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Growth and exploitation parameters of *Oreochromis niloticus* (Linné, 1758) in Guessabo Lake (Middlee - West: Côte d'Ivoire).

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Abstract

Growth and exploitation parameters of *Oreochromis niloticus* were determined in Guessabo Lake. The study involved 515 individuals of *Oreochromis niloticus* collected monthly between August 2019 and July 2020. The values of the asymptotic length ($L\infty$), growth coefficient (K) and growth performance index (Φ') are 21.57 cm; 0.93 yr^{-1} and 2.66, respectively. The values of total (Z) natural (M) and fishing (F) mortality obtained in this study for the species *Oreochromis niloticus* are 2.84 yr^{-1}, 1.82 yr^{-1} and 1.02 yr^{-1} respectively. The operating ratio E is 0.36. The Z/K and M/K ratios are 3.05 and 1.95 respectively. The results show that natural mortality predominates over fishing mortality. Recruitment occurs twice a year with peaks in June and July.

Keywords: Growth and exploitation parameters; *Oreochromis niloticus*; Guessabo Lake; Côte d'Ivoire

1 Introduction

Fish is an important economic resource for both fisheries and aquaculture [1]. Global fish requirements increased more than fivefold between 1961 and 2010, from 28 to 148 million tons [2]. Moreover, the apparent consumption of fish per person has increased from an average of 9.9 kg in the 1960s to 19.2 kg in 2012[3]. Indeed, the increase in the world population has led to a correlative increase in the demand for proteins, particularly animal proteins. In some developing countries, fishery products are the only source of animal protein [4,5]. Moreover, in many African countries, fish is the main source of animal protein in the human diet [6]. Fish stocks directly threatened by exploitation are mostly those of economic interest. These stocks are particularly targeted and experience high fishing pressure that is often beyond their sustainable level [7]. In Côte d'Ivoire, Tilapia *Oreochromis niloticus* is a species encountered in almost all continental waters. In the Sassandra River precisely in Guessabo Lake tilapia occupies the first place in all fishermen's landings [8]. Moreover, of all the species of the genus tilapia met in this lake the species *Oreochromis niloticus* is the most appreciated by the population what makes this species a preferential target of the fishermen. However, as indicated by [9], over-intensive fishing reduces the life span of the fish. It also leads to a reduction in the size of the individuals landed, a reduction in abundance and yields, hence the need to study the exploitation dynamics of this species. The aim of this study is to determine the growth parameters and to evaluate the level of exploitation of *Oreochromis niloticus* in order to manage this resource in Guessabo Lake in a sustainable and rational way.

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2 Material and methods

2.1 Collection of data

Specimens of *Oreochromis niloticus* were collected monthly between August 2019 and July 2020 at the large bridge in Guessabo (6°44’59.34’’ N, 6°59’1.77’’ W), Figure 1. The collected specimens were measured (total length and standard length) and weighed (total weight of the uneviscerated animal). The measured and weighed specimens were from the commercial fishery. Identification of these was done at the specific level using the identification keys proposed by [10,11,12].

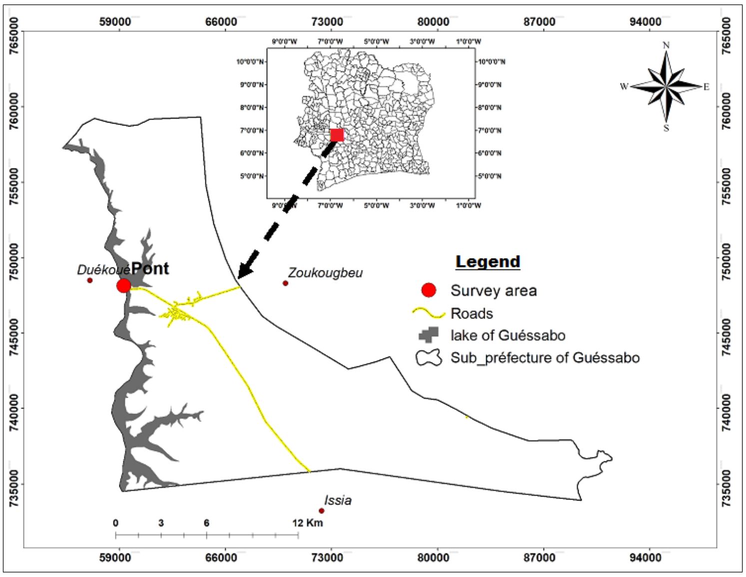

Figure 1 Fish measuring and weighing area

2.2 Size structure

The size classes were obtained according to the rule of [13] using the following formula: K = 1 + (3.332 × log10(n)); with n = total number of employees and K: the number of classes. Concerning the class interval, it is calculated as follows: IC = (Ls max - Ls min) / (Number of class); with Ls: standard length and IC the number of steps for each class interval.

2.3 Growth parameters according to the Von Bertalanffy model

These parameters were determined based on size frequency histograms [14,15]. The Fisat II program ELEFAN I [16] was used to determine the asymptotic length (L∞) and growth coefficient (K). Thus the mathematical model that was used in this study to estimate the growth parameters is that of [17] whose equation is as follows: L(t) = L∞ (1 - e-K(t-t0)); with

L(t): Length of the fish at the time considered; L∞: length to infinity which is the length the fish could reach if it were allowed to live until an indefinite date; K: the growth coefficient characterizing the speed with which the species grows towards L∞ and to: theoretical age of the fish when its length is assumed to be zero.

The empirical equation of [18] was used to obtain the parameter to

$$\log_{10}(-t_0) = -0{,}392 - 0{,}275 \log_{10} L\infty - 1{,}038 \log_{10} K$$

The size growth performance index in both fish species was determined by the equation of [19]:

$$\Phi' = \log K + 2\log L\infty.$$

The longevity or maximum age (Tmax) was calculated with the formula of [20]:

$$T_{max} = 2{,}9957 / K$$

2.4 Mortality and exploitation rates

Total, natural and fishing mortality are those determined in this study. Total mortality Z where at each time the number of survivors of a group of individuals is assumed to be governed by a negative exponential and the number of individuals that disappear is proportional to the initial population size [21] such that:

$$N(t) = N_0 e^{-Z t};$$

Thus, it was determined from the so-called method of catch curves according to the lengths that are accessible through the FiSAT software [16].

Natural mortality (M) was determined from the empirical equation of Pauly (1985) using the formula:

$$\log 10 (M) = - 0,0066 - 0,279 \log 10 (L\infty) + 0,6543 \log 10 (K) + 0,4634 \log 10 (T)$$

With: M: natural mortality (yr^{-1}); L∞: length to infinity; K: growth coefficient; and T: annual water temperature (°C) which is 26.5°.

However that Z and M are known, fishing mortality (F) was obtained according to [15] and [22] by the following formula:

$$F= Z - M.$$

Exploitation rate indicates the degree of exploitation of a stock. The exploitation rate (E) according to [20] shows that the stock is underexploited if ($E < 0.5$), the stock is overexploited if ($E > 0.5$) and the stock is at its optimum exploitation if F = M or E = 0.5[23].

The exploitation rate is determined according to [20] by the ratio:

$$E = F/Z = F / (F+M);$$

where: F = fishing mortality coefficient; M = natural mortality coefficient; Z = total mortality coefficient.

2.5 First capture size

The different catch probabilities are obtained using the left ascending points of the catch curve for each size class [24]. This method allowed the determination of selectivity parameters including the size (Lc or L50) for which the probability of capture is 50% of the total catch [25].

2.6 Recruitment of young fishes

Recruitment is defined as the entry of a fish into the fishery exploitable phase. With parameters such as L∞, K, and to, the ELEFAN I program incorporated into FiSat II constructed the histograms of relative birth frequencies by month. This graph shows monthly variations in juvenile fish recruitment [26].

2.7 Yield and biomass per recruit

To predict relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R), the FiSaT II program model of [27] was also used. Thus the relative yield per recruit (Y'/R) is expressed by the following relationship:

$$Y'/R = E\, U^{M/K} (1 - (3U/1+m) + (3U^2/1+2m) - (U^3/1+3m));$$

$$\text{avec : } U = 1- (Lc / L\infty) ; m = (1- E) / (M / K) = (K / Z) ; E = F / Z.$$

The relative biomass per recruit (B'/R) is estimated from the relationship:

$$B'/R = (Y'/R) / F.$$

The relative yield (Y'/R) and relative biomass (B'/R) curves for fixed values of Lc/ L∞ and M/K allowed us to determine the biological reference points Emax, $E_{0.1}$ and $E_{0.5}$. Emax in yellow corresponds to the farm with maximum productive yield, E0.1 in green to the exploitation rate for an increase in yield per relative recruit of 1/10 of its value at E = 0 and

E0.5 in red corresponding to the value of E for which the stock is reduced to 50% of its unexploited biomass. All these plots were made with the FiSAT II software (Version 1.2.2).

3 Results

3.1 Size structure

A total of 515 specimens of *Oreochromis niloticus* with sizes ranging from 6 cm to 20 cm were studied. Figure 2 is the histogram representation of the size frequency distributions of *Oreochromis niloticus*. These histograms show a unimodal size distribution of all individuals. Moreover, the size frequency distribution showed that the fishermen's catches are dominated by individuals with sizes between 8.4 and 15.6 cm Ls, i.e. 75.72%.

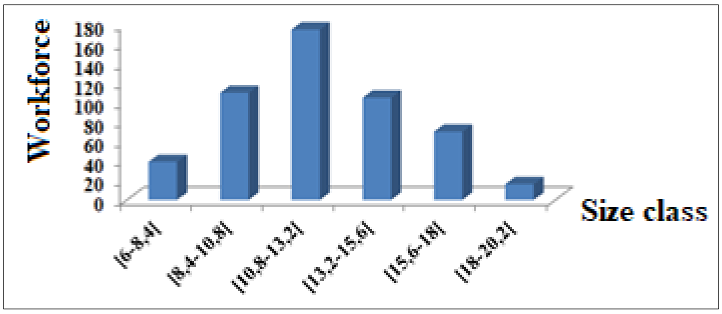

Figure 2 Size structure of *Oreochromis niloticus* exploited in Guessabo Lake

3.2 Growth parameters according to the Von Bertalanffy model

The growth parameters in *Oreochromis niloticus* species were estimated from the size frequency distributions. Thus, the graphical representation that allowed to determine the values of the asymptotic length (L∞), the growth coefficient (K) retained as correct as well as the growth performance index (Φ') is presented by figure 3. The value of the fit index (Rn) that allowed the best curve to be selected is 0.659. The values of L∞, K and Φ' obtained are 21.57 cm, 0.93 yr-1 and 2.66, respectively. The longevity is 3.22 years for a To equal to -0.18. Thus the growth model according to Von Bertalanffy using the obtained growth parameters becomes:

Oreochromis niloticus: L(t) = 21.57 [1 - e- 0.93 (t + 0.188)]

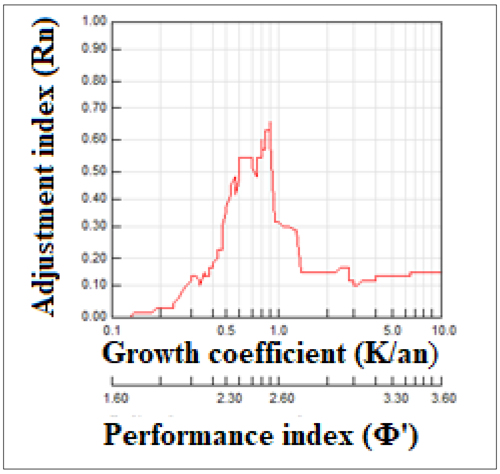

Figure 3 Curve of variation of the adjustment index (Rn) as a function of the growth coefficient (K/an) and the performance index (Φ') of *Oreochromis niloticus* exploited in Guessabo Lake

3.3 Mortality and exploitation rates

The values of total (Z), natural (M) and fishing (F) mortality obtained in this study for the species *Oreochromis niloticus* are 2.84 yr^{-1} ; 1.82 yr^{-1} and 1.02 yr^{-1} respectively (Figure 4). The results reveal that natural mortality predominates over fishing mortality. The exploitation rate E is 0.36. The Z/K and M/K ratios are 3.05 and 1.95, respectively.

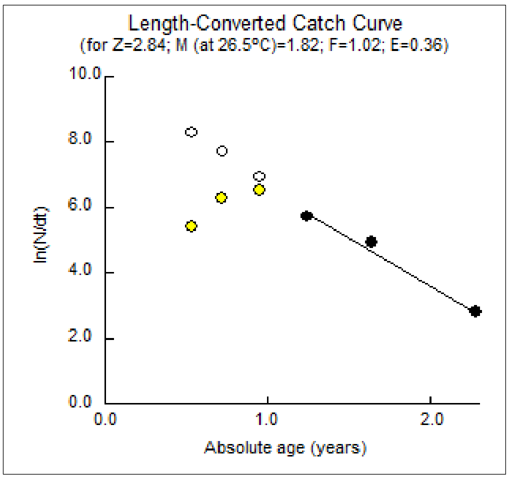

Figure 4 Linearized catch curves of *Oreochromis niloticus* exploited in Guessabo Lake

3.4 First capture size

Figure 5 is a graphical representation of the selectivity curves showing the variation of the probability of capture according to the sizes of *Oreochromis niloticus* exploited in Guessabo Lake. Thus the figure reveals that the size of first capture for the species *Oreochromis niloticus* at the time of sampling in Lake Guessabo was 10.6 cm.

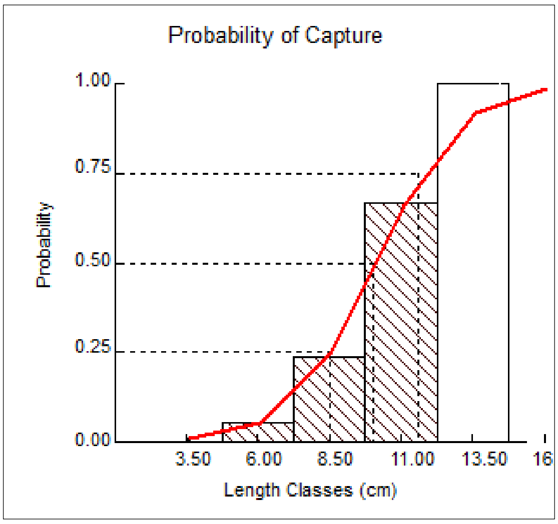

Figure 5 Selectivity curves showing the variation of the probability of capture and evaluation of sizes L25, L50, L75 of *Oreochromis niloticus* exploited in Guessabo Lake

3.5 Recruitment of young fishes

Histograms of relative birth frequencies by month showing recruitment of juvenile *Oreochromis niloticus* fish show that recruitment occurs twice during the year and the greatest recruitment was observed in July with a percentage of 17.81 (Figure 6).

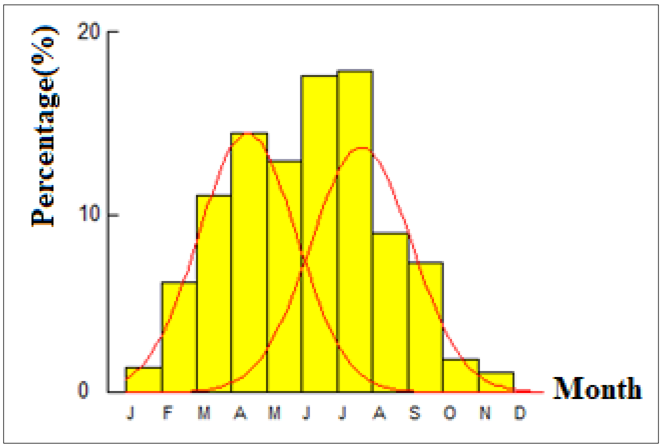

Figure 6 Recruitment curves of *Oreochromis niloticus* populations exploited in Guessabo Lake

3.6 Yield and biomass per recruit

Analysis of the Yield and biomass per recruit curves (Figure 7) shows that the Beverton and Holt biological reference point values (E0.1; E0.5 and Emax) are 0.656; 0.352 and 0.768.

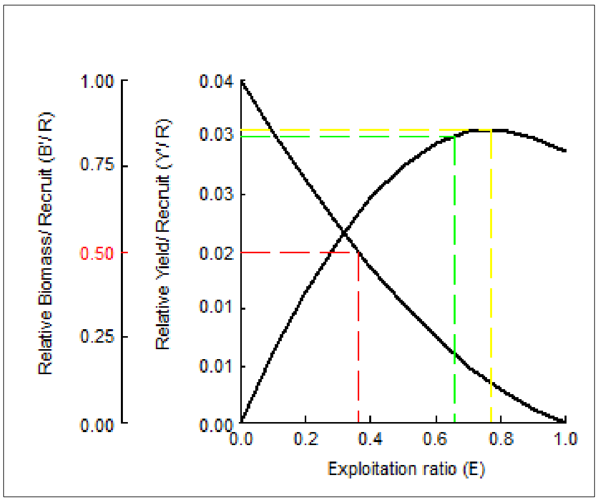

Figure 7 Curves of the variation of relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) as a function of exploitation rate (E) of *Oreochromis niloticus* exploited in Gueassabo Lake

4 Discussion

The study involved 515 individuals with sizes ranging from 6 cm to 20 cm for an average of 13.09 ± 3.09 cm. The size structure showed that the fishermen's catches are dominated by individuals with sizes between 8.4 and 15.6 cm Ls either 75.72%. The average observed size of all the individuals of *Oreochromis niloticus* captured (13.09 ± 3.09 cm) is greater than the size of first capture (L50 = 10.6 cm) translating thus that the individuals captured had reached their minimum size to be captured. Moreover, according to [28], when the Lc/L∞ ratio is less than 0.5, the fishermen's catches are dominated by small-sized individuals, whereas when this ratio is greater than 0.5, the individuals caught are dominated by large-sized ones. In this study the ratio (Lc/ L∞ = 0.49) is roughly equal to 0.5. It could be said that the individuals caught by the fishermen are of average size. Following the mathematical model of Von Bertalanffy the values of the growth parameters determined in this study are those of the asymptotic length (L∞), the growth coefficient (K) and the theoretical age (to) for which the fish has zero length. The fit coefficient (Rn) obtained is 0.659, a value which is between 0 and 1 recommended by [29] who says that when the value of Rn is within this range then the method used to determine the growth parameters best fits the data collected and the estimated parameters are reliable. *Oreochromis niloticus* shows in this study an asymptotic length (L∞ =21, 57 cm) is less than that obtained (L∞ = 23.74 cm) in the village of Bagbé in southern Togo by [30, 31] in Buyo Lake (L∞ = 32.77 cm) and from [32] in the Kou Valley lake in Burkina (L∞ = 462 mm). This result reflects that the individuals caught in this study are smaller than those obtained in other rivers and this could be due to several factors such as fishing pressure [33], on the one hand and ecological characteristics specific to each study area on the other hand [34]. These parameters may influence the maximum average population size of a given stock in some way [35]. The value of the growth coefficient of *Oreochromis niloticus* ($K = 0.93\ yr^{-1}$) indicates that the species is fast growing. These parameters may influence in some way the maximum average population size of a given stock [35]. The value of the growth coefficient of *Oreochromis niloticus* ($K = 0.93\ yr^{-1}$) indicates that the species is fast growing. Furthermore, the value of the growth coefficient obtained in this study ($K = 0.93\ yr^{-1}$) is higher than that obtained by [32] in Kou Valley Lake (0, 33 yr^{-1}) thus implying that *Oreochromis niloticus* in this study grows faster towards its length at infinity than *Oreochromis niloticus* in Kou Valley Lake. In view of the length to infinity and the growth coefficient of growth we could say that the greater the growth coefficient the less the length to infinity is. It could be said that the species develops certain mechanisms that allow it to quickly reach infinite length hence the high growth coefficient. The growth performance index (Φ') of *Oreochromis niloticus* in Guessabo Lake is 2.66. This value is within the range of values (2.65 to 3.32) recommended by [36] for African fish. This variability of growth parameters of *Oreochromis niloticus* from one ecosystem to another could be due to several factors. These include food availability and population density [37] difference in food accessibility [1], difference in ecosystem temperature [38,39], fishery degradation [40] and fishing pressure [41].

The values of the total (Z), natural (N) and fishing (F) mortality coefficients determined for the species *Oreochromis niloticus* are 2.84 yr^{-1}, 1.82 yr^{-1} and 1.02 yr^{-1}. Thus, the natural mortality (1.82 yr^{-1}) is higher than the fishing mortality (1.02 yr^{-1}), thus reflecting a low exploitation of the species by fishing in Guessabo Lake. This result confirms the exploitation rate (E = 0.36) which is not only lower than the optimum reference rate defined by [23] but also lower than the maximum exploitation (Emax = 0.768). This result differs from that obtained for the same species in Kou Valley Lake by [32] who found that this species is overexploited in this lake (E = 0.64). It is true that the species is under-exploited, but the Z/K ratio obtained is 3.05, indicating that the *Oreochromis niloticus* population is declining in Guessabo Lake. Indeed for the authors [42] when $Z/K < 1$ then the population increases so growth dominates over mortality, if Z/K > then the population decreases so mortality dominates over growth, If Z/K = 1 then mortality balances the population increase and finally if $Z/K \approx 2$, the population is little exploited. Furthermore, the fact that the exploitation rate (E0.5 = 0.352) is roughly equal to the exploitation rate (E= 0.36) translates according to [27] that the initial biomass of *Oreochromis niloticus* in Guessabo Lake is reduced by 50%. The recruitment for *Oreochromis niloticus* is continuous throughout the year and shows two Gaussian curves implying that the recruitment occurs twice a year with peaks in the months of June (17.65%) and July (17.81%). The observation of two peaks during the year is also supported by [43] according to whom, tropical fishes present a double annual recruitment.

5 Conclusion

The study on the growth and exploitation parameters of *Oreochromis niloticus* was conducted in Guessabo Lake between August 2019 and July 2020. The growth coefficient revealed that *Oreochromis niloticus* is fast growing. The values of the mortality parameters revealed that the mortality of individuals of *Oreochromis niloticus* is more due to natural conditions than to fishing, thus translating a low exploitation of the species by fishing in Guessabo Lake. Although the exploitation rate obtained shows that the species is under-exploited, the Z/K ratio obtained reflects that the population of *Oreochromis niloticus* is declining in Lake Guessabo. Recruitment occurs twice a year with peaks in June and July.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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