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SEASON, GROWTH AND POPULATION INDICES OF Chrysichthys nigrodigitatus, Bagrus bayad AND Synodontis clarias IN LOWER RIVER BENUE

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ABSTRACT

Data on three freshwater fish species: Chrysichthys nigrodigitatus, Bagrus bayad, and Synodontis clarias from lower river Benue were gathered between July 2018 and June 2019. This study aims to estimate the population parameters of the species and assess the stocks based on length frequency data collected and analysed using FiSAT II software. The length-weight relationships were determined to be: Log10Wt = -0.524+1.8516Log10L; Log10Wt = 0.4609+1.0963Log10L and Log10Wt = 0.3399+1.0399Log10L for C. nigrodigitatus, B. bayad and S. clarias respectively. The condition factors (K) were not significantly different (p>0.05) between the two seasons for C. nigrodigitatus and B. bayad but were significantly different (p<0.05) for S. clarias. The asymptotic lengths (L∞) derived from the von Bertalanffy growth curves were 42.52cm, 41.50cm, and 39.38cm for S. clarias, C. nigrodigitatus, and B. bayad. The annual growth coefficient (K) was 0.57y-1, 1.30y-1, and 1.50y-1. The growth performance index (ø) was estimated as 2.99 for C. nigrodigitatus, and 3.37 for both B. bayad and S. clarias. The estimated values of the total, natural and fishing mortalities were Z = 1.77, 2.232, and 2.449; M= 0.993, 1.248, and 1.963; F = 0.77, 0.984 and 0.486 for C. nigrodigitatus, B. bayad and S. clarias respectively. The current exploitation rates of the species were 0.439, 0.441, and 0.198 respectively. Although these rates were less than the threshold level of 0.5, they were higher than Emax and E0.1. it was conclud there is overfishing and lends credence to the arguments that more accurate biological reference points need to be utilized. Based on the findings of this study I recommend that strict measures should be employed to discourage overfishing to avoid extinction on these species.

Keywords: Season, Growth Rates, Mortality, Exploitation, Overfishing Stocks.

1. INTRODUCTION

Due to variations in elements, including food composition and availability (Jafor Bapary et al., 2012), spawning rate (Gutmann Roberts and Britton, 2020), and other environmental conditions (Dantas *et al.*, 2019; FAO, 2022), fish located in the tropics and tropical water bodies face alterations in their biological parameters and behaviors. These changes drive population dynamics within the ecosystem and create ecological balance. However, fish harvest within a fishery changes the population structure and can have long-lasting effects on the population, with delays in recovery (Jørgensen and Fiksen, 2010).

The inland freshwater fisheries production in Africa is reported to rise annually, but there is doubt regarding the authenticity of available data (Welcomme and Lymer, 2012). This report notwithstanding, there are many species of commercial importance within the freshwater basins of Africa and Nigeria. Nigeria's River Niger and River Benue are important fish production basins within the freshwater aquatic ecosystem (Neiland and Béné, 2008).

Within the river Benue, species such as *Clarias gariepinus*, ***Chrysichthys nigrodigitatus,*** *Auchenoglanis occidentalis*, *Bagrus bayad* **,** ***Clarotes laticeps, Distichodus rostratus,*** **and** *Synodontis clarias* have been reported (Ikongbeh *et al*., 2017). These species have commercial value and are more abundant in the wet season.

The study of the biology of these species has been mostly restricted to their age and growth indices. Ikongbeh *et al*. (2015) reported the age, growth, and mortality indices of *Chrysichthys nigrodigitatus* from lake Akata, a tributary of the river Benue. There is also a report on the numerical abundance of *Bagrus docmac* from lake Akata (Ikongbeh and Ogbe, 2021). Estimates of the length-weight relationship and condition factor of *Synodontis clarias* from river Benue have been reported by Akombo *et al*. (2015).

Multi-species and ecosystem models have a lot to offer, but due to their sophistication and data needs, they are sometimes inappropriate for generating management recommendations (Headley, 2020). Fish stock evaluations are typically carried out for a particular species or stock, which describes the management units of a population for management purposes (Hoggarth *et al.*, 2006).

A traditional fish stock assessment that is only based on length-frequency (LFQ) data from a single year is beneficial for fisheries with a lack of data (Froese *et al*., 2018; Zhang *et al*., 2021). Compared to long-time series of catch and effort or catch-at-age data, LFQ data has several advantages in its use for fish stock assessment (Wang and Somers, 1996). Important biological stock features and input factors for population dynamics and yield per recruit models include growth, natural mortality, recruitment patterns, and the link between stock and recruitment (Mildenberger *et al*., 2017; Taylor and Mildenberger, 2017).

Therefore, the present study utilized the fisheries-dependent data collection method to obtain the length and weight of three species: *Chrysichthys nigrodigitatus*, *Bagrus bayad* and *Synodontis clarias* in lower river Benue. This research aimed to use the LFQ data for each species to estimate their population parameters using virtual population analysis (VPA).

2. MATERIALS AND METHOD

Study Area and sampling

The study was conducted near the lower Benue River in Makurdi (Figure 1), Nigeria (7°43°N and 8°32°E). Samples from the daily catch of a randomly selected group of artisanal fishermen who land their catch at the Wadata market landing point were taken. After collection, the samples were brought to the general purpose laboratory, Department of Fisheries and Aquaculture, Joseph Sarwuan Tarka University, Makurdi, where morphometric features were measured. Babatunde and Aminu (1998); Idodo-Umeh (2003), and Olaosebikan and Raji (2004) offered a guide to identifying the fish species.

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Sample collection was carried out once every month between July 2018 and June 2019. A total of four hundred and twenty-six (426) samples were collected regardless of the species (Table 1).

Table 1: Sample size of the three species studied from Lower River Benue

Fish Species	No.
Bagrus bayad	131
Chrysitchthys nigrodigitatus	158
Synodontis clarias	137
Total	426

Morphometric data

Validation of the three species was done by comparing the values of the body proportions obtained with standard keys by Paugy et al. (2003) and (Vos, 1995). Lengths (cm) were measured with a measuring board, measuring tape, and a pair of dividers. Weights (g) were determined using an electronic weighing balance.

Length-Weight Relationship (LWR)

The length-weight relationship of male, female and combined sexes were determined according to the formula by Pauly (1983):

$$W = aL^b$$

The linear transformation of this power function predicting the logarithm of the weight of the fish from the logarithm of its length was utilized following Brodziak (2012):

$$logW = loga + b.logL$$

Where

W = body weight of fish (g); *L* = standard or total body length of fish (cm); a = intercept;
b = growth exponent or regression coefficient

Condition Factor (K)

The sex-disaggregated and combined condition factors (K) of all samples were calculated using the Pauly (1983) formula:

$$K = {}^{100W}/_{L^b}$$

Where

K = Condition factor; L = Total length (cm) and W = Weight of fish (g)

Growth parameters

The Von Bertalanffy Growth Function (VBGF) uses three factors to explain the growth of fish. Using the ELEFAN I (Electronic Length Frequency Analysis) module of FiSAT II software (Gayanilo and Sparre, 2005), the asymptotic length ($L\infty$) and the growth coefficient (K), the first two parameters of Von Bertalanffy growth parameters were calculated. The maximum theoretical length a fish within a population can attain is the asymptotic length $L\infty$. The rate at which length approaches its maximum size is measured by the growth coefficient K. If fish specimens had grown following VBGF, the hypothetical age at which fish would have had zero length is represented as t_0 (Cadima, 2003; Gulland, 1983).

$$L_t = \left[1 - e^{-K(t-t_0)}\right]$$

Where; L_t = predicted length at time t; L_∞ = maximum length predicted by the equation; e = base of the natural logarithm; t = time; K = the growth coefficient (instantaneous rate) and t_o= size at which the organism would theoretically have been age 0, estimated using the empirical equation of Pauly (1979):

$$log(-t_0) = -0.275 log L_\infty - 1.0381K - 0.392$$

The growth Performance Index (Ø) was obtained using the formula developed by Pauly and Munro (1984):

$$\emptyset = log_{10}K + 2log_{10}L_\infty$$

Where:

K = Growth coefficient; L_∞ = Predicted maximum length

Mortality

Using Pauly's empirical relationship (Pauly, 1980), the natural mortality rate (M) was calculated using 30.82°C as the mean water temperature (Gbaaondo, 2021).

$$LogM = 0.0066 - 0.279log_{10}L_\infty + 0.6543log_{10}K + 0.4634log_{10}T$$

Where T = mean water temperature over 12 months within the study area

Total mortality (Z)

Beverton and Holt (1956) proved that there is a functional connection between total mortality (Z) and the average length of a fish ($\bar{L}$). Therefore, with an array of length-frequency data, Z can be estimated for a given stock using:

$$Z = K\left[\frac{L_\infty - \bar{L}}{\bar{L} - L'}\right]$$

Where L' is the smallest length of fish that are within the samples

The total mortality of the studied species was estimated using the equation above as implemented in FiSAT II (Gayanilo & Sparre, 2005).

Fishing mortality (F) and Exploitation rate (E)

Pauly (in 1980) defined fishing mortality (F) as the difference between Z and M.

$$F = Z - M$$

The exploitation ratio (E) was calculated as a ratio of fishing mortality to total mortality (Pauly 1984).

$$E = {}^{F}/_{Z}$$

The ideal degree of exploitation (E) is considered close to 0.5, and a situation of overexploitation is E > 0.5 (Gulland, 1971).

Relative yield per recruit (Y/R)

The Beverton and Holt model (Beverton and Holt, 1966), as modified by Pauly and Soriano (1986), was used to estimate the relative yield per recruitment (Y/R) and relative biomass-per-recruitment (B/R). This estimation was done using the knife-edge selection procedure as a function of E (exploitation rate) of the species in FiSAT II software. L, K, and t0 from the VBGF were used as inputs.

3. RESULTS

Length-Weight Relationship (LWR), Condition Factor (K)

The length-weight relationships of *C. nigrodigitatus, B. bayad*, and *S. clarias* (Figures 2 – 4) were quite strong, with high coefficients of determination that were highly significant (p<0.05). The coefficients of determination ranged between 0.90 and 0.91.

The findings of this investigation demonstrated that, for all the species, the slope of the regression equation was substantially different (P<0.05) from the isometric value of 3, representing an allometric growth. The growth coefficient 'b' was highest in *C. nigrodigitatus* (1.85), followed by *B. bayad* (1.10), while *S. clarias* had the least (1.04).

The mean monthly condition factor (K) of the three species of fish considered from July 2018 to June 2019 (Table 2) was observed to be higher in the rainy season in both sexes of *B. bayad* and *S. clarias*. However, there was a significant difference in the condition of only *S. clarias* between the rainy and dry seasons.

Table 2 Condition Factor of in Lower River Benue

Sex	Season		T-Value	P-Value
	Dry	Rainy		
Bagrus bayad				
Female	0.85±0.08	1.10±0.13	1.57	0.12
Male	0.88±0.14	0.97±0.07	0.56	0.57
Combined	0.87±0.08	1.03±0.07	1.46	0.14
C. nigrodigitatus				
Female	1.37±0.13	1.27±0.21	0.44	0.65

Male	1.5±0.44	1.20±0.18	0.78	0.44
Combined	1.47±0.21	1.23±0.14	0.93	0.35
Synodontis clarias				
Female	0.2±0.03	1.29±0.13	4.25	<0.01*
Male	0.73±0.02	1.24±0.13	3.99	<0.01*
Combined	0.72±0.02	1.26±0.09	5.56	<0.01*

*indicates statistical significance at 95% CL

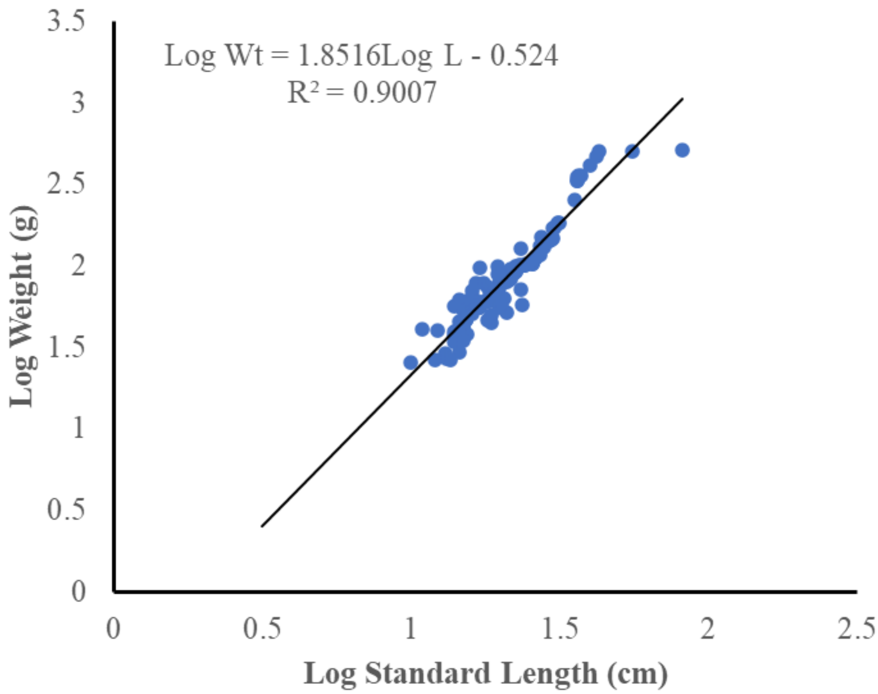

Figure 2. Length-weight relationship of *Chrysitcthys nigrodigitatus* in lower river Benue

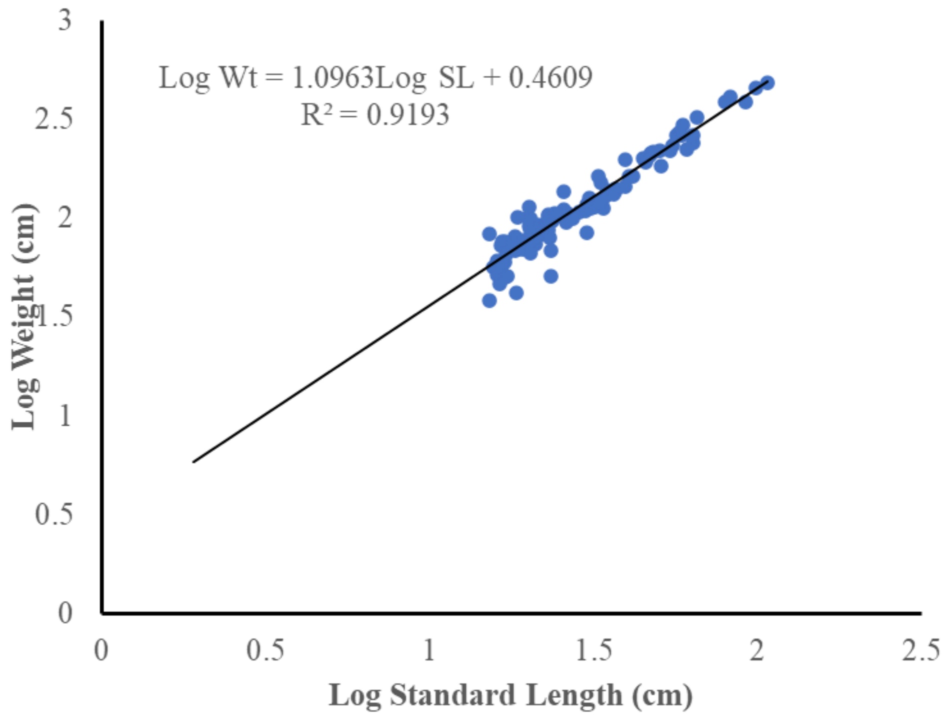

Figure 3. Length-weight relationship of *Bagrus bayad* in lower river Benue

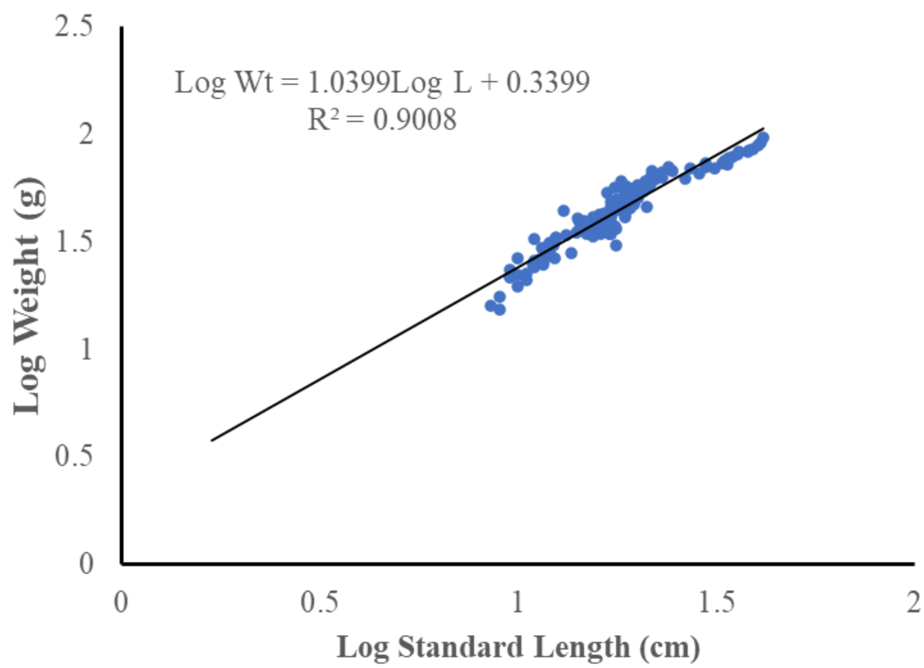

Figure 4. Length-weight relationship of *Synodontis clarias* in lower river Benue

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Growth parameters

As determined by the K-scan approach (Figures 5 – 7) in ELEFAN I procedure of FiSAT II, the asymptotic lengths (L_∞) for the three species (Figures 8 – 10) were 42.52, 41.50, and 39.38 cm for *S. clarias, C. nigrodigitatus* and *B. bayad.* The annual growth coefficient (K) were 1.50, 1.30, and 0.57 cm for *B. bayad, C. nigrodigitatus,* and. *S. clarias*

The age at length zero (t_0), was estimated as – 0.13, –0.05, and –0.06 years for *C. nigrodigitatus*, *B. bayad* and *S. clarias* respectively. The growth performance index (ø) was determined to be 2.99 for *C. nigrodigitatus*, and 3.37 for both *B. bayad* and *S. clarias*. According to the parameters discovered in this study, the Von Bertalanffy equations for determining length at any given age in the three species are as follows:

$L_t = \left[1 - e^{-0.57(t+0.13)}\right]$ for *C. nigrodigitatus*

$L_t = \left[1 - e^{-1.50(t+0.05)}\right]$ for *B. bayad*

$L_t = \left[1 - e^{-1.30(t+0.06)}\right]$ for *S. clarias*

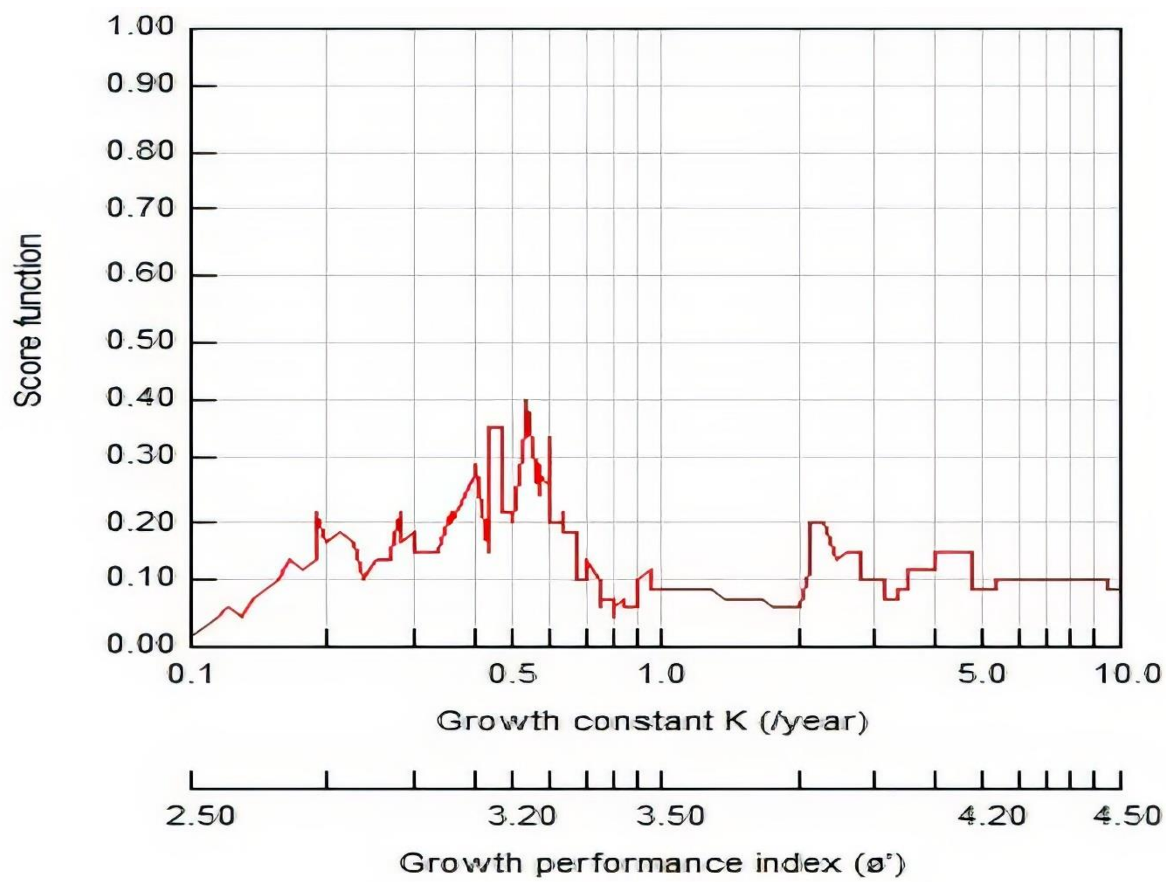

Figure 5. ELEFAN 1 K-scan for *Chrysichthys nigrodigitatus* in Lower River Benue

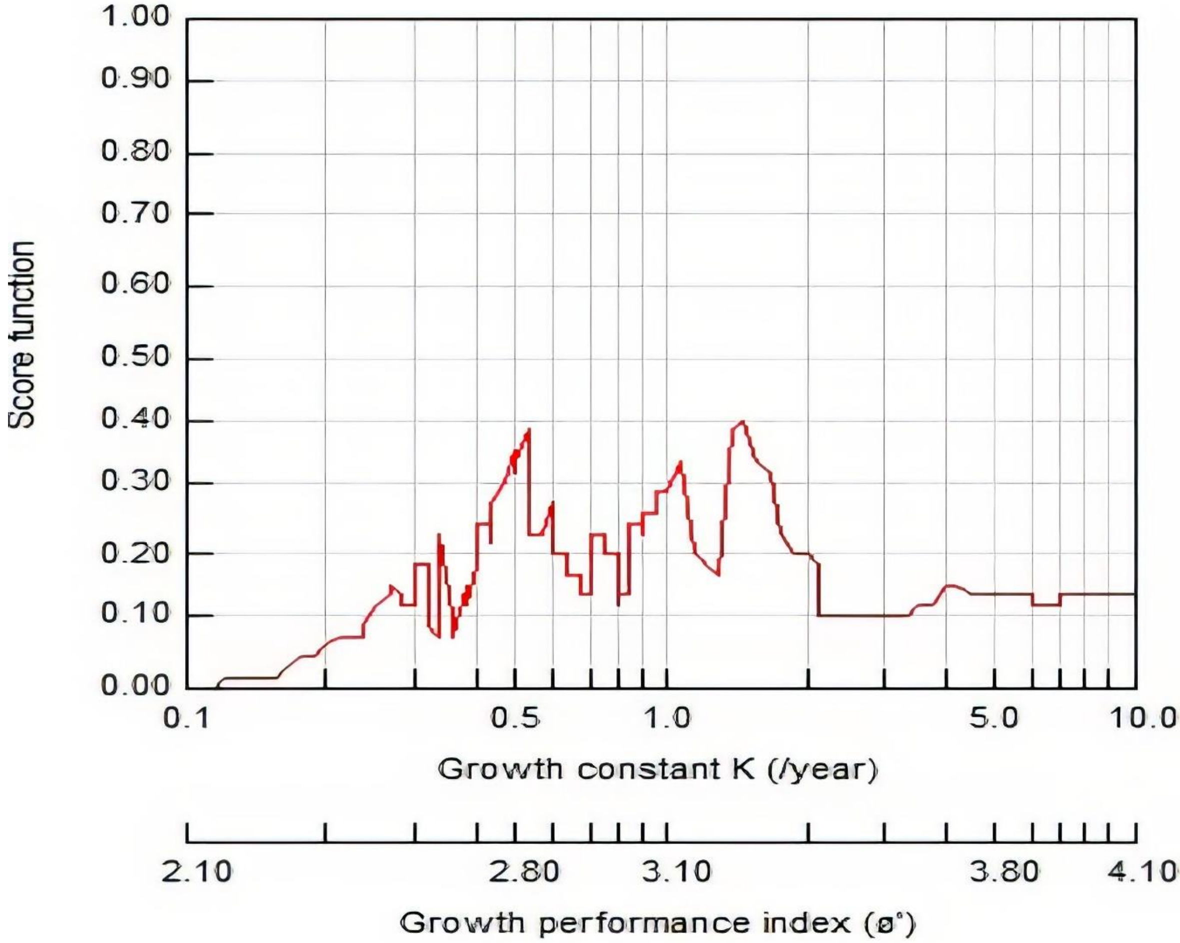

Figure 6. ELEFAN 1 K-scan for *Bagrus bayad* in Lower River Benue

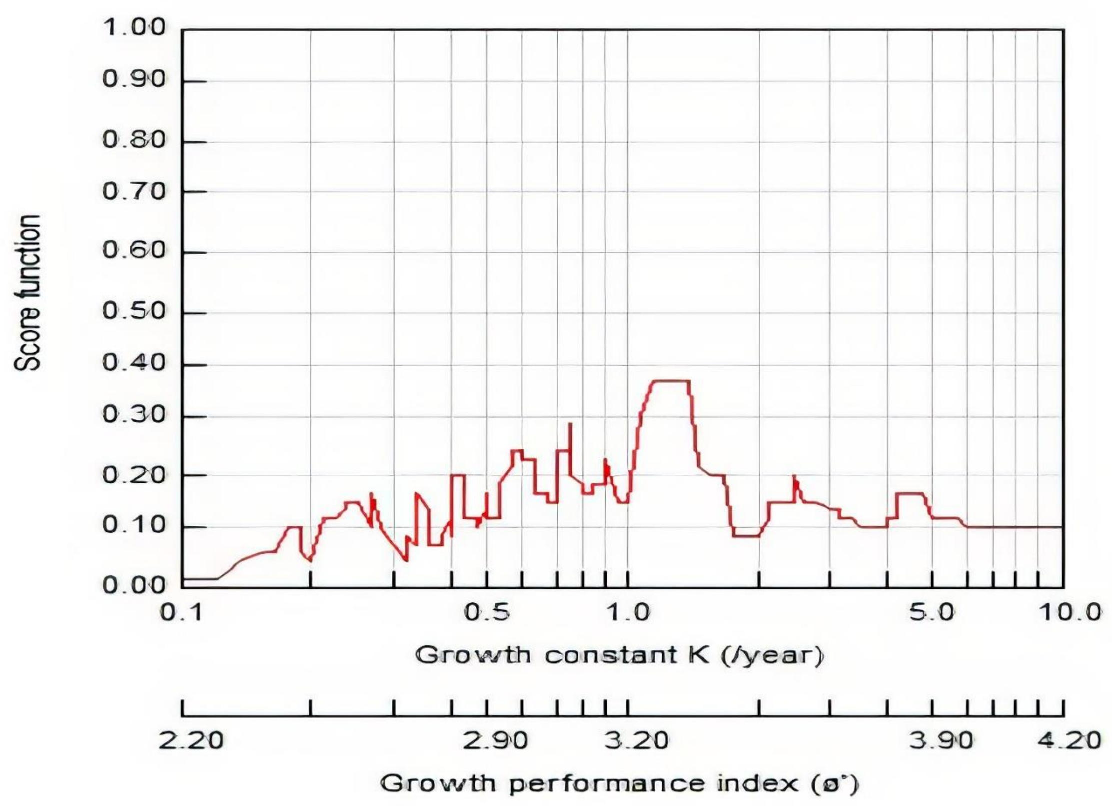

Figure 7. ELEFAN 1 K-scan for *Synodontis clarias* in Lower River Benue

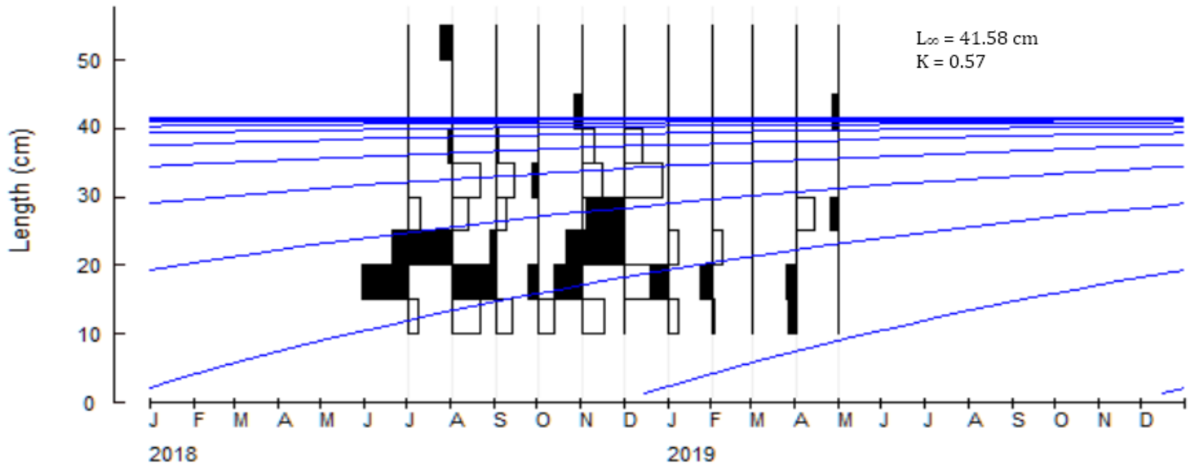

Figure 8. Length frequency distribution and von Bertalanffy growth curve for *Chrysichthys nigrodigitatus* in Lower River Benue

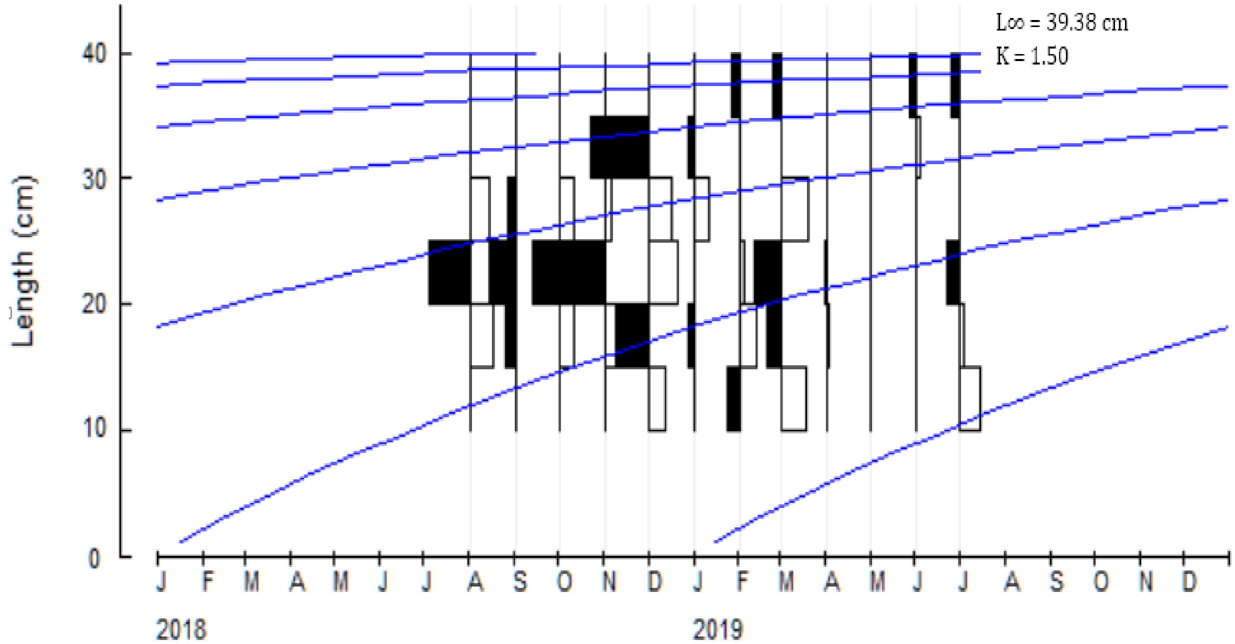

Figure 9. Length frequency distribution and von Bertalanffy growth curve for *Bagrus bayad* in Lower River Benue

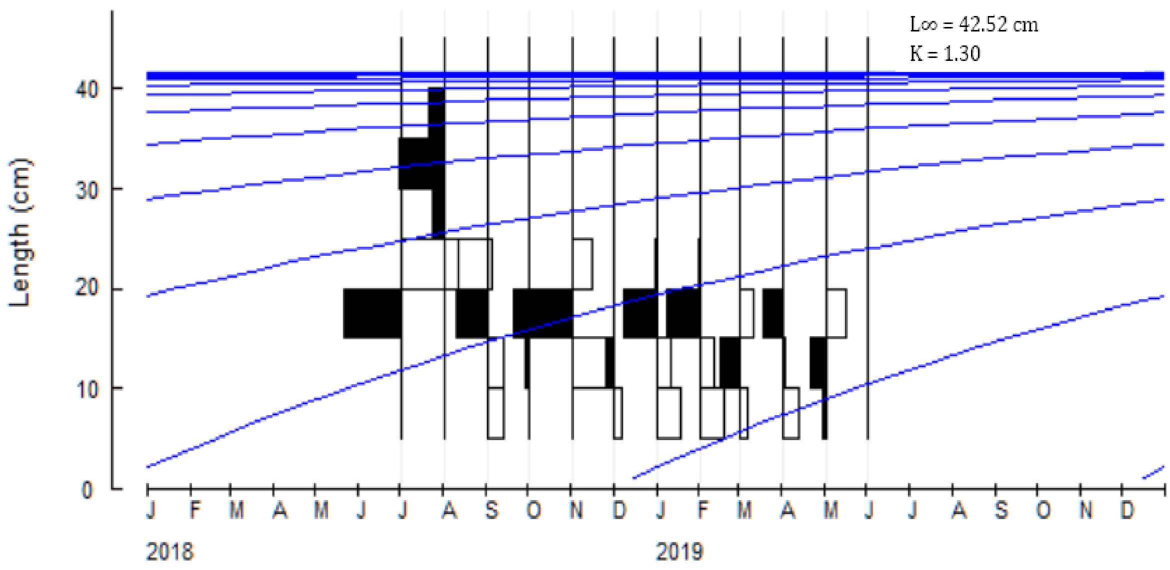

Figure 10. Length frequency distribution and von Bertalanffy growth curve for *Synodontis clarias* in Lower River Benue

Mortality and exploitation rates

Estimates of mortality (Table 3), indicates that the total mortality (Z) coefficients for the three species ranged from 1.770 to 2.449. Natural mortality (M) ranged from 0.99 to 1.96. Based on these, the fishing mortality coefficients (F) ranged between 0.486 to 0.984.

Table 3. Mortality/year of the three species in Lower River Benue

Fish Species	Mortality/year			Exploitation rate (E)
	Fishing (F)	Natural (M)	Total (Z)	
C. nigrodigitatus	0.777	0.993	1.770	0.439
B. bayad	0.984	1.248	2.232	0.441
S. clarias	0.486	1.963	2.449	0.198

The current exploitation rates for the species studied (Table 3) was similar in two species: *C. nigrodigitatus* (0.439) and *B. bayad* (0.441) while the value for *S. clarias* was quite low (0.198). The natural mortalities were higher than the fishing mortalities in all three species.

The maximum sustainable yields (MSY) for the three species (Figure 11 – 13) occur at exploitation rates of 0.370, 0.388 and 0.386 for *C. nigrodigitatus, B. bayad* and *S. clarias* respectively (Table 4).

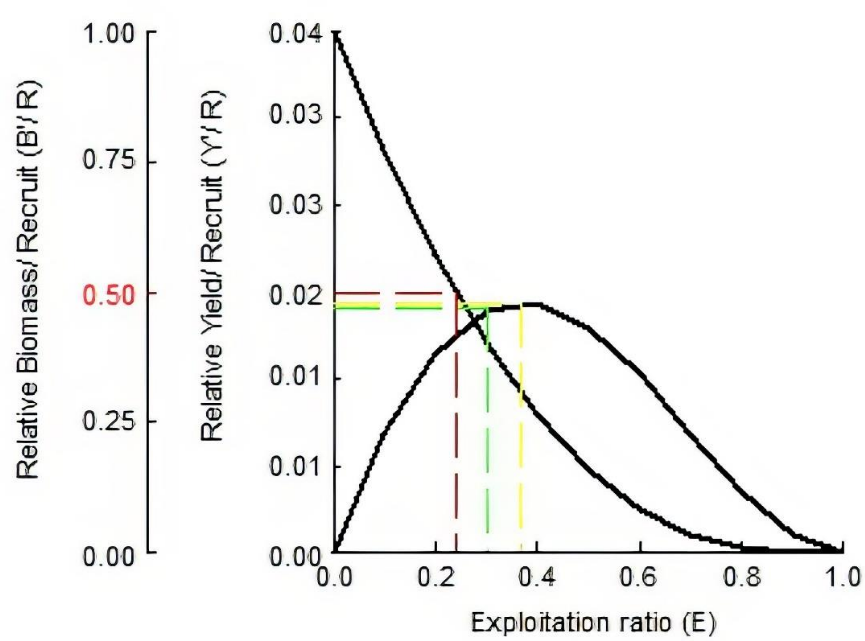

Figure 11. Yield-per-recruit and average biomass-per-recruit plots for *C. nigrodigitatus* from lower river Benue

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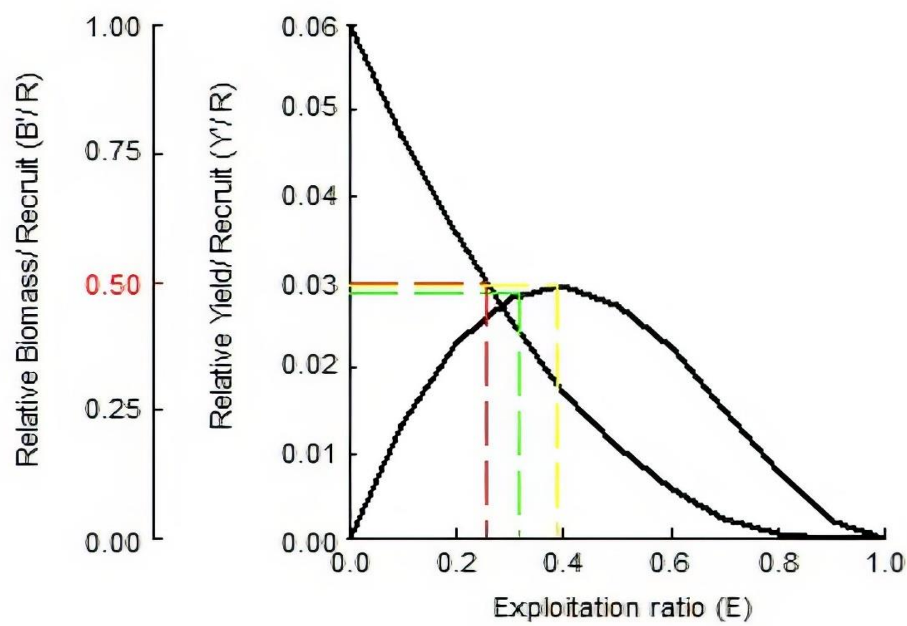

Figure 12. Yield-per-recruit and average biomass-per-recruit plots for *B. bayad* from lower river Benue

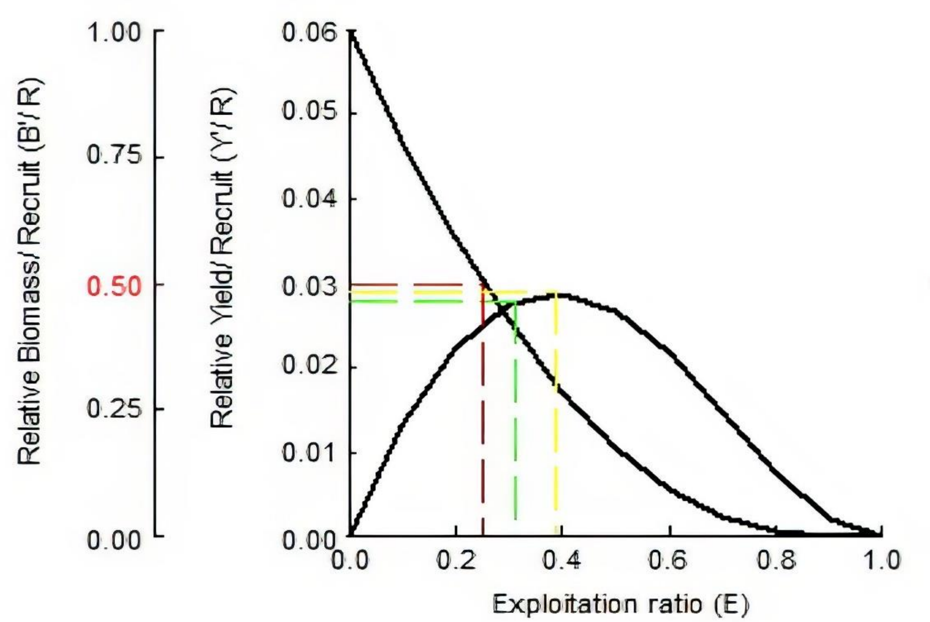

Figure 13. Yield-per-recruit and average biomass-per-recruit plots for *S. clarias* from lower river Benue

Table 4. Reference points for fisheries of three species of fish from lower river Benue

Fish Species	E_{max}	$E_{0.5}$	$E_{0.1}$	F_{max}	$F_{0.5}$	$F_{0.1}$
C. nigrodigitatus	0.370	0.241	0.304	0.655	0.427	0.538
B. bayad	0.388	0.254	0.316	0.866	0.567	0.705
S. clarias	0.386	0.253	0.314	0.945	0.620	0.769

4. DISCUSSION

Growth Parameters

The asymptotic length of *S. clarias* was marginally greater than the maximum length of fish observed in this study. This indicates that if conditions in the river are favorable, these species tend to grow more. There was little difference between the minimum and maximum lengths of *B. bayad* and *C. nigrodgitatus*, indicating that the values obtained were reasonable for the species in the river.

(Araoye, 1997) calculated the L_∞ of *S. schall* in Asa lake using observed, back-calculated, and integrated techniques as 50.4, 49.5, and 50 cm, respectively. Abowei and Hart (2009) stated that the L_∞ of *S. schall* in the lower Mum River in the Niger Delta is 38.7cm, while that of *S. clarias* is 35.56 cm.

The variable asymptotic lengths reported in different locales, even among the same species, can be attributed to varying environmental conditions and intense fishing pressure. Sparre and Venema (1992) demonstrated that the growth of fishes of different species and stocks, as well as within the same species, is influenced by environmental conditions. According to King (1996), the greatest size obtained by fish is typically location-dependent. Abowei and Hart (2008) ascribed the variation in the maximum size of *C. nigtodigiataus* in the lower river run to fishing pressure, pollution, and degradation.

Bagrus bayad had the highest growth rate, followed by *S. clarias* and *C. nigrodigitatus*. This indicates that *B. bayed* grows at a different rate than the other species. Within the Num river, Abowei and Hart (2009) reported growth rates of *S. schall*, *S. clarias*, and *S. membranaceus* as 0.64, 0.43, and $0.38y^{-1}$, respectively. Lebo et al. (2010) determined the growth rate of *Schibe mystus* in cross river to be $0.33y^{-1}$.

Mortality and Exploitation Rates

Mortality refers specifically to the amount of fish that die within a certain year or season. Natural mortality (M) refers to all causes of death besides human fishing. These include predation, sickness, accidents, senility, a shortage of dissolved oxygen and food, overpopulation, and improper management methods, among others (King, 1994). Mortality from fishing (F) refers to deaths caused by anthropological fishing activities.

The results of this study indicate a high mortality rate for the species, which is consistent with the findings of Abowei and Hart (2009) from the lower Num River in the Niger Delta. This is also consistent with the findings of Ogueri et al. (2009), who determined a total mortality (Z) range of 0.61 – 1.25 for several fish species in the Katisna-Ala River.

The rate of exploitation is an indicator of the level of harvest from a fishery. It determines whether or not a stock is overfished, assuming that the optimal value (E) is equal to 0.5 (Pauly, 1984). The usage of E or 0.5 as the best exploitation rate is predicated on the assumption that the sustainable yield is maximized when F = M (Francis, 1974).

The exploitation ratio identified in this study is lower than in other locations. Olaosebikan *et al*. (2006) calculated E_{max} for *Parailia pellucida* in the upper arm of Jebba reservoir to be 0.454. (Lebo *et al*., 2010) observed E_{max} to be 0.59 for *Schilbe mystus*. Uneke *et al*. (2010) observed that the E_{max} for *Pellonula leonensis* in the cross river (a tropical flood river system) was 0.641.

The exploitation rate $E_{0.1}$ indicates the point when the fishing mortality rate at which the marginal yield-per-recruit is only 10 percent of the marginal yield-per-recruit on the unexploited stock. In other words, it is the exploitation at the point the fishing mortality rate on the yield-per-recruitment curve slope is just a tenth of the slope at the curve's inception (Gulland and Boerema, 1973). The $E_{0.1}$ was estimated to be 0.316 for *B. bayad*, 0.304 for *C. nigrodigitatus*, and 0.314 for *S. clarias*. The study's findings were consistent with those reported elsewhere. Olaosebikan *et al*. (2006) reported an $E_{0.1}$ value of 0.360 for *P. pellicida* in the upper arm of Jebba reservoir, but Idumah (2011) found an $E_{0.1}$ value of 0.5 for *Clarias gariepinus* in the mid-cross river flood plain environment.

The current exploitation rates generated using the yield per recruit analysis show that exploitation is far above the level that is expected to remove 50% of the stock biomass as yield annually. Furthermore, the E_{max} is less than the current exploitation rates but these rates are less than the theoretical threshold of 0.5. Looking further at the exploitation rates and fishing mortality, it is clear that the present fishing mortality is greater than F_{max}. These indices suggest overfishing as against using the threshold of $E>0.5$. The arguments for a better metric to judge exploitation and set management goals have been ongoing (Collie and Gislason, 2001; Smith et al., 1993). However, Gabriel and Mace (1999) suggested the adoption of $F_{0.1}$ as a precautionary threshold.

5. CONCLUSION

Of the three species studied, two: *B. bayad* and *S. clarias* were in better condition in the wet season than the dry season while *C. nigrodigitatus* presented the opposite scenario. The three species exhibit negative allometric growth. The fishing mortalities for the three species were lower than natural mortality in each case. However, the current exploitation rate exceeds the maximum exploitation rate (E_{max}) needed for a maximum sustainable yield. Although the current exploitation rates were less than the threshold of 0.5, the aforementioned disparity shows overfishing and this implies the threshold may not be an adequate biological reference point for setting management goals for these species.

REFERENCES

Abowei, F. N., & Hart, A. I. (2009). Some morph metric parameters of 10 fin fish species from the lower Nun River, Niger Delta, Nigeria. *Research Journal of Biological Sciences, 4*, 282-288.

Abowei, J. F. N. (2010). Some Population Parameters of *Distichodus rostratus*(Gunther, 1864) from theFresh Water Reaches of Lower Nun River, Niger Delta, Nigeria. *Advance Journal of Food Science and Technology, 2*(2), 84-90.

Abowei, J. F. N., & Hart, A. I. (2008). Artisanal fisheries characteristics of the fresh water reaches of lower Nun River, Niger Delta, Nigeria. *Journal of Applied Sciences and Environmental Management*, *12*(1).

Akombo, P. M., Akange, E. T., Amali, B. O., & Shima, J. N. (2015). Length-weight Relationship, Condition Factor and Feeding Habits of *Synodontis clarias* (Linnaeus, 1758) in the Lower River Benue at Makurdi, Nigeria. *Nigerian Annals of Pure and Applied Sciences*, *6*, 59-67.

Arame, H., Adite, A., Adjibade, N., Imorou, R. S., & Sonon, P. (2020). Length-weight relationships and condition factors of Mochokidae (Pisces: Teleostei: Siluriformes) from Niger River, Northern Benin. *Aquatic Research*, *3*(2), 72-84.

Araoye, P. A. (1997). Bio-Ecology of a Mochokid *Synodontis Schall* (Bloch and Schneider, 1801) in Asa Lake, Ilorin, Nigeria.

Babatunde, D. O., & Aminu, R. (1998). *Field Guide to Nigerian Freshwater Fishes.* Federal College of Freshwater Fisheries Techonology.

Bagenal, T. B. (1978). *Methods for Assessment of Fish Production in Fresh Waters* (T. B. Bagenal & W. E. Ricker, Eds.). Blackwell Scientific. https://books.google.com.ng/books?id=DXNVjgEACAAJ

Beverton, R. H., & Holt, S. J. (1966). Manual of methods for fish stock assessment. Part II. Tables of yield function. *FAO Fish Biology Technical Paper*, *38*(10), 1-67.

Beverton, R. J. H., & Holt, S. J. (1956). A review of methods for estimating mortality rates in fish populations, with special reference to sources of bias in catch sampling. *Rapp Proces-verb Reun Cons Int Explor Mer*, *140*, 67-83.

Brodziak, J. K. T. (2012). *Fitting length-weight relationships with linear regression using the log-transformed allometric model with bias-correction: Administrative Report H-12-03*. National Oceanic and Atmospheric Administration. Pacific Islands Fisheries Science Center.

Cadima, E. L. (2003). *Fish stock assessment manual* (Vol. 393). Daya Publishing House.

Chen, X., Liu, B., & Fang, Z. (2022). Age and Growth of Fish. In X. Chen & B. Liu (Eds.), *Biology of Fishery Resources* (pp. 71-112). Springer Nature.

Collie, J. S., & Gislason, H. (2001). Biological reference points for fish stocks in a multispecies context. *Canadian Journal of Fisheries and Aquatic Sciences*, *58*(11), 2167-2176.

Dantas, D. D. F., Caliman, A., Guariento, R. D., Angelini, R., Carneiro, L. S., Lima, S. M. Q., Martinez, P. A., & Attayde, J. L. (2019). Climate effects on fish body size–trophic position relationship depend on ecosystem type. *Ecography*, *42*(9), 1579-1586.

Dewiyanti, I., Aminah, S., Helmahera, A., Nurfadillah, N., & Defira, C. N. (2020). Growth patterns and condition factor of fish living in Kuala Gigieng waters of Aceh Besar as the basic for sustainable fisheries development. International Conference on Sustainable Aquatic Resources,

El-Badawy, A. A. (1991). Biological study on some fishes [maturation time, seasonal changes in gonad] of High Dam Lake [Egypt].

El-Drawany, M. A., & Elnagar, W. G. (2015). Growth, Food and Feeding Habits of *Bagrus bayad* and *Bagrus docmac* Inhibiting Muess Channel, Sharkia Province, Egypt. *Journal of Aquaculture Research & Development*, *6*(7), 1000348.

Essien-Ibok, M. A., Ekpo, I. E., & Bassey, H. E. (2015). Studies on the aspect of the biology of Mochokidae in the lower Cross River, Akwa Ibom State, Nigeria. *Direct Research Journal of Agriculture and Food Science*, *3*(11), 193-205.

FAO. (2022). *The State of World Fisheries and Aquaculture 2022: Towards Blue Transformation*. FAO. https://doi.org/10.4060/cc0461en

Francis, A., & Elenwu, U. (2012). Aspects of the biology of *Chrysichthys nigrodigitatus* (Lacepede: 1803) from the New Calabar River, Nigeria. *International Journal of Fisheries and Aquaculture*, *4*(6), 99-104.

Francis, R. C. (1974). Relationship of fishing mortality to natural mortality at the level of maximum sustainable yield under the logistic stock production model. *Journal of the Fisheries Board of Canada*, *31*(9), 1539-1542.

Froese, R., Winker, H., Coro, G., Demirel, N., Tsikliras, A. C., Dimarchopoulou, D., Scarcella, G., Probst, W. N., Dureuil, M., & Pauly, D. (2018). A new approach for estimating stock status from length frequency data. *ICES Journal of Marine Science*, *75*(6), 2004-2015.

Gabriel, W. L., & Mace, P. M. (1999, 1999). A review of biological reference points in the context of the precautionary approach.

Gayanilo, F. C., & Sparre, P. (2005). *FAO-ICLARM stock assessment tools II: FiSAT II: user's guide*. Food & Agriculture Org.

Gbaaondo, T. (2021). *Some Aspects of the Biology of Three Selected Fish Species from Lower River Benue.* MS.c. Thesis Joseph Sarwuan Tarka, University. Makurdi, Nigeria.

Gulland, J. A. (1971). *The Fish Resources of the Ocean*. Fishing News (Books).

Gulland, J. A. (1983). *Fish stock assessment: a manual of basic methods* (Vol. 1). Wiley.

Gulland, J. A., & Boerema, L. K. (1973). Scientific advice on catch levels. *Fishery Bulletin*, *71*(2), 325-335.

Gutmann Roberts, C., & Britton, J. R. (2020). Spawning strategies in cypriniform fishes in a lowland river invaded by non-indigenous European barbel *Barbus barbus*. *Hydrobiologia*, *847*(19), 4031-4047. https://doi.org/10.1007/s10750-020-04394-9

Headley, M. (2020). *Determining the status of fish stocks in data-poor environments and multispecies fisheries*. IISD: International Institute for Sustainable Development. https://www.iisd.org/system/files/publications/fish-stocks-multispecies-fisheries.pdf

Hoggarth, D. D., Abeyasekera, S., Arthur, R. I., Beddington, J. R., Burn, R. W., Halls, A. S., Kirkwood, G. P., McAllister, M., Medley, P., Mees, C. C., Parkes, G. B., Pilling, G. M., Wakeford, R. C., & Welcomme, R. L. (2006). *Stock assessment for fishery management – A framework guide to the stock assessment tools of the Fisheries Management Science Programme (FMSP)*. FAO.

Idodo-Umeh, G. (2003). *Freshwater Fishes of Nigeria: Taxonomy, Ecological Notes, Diet and Utilization*. Idodo Umeh Publishers.

Idumah, O. O. (2011). Age, growth and mortality of *Clarias gariepinus* (Siluriformes: Clariidae) in the Mid-Cross River-Floodplain ecosystem, Nigeria. *Revista de Biología Tropical*, *59*(4), 1707-1716.

Ikongbeh, A. O., Tiamiyu, L. O., & Ayuba, V. O. (2017). Fish Species Diversity and Seasonal Abundance of Lake Akata, Benue State, Nigeria. *Octa Journal of Biosciences*, *5*(2), 56-60.

Ikongbeh, O. A., & Ogbe, F. G. (2021). Seasonal numerical abundance and determination of size distribution of *Bagrus docmac* from Lake Akata, Benue State, Nigeria. *Journal of Research in Forestry, Wildlife and Environment*, *13*(2), 152-159.

Ikongbeh, O. A., Ogbe, F. G., Solomon, S. G., & Ataguba, G. A. (2015). Age, growth and mortality of *Chrysichthyes nigrodigitatus* (Lacépède, 1803) from Lake Akata, Benue State, Nigeria. *Asian Journal of Conservation Biology*, *4*, : 81-88.

Inyang, N. M., & Ezenwaji, H. M. G. (2004). Size, Length-Weight Relationships, Reproduction and Trophic Biology of *Chrysichthys nigrodigitatus* and *Chrysichthys auratus* (Siluriformes: Bagridae) In A Natural West African Lake. *Journal of Biological Research and Biotechnology*, *2*(1), 47-58.

Jafor Bapary, M. A., Nurul Amin, M., & Takemura, A. (2012). Food availability as a possible determinant for initiation and termination of reproductive activity in the tropical damselfish *Chrysiptera cyanea*. *Marine biology research*, *8*(2), 154-162.

Jones, C. M. (2009). Age and Growth. In L. A. Fuiman & R. G. Werner (Eds.), *Fishery Science: The Unique Contributions of Early Life Stages* (pp. 33 - 63). John Wiley & Son.

Jørgensen, C., & Fiksen, Ø. (2010). Modelling fishing-induced adaptations and consequences for natural mortality. *Canadian Journal of Fisheries and Aquatic Sciences*, *67*(7), 1086-1097. https://doi.org/10.1139/F10-049

King, M. G. (1994). *Fisheries biology, assessment, and management*. Fishing News Books.

King, R. P. (1996). Length-weight relationships of Nigerian coastal water fishes.

Kumar, S. A., & Kumar, N. S. R. (2015). Length-weight Relationship and Condition Factor in *Channa punctatus* (Bloch) from Hussainsagar Lake, Hyderabad, Andhra Pradesh, India. In M. Rawat, S. Dookia, & C. Sivaperuman (Eds.), *Aquatic Ecosystem: Biodiversity, Ecology and Conservation* (pp. 283-286). Springer.

Lalèyè, P., Chikou, A., Gnohossou, P., Vandewalle, P., Philippart, J. C., & Teugels, G. (2006). Studies on the biology of two species of catfish *Synodontis schall* and *Synodontis nigrita* (Ostariophysi: Mochokidae) from the Ouémé River, Bénin. *Belgium Journal of Zoology*, *136*(2), 193-201.

Lebo, P. E., King, R. P., Etim, L., Akpan, B. E., & Jonathan, G. E. (2010). Breeding seasonality and population dynamics of the catfish *Schilbe mystus* (Schilbeidae) in the Cross River, Nigeria. *v. 7*.

Midhat, A. E. K., Mohammed, M. N. A., & Seham, A. I. (2012). Environmental studies on *Synodontis schall* (Bloch and Schneider, 1801),(Pisces: Mochokidae) in the river Nile at Gizza sector, Egypt: Biological aspects of population dynamics. *Journal of Fisheries and Aquatic*, *7*, 104-133.

Mildenberger, T. K., Taylor, M. H., & Wolff, M. (2017). TropFishR: an R package for fisheries analysis with length-frequency data. *Methods in Ecology and Evolution*, *8*(11), 1520-1527.

Mir, J. I., Shabir, R., & Mir, F. A. (2012). Length-weight relationship and condition factor of *Schizopyge curvifrons* (Heckel, 1838) from River Jhelum, Kashmir, India. *World Journal of Fish and Marine Sciences*, *4*(3), 325-329.

Morgan, M. J. (2004). The relationship between fish condition and the probability of being mature in American plaice (*Hippoglossoides platessoides*). *ICES Journal of Marine Science*, *61*(1), 64-70.

Musa, H., Mahmud, U., Safiyanu, I., Bashir, S. I., & Kutama, A. S. (2016). Some Ecological Aspects of *Bagrus bayad* and *Clarias gariepinus* in Thomas Lake, Kano State, Nigeria. *Global Advanced Research Journal of Agricultural Science*, *5*(5), 165-174.

Ogbe, F. G., & Fagade, S. O. (2002). Distribution, Abundance and Dimensional Features of *Clarotes laticeps* (Rupell) and *C. macrocephalus* (Daget) in Lower Benue River, Makurdi, Nigeria. *Journal of Prospects in Science*, *6*, 18-23.

Ogueri, C., Adaka, G. S., Nlewadim, A. A., & Ben-Chendo, G. N. (2009). Comparative analysis of growth parameters and ages of fish species in River Katsin-Ala, Nigeria. *Nigerian Journal of Fisheries*, *6*(1&2), 35-43.

Olaosebikan, B. D., Muschoot, T., & Umar, Y. (2006). Growth, Mortality and yield of *Parailia pellucida* (Siruliformes: Schilbeidae) in the upper portion of Jebba Reservoir, Nigeria. *Nigerian Journal of Fisheries*, *2*(3), 2.

Paugy, D., Lévêque, C., & Teugels, G. G. (2003). The fresh and brackish water fishes of West Africa.

Pauly, D. (1979). *Theory and management of tropical multispecies stocks: a review, with emphasis on the Southeast Asian demersal fisheries* (Vol. 1). International Center for Living Aquatic Resources Management (ICLARM).

Pauly, D. (1980). On the Interrelationships Between Natural Mortality, Growth Parameters, and Mean Environmental Temperature in 175 Fish Stocks. *ICES Journal of Marine Science*, *39*(2), 175-192. https://doi.org/10.1093/icesjms/39.2.175.

Pauly, D. (1983). *Some simple methods for the assessment of tropical fish stocks*. Food & Agriculture Org.

Pauly, D. (1984). *Fish Population Dynamics in Tropical Waters: A Manual for Use with Programmable Calculators*. International Center for Living Aquatic Resources Management.

Pauly, D., & Munro, J. L. (1984). Once more on the comparison of growth in fish and invertebrates. *Fishbyte*, *2*(1), 1-21.

Pauly, D., & Soriano, M. L. (1986). Some practical extensions to Beverton and Holt's relative yield-per-recruit model.

Smith, S. J., Hunt, J. J., & Rivard, D. (1993). *Risk evaluation and biological reference points for fisheries management*. NRC Research Press.

Sparre, P., & Venema, S. C. (1992). Introduction to tropical fish stock assessment. Pt. 1: Manual (Vietnamese ed.). *FAO Fisheries Technical Paper (Vietnamese ed.)(FAO) eng no. 306*.

Taylor, M. H., & Mildenberger, T. K. (2017). Extending electronic length frequency analysis in R. *Fisheries Management and Ecology*, *24*(4), 330-338.

Uneke, B. I., Nwani, C. D., Okogwu, O., & Okoh, F. (2010). Growth, mortality, recruitment and yield of *Pellonula leonensis* Boulenger, 1917 (Osteichthyes: Clupeidae) in a tropical flood river system. *Journal of Fisheries International*, *1*(5), 19-26.

Utne, K. R., Pauli, B. D., Haugland, M., Jacobsen, J. A., Maoileidigh, N., Melle, W., Broms, C. T., Nøttestad, L., Holm, M., & Thomas, K. (2021). Poor feeding opportunities and reduced condition factor for salmon post-smolts in the Northeast Atlantic Ocean. *ICES Journal of Marine Science*, *78*(8), 2844-2857.

Vos, L. d. (1995). A systematic revision of the African Schilbeidae (Teleostei, Siluriformes) with an annotated bibliography. *Annales-Musee Royal de l'Afrique Centrale. Sciences Zoologiques (Belgium)*.

Wang, Y.-G., & Somers, I. F. (1996). A simple method for estimating growth parameters from multiple length-frequency data in presence of continuous recruitment. *Fisheries Research*, *28*(1), 45-56. https://doi.org/https://doi.org/10.1016/0165-7836(96)00484-5

Zafar, M., Mussaddeq, Y., Akhter, S., & Sultan, A. (2003). Weight-length and Condition Factor Relationship of Thaila, *Catla catla*. *Pakistan Journal of Biological Sciences*, *6*(17), 1532-1534.

Zhang, K., Li, J., Hou, G., Huang, Z., Shi, D., Chen, Z., & Qiu, Y. (2021). Length-based assessment of fish stocks in a data-poor, jointly exploited (China and Vietnam) fishing ground, northern South China Sea. *Frontiers in Marine Science*, 1043.