Impact of environmental variables on abundance, growth and condition factor of *Gymnarchus niloticus* (Curvier, 1829) from Umueze-Ossissa lake system, Southern Nigeria

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Abstract
The impact of environmental variables on abundance, growth and condition factor of *Gymnarchus niloticus* from two lakes in Umueze-Ossissa, Southern Nigeria was investigated to provide baseline information for effective management of the lakes. *G. niloticus* were collected fortnightly for a period of 12 months from fishermen who used set nets and percentage abundance determined. Length-weight relationship was used to determine growth pattern, condition factor and relative condition factor. Environmental variables such as water quality parameters affecting fish abundance were predicted with multiple regression analysis. *G. niloticus* was more abundant in Otu Lake than in Abiandu Lake. Male *G. niloticus* were significantly ($P<0.05$) more than female with male to female ratio of 1:1.8 and 1:1.7 in Otu and Abiandu lakes respectively. *Gymnarchus niloticus* showed negative allometric growth in the two lakes studied meaning that fish get slimmer as it increases in size. Condition factor of *G. niloticus* ranged from 0.24 to 4.09 and 0.59 to 3.73 and relative condition factor from 0.82 to 1.08 and from 0.92 to 1.12 in Otu and Abiandu Lakes respectively. High air temperature observed corresponded with high number of fish, while high amount of rainfall corresponded with low number of *G. niloticus.* Water quality parameters showed that depth, transparency, DO and BOD were significantly higher ($P<0.05$). The model used successfully predicted *G. niloticus* abundance. These findings are useful during planning for effective management of the lakes for sustainable economic and livelihood development of the area.
Key words: Environment, *Gymnarchus*, growth, lake, Ossissa, Nigeria

Introduction

Fish is an important source of food and cheap protein for the over 186 million teaming population of Nigeria with abundant natural water resources (Ezeabasili et al., 2014; Idu, 2015) and some aquacultural production systems (Offem et al., 2010; Bradley et al. 2020) for fish food supplies from capture and culture respectively. Human exploitation of these water resources causes environmental degradation affecting aquatic environment in the form of sub-lethal pollution resulting in negative effects on aquatic life (Adeyemo, 2003). The country now depends on importation of fish to meet up the gap between demand and supply of fish (Oluwarore, 2018; Nwokedi et al., 2020). Recently, there has been a growing interest in agricultural drive for increased food production, including fish production (Olaoye and Ojebiyi, 2018). The production of catfish, mainly *Clarias* and H*eterobranchus* species has been favoured (Adewumi and Olaleye, 2011) while researches are ongoing to identify other possible culturable fish species for subsistence and possibly commercial production (Agwumba et al., 1985; Ngueku, 2015).

Gymnarchus niloticus belongs to Family Gymnarchidae, a mono-specific genus. It is a common fish species in Nigeria and several West African countries. The fish is considered a highly priced ceremonial fish in Nigeria (Idodo-Umeh, 2003). The fish is not only an economic fish food but also of great socio-cultural importance in Nigeria (Ayoola and Abotti, 2010; Oladosu et al., 2012) which endears it as one of the most highly valued freshwater fishes in Nigeria. Despite its aquaculture potentials including rapid growth, high premium, tasteful, seasonal availability of wild growers (Kigbu et al., 2014), the supply of *G. niloticus* relies greatly on wild collection which is insufficient for its demands (Oladosu et al., 2012). A careful study of environmental factors influencing growth of *G. niloticus* is important for culture trials. Greshishchev et al. (2015) observed that great variability exist in most environmental variables and opined that these variables were related to different species of fish, including some endangered species. The influence of environmental factors such as temperature and depth on distribution pattern and diversities of fish species have been reported (Araoye, 2009; Nsor, 2016).

Interactions between the exogenous and endogenous factors on fish biometrical parameters have remained an important issue in fish management practices. Ahmed et al. (2020) reported that exogenous and endogenous factors can affect haematologic parameters of fish which can act as biomarkers in toxicology and aquaculture studies. The interrelationships of ecological factors can have effect on the different fish species of the world. Jobling (2008) reported that environmental factors can affect fish growth while Eriegha and Ekokotu (2017) noted several factors which affect fish biometry as management practices, environmental conditions, feed quality, inherent genetic factor and physiological condition of the fish. The distribution, occurrence, aspects of biology and tolerable environmental conditions for survival of the fish species have been documented (Bennett, 1971; Riede, 2004; Akinsanya et al., 2007; Kakareko et al., 2005; Ara et al., 2011; Oluwale et al., 2019).

This study examines the impact of environmental variables on abundance, growth and condition factor of *Gymnarchus niloticus*, commonly known as Aba, Knife fish or trunk fish in Umueze-Ossissa lake system, Southern Nigeria. A baseline study of this nature is important as there are no literature on the lake system of Ossissa to provide useful information on growth conditions of *Gymnarchus niloticus*, which is important for sustainable fisheries management.

Materials and Methods

Description of Study Area

The two lakes of study are Otu Lake and Abiandu Lake both located in Umueze, one of the major communities in Ossissa. Ossissa is a town with coordinates $5^{o}57'$ 00"N and $6^{o}30'$ 00"E, located in Ndokwa East Local Government of Delta State, Nigeria. There are two natural lakes and several natural ponds in Umueze-Ossissa, around where the Adofi River discharges into Oshimili River. Otu Lake is the largest of the two with approximately 0.8 km in width and 1.5 km in length and about 30 m deep. Abiandu Lake measures approximately 0.55 km in width, 0.7 km in length and about 18 m deep. The two lakes are situated north of Adofi River. Inhabitants of Umueze-Ossissa have to use canoe to cross the Adofi River in order to access the lakes or take a longer motor able route out of their community to access the lakes from the back end of Umueze-Ossissa. During periods of flood in the rainy season (between April and September) River Oshimili over flows its banks and forms a continuum with the two lakes. However, in the dry season (October to March), the two lakes are distinct from each other and the River Oshimili. There is an excessive growth of water hyacinth (*Eichhornia crassipes*) in the lakes, particularly Otu Lake. A vast portion of the water surface is covered up with *Eichhornia crassipes*. Other aquatic vegetation are also present but are suppressed by the growth of the water hyacinth. Fishermen normally paddle dug-out canoe in the lake by cutting their way through the water hyacinth bloom with machete to make for easy passage. Figure 1 shows the sampling stations at Otu Lake (Station 1) and Abiandu Lake (Station 2) at Umueze-Ossissa.

Collection of fish samples

G. niloticus samples for studies were purchased fortnightly for twelve months from September, 2018 to August 2019 from fishermen who fished in the lakes using set net. Other fishes were also present in the lakes. A total of 529 *G. niloticus* samples used for the study were immediately kept in ice-chest and transported to the laboratory of the Department of Fisheries, Delta State University, Asaba Campus for biometric analysis. Fish samples were identified up to the species level (Reed et al., 1967; Idodo-Umeh, 2003).

Biometry of fish samples

Total length and standard length of fish samples were measured from the tip of the snout to the end of the caudal fin using a meter rule and recorded to the nearest 1.0 cm while weight measurements was done using a digital balance to 100 g accuracy. Then the girth length for all samples were taken.

Water quality parameter

Samples of water were collected between 7.00 and 10.00 hours using 250 ml corked bottles from the three points in each station based on ecological feature such as presence or absence on water of water hyacinth bloom and domestic activities and some selected physicochemical parameters determined. Temperature, dissolved oxygen (DO), hydrogen ion concentration (pH) and conductivity were measured *in-situ* using Hanna portable instrument. DO meter, conductivity meter and pH meter were calibrated before use. For BOD, the dark sterile cocked bottle was left under water at the bank of the lake and BOD determined after 10 hours. Depth was measured with a graduated rope dropped from a canoe at the center of the lakes. Transparency was by secchi disc. Total dissolved solids (TDS) and Total suspended sediments (TSS) were determined according to methods described by APHA (2005).

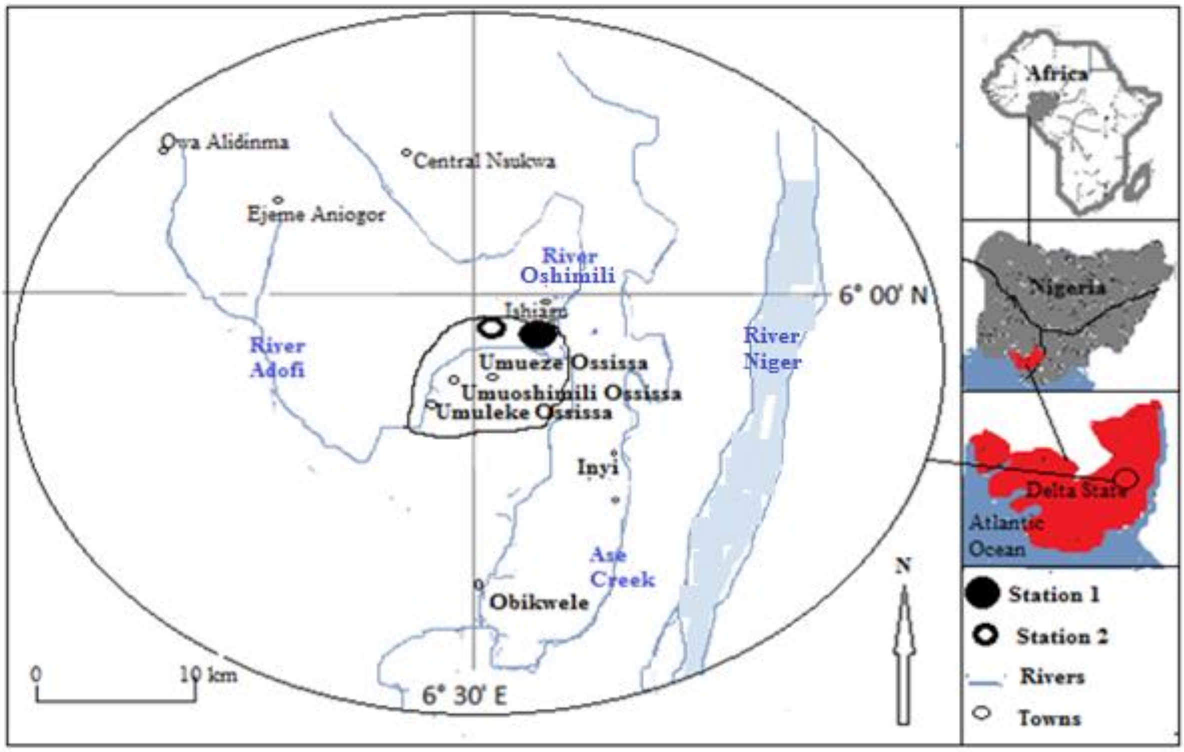

Figure-1. Study stations at Umueze Ossissa: Station1, Otu Lake and Station 2, Abiandu Lake (Inserts: Maps of Africa, Nigeria and Delta State).

Growth condition

The growth condition of *G. niloticus* was determined by length-weight relationship (LWR), condition factor (K) and relative condition factor (Kn). The LWR was determined from the formula: W = aLb. Using logarithmic transformation, parameters a and b in the formula were estimated as: Log W = Log a + b Log L

where, W = Total body weight of fish, L = Total length of fish (cm), b = growth exponent or regression coefficient and Log a = intercept on the Y-axis.

The condition factor of *G. niloticus* was calculated from the length and weight relationship using Fulton's formula, given by Le Cren (1951): $K=W100/L^3$

where K = Condition factor, L= Standard length of fish (cm), W= Weight of fish (g).

While relative condition factor, K_n was calculated from the length-weight regression (Le Cren, 1951) for both male and female fish. K_n was established to assess the condition of *G. niloticus* fish samples under study. K_n is given as: Kn= w/W

where, w is observed weight of a fish at a given length and W, expected weight of a fish of the same length.

Environmental variables

Impact of environmental variables on the abundance of *G. niloticus* was determined using multiple regression analysis. Environmental variables likely to affect abundance of *G. niloticus* were water quality parameters such as sub surface water temperature, depth, transparency, total suspended sediments (TSS), total dissolved solids (TDS), hydrogen ion concentration (pH), dissolved oxygen (DO), biological oxygen demand (BOD), nitrate and phosphate levels. The regression model used was stated in equation form as:

$Y = f(X_1,X_2,X_3,X_4,X_5,X_6,X_7,X_8,X_9,X_{10}, e)$

$Y=f(\text{temp}_1, \text{depth}_2, \text{transparency}_3, TSS_4, TDS_5, pH_6, DO_7, BOD_8, \text{Nitrate}_9, \text{phosphate}_{10}, e)$

Where: Y= dependent variable (*G. niloticus* abundance)

$X_1 \ldots X_{10}$ = independent variables e = Random Error

(Udoh and Nyienakuna, 2008).

Three functional forms of the model such as linear, semi-log and double-log functions were used (Almeida et al., 2001). The one with the best fit was used as the lead function based on having the highest value of the coefficient of multiple determination, highest number of significant variables and conformity to a priori expectations. Abundance of *G. niloticus* was inputted as the dependent variable while water quality parameters were taken as the independent variables.

Statistical Analysis

Data collected were analyzed by descriptive statistics, correlation, linear and multiple regression analyses at $P<0.05$ using SPSS 17.

Results

Gymnarchus niloticus had a peak of abundance in Station 1 in the month of January while in Station 2, *G. niloticus* was more abundant in November, December and January during the study. Male fish were more in number with a ratio of male to female of 1.76:1 and 1.66:1 for *G. niloticus* from Stations 1 and 2 respectively. *G. niloticus* was more abundant in Station 1 than in Station 2. Fish sampled from Station 1 amounted to 67.3% of all *G. niloticus* collected during the study. Figure 2 shows percentage abundance of *G. niloticus* in Otu Lake (Station 1) and Abiandu Lake (Station 2). A comparison of rainfall amount and prevailing air temperatures of the study area shows that rainfall was higher in August and > September, while temperature was higher in February followed by January. The high temperature observed in January corresponded with high number of fish, while high amount of rainfall corresponded with low number of *G. niloticus* harvested (Figure 3).

G. niloticus from Station 1, Otu Lake, ranged in total length from 25 cm to 136 cm and body weight from 520 g to 6,900 g . While in Station 2, *G. niloticus* ranged from 24 cm to 80 cm with weight ranging from of 500 g to 3,800 g. The length-weight relationships of *G. niloticus* is presented in Table 1. *Gymnarchus niloticus* showed allometric growth in the two lakes studied because all exponential 'b' value obtained were less than 3 ($b<3$) for male and female fish as well as for combined sexes of fish. A high R^2 was obtained in all groups of *G. niloticus*. The regression equation of body weight on total length of both sexes of *G. niloticus* in Stations 1 and 2 were $y=1.051+1.321x$ and $y=0.26+1.809x$ respectively (Figures 4 and 5).

Table-1. Length-weight and parametric relationships of *G. niloticus* from study lakes in Ossissa

Stations		N	*A*	*B*	S.E.(*b*)	R	R^2	*P value*
Otu Lake	Male	227	1.012	1.332	0.040	0.911	0.829	0.000
	Female	129	1.143	1.289	0.038	0.950	0.902	0.000
	Both sexes	356	1.051	1.321	0.031	0.916	0.839	0.000
Abiandu Lake	Male	108	0.241	1.831	0.048	0.965	0.931	0.003
	Female	65	0.297	1.767	0.165	0.803	0.645	0.266
	Both sexes	173	0.260	1.809	0.074	0.883	0.779	0.033

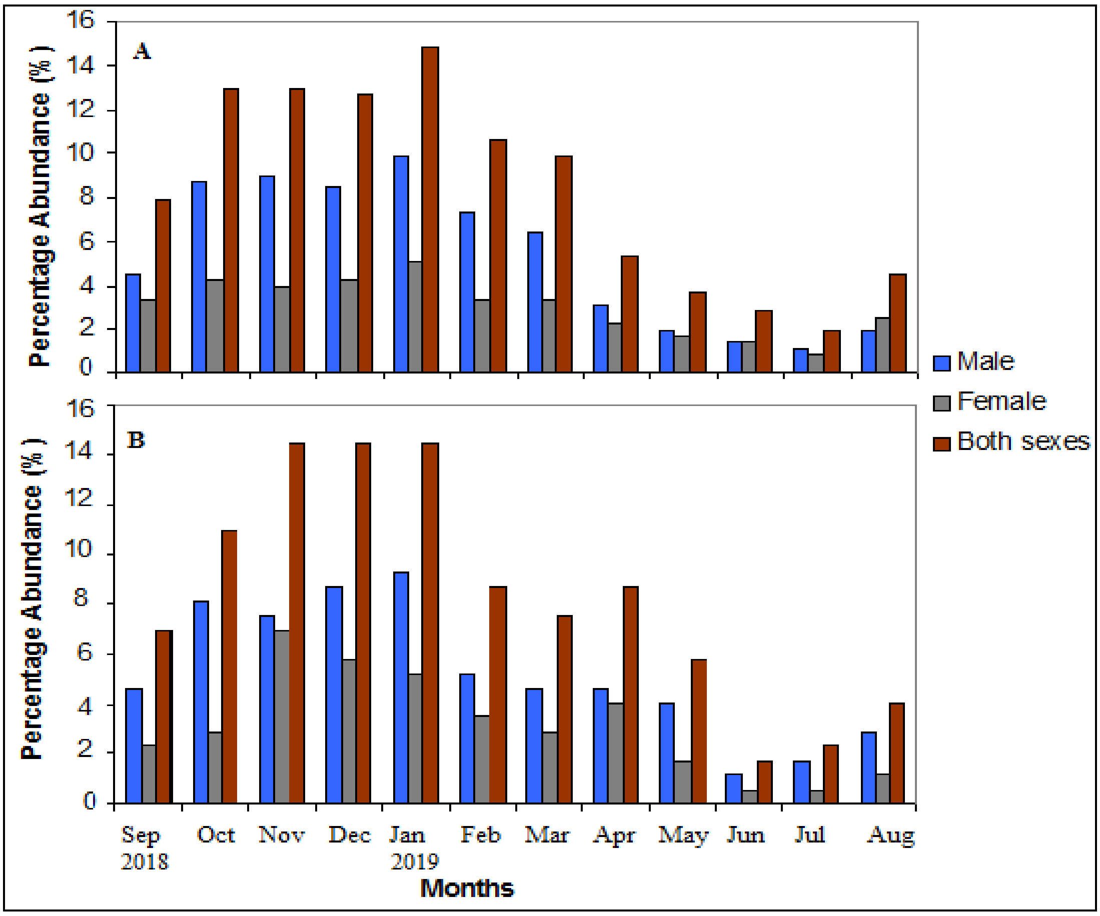

Figure-2. Percentage abundance of *G. niloticus* in Otu Lake (A) and Abiandu Lake (B).

Condition factor, K of *G. niloticus* in Otu Lake ranged from 0.24 to 4.06 for males and from 0.26 to 4.09 for females. In Abiandu Lake, condition factor was between 0.59 and 3.73 for males and between 0.79 and 3.64 for female fish respectively. For relative condition, K_n of Otu Lake ranged in values from 0.82 to 1.07 and from 0.96 to 1.08 for male and female fish. While in Abiandu Lake male ranged from 0.90 to 1.19 and female from 0.97 to 1.12 respectively (Table 2). The water quality parameters analyzed (Table 3) show that depth, transparency, DO and BOD were significantly higher ($P<0.05$) in Station 1 than in Station 2.

Table-2. Mean (S.D.) Condition factor (K) and relative condition factor (Kn) of *Gymnarchus niloticus* from Otu and Abiandu Lakes

Stations	K male	K female	K both sexes	Kn male	Kn female	Kn both sexes
Station 1 Otu	1.55±1.29	1.81 ± 1.24	1.70± 1.26	1.07±0.27	1.08±0.19	1.08±0.24
Station 2 Abiandu	1.41±1.02	1.80 ± 1.31	1.61 ± 1.17	0.98±0.17	0.96±0.25	0.97±0.21

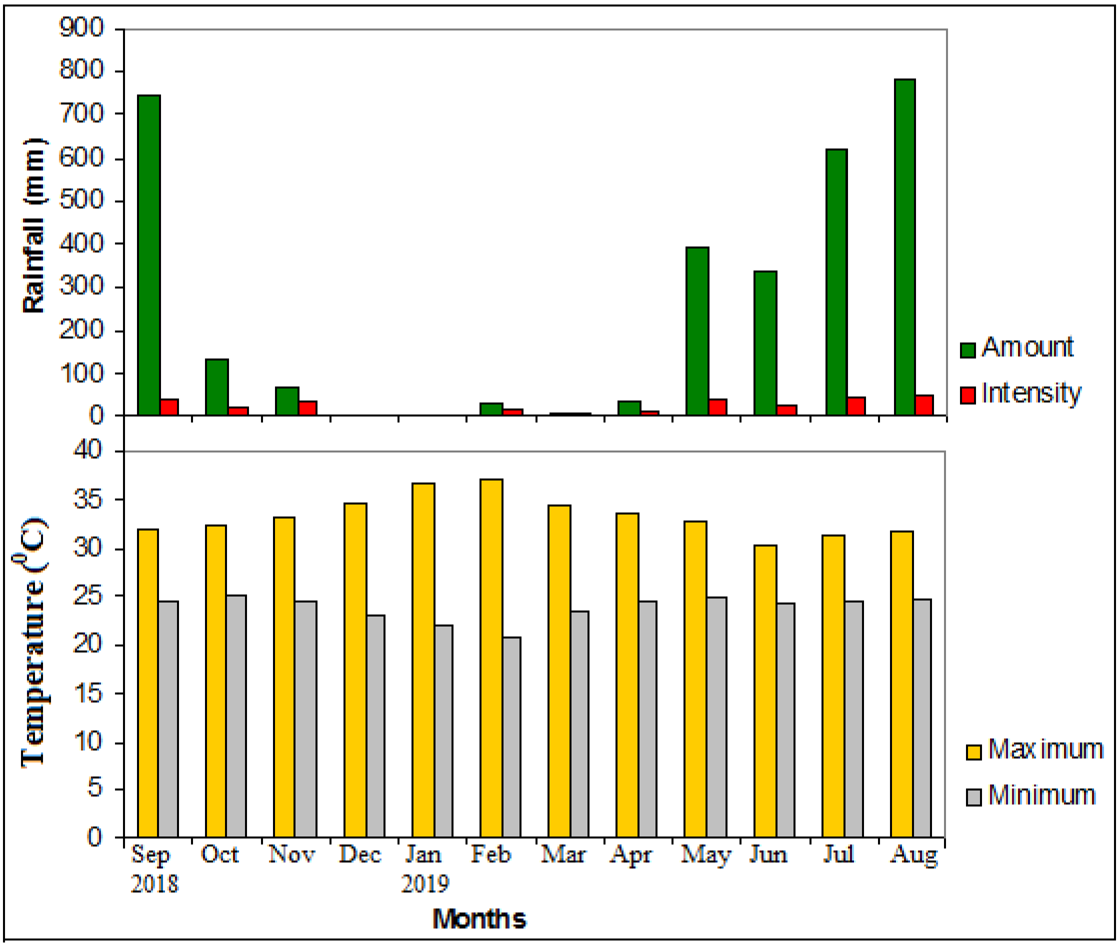

Figure-3. Prevailing Rainfall and Temperature Patterns of Asaba over study area (NIMET, 2019).

Table-3. Mean (SD) water quality parameters of study stations

Water quality Parameters	Station 1 OtuLake	Station 2 Abiandu Lake
Temperature ^{0}C	27.96 ±0.57a	27.91 ±0.38a
Depth (m)	24.01 ±1.56b	16.00 ±0.97a
Transparency (cm)	28.11 ±7.12b	16.00 ±1.09a
Total suspended sediments (mg/L)	0.08 ±0.04a	0.08 ±0.04a
Total dissolved solids (mg/L)	0.09 ±0.02a	0.08 ±0.04a
pH	6.61 ±0.14a	6.67 ±0.06a
DO (mg/L)	10.08 ±0.46b	7.57 ±0.44a
BOD (mg/L)	8.48 ±0.70b	7.18±0.49a
Nitrate (mg/L)	5.71±1.15a	3.18±0.41a
Phosphate (mg/L)	39.46 ±1.89a	45.07 ±5.79a

Means (+S.D) on same row with different letters are significantly different at P<0.05. (Field survey, 2019).

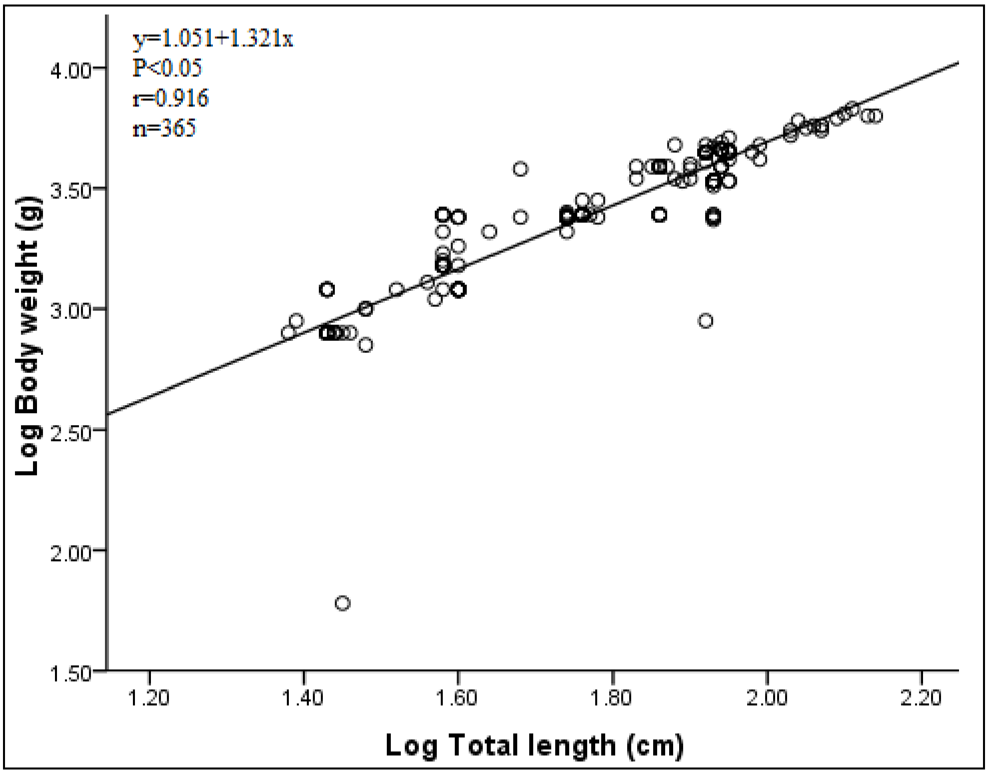

Figure-4. Length-weight relationship of *G. niloticus* from Otu Lake, Umueze-Ossissa (combined sexes).

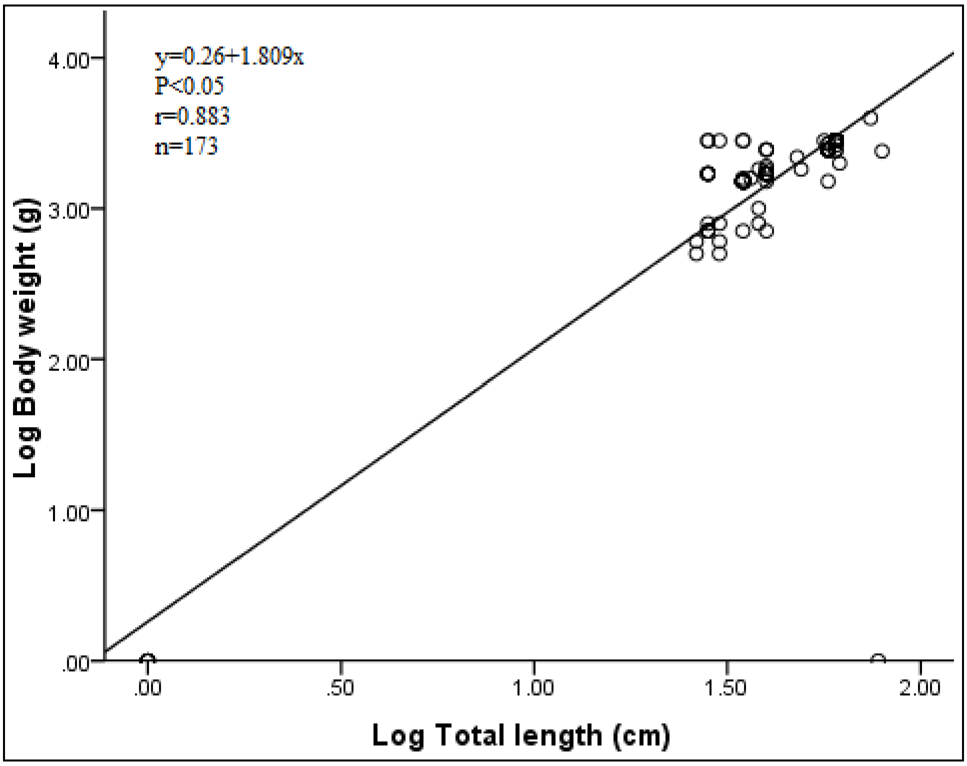

Figure-5. Length-weight relationship of *Gymnarchus niloticus* from Abiandu Lake, Umueze-Ossissa (combined sexes).

The R-square (R^2) of 0.988 and 0.957 were obtained for Stations 1 and 2 respectively. The F value of 8.008 and 2.241 were significant (P<0.05) with a *P<0.209* and *P<0.481* for Stations 1 and 2 respectively. Results of multiple regression analyses of impact of environmental variables on abundance of *G. niloticus* in Stations 1 and 2 are presented in Tables 4 and 5.

Table-4. Results of multiple regression analysis on determinants of *G. niloticus* abundance in Station 1, Otu Lake.

Independent variables	Coefficients	± S. E	T	*P value*
Constant	-456.415	348.867	-1.308	0.415
Water temperature (^{0}C)	8.594	4.098	2.097	0.283*
Depth (m)	1.039	2.392	0.434	0.739
Transparency (cm)	0.252	.140	1.809	0.321*
Total suspended sediments (mg/L)	-80.818	327.555	-0.247	0.846
Total dissolved solids (mg/L)	-42.422	111.013	-0.382	0.768
pH	22.310	44.742	0.499	0.706
Dissolved oxygen (mg/L)	-10.296	12.020	-0.857	0.549
Biological oxygen demand (mg/L)	7.646	6.868	1.113	0.466*
Nitrate (mg/L)	3.210	7.668	0.419	0.748
Phosphate (mg/L)	1.152	3.537	0.326	0.800

*significant at P<0.05; Source: Field survey, 2019.

Table-5. Results of multiple regression analysis on determinants of *G. niloticus* abundance in Station 2, Abiandu Lake.

Independent variables	Coefficients	± S. E	T	*P value*
Constant	95.829	219.262	0.437	0.738
Water temperature (^{0}C)	1.733	7.372	0.235	0.853
Depth (m)	-5.963	6.183	-0.964	0.512
Transparency (cm)	0.114	0.207	0.552	0.679
Total suspended sediments (mg/L)	17.126	59.650	0.287	0.822
Total dissolved solids (mg/L)	14.607	39.268	0.372	0.773
pH	-8.615	39.405	-0.219	0.863
Dissolved oxygen (mg/L)	11.783	7.237	1.628	0.351*
Biological oxygen demand (mg/L)	-9.305	22.533	-0.413	0.751
Nitrate (mg/L)	-13.765	26.266	-0.524	0.693
Phosphate (mg/L)	0.678	0.343	1.981	0.298*

*significant at P<0.05; Source: Field survey, 2019.

Discussion

Gymnarchus niloticus was more abundant in Otu Lake than in Abiandu Lake. There were more male than female *G. niloticus* in this study with male to female ratio of 1:1.8 and 1:1.7 in Otu and Abiandu lakes respectively. Opadokun and Ajani (2015) reported a similar ratio and noted that this was a departure from the theoretical 1:1 ratio expected in nature. Evolutionary studies have shown that sex ratios can be highly variable with deviations and biases in both male and female fish occurring in natural environments (McKellar et al., 2009; Liker et al., 2013; Sowerby et al., 2020).

The influence of prevailing environmental temperatures, rainfall amount and intensity of Asaba being under the same tropical rainfall zone with the study area was compared with the percentage abundance of *G. niloticus* in the study stations. It was observed that rainfall was higher in August and > September, while temperature was higher in February followed by January. The high temperature observed in January corresponded with high number of fish, while high amount of rainfall corresponded with low number of *G. niloticus* harvested. Fish abundance have been reported to be affected by temperature and rainfall pattern as well as other environmental factors (Ayub, 2010; Castillo-Rivera, 2013). These relationships could be attributed to the fact that a higher temperature can result in a reduction in water level and with reduced water level the fishes are usually more available for harvesting. This may have accounted for the higher abundance of fish species in the dry season and the lower abundance in the rainy season.

Depth, transparency, dissolved oxygen and biological oxygen demand were significant water quality parameters observed in the two lakes. Water quality parameters are interrelated in their effects in the lakes. While depth may have encouraged luxuriant growth of roots of *Eichhornia crassipes* in Otu Lake especially, the resulting bloom may have led to a reduction in transparency and dissolved oxygen levels. Otu lake is definitely deeper and less transparent with heavy growth of *Eichhornia crassipes*. This may have impacted on the oxygen content of the lake resulting in a difference when compared with Abiandu Lake. The bloom of *Eichhornia crassipes* observed was also a reason fishermen were observed to have problems of navigating their canoe during fish sampling. The infestation of ponds with *Eichhornia crassipes* have been reported to have both positive and negative effects on fish. While the roots of *Eichhornia crassipes* provided nesting grounds and increase fish abundance and diversity, water parameters such as dissolved oxygen, nitrate and phosphorus concentrations were significantly reduced (Villamagna and Murphy, 2010; Yongo et al., 2017). Abnormal levels in abiotic factors result in stress in fish which can prevent or reduce fish growth. Wahl and Claramunt (2000) reported that abiotic factors can determine larval fish growth rates and hence fish recruitment and that factors such as temperature and lake size were important in explaining growth of fish species. Mahavadiya et al. (2018) opined that stress can also prevent fish from feeding. Daga et al. (2012) also observed that abiotic variables such as total phosphorus, dissolved oxygen and conductivity, temperature and pH determine the distribution of fish assemblages and that an understanding of the relationship between species and their environment is crucial for conservation.

The allometric growth of *G. niloticus* observed in this study indicates that fish growth is faster in length than in weight. A value of 'b' lower than 3, that is, when 'b' < 3, is indicative of negative allometry in growth pattern. This means that fish get slimmer as it increases in size. Similar low 'b' values have been reported for *Bagrus bayad* male from River Adofi (Nwabueze and Garba, 2015). Jisr et al. (2018) reported that when 'b'<3, there is negative allometry and when 'b'>3 is positive allometry, whereas isometric growth occurs when 'b'=3. Length-weight relationships and relative condition factor are indicators of general well being of fish and are of great importance in the assessment of any fishery since it provide information about the growth of the fish and fitness of fish (Sanjay et al., 2015; Jisr et al., 2018). Condition factor describes the body condition of fish, which is a key indicator of health at individual or population level (Peig and Green, 2009). It is also, closely related to growth (Lloret et al., 2002) and survival (Peig and Green, 2009; 2010). In this study, the relative condition, K_n, obtained for *G. niloticus* in both Otu and Abiandu Lakes ranged in values from 0.82 to 1.19. These findings are acceptable since good fish growth condition occurs when $K_n \geq 1$, while the fish can be said to be in poor growth condition compared to an average individual with the same length when $K_n < 1$ (Jisr et al., 2018).

During period of floods in the rainy season, mixing of fish from the water bodies which form a continuum cannot be completely ruled out because fishes are free to swim about within the water bodies. There is therefore a possibility of fishes from the two lakes mixing. However, over the years, it has been noted that fishes from Otu lake are clearly darker in colour than fishes from nearby water bodies, probably due to the abundance of macrophytes, depth and darker colour of the water. Pond coloration have been reported to signify nutrient load and an abundance of algae and macrophytes. Mane et al. (2017) noted that pond colour is associated with the promotion or abundance of desirable plankton species which plays a vital role in extensive and semi-intensive fish culture practices. Also, fish samples were harvested from set nets in different locations of the two lakes, thus representing fish samples from the individual lakes.

The R-square (R^2) obtained in the analyses shows that the model used was a good fit, implying that 98.8 % and 95.7% of *G. niloticus* abundance was accounted for by the independent variables. In Station 1, water temperature, transparency and BOD were significant variables while in Station 2, DO and phosphate were significant. These independent variables are likely important factors affecting the abundance of *G. niloticus* in the study stations. These variables were also significant water quality parameters observed in this study. Total suspended sediments, total dissolved solids and dissolved oxygen obtained for Station 1 and depth, pH, biological oxygen demand and nitrate obtained for Station 2, had negative coefficients, thus, implies that increases in the magnitude of these variables may lead to a reduction in the abundance of *G. niloticus*. The positive coefficients are indicative of factors that could increase abundance of *G. niloticus*. These findings are important baseline information for effective management of the lakes. Francis et al. (2005) successfully used predictive models to predict the effect of environmental factors on fish presence and abundance and opined that for independent data set the predictors could be useful for guiding the management of human activities in planning intensive process-based research.

Conclusion

This study has shown that *G. niloticus* exhibited negative allometric growth pattern in the two lakes studied. Condition factor and relative condition factor were within limit for acceptable good fish growth. Environmental variables such as air temperature, rainfall amount and water quality parameters impacted on abundance of *G. niloticus.* An understanding of the relationship between this fish species and its environment is crucial for conservation to determine fish growth, survival and distribution patterns. These findings are useful baseline information on *G. niloticus* biometric parameters needed during planning for effective management of the lakes for sustainable economic and livelihood development of the area.

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Contribution of Authors

Nwabueze AA, : Originated the research idea, involved in planning and logistics, data collection, analysis of data, interpretation of results and manuscript preparation.

Nwabueze EO, : Involved in logistics and data collection