufficient information on the population dynamics of these commercial fish stocks. Therefore, this paper aims to make available the latest information on the growth and mortality parameters of these selected fish stocks for effective management and conservation strategies.

2. Materials and Methods

2.1 Study Area

This study was conducted in Lekki Lagoon. Lekki Lagoon is situated on latitude 4°00' and 4°15' E and longitude 6°25' and 6°37' N in Nigeria (Figure 1). The lagoon is about 64 m deep with a surface area of 247 m^2 (Akinsanya et al., 2019). It is a combination of wetlands from different creeks along the southwestern coast of Nigeria. The lagoon extends about 200 km from the Dahomey border to the Niger Delta (Adekoya, 1995). The freshwater Epe Lagoon is connected to it to the east, while the brackish water Lagos Lagoon runs into the coastal water body from the west (Akinsanya et al., 2019).

2.2 Sampling Procedures

Specimens were collected from five landing sites (Wharf, Agbalegiyo, Ebute-Oni, Ilumofin, and Luboye) using proportional sampling which depended on the level of fishing activities. Sampling was carried out between January – December 2022. A total of 18,001 fish specimens of the selected fish stocks were collected from the local commercial fishermen immediately after harvesting using various fishing gear types which were seine nets, gillnets, cast nets, and traps. Fish identification keys (Olaosebikan and Raji, 2013) were used in identifying samples at the species level. Fish specimens were measured from the end of the snout to the tip of the caudal fin to the nearest ±0.1 cm for the total length (TL) using an ichthyoboard, while the weight was taken at the nearest ±0.01 g using an electronic weighing balance (MH-999) according to Dienye et al. (2021). Fish specimens for *E. lacerta* were not landed for January, November, and December during the study period.

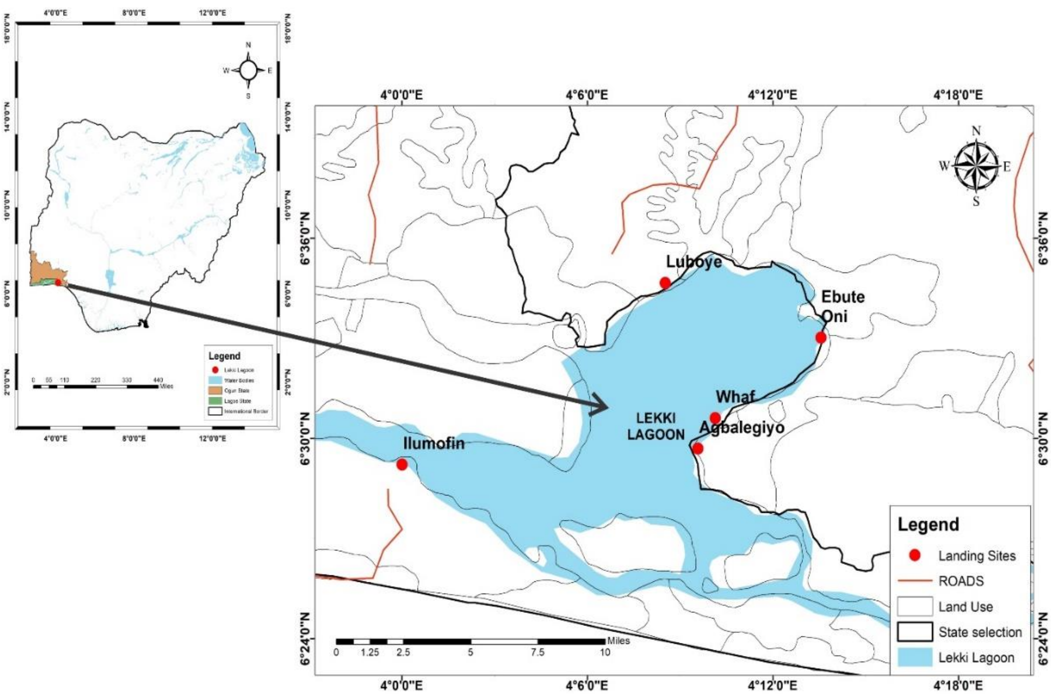

Figure 1. Study area showing sampling sites (Source: Field Survey, 2022)

2.3 Growth parameters

The length-frequency data were analyzed using Length Frequency Distribution Analysis software (LFDA) version 5.0 (Kirkwood et al., 2003) developed by the Marine Resources Assessment Group (MRAG), United Kingdom. Data collected were pooled monthly and sorted into a class size of 1 cm and the number of occurrences was recorded against every class size for all selected fish species. This grouped data was then entered into the LFDA software taking note of the sample timings by entering the dates for sample collection. The growth parameters estimated were considered to align with the growth equation: $L_t = L_\infty (1- e^{-K(t-to)})$ of von Bertalanffy (Sparre and Venema, 1992). Estimation of the von Bertalanffy growth parameters: asymptotic length (L_∞), growth coefficient (K), and hypothetical age (t_o) were determined by grid boundaries using Electronic Length Frequency Analysis (ELEFAN) as reported by Maguza-Tembo et al. (2009). Data and frequency plots were carried out using the ‘Data’.

2.4 Mortality parameters (Z, M, F)

The parameters $L\infty$ and K were used as input to length-converted catch curve analysis to obtain estimates of the total annual instantaneous mortality (Z) following (Ricker W, 1980):

$N(t) = N_0 \, e^{-Zt}$;

N (t) is the number of survivors at time t; N_0 is the initial number of individuals at time t_0 taken as origin; Z is the total mortality.

Natural mortality (M) was estimated using the empirical formula of (Pauly D, 1980):

$Log\ (M) = -0.0066 - 0.2790\ Log\ (L\infty) + 0.6543\ Log\ (K) + 0.4634\ Log\ (T)$;

With *"T"* as the mean environmental temperature (°C).

The mean annual habitat temperature for the current study was 28.55°C.

The fishing mortality rate (F) was calculated as:

$F = Z-M$ (Abowei et al., 2010).

The exploitation rate (E) was computed as:

$E = F/Z$ (Pauly, 1985).

The exploitation rate indicates whether the stock is lightly ($E < 0.5$) or strongly ($E > 0.5$) exploited, based on the assumption that the fish are optimally exploited when F = M or E = 0.5 (Gulland, 1971).

3. Results

3.1 Length Frequency Distribution

Figure 2 shows that *C. nigrodigitatus* exbited a wide size range of 5.5 cm – 64.0 cm TL. The highest frequency occurred between sizes 12.0-16.9 cm TL and the lowest at both extremes. *C. zillii* from the lagoon (Figure 3) exhibits a skewed distribution, with the highest frequencies between 15.0-17.9 cm and much lower frequencies at both smaller (8.2-10.9 cm TL) and larger (30.0-36.8 cm) sizes. The length distribution for *E. fimbriata* (Figure 4) presents a smaller size range of 6.4 – 22.5 cm TL. A single peak appears between length sizes 10.0-11.9 cm TL while very low frequencies exist beyond this size. *E. fimbriata* shows a distribution that could be suggestive of a population dominated by a few cohorts or size groups. *E. lacerta* (Figure 5) however presents a bimodal distribution within the range of 12.8 to 25.2 cm TL, with peaks at 15.0-16.9 cm TL and 23.0-24.9 cm TL, and very low frequencies in between.

3.2 Growth Parameters

The fitted non-seasonal von Bertalanffy Growth Function using ELEFAN of the four fish species is presented in Figures 6 – 9. The asymptotic lengths (L_∞) of *C. nigrodigitatus*, *C. zillii*, *E. fimbriata*, and *E. lacerta* were calculated as 53.94, 39.15, 22.14, and 28.40 cm, respectively. *C. nigrodigitatus* recorded the highest growth rate (1.30 yr^{-1}) while *C. zillii* had the smallest growth rate of 0.44 yr^{-1}. The age of the fish species at zero length (t_0) were -0.16, -0.73, -0.23, and -0.18 for *C. nigrodigitatus*, *C. zillii*, *E. fimbriata*, and *E. lacerta*, respectively.

3.3 Mortality Parameters

Estimations for mortality parameters from the linearized length-converted catch curve analysis by FiSAT software are presented in Table 1. *C. nigrodigitatus* has a total mortality rate (Z) of 10.67 yr^{-1} with a natural mortality rate (M) of 1.82 yr^{-1} and fishing mortality rate (F) of 8.85 yr^{-1} giving a high exploitation rate (E) of 0.83. Mortality parameters for *C. zillii* are 1.70 yr^{-1}, 0.98 yr^{-1}, 0.72 yr^{-1}, and 0.42 for total mortality, natural mortality, fishing mortality, and exploitation rates, respectively. Fishing mortality and exploitation rates for *E. fimbriata* and *E. lacerta* are (0.28 yr^{-1} and 0.12) and (0.25 yr^{-1} and 0.16), respectively.

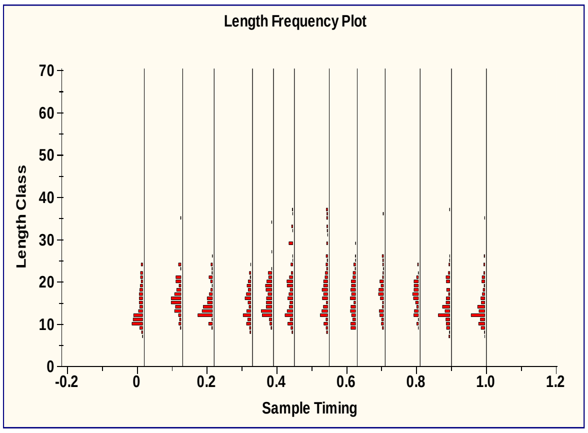

Figure 2. Length-frequency distribution output from LFDA for *Chrysichthys nigrodigitatus* from Lekki Lagoon

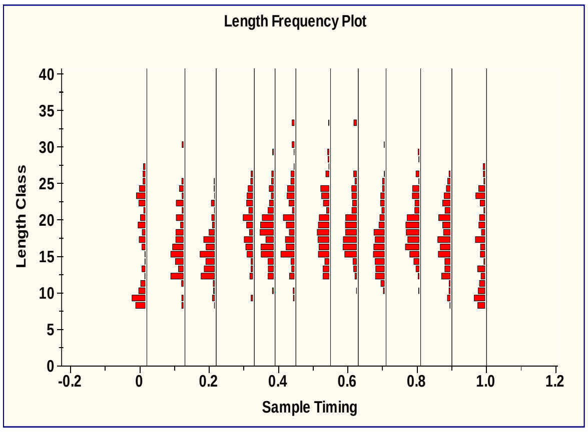

Figure 3. Length-frequency distribution output from LFDA for *Coptodon zillii* from Lekki Lagoon

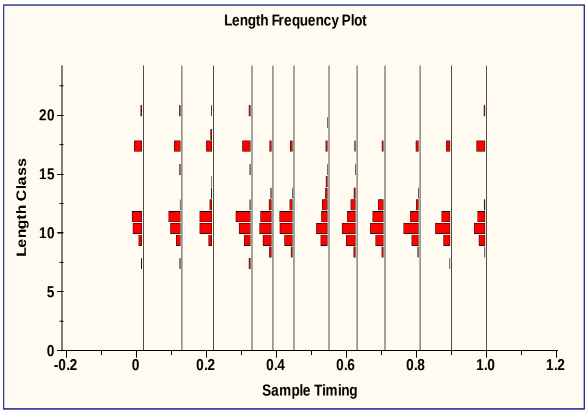

Figure 4. Length-frequency distribution output from LFDA for *Ethmalosa fimbriata* from Lekki Lagoon

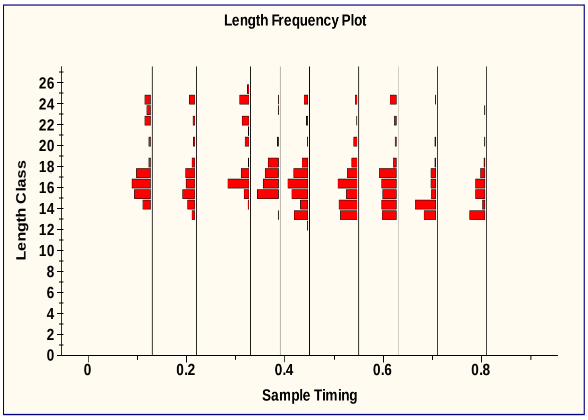

Figure 5. Length-frequency distribution output from LFDA for *Elops lacerta* from Lekki Lagoon

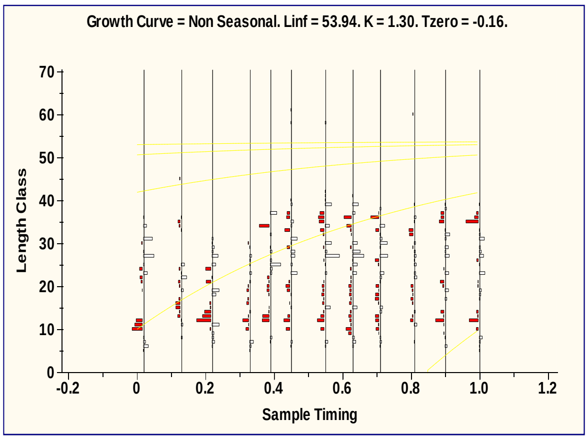

Figure 6. Converted (fitted) non-seasonal growth curve from LFDA for *C. nigrodigitatus* from Lekki Lagoon
Hint: Yello line-von Bertalanffy growth model fit

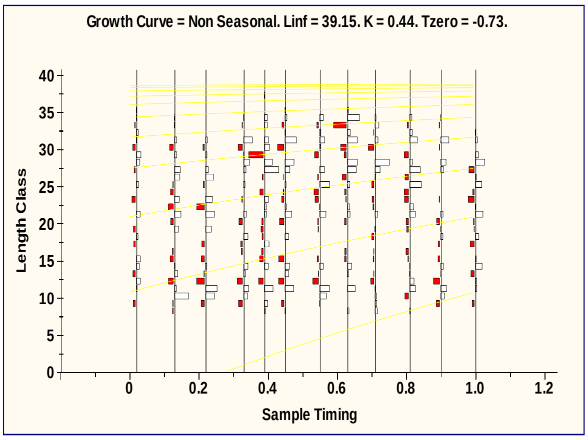

Figure 7. Converted (fitted) non-seasonal growth curve from LFDA for *C. zillii* from Lekki Lagoon
Hint: Yello line-von Bertalanffy growth model fit

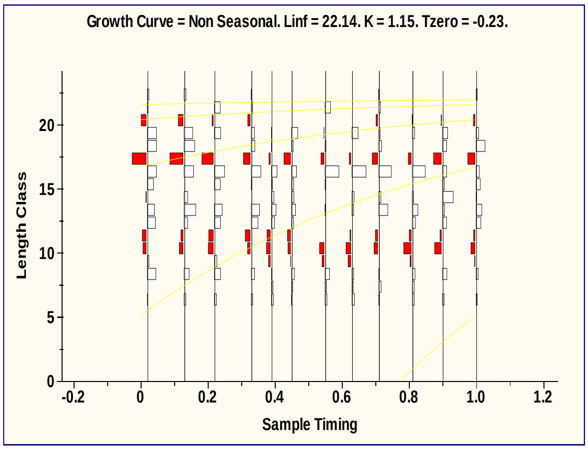

Figure 8. Converted (fitted) non-seasonal growth curve from LFDA for *E. fimbriata* from Lekki Lagoon
Hint: Yello line-von Bertalanffy growth model fit

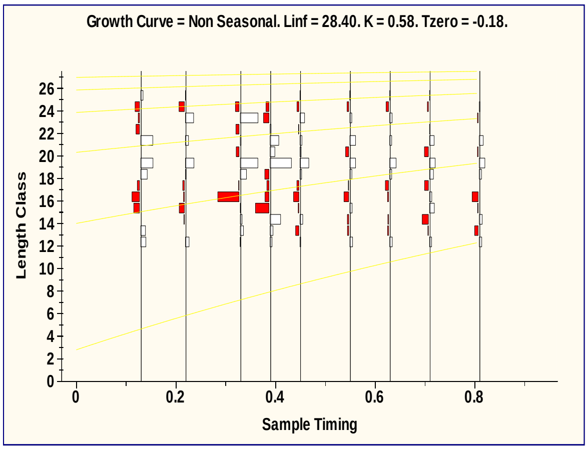

Figure 9. Converted (fitted) non-seasonal growth curve from LFDA for *E. lacerta* from Lekki Lagoon
Hint: Yello line-von Bertalanffy growth model fit

Table 1: Estimated mortality parameters of selected fish species in Lekki Lagoon

Fish Species	**Z (yr^{-1})**	**M (yr^{-1})**	**F (yr^{-1})**	**E**
Chrysichthys nigrodigitatus	10.67	1.82	8.85	0.83
Coptodon zillii	1.70	0.98	0.72	0.42
Ethmalosa fimbriata	2.43	2.15	0.28	0.12
Elops lacerta	1.53	1.28	0.25	0.16

Key: Z= Total mortality, M = Natural mortality, F = Fishing mortality and E= Exploitation rate

4. Discussion

4.1 Length Frequency Distributions

The length-frequency distributions observed for the four fish species in Lekki Lagoon presents information on the population structure and exploitation patterns. The total length of *Chrysichthys nigrodigitatus* ranged between 5.0 and 64.9 cm TL which shows a wide population spread. This is in agreement with the research of Abdul (2015) who reported active recruitment and exploitation of young individuals in the same lagoon. The length size recorded by *C. nigrodigitus* in current study is however dissimilar with the findings of Amponsah (2024) in Lake Volta, Ghana who reported smaller maximum lengths. This could be due to differences in fishing gear selectivity, lagoon productivity and fishing pressure. *Coptodon zillii* exhibited a length distribution skewed toward smaller individuals with dominant sizes between 15.0–17.9 cm TL. An explanation to this distribution pattern could be the widespread use of small-mesh nets as reported by Abdul et al. (2012). Amponsah (2024) also reported similar modal sizes from Lake Volta. This means that the fish species is under comparable exploitation pressure across regions. The narrow size range (6.0–22.9 cm TL) and dominant modal length (10.0–11.9 TL) cm exhibited by *Ethmalosa fimbriata* shows that recruitment comprised primarily juvenile individuals. This is in agreement with findings by Ama-Abasi and Holzloehner (2002) in the Cross River Estuary, where distinct juvenile and adult size classes were reported. The reason for the smaller sizes recorded in Lekki Lagoon could be due to environmental differences specifically lower salinity levels which can constrain the distribution and growth of the fish species. *Elops lacerta* shows a bimodal length distribution (12.8–25.2 cm TL) with frequencies being highest at 15.0–16.9 cm TL and 23.0–24.9 cm TL. This could mean the presence of at least two active cohorts within the population. Loukou et al. (2021) reported broader range and larger sizes in the Ivorian exclusive economic zone. A possible explanation could be that there reduced fishing pressure and better migratory routes in open coastal waters. The partial enclosure of the Lekki Lagoon could be the reason for the presence of limited maximum sizes. Another reason may be that fishing pressure is higher in Lekki Lagoon.

4.2 Growth Parameters

Growth parameters are critical in carrying out stock assessments. Growth coefficient (K) refers to the rate at which a fish grows to its final size while the maximum theoretical mean length that it can attain if it grows throughout its life in a natural habitat is called the asymptotic length (L_∞) (Dienye et al., 2021). These growth dynamics presents species-specific life history traits and are influenced by ecological conditions (Rangely et al., 2023). *C. nigrodigitatus* recorded an asymptotic length (L_∞) and growth coefficient (K) of 53.94 cm and 1.30 yr^{-1}, respectively. This is dissimilar with the findings of Martin et al. (2021) in Aghien Lagoon, Côte d'Ivoire (L_∞ = 38.1 cm SL, K = 0.48 yr^{-1}). The growth parameters recorded for *C. nigrodigitatus* in this present study are also different from those reported by Abdul (2015) who recorded a smaller asymptotic length (L_∞) of 49.88 cm and a higher growth coefficient (K) of 1.45 yr^{-1} for *C. nigrodigitatus* from the same lagoon. Furthermore, the current findings contradict the result of Ouattara et al. (2023) in Buyo Lake of Côte d'Ivoire. They estimated a higher asymptotic length (L_∞ = 69.35 cm) and a slower growth rate of 0.78 year^{-1} and reported that the species exhibited a long survival time in the lake. Fish species with higher growth coefficients generally grow faster to their asymptotic length. Phenotypic plasticity is conferred by fish maturing at smaller sizes in response to fishing pressure, which may explain the lower K value recorded in the present study. Amponsah (2024) however, reported similar values, a lower L_∞ (27.3 cm) but moderately high K (0.57 yr^{-1}) for the same species in Lake Volta.

C. zillii recorded an L_∞ of 39.15 cm and a low K of 0.44 yr^{-1} which is consistent with previous estimates in West African waters by Amponsah (2024) who reported L_∞ = 30.4 cm and K = 0.38 yr^{-1}. These values are associated with relatively slow-growing species with a longer lifespan. An explanation for the lower K value recorded may also be associated with a stable habitat and reduced metabolic demands especially in less turbulent lagoon environments. The values for asymptotic length and growth rate for *E. fimbriata* in the present study were 22.14 cm and K = 1.15 yr^{-1}. This means that *E. fimbriata* is a short-lived but fast-growing species. This is similar with findings of Ama-Abasi and Holzloehner (2002), who documented high growth rate by the fish species even though their modal lengths extended to 33 cm in coastal habitats larger than those seen in Lekki Lagoon. The discrepancy may be as a result of differences in environmental variables as the species thrives in saline conditions which are more prominent in estuarine and coastal environments unlike Lekki Lagoon which is predominantly a freshwater ecosystem. Moreso, *E. lacerta* showed moderate growth with L_∞ = 28.40 cm and K = 0.58 yr^{-1}. This is similar to estimates by Dienye et al. (2021) in Obuama Creek (L_∞ = 30.13 cm, K = 1.1 yr^{-1}) but much lower than Loukou et al. (2021) in Côte d'Ivoire (L_∞ = 60.38 cm, K = 0.39 yr^{-1}). The lower maximum size in Lekki Lagoon could be attributed to restricted migratory pathways and habitat fragmentation compared to the Ivorian exclusive economic zone which is more or less an open marine ecosystem. Several factors such as environmental conditions, fishing pressure, food availability, pollution levels and habitat type could be responsible for the overall variation in growth parameters among species and across regions (Santos et al., 2022).

4.3 Mortality Rates

Mortality estimates are responsible for the assessment of the sustainability of fish populations under exploitation. *C. nigrodigitatus* presents the highest total mortality (Z = 10.67 yr^{-1}) and fishing mortality (F = 8.85 yr^{-1}) with an exploitation rate (E = 0.83) which is much higher than the optimal exploitation level (E = 0.5). This indicates severe overfishing similar with findings by Martin et al. (2021) in Aghien Lagoon (E = 0.74), thus suggesting the need for urgent regulatory intervention such as closed seasons or gear restrictions. *C. zillii* on the other hand presented lower mortality values (Z = 1.70 yr^{-1}; F = 0.72 yr^{-1}) and an exploitation rate (E = 0.42) which is close to the sustainable threshold. This means that the fish species is optimally exploitated in the lagoon. This result corroborates the reports of *C. zillii* been prolific, thus sustaining its population. Incidentally, Amponsah (2024) reported a similar exploitation rate (E = 0.42) for the same species in Lake Volta, although his study indicated underexploitation based on E_{msy} = 0.56 which requires ecosystem-specific benchmarks. A relatively low fishing mortality (F = 0.28 yr^{-1}) and an exploitation rate of 0.12 was recorded by *E. fimbriata*. This means that it is significantly underexploited. The low fishing pressure shows that the stock is currently sustainable despite the high natural mortality (M = 2.15 yr^{-1}). This could be due to the low salt content of the lagoon that may act as a partial refuge. The present study supports the reports of Ama-Abasi and Holzloehner (2002) which stated the ecological importance of estuarine habitats as nursery grounds for the fish species. Similary, *E. lacerta* recorded low fishing mortality (F = 0.25 yr^{-1}) and an exploitation rate of 0.16. These values are consistent with the values reported by Loukou et al. (2021) who documented an exploitation rate, of 0.49 in Côte d'Ivoire. The fish species is also underfished as the values of the current study fall below the sustainable limit. The fishing mortality recorded in this study is also similar with value reported by Dienye et al. (2021).

5. Conclusion

Relevant information on population dynamics has been provided by this study on the growth and mortality rates of the four fish species. *Chrysichthys nigroditatus* and *Ethmalosa fimbriata* were more exploited, thus exhibiting rapid growth and high mortalities. Management measures such as size limits, closed season, and small mesh size regulations are required to avoid recruitment overfishing of these fishes. It is also important to monitor the populations of *Coptodon zillii* and *Elops lacerta* to avert any future over-exploitation. Therefore, the collaborative efforts of all stakeholders in the fisheries sector are required to ensure the sustainability of fishery resources in the lagoon.

Compliance with Ethical Standards

Conflict of interest

The authors declare that they have no competing interests**.**

Ethical approval

Ethics committee approval is not required.

Data availability

Not applicable.

Consent for publication

Not applicable.

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