

Population dynamics of *Chrysichthys nigrodigitatus* (Lacépède, 1803) in Ikere-gorge, Oyo State, Nigeria

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ABSTRACT

The growth and mortality parameters of *Chrysichthys nigrodigitatus* were estimated to assess the sustainability of its exploitation in Ikere-gorge, Oyo State, Nigeria. A total of 1210 of *Chrysichthys nigrodigitatus* were sampled from fishermen catches between January, 2017 and December, 2018. *C. nigrodigitatus* were exploited with gillnet, cast net and traps (Malian trap net and bamboo). Total lengths were measured with fish measuring board. The FAO-ICLARM Stock Assessment Tool (FiSAT II) software was used to analyze length-frequency data of the fish. The estimated growth parameters are: asymptotic length is 60.9 cm, growth coefficient is 0.96, optimum length is 38.51 cm; length at maturity is 33.44 cm while length-at-first-capture is 12.62 cm. The estimated mortality parameters are: total mortality is 3.29 per year, natural mortality is 1.43 per year and fishing mortality is 1.86. It was observed that *C. nigrodigitatus* of Ikere-gorge were more vulnerable to exploitation at sizes less than their length at maturity. Likewise, the exploitation rate ($E = 0.57 \text{ yr}^{-1}$) is greater than sustainable exploitation rate ($E_{\max} = 0.46 \text{ yr}^{-1}$). This shows that exploitation of *C. nigrodigitatus* in Ikere-gorge is not sustainable. Therefore, there is need to reduce fishing pressure on *C. nigrodigitatus* to ensure its sustainability in Ikere-gorge.

Keywords: Exploitation; Fish species; Growth performance; Recruitment; Sustainable

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Introduction

Fish population is a group of the same species or subspecies of fish that are spatially and genetically separated from other groups (Pope *et al.*, 2010). Fish population dynamics is the study of continuous changing of fish stock with

time due to factors such as reproduction (recruitment), mortality, migration (immigration and emigration), growth and yield. The objective of studying fish population dynamics is to ensure rational management and conservation of fishery resources (Udoh *et al.*, 2015).

Fish stock is a sub-set of one fish species having the same growth and mortality parameters and inhabiting a particular geographical area (Ajang *et al.*, 2013). Stock is a fundamental concept to fish population dynamics. The most important task is to estimate population parameters (i.e. growth, recruitment, mortality and migration) of a specific fish or a group of fish species. Among these four variables, Pope *et al.* (2010) reviewed that annual recruitment is typically the most variable factor affecting the dynamics of fish populations but it can provide substantial insight into why fish populations may vary in size and structure.

Chrysichthys nigrodigitatus is an important ecological and commercial fish species in tropical freshwater ecosystems (Ikongbeh *et al.*, 2015). This fish is abundant in Ikere-gorge and it occurs in every catch of fishermen. However, smaller sizes and juveniles are predominant in their catches, an indication of growth overfishing threat to the

fisheries. The fishermen of Ikere-gorge employ different types of fishing gears to exploit *C. nigrodigitatus*. These gears include gillnets of various mesh sizes, cast nets, bamboo traps (Kolombo), Malian traps (Gura), wire nets and hooks. This study aimed to assess the growth and mortality parameters of *C. nigrodigitatus* of Ikere-gorge so as to provide useful information on the management of the fish in the gorge.

Materials and Methods

Study area

Ikere-gorge is located between longitude 8°10' and 8° 20'N and latitude 3° 40' and 3° 50'E (Figure 1). Ikere-gorge is a 565 million cubic metres multipurpose dam located at Ikere village, about 28 km, North East of Iseyin in Oyo State. The southern parts of the dam are characterised with rocky hills and valley. The water bed comprises mainly of fine and coarse sand particles and gravels.

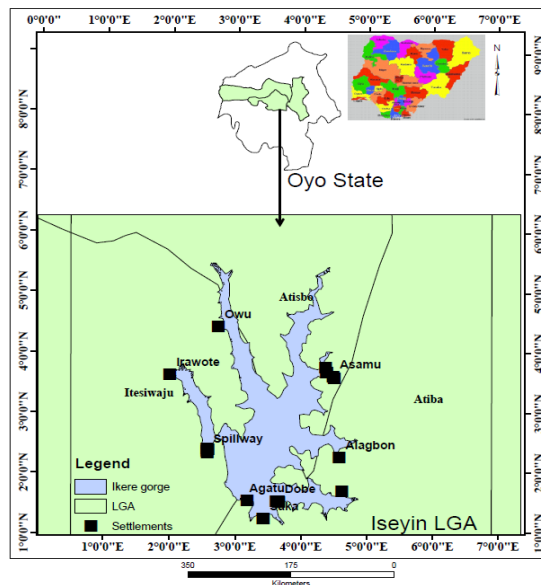


Fig. 1: Map of Ikere-gorge (showing some fishing villages), Oyo State, Nigeria

Fish sampling

The fishermen of Ikere-gorge exploit *C. nigrodigitatus* with different types of fishing gears such as gillnets, cast nets, bamboo traps (Kolombo), Malian traps (Gura) and wire nets. A total 1210 of *C. nigrodigitatus* was sampled from the catches of commercial fishermen between 8 am and 12 noon from January, 2017 to December, 2018. The fish was identified with keys provided by Olaosebikan and Raji (2013). The total length of the fish was measured with a fish measuring board to the nearest centimetre (cm)

Estimation of growth and mortality parameters

The means of the two years (2017 and 2018) monthly length-frequency distribution of *C. nigrodigitatus* were pooled together as annual data. They were analyzed using the procedure of Gayanilo Jr. *et al.* (2005) of the FiSAT II (version 1.2.2) computer software package of fish stock assessment. ELEFANI (nonparametric scoring of von Bertalanffy Growth Function VBGF Fit) and II subroutines of the software were used to estimate von Bertalanffy growth and mortality parameters, recruitment patterns and probability of capture. The equation for growth in length is given by,

$$L_t = L_\infty [1 - \exp\{-K(t - t_0)\}] \quad [1]$$

Where: L_t is the estimated length at age t ; L_∞ is the asymptotic length in cm; K is a growth coefficient; ' t_0 ' is the theoretical age at which fish would have had zero length (Pauly 1986; Abdul *et al.* 2012).

The overall growth performances index (\emptyset') for the selected fish species were computed using the Pauly and Munro (1984):

$$\emptyset' = \log_{10} K + 2 \log_{10} L_\infty \quad [2]$$

Natural mortality was estimated using Pauly (1980)

$$\ln M = -0.0152 - 0.279 \ln L_\infty + 0.06543 \ln K + 0.4634 \ln \bar{T} \quad [3]$$

Where: M is the natural mortality; \bar{T} was 28.14°C, the annual mean surface water temperature of Ikere gorge.

The total mortality, Z , was obtained according to the model proposed by Ssentongo and Lar-kin (1973):

$$Z = (nK/(n+1) (\ln(L_\infty - L_c) (L_\infty - \bar{L}))^{-1} \quad [4]$$

Where: n is the number of fishes sampled; L_c is the length of the smallest fish in the sample; \bar{L} is the average length in the samples

But, total fishing mortality is:

$$Z = F + M \quad [5]$$

Therefore, fishing mortality (F) can be estimated as:

$$F = Z - M \quad [6]$$

Therefore, exploitation rate (E) which is the mortality rate due to fishing activities can be estimated as:

$$E = F/F+M = F/Z \quad [7]$$

Length-at-first-maturity, L was estimated as:

$$\log L_m = 0.8776 \log L_\infty - 0.38 \quad [8]$$

Longevity was obtained from the following equation (Pauly 1983):

$$t_{max} = t_0 + 3/K \quad [9]$$

Where: t_{max} is the approximate maximum age the fish of a given population would reach.

Results and Discussion

The growth and the mortality parameters of *Chrysichthys nigrodigitatus* of Ikere gorge are presented in Table 1. The total number of *C. nigrodigitatus* sampled during the study was 1,210 and the length of the fish varied from 8.0 to 58.0 cm with a mean of 21.54 ± 5.83 cm. Table 2 shows the total number of *C. nigrodigitatus* caught, in which corresponding months of each year (the years 2017 and 2018) were added to make data for the month. However, Famofo and Abdul (2020) reported that the

length of *C. nigrodigitatus* in Iwopin freshwater ecotype of Lekki Lagoon, Ogun State, Southwest Nigeria ranged from 12.2 to 34.8 cm with a mean of 27.2 ± 1.0 cm.

Figure 2 shows the von Bertalanffy growth curves for *C. nigrodigitatus*. The asymptotic length or the theoretical maximum length (L_{∞}) for which *C. nigrodigitatus* of Ikere gorge would reach if it lived indefinitely was 60.90 cm. There is a simple relationship between maximum length and asymptotic length in which the latter is about 5.0% longer than the former (Froese & Binohlan, 2000). The value of L_{∞} , 60.90 cm observed in this study was lower than the value (98.25 cm) reported by Ajang et al. (2013) in the lower reaches of the Cross River Estuary, Nigeria. But the asymptotic length (L_{∞}) of *C. nigrodigitatus* of Ikere gorge was greater than 44.5 cm reported by Ofori-Danson et al. (2002) for *C. nigrodigitatus* in Lake Volta, Ghana. It is also greater than 29.93 cm reported by Uneke (2018) for *C. nigrodigitatus* in the Mid Cross River Flood System, South Eastern Nigeria and 37.28 cm reported by Ikongbeh et al. (2015) for *C. nigrodigitatus* from Lake Akata, Benue State, Nigeria.

The growth coefficient (K) of *C. nigrodigitatus* of Ikere gorge was 0.96/year. This is the rate at which *C. nigrodigitatus* would attain its maximum length in Ikere-gorge. This value is consistent with the result of Ajang et al. (2013) for *C. nigrodigitatus* in lower reaches of the Cross River Estuary, Nigeria. However, Ofori-Danson et al. (2002) reported K -value of 0.65/year for *C. nigrodigitatus* in Lake Volta, Ghana. Likewise, the growth performance (\emptyset') of *C. nigrodigitatus* of Ikere gorge was 3.55 while its longevity was 3.13 years. There is an inverse relationship between K -value and longevity of a fish; as the K -value increases,

the longevity decreases and vice versa (Sparre & Venema, 1998). The K -value, longevity and growth performance of *C. nigrodigitatus* obtained in this study were in agreement with the findings of Abdul et al. (2009), who reported K -value, longevity and growth performance of 0.98 /year, 3.06 years and 3.66 respectively for *C. nigrodigitatus* in Iwopin area of Lekki Lagoon, Ogun State.

Length at first capture or 50% of the stock (L_{50}) being vulnerable to fishing gear was 12.62 cm. The length at first maturity (L_m) of *C. nigrodigitatus* was 33.44 cm while the optimum length (L_{opt}) which is the length at which the total biomass of a year-class reaches a maximum value was 38.51 cm. This shows that *C. nigrodigitatus* of Ikere-gorge are vulnerable to exploitation at smaller sizes than their maturity size. Growth overfishing would be avoided if a fish was allowed to reproduce at least once before it becomes vulnerable to exploitation (Kennelly, 2007; King, 2007; Humphries & Walker, 2013).

The recruitment patterns of *C. nigrodigitatus* in Ikere-gorge shows two recruitment cycles per year (Figure 3) during the period of study (2017 and 2018). The first recruitment occurred from February to June and the peak was in June. The second recruitment period occurred from August to November, and the peak was in October. This observation is in agreement with Pauly (1982) that tropical fish species are short-lived and have double recruitment pulses per year. The recruitment pattern for *C. nigrodigitatus* in Ikere-gorge was consistent with that which was reported for *C. auratus* in Damietta branch of the River Nile in Egypt (Ragheb, 2016).

The instantaneous rate of total mortality per year (Z) of *C. nigrodigitatus* was 3.29/year, the natural mortality, M was 1.43/year, the

fishing mortality, F was 1.86/year and the exploitation rate was 0.57/year, and the average temperature of 28.14°C in Ikere-gorge (Figure 4). These were lower than the total mortality (Z) of 6.27/year and fishing mortality (F) of 5.05/year reported by Ajang *et al.* (2013) for *C. nigrodigitatus* in lower reaches of the Cross River Estuary, Nigeria. Ofori-Danson *et al.* (2002), reported that mortality rate estimates for *C. nigrodigitatus* in Lake Volta, Ghana were $Z = 3.77$ /year, $M = 1.24$ /year, $F = 2.53$ /year and exploitation ratio, $E = 0.67$. In addition, the difference between the current exploitation rate ($E = 0.57$) and sustainable exploitation rate ($E_{max} = 0.46$) shows that *C. nigrodigitatus* is one of the most exploited fish in Ikere-gorge and its current rate of exploitation has to be reduced by 23.91% for the exploitation to be sustainable. This is in agreement with the report of Udoh *et al.* (2015) in which they suggested 10 – 40% reduction in fishing mortality of *C. nigrodigitatus* in Lower Cross River, Nigeria

The virtual population of *C. nigrodigitatus* in Ikere-gorge showed that fishing mortality of the stock was highest between the length range of 18.0 and 28.0 cm. This is the length range of *C. nigrodigitatus* that was heavily exploited in Ikere-gorge. Figure 5 shows that natural mortality (as a result of predation, diseases etc) predominates within the unexploited length range of 6.0 to 10.0 cm of all *C. nigrodigitatus* mortality. Fishing mortality increased steadily from length 10.0 cm and it predominated at a length of 18.0 cm. There was full exploitation at sizes 28.0 cm and above. This suggests that there was growth overfishing of *C. nigrodigitatus* in Ikere-gorge, because most *C. nigrodigitatus* were not allowed to grow and mature enough to reproduce or

recruit at least once before capture. The ratio of length-at-first-capture to asymptotic length (L_c/L_∞) was 0.21. This shows that *C. nigrodigitatus* of Ikere-gorge is vulnerable to gear or capture when it is just 21% of its asymptotic length. Likewise, the ratio of natural mortality to von Bertalanffy growth coefficient (M/K) was 1.49. The value of M/K (1.49) obtained in this study was within the range recommended by Beverton and Holt (1966) which was 1.0 to 2.5. This is an indication that growth and mortality parameters obtained in this study are valid for scientific deduction and interpretation. Also, the ratio of total mortality to von Bertalanffy growth coefficient (Z/K) obtained in this work is greater than 1 ($Z/K > 1$), then it showed that mortality dominate *C. nigrodigitatus* population in Ikere-gorge (Udoh *et al.*, 2015).

TABLE 1
Growth and mortality parameters of *Chrysichthys nigrodigitatus* (January 2017 to December 2018) in Ikere-gorge, Iseyin, Oyo State, Nigeria

Parameter	Value
Total number of individual fish sampled	1, 210
Maximum length, L_{max} (cm)	58.0
Minimum length, L_{min} (cm)	8.0
Asymptotic length, L_∞ (cm)	60.9
Growth coefficient, K (VBGF) /year	0.96
Overall growth performance index, ϕ'	3.55
Optimum length L_{opt} (cm)	38.51
Length at maturity, L_m (cm)	33.4
Length at first capture, L_{50} (cm)	12.6
Total mortality, Z , (yr^{-1})	3.29
Natural mortality, M , (yr^{-1})	1.43
Fishing mortality, F , (yr^{-1})	1.86
Z/K	3.43
M/K	1.49
Sustainable exploitation ($E_{max} yr^{-1}$)	0.46
Exploitation rate, E (yr^{-1})	0.57
L_c/L_∞	0.21
Longevity (year)	3.13

Key: Z/K : ratio of total mortality to von Bertalanffy growth coefficient; M/K : the ratio of natural mortality to von Bertalanffy growth coefficient; L_c/L_∞ : the ratio of length-at-first-capture to asymptotic length

TABLE 2

Monthly data of *Chrysichthys nigrodigitatus* caught between January 2017 and December 2018 in Ikere-gorge, Iseyin, Oyo State, Nigeria

Months	Number of <i>Chrysichthys nigrodigitatus</i> caught
January	125
February	99
March	104
April	130
May	78
June	123
July	163
August	133
September	63
October	97
November	52
December	43
Total	1210

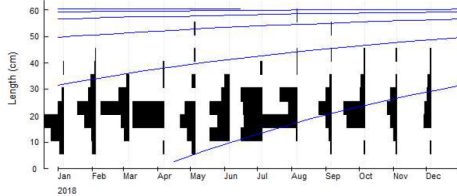


Fig. 2: The von Bertalanffy growth function curves of *C. nigrodigitatus* (2017 and 2018) in Ikere-gorge, Iseyin, Oyo State, Nigeria (drawn using ELEFAN 1 programme; $L_{\infty} = 60.9$ cm; $K = 0.96/\text{year}$)

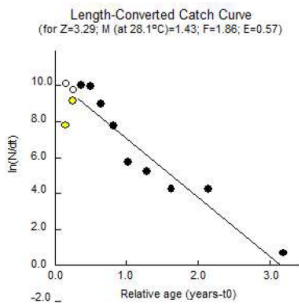


Fig. 3: The recruitment pattern of *Chrysichthys nigrodigitatus* (2017 and 2018) in Ikere-gorge, Iseyin, Oyo State, Nigeria

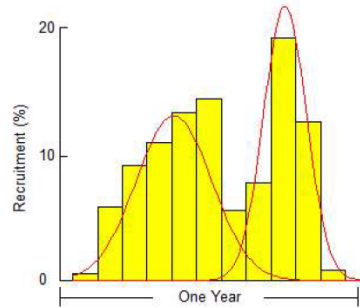


Fig. 4: The length converted catch curve of *Chrysichthys nigrodigitatus* (2017 and 2018) in Ikere-gorge, Iseyin, Oyo State, Nigeria

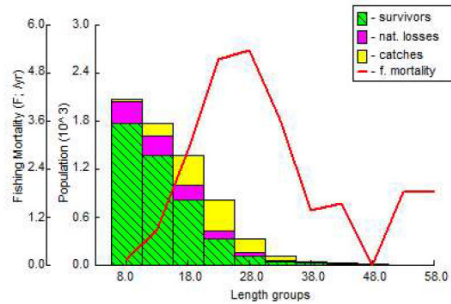


Fig. 5: Virtual population analysis of *Chrysichthys nigrodigitatus* (2017 and 2018) in Ikere-gorge, Iseyin, Oyo State, Nigeria

Conclusion

The growth and mortality parameters of *C. nigrodigitatus* of Ikere-gorge, Iseyin, Oyo State, Nigeria were estimated in this study. Result obtained shows that *C. nigrodigitatus* of Ikere-gorge are vulnerable to exploitation at length ($L_{50} = 12.6$ cm) smaller than their length at maturity ($L_m = 33.4$ cm). Likewise, the exploitation rate ($E = 0.57$) is greater than sustainable exploitation rate ($E_{max} = 0.46$). This shows that exploitation of *C. nigrodigitatus* in Ikere-gorge is not sustainable. In order for the exploitation of *C. nigrodigitatus* in Ikere-gorge to be sustainable, the exploitation rate has to be reduced by at least 23.91% based on the

difference between the current and sustainable exploitation rates.

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Appendix

TABLE 3

Monthly recruitment value of *Chrysichthys nigrodigitatus* in Ikere-gorge, Iseyin, Oyo State, Nigeria

Months	Recruitment values
January	3.39
February	3.62
March	10.86
April	9.46
May	15.81
June	12.33
July	5.57
August	6.52
September	22.62
October	9.74
November	0.1
December	0

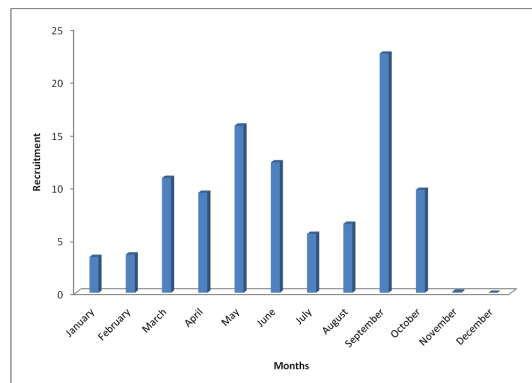


Fig. 6: Recruitment pattern of *Chrysichthys nigrodigitatus* in Ikere-gorge, Iseyin, Oyo State, Nigeria