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Comparative Growth Dynamics and Exploitation of *Lates niloticus* (Linnaeus, 1758) and *Oreochromis niloticus* (Linnaeus, 1758) in the Nangbeto Dam Lake in Togo

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Abstract: The main objective of this study is to characterize the stock status of two of the most abundant fish species in the commercial catch, *Lates niloticus* (Linnaeus, 1758) and *Oreochromis niloticus* (Linnaeus, 1758) in order to propose a sustainable management measures for a resilient exploitation of both species. A total of 214 individuals of *L. niloticus* and 1088 individuals of *O. niloticus* were measured from July 2018 to November 2018. The total lengths ranged from 9.5 cm to 79.5 cm for *L. niloticus* and 8 cm to 34 cm for *O. niloticus*. The weights ranged from 13 g to 6300 g for *L. niloticus* and from 11 g to 635 g for *O. niloticus*. The study of the growth dynamics from the frequencies of grouped lengths was done by using the FISAT II software version 1.2.2. The asymptotic lengths found are 83.48 cm and 35.7 cm respectively for *L. niloticus* and *O. niloticus* while their respective growth coefficients are 0.03 $year^{-1}$ and 0.07 $year^{-1}$. The growth performance indices obtained are Φ' = 2.32 for *L. niloticus* and Φ' = 1.95 for *O. niloticus*. Total, natural and fishing mortality rates were Z = 0.33 yr^{-1}, M=0.13yr^{-1}, F = 0.20 yr^{-1} for *L. Niloticus* and Z = 0.84 yr^{-1}, M = 0.29yr^{-1}, F = 0.55 yr^{-1} for *O. niloticus*. The species at Nangbeto dam lake live in poor habitat conditions with fairly low condition factors 1.88 for *L. niloticus* and 1.99 for *O. niloticus*. They both show minority allometry. The weight-length relationship parameters are respectively a = 0.061 and b = 2.54 (r^2 = 0.92) and a = 0.067 and b = 2.58 (r^2 = 0.96) for *L. niloticus* and *O. niloticus*. Both species are over-exploited (E = 0.60 for *L. niloticus* E = 0.65 for *O. niloticus*). Overall, given that Nangbeto dam lake has an important place in the supply of protein of halieutic origin to the riparian communities and to the Togolese population, our study revealed that both *L. niloticus* and *O. niloticus* are overexploited. The species fishing related mortality rates are far greater than their natural mortality rates. Their total mortality rates are higher than their growth rates. The stocks of both species are undergoing a depletion. An extension of the biological resting period and the regulation of the fishing mesh sizes could be implemented as sustainable management measures for the renewal of fish stocks in the Nangbeto dam lake.

Keywords: Growth Dynamics, *Lates niloticus*, *Oreochromis niloticus*, Weight-Length, Nangbeto Dam Lake

1. Introduction

The study of the dynamics of exploited populations is essentially concerned with predicting the practical effects of an increase or reduction in fishing intensity, and the consequences of any regulatory measures that might be proposed and implemented [4]. For hundreds of millions of people around the world, fisheries remain the primary resource of importance, whether for food, nutrition, income, or livelihood [6]. In Togo, fish take a paramount place in the human daily diet. They are obtained mainly through fishing and local fish-farming to meet the needs for fish products estimated at over 70,000 tons per year [14]. The Nangbeto dam lake is a fairly productive aquatic ecosystem in the continental fishing sector with a potential fishing production estimated at 1000 and 1500 tons per year; and yields that can reach 100 kg/ha/year [11]. Despite the diversity of its ichthyofauna [11], some species are more abundant in the commercial catches than others. This is the case for example of: *Oreochromis niloticus* (Linnaeus, 1758) and *Lates niloticus* (Linnaeus, 1758). The present study aims then to characterize the growth parameters and exploitation status of the above two species.

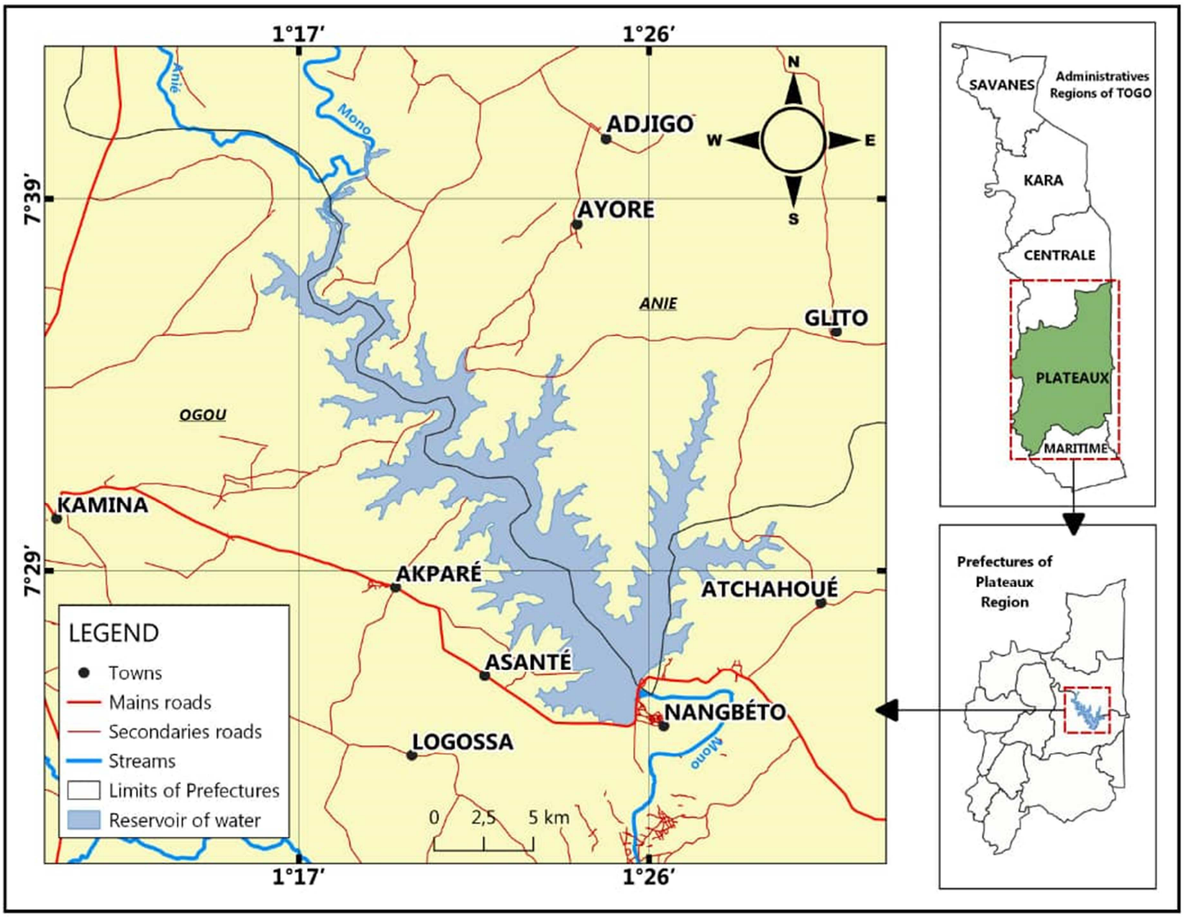


Figure 1. *Map of the study area.*

2. Materials and Methods

2.1. Study Area

The Nangbeto dam is located in the plateau Region, at 40 km East of Atakpamé, in Akparé district. It is an artificial lake covering an area of 180 km^2 at its maximum coast (144m) for a water volume of 1.7 billion m^3 and 41 km^2 at its minimum coast (130 m) for a water volume of 250 million m^3. Its average depth is between 9.5 m and 6.2 m, the maximum recorded being 38 m. The dam is fed by the waters of the Mono River and those drained by its watershed [11]. The Nangbeto hydroelectric dam is easily accessible with the geographic coordinates 7°25'29.56" N 1°26'6.66" E. The region falls under the sub-equatorial climate characterized by two dry and two rainy seasons [3]. The main rainy season extends from March to June. It is followed by the short dry season (July to August). Then comes the short rainy season (September to October) and finally the long dry season (November to February). The average rainfall hovers around 1,000 mm of water per year [5]. Each year, rainfall averages 1,027 mm. Records from the Nangbeto Central Directorate during 2018 reveal an annual rainfall of 1,302.4 mm with a maximum recorded in July (322.4 mm). The average temperature of the Nangbeto area is 27.1°C. The Nangbeto area falls in the ecological zone III. The dominant vegetation types are wooded Guinean savannahs with varying degrees of tree percentages, fallow land and crop fields. There are also open forests and discontinuous gallery forests along the main rivers [8].

2.2. Data Collection

Individuals of *Oreochromis niloticus* and *Lates niloticus* were sampled from the commercial artisanal fishery catches from July to November 2018. Using an ichthyometer, measurements of total length (Lt) and standard length (Ls) were recorded for each individual of both species. The individual total weight (Wt) was also measured through an electronic balance with 0.1g of precision.

2.3. Data Processing

The total lengths and weights recorded on the individuals were used to analyze the growth dynamics of the two species. The growth and exploitation parameters were estimated by using the FISAT II software version 1.2.2. Analyses were done using the frequencies of total grouped lengths. The different parameters found were used to model growth of the two fish species.

2.3.1. Growth and Age Parameters

Growth parameters such as growth coefficient (K) and asymptotic length (L∞) were determined by the ELEFAN I routine of FISAT II software. The linear growths of *L. niloticus* and *O. niloticus* were modeled using the mathematical equation of Von Bertalanffy (VBGF) [12]:

$$Lt = L\infty\left(1 - e^{-K(t-to)}\right) \quad (1)$$

The theoretical age to at size zero of the fish was obtained by Pauly's equation [13]:

$$\log_{10}(-to) = -0{,}392 - 0{,}275\log_{10}L\infty - 1{,}038\log_{10}K \quad (2)$$

The longevity t_{max} expressing the age at which 95% of the asymptotic length (L∞) is reached was estimated by the relationship:

$$t_{max} = 3/K + to \text{ (Source: [12])} \quad (3)$$

The length growth performance index (Φ') was determined by the equation.

$$\Phi' = \log K + 2 \log L\infty \text{ (Source: [13])} \quad (4)$$

Growth types were characterized by the weight-length relationship.

$$Wt = aLt^b \text{ (Source: [9])} \quad (5)$$

Also, the species over weight was characterized by determining condition factors.

$$K = 100\ (W/L^3) \text{ (Source: [10])} \quad (6)$$

2.3.2. Exploitation Parameters

The total mortality coefficient (Z) was estimated using the length-frequency based on the catch curve. Also using this curve, the lengths for which the probability of capture is equal to 0.5 were determined. The natural mortality rate (M) was calculated using the empirical equation of Pauly (1980) expressed below using a mean surface temperature (T) of 27.1°C:

$$\log_{10} M = -0{,}0066 - 0{,}279\log_{10}L\infty + 0{,}6543\log_{10}K + 0{,}4634\log_{10}T. \quad (7)$$

Where M is the instantaneous natural mortality, L∞ is the asymptotic length, T is the mean surface temperature, and K denotes the growth rate coefficient of VBGF.

Fishing mortality (F) was calculated using the relationship:

$$F = Z - M \text{ (Source: [7])} \quad (8)$$

The different exploitation rates (E) were determined using the fishing and total mortality coefficients according to the equation:

$$E = F / Z. \quad (9)$$

The Z/K (10) ratio [2] was used to show the predominance between growth and mortality of the species.

2.3.3. Demographic Parameters

Recruitment represents the process by which the youngest fraction of the population becomes part of the pool of fish accessible to fishing gear for the first time, the process by which fish acquire a property that makes them exploitable [13]. It is therefore the process of moving from the unexploited to the exploited phase of a fish individual, thus a recruited fish is a fish at a fishable age [13]. FISAT II software was used to estimate the various periods of the process from the restructured length frequency data of *L. niloticus* and *O. niloticus* samples.

3. Results

The five months of data collection allowed to record the total length, standard length and total weight of a set of 1,302 fish comprising 214 *L. niloticus* and 1,088 *O. niloticus. L. niloticus* total length ranged from 9.5 cm to 79.5 cm. Its standard length from 8.5 cm to 68 cm, and weight from 13 g to 6300 g. The sample of *O. niloticus* has extreme total lengths of 8 cm and 34 cm. Its standard length falls between 6 cm and 28 cm while the weights ranged from 11 g to 635 g. For both fish species, the total and standard lengths are correlated (r^2 is 0.99 and 0.98 respectively for *L. niloticus* and *O. niloticus*).

3.1. Linear Growth

The linear growth parameters, growth coefficient (K) and asymptotic length (L∞) determined are respectively:

Lates niloticus: K = 0.03 an^{-1} and L∞ = 83.48 cm.

Oreochromis niloticus: K = 0.07 an^{-1} and L∞ = 35.7 cm.

The theoretical age at size zero (t_o) for *L. niloticus* is -4.57 year and -2.4 year for *O. niloticus*. The Von Bertalanffy's growth equations for the two species are:

L_t= 83.48 (1- $e^{-0.03(t+4.57)}$) for *Lates niloticus.*

L_t= 35.7 (1- $e^{-0.07(t+2.4)}$) for *Oreochromis niloticus*.

The t_{max} ages (longevity) gave 95.43 year for *L. niloticus* and 40.46 year for *O. niloticus* by calculation. The calculated performance index were Φ'=2.32 for *L. niloticus* and Φ'= 1.95 for *O. niloticus.*

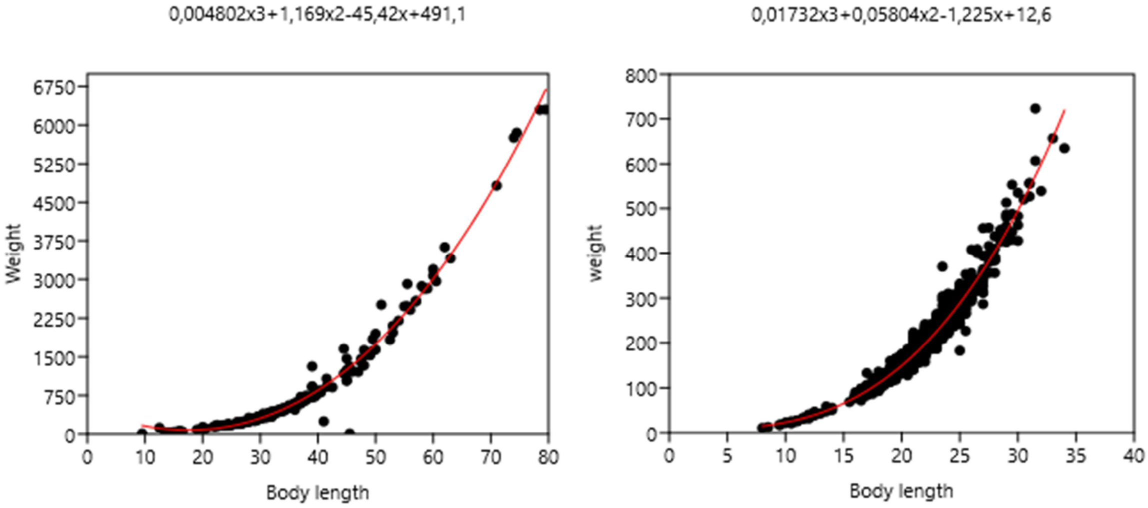
3.2. Weight-Length Relationship (Using AIC)

The regression parameters obtained are a= 0.061 and b= 2.54 (R^2 = 0.92) for *Lates niloticu*s and a=0.067 and b=2.58 (R^2 = 0.96) for *Oreochromis niloticus*.

The weight-length relationship is then respectively:

Lates niloticus: Wt= 0.061 $Lt^{2.54}$

Oreochromis niloticus: Wt= 0.067 $Lt^{2.58}$



Lates niloticus *Oreochromis niloticus*

Figure 2. *Weight-length relationship.*

3.3. Condition Factor

The condition factors (k) computed for the sampling period was 1.88 and 1.99 for *L. niloticus* and *O. niloticus* respectively. It varies from month to month for both species and the values are summarized in table 1.

Table 1. *Monthly variation of the condition factor.*

		Lates niloticus	***Oreochromis niloticus***
	July	1.57	1.94
k	August	2.01	1.93
	October	2.18	2.98

3.4. Exploitation Parameters: Mortality Rates Z, M and F

The catch curves provided the different mortality rates of the two species and their exploitation rates.

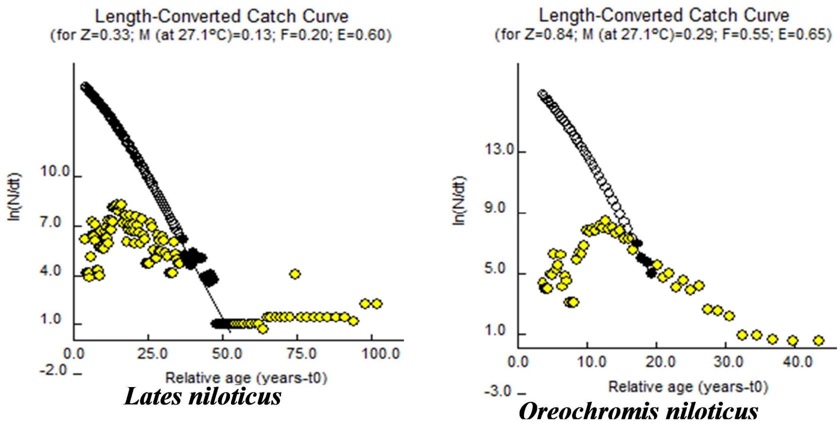


Figure 3. *Catch curves.*

The different values are recorded in table 2.

Table 2. *Summary of the exploitation parameters.*

	L. niloticus	***O. niloticus***
Total mortality (Z)	0,33	0,84
Natural mortality (M)	0,13	0,29
Fishing mortality (F)	0,20	0,55
Exploitation rate (E)	0,60	0,65

The Z/K ratio is equal to 11 for *L. niloticus* and 12 for *O. niloticus*.

3.5. Recruitment

The NORMSEP routine generated two Gaussian distributions as shown on the captions of the species. Both species have two recruitment periods.

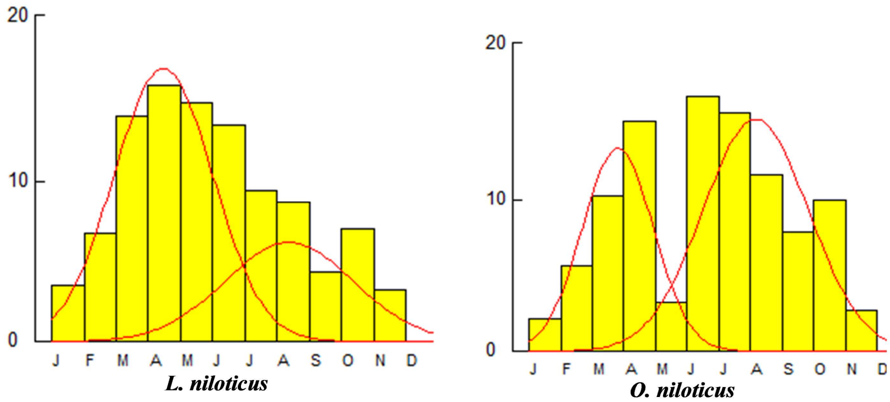


Figure 4. *Recruitment curves.*

4. Discussion

The present study has accessed the growth and exploitation status of two species among the most abundant and preferred of the catches at the Nangbeto dam lake through the estimation of their growth and exploitation parameters.

The values of the asymptotic lengths L∞ found are relatively high (83.48 cm for *L. niloticus* and 35.7 cm for *O. niloticus*). This shows that the measured individuals are large in size. In fact, during the data collection period, the fishermen and fishmongers at Nangbeto dam lake were against the measurement of juveniles, which are the most abundant in the catches. However, the values found for the asymptotic lengths are not extraordinary. Yongo et al. found in Lake Victoria an L∞ equal to 124 cm for *L. niloticus*, a value that far exceeds the one obtained in this research [15]. The asymptotic length found for *O. niloticus* (35.7 cm) is similar to the one recorded by Ahouansou-Montcho et al [1]. In Lake Toho, in Benin, Ahouansou-Montcho et al. recorded a maximum total length of 40.2 cm for an asymptotic length estimate of 41.5 cm for *O. niloticus* [1].

Both species have a very low growth coefficient of 0.03 yr^{-1} for L. niloticus and 0.07 yr^{-1} for *O. niloticus*. Elsewhere, Ahouansou-Montcho et al. found a value of K= 0.33 yr^{-1} in Lake Toho for *O. niloticus* [1] while Yongo et al. recorded a value of 0.22 yr^{-1} for *L. niloticus* [15]. The low growth rate found in this research could be explained by the fact that the individuals measured are already mature.

The growth performance indices Φ' estimated were 2.32 for *L. niloticus* and 1.95 for *O. niloticus*. All the values fall within the range of 2.65 to 3.32 defined by Baijot and Moreau [10] as the range taken by Φ' for fish from African water bodies. Thus, both fish species possess poor growth performance.

In this study, the linear regression curves parameters of the weight-length relationship of *L. niloticus* and *O. niloticus* were respectively: a = 0.061 and b = 2.54 (r = 0.92) then a = 0.067 and b = 2.58 (r = 0.96). These values have shown a minor allometry for both fish species because the values of b are all less than 3. However this allometry is much more prominent for *Lates niloticus* than for *Oreochromis niloticus*. *L. niloticus* are then more malformed than *O. niloticus*. These species then are growing more in length than they gaining weight. This could also be due to the low biomass related to high stress levels and disruption of their metabolism. However, [10] found in the Mono basin (including the Nangbeto dam lake) an isometric growth of *O. niloticus* for a value of b equal to 2.934 and a minor allometry for *L. niloticus* having presented a value of 2.754 as the allometry coefficient.

The species *O. niloticus* and *L. niloticus* in the dam lake are subject to total mortality rates (Z) of 0.84 yr^{-1} and 0.33 yr^{-1} respectively. These values are never the less much lower than those obtained by Ahouansou-Montcho et al. and Yongo et al. for *O. niloticus* (Z= 1.1 yr^{-1}) and *L. niloticus* (Z= 0.96 yr^{-1}) respectively [1, 15]. The most important cause of mortality was fishing (F= 0.20 yr^{-1} for *L. niloticus* and F=0.55 yr^{-1} for *L. niloticus*). In the Nangbeto dam lake, both species are more vulnerable to fishing gear than to natural mortality.

For both species, the reliability of natural mortality rates was tested using the M/K ratio [10]. According to Sarr; for most fish species, this ratio is between 1.5 and 2.5 [13]. However we found, 4.33 and 4.14 respectively for *L. niloticus* and *O. niloticus*. The high ratios obtained can be explained by two factors: a low value of K (growth rate) or environmental variables which are not the only causes of natural mortality for the species. Physiological factors could impact as well [13].

Mortality and growth parameters are antagonistic factors in population dynamics [1]. The dominance between growth and mortality tested by the Z/K ratio computed were 11 and 12 for *L. niloticus* and *O. niloticus* respectively. According to Barry et al., the equilibrium value is 1 [2]. In our study, the mortality rate is higher than the growth. Showing that the species are overexploited. This finding is confirmed by the exploitation rates obtained. The stocks are undergoing depletion. Indeed, both species are exploited at quite high rates with values of E= 0.60 (for *L. niloticus*) and E= 0.65 (for *O. niloticus*). In both cases, the optimal value of 0.50 assuming that the potential balanced catch is optimized is largely exceeded [7]. The constraints generated by the fishing gears predominate over the natural mortality causes. The species are therefore overfished, the stocks would then be made up of young and juvenile individuals due to the decrease in life expectancy and consequently low fecundity [13]. The recruitment curves reveal that both species have two recruitment periods during the year. These periods are mostly located during the two rainy seasons. In Lake Toho, Ahouansou-Montcho et al. noted a continuous recruitment for *O. niloticus* throughout the year with a peak from May to July [1]. This observed difference in recruitment rate for *O. niloticus* between Lake Toho and Nangbeto dam lake could be explained by climatic conditions. For *L. niloticus*, [15] recorded in Lake Victoria almost similar results to ours. They also noted two recruitment peaks with the smallest occurring in March and the largest in July. In this study, the largest recruitment peak is noted in April-May followed by the smallest one in July-August. Therefore the April-May and July-August catches would then be dominated by juveniles for both species. These two periods will then have the highest total mortality rates because the fisheries will be more fruitful during these periods.

The calculated Fulton condition factors values were 1.88 and 1.99 for *L. niloticus* and *O. niloticus* respectively. The species live in a poor environment for their growth dynamics. Indeed, the higher the condition factor k is, the better the habitat conditions are and the more overweight are the fish individuals. Also none of the values obtained obey the theory of Bagenal and Tesch according to which for freshwater fish species, k values fall between 2.9 and 4.8 [10].

The monthly calculated condition factors show that habitat conditions are harsher for fish in the last months before lake closure. Indeed in the months of July and early August, the demand for fish products becomes greater. Many operators seek to stock fish that can meet their needs of fishery products during the dam lake closure period. The k values are 1.94 in July and 1.93 in August for *O. niloticus,* but at the opening of the dam lake (just after its closure) this value in October increases up to 2.98. Thus respecting the law of Bagenal and Tesch [10]. The improvement of the value of k following the closure of the lake is also observed in *L. niloticus*. In July and August k values are respectively 1.57 and 2.01, after the biological resting period in October it reached 2.18.

5. Conclusion

The Nangbeto dam lake is an important place of halieutic protein supplying source to the riparian communities and the Togolese population. The use of the frequency of grouped lengths through FISAT II software revealed that *L. niloticus* and *O. niloticus* are overexploited. The fishing-related mortality factors are far greater than natural mortality causes. Both species mortality rates are higher than their growth rates. The stocks of both species are undergoing depletion. An extension of the biological resting period and the regulation of the fishing mesh sizes could be implemented as a sustainable management measures to allow the renewal the fish stocks in the Nangbeto dam lake.

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