International Journal of Fisheries and Aquatic Studies 2015; 2(3): 141-145

ISSN: 2347-5129
IJFAS 2015; 2(3): 141-145

www.fisheriesjournal.com
Received: 05-12-2014
Accepted: 21-12-2014

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Population parameters of *Oreochromis niloticus* (Cichlidae) recently introduced in lake Toho (Benin, West Africa)

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Abstract
Population parameters of *Oreochromis niloticus*, introduced in Lake Toho in 1995, were investigated using the FiSAT software. Data was collected monthly from January to December 2007. Total length of 1047 specimens ranged from 4.1 to 40.2 cm. The growth parameter K was estimated to 0.33 $year^{-1}$ with asymptotic length $L\infty$ = 41.5 cm. The recruitment pattern was continuous year-round with one peak (May-July). The total (Z), natural (M) and fishing (F) mortalities were 1.10 $year^{-1}$, 0.74 $year^{-1}$ and 0.36 $year^{-1}$ respectively. The Z/K ratio was 3.7, the exploitation rate (E) 0.33 and the relative yield/biomass per recruit E_{max} 0.65. The fishing effort is slow with a dominance of small size individuals in the captures. There is growth-overfishing and an increase in the mesh size of fishing gears should go along with that of fishing effort to preserve the population on the species.

Keywords: Lake Toho, *Oreochromis niloticus*, growth, mortality, exploitation.

1. Introduction
Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) is a native species of Africa often met in the tropical region [1]. In West Africa, its natural distribution area covers the basins of the Senegal, Gambia, Volta, Niger, Benue and Chad [2]. Because of these good qualities of the species for fish farming, it was introduced all over the world and in several regions. Therefore, it has often been reported from several coastal West African basins. In Benin, the water courses where *O. niloticus* is originally are the tributaries of the Niger and Volta basins in the North of the country [3, 4]. It has been introduced in the south of Benin, the coastal region, in the Ouémé basin [5] and in the Mono basin [6].
The first transfer of the species in the coastal region of Benin has been in 1979 from CTFT-Côte d'Ivoire to Aquaculture center of Godomey (Benin) and the second in 1992 from CTFT-Bukina-Faso to the beninese small aquaculture ponds by the "Centre Agricole Régional pour le Développement Rural" [7, 8]. But, due to an uncommon flood of Lake Toho in 1995, some individual fishes escaped from the ponds and entered into the lake resulting introduction of this species [6]. The species spawns normally and occurs frequently in artisanal catches [9]. Nowadays, it is the most desired fish by fishermen because looked for by consumers.
A better understanding of its population parameters is necessary for good management. This study is a contribution for the constitution of database on the population dynamics of this fish species in Benin. Thus, the present paper provides information on the growth, mortality, recruitment patterns and statute of exploitation parameters of its population.

2. Materials and methods
2.1. Study area
Lake Toho (6°35 - 6°40 N et 1°45 - 1°50 E, Figure 1) is located in the South of Benin. Its surface varied between 9.6 km² and 15 km² with a mean depth of 2.1 m [9]. The length of the lake is up to 7 km and its width varies from 0.5 to 2.5 km. It is fed by the rivers Adiko and Akpatohoun during the rainy season (May-October). The Sazué river valley serves as outlet during the flood season through two channels.

This valley also serves as tributary when floods of the Mono River make water overflow. Surrounding aquaculture ponds are owned by local population.

The climate is subequatorial with two rainy seasons (mid-March to mid-July, mid-August to mid-November) and two dry seasons (mid-November to mid-March, mid-July to mid-August). The maximum rainfalls of 152.1 mm and 124.7 mm are recorded in June and October, the minimum of 23 mm and 6.3 mm in December and January, respectively.

2.2. Fish sampling and data analysis

Fish collection was based on artisanal fishing using landing net, gill net and hook. Fish were collected monthly from January to December 2007 at the different stations (Figure 1). The total length of 1047 fish, measured to nearest 0.1 cm, ranged from 4.1 to 40.2 cm and was grouped into class intervals of 2.0 cm.

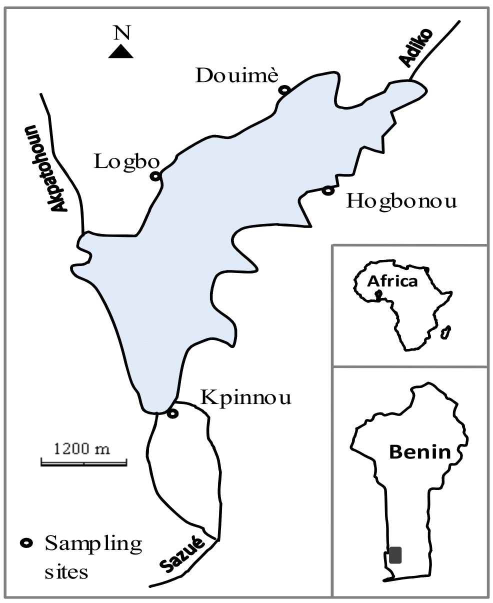

Fig 1: Sampling stations at Lake Toho.

The von Bertalanffy growth parameters were estimated using the FiSAT II software package [10] which incorporate a routine ELEFAN I computer program, through the length frequency distributions.

The ELEFAN I, based on the von Bertalanffy growth formula (VBGF), was expressed in the form $Lt = L\infty\,[1 - e^{-K\,(t-t0)}]$ [11] where Lt is the predicted length at age t, L∞ (cm) is the asymptotic length, K ($year^{-1}$) is a growth coefficient and t_0 is the age the fish would have been at length zero. The t_0 was calculated independently, using the empirical formula $\log10\,(-t_0) = -3.922 - 0.2752 \log10 L\infty - 1.038 \log10 K$ [11]. The longevity of individuals (*tmax*) was estimated using the following equation: $t\max = 3/K + t_0$ [12]. The growth performance index (*Φ'*) was calculated using $\Phi' = \log K + 2 \log L\infty$ [13]. The distribution of *Φ'*-values obtained in this study and other previous estimates available in the literature were tested using the Shapiro-Wilk test.

The L∞ and K values were used as input to length-converted catch curve analyses in order to obtain estimates of the total mortality (Z) according to [12]. The natural mortality (M) was estimated using the empirical formula [14]: $\log10M = 0.0066 \log10K - 0.279 \log10L\infty + 0.6543 \log10K + 0.4634 \log10T$, where T is the mean annual environmental temperature (29.3◦C). The fishing mortality rate, F, was calculated as Z – M and the exploitation rate, E, was computed as F/Z [15].

The recruitment model is obtained by projecting the length frequency data back on the time axis using the growth parameters [16]. The normal distribution of the recruitment model was determined by NORMSEP [17] in FiSAT II.

The model of Beverton and Holt [18] as modified by Pauly and Soriano [19] was used to predict the relative yield per recruit (Y'/R) of the species to the fisheries:

$(Y'/R) = EU^{M/K\,[1 - (3U)/(1 + m) + (3U^2)/(1 + 2m) - (U^3)/(1 + 3m)]}$, where E = the current exploitation rate, U = 1 – (Lc / L∞) = the fraction of growth to be completed by fish after entry into the exploitation phase, m = (1 – E) / (M/K) = K/Z.

The relative biomass per recruit (B'/R) was estimated as B'/R = (Y'/R)/F. Then, E_{max} (exploitation rate producing maximum yield), $E_{0.1}$ (exploitation rate at which the marginal increase of Y'/R is 10% of its virgin stock) and $E_{0.5}$ (exploitation rate under which the stock is reduced to half its virgin biomass) were computed through the first derivative of the Beverton and Holt [18] function. Yield contours were plotted to assess the impact on yield of changes in exploitation rate E and critical length ratio Lc/L∞.

3. Results

The von Bertalanffy growth curve is presented in Figure 2. The parameters of the VBGF are: L∞ = 41.5 cm TL, K = 0.30 $year^{-1}$ and t_0 = – 0.75 year. The value of *Φ'* and t_{max} were 2.71 and 9.25 years respectively.

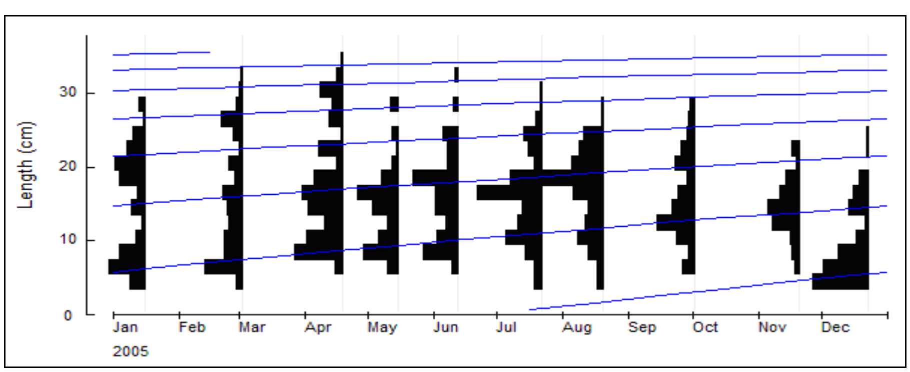

Fig 2: Growth curves superimposed over total length-frequency histogram for *O. niloticus* from Lake Toho.

A continuous recruitment of *O. niloticus* was done all along the year. It shows that there is one peak from May to July with 54.8 % (Figure 3).

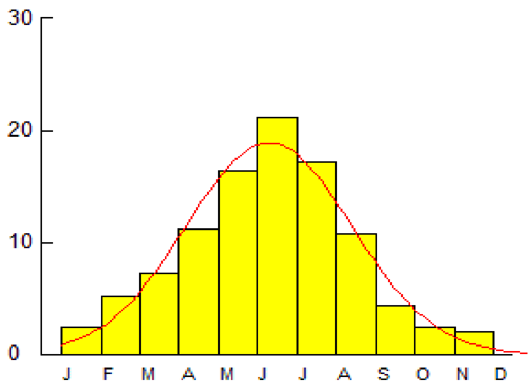

Fig 3: Recruitment pattern of *O. niloticus* from Lake Toho.

The total mortality (*Z*) was estimated to 1.10 year^{-1}, natural mortality to 0.74 year^{-1} and fishing mortality (*F*) to 0.36 year^{-1}. The exploitation rate corresponding to F is 0.33 viz 33 % (Figure 4).

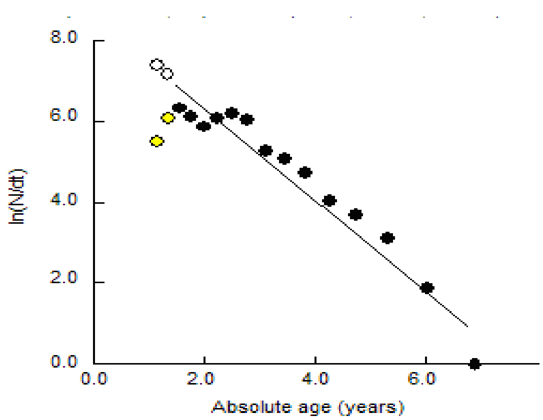

Fig 4: Length-converted catch curves (*Z* = 1.10 year^{-1}; M (29.3 °C) = 0.74 year^{-1}, *F* = 0.36 year^{-1} and E = 0.33) of *O. niloticus* from the Lake Toho.

This value is lower than E_{max} = 0.65, than $E_{0.1}$ = 0.51 and equal to $E_{0.5}$ = 0.33 obtained by relative yield and biomass per recruit (Figure 5).

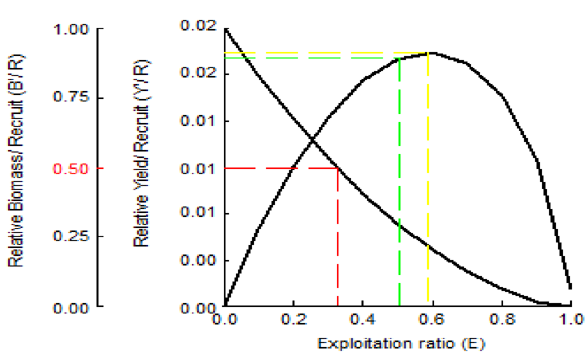

Fig 5: Relative yield and biomass per recruit (selection ogive) of *O. niloticus* from the lake Toho.

4. Discussion

A glance at the beginning of the growth curve (Figure 2) shows that the spawning period of *O. niloticus* occurs between July and August. A previous study [9] in the same lake demonstrated that the spawning occurred throughout the year but was intensive from June to November and coincided with the rainy season. The same results were obtained in studies carried out on Lake Victoria [20], in equatorial water [21], at the coastal Mississippi watersheds [22] and at the Emiliano Zapata Dam in Mexico [23]. From the recruitment pattern analysis, it emerged that major recruitment occurred during the rainy season and/or flood [9]. As noticed at the level of other beninese freshwater fish [24-31], the strategy of this species consists in making peak in reproductive activity correspond to the rainy season or flood.

Fish grow all its lifetime. L∞ is the largest theoretical length that individual of one species can reach in optimal conditions and K is the speed of their growth in order to reach that final length. At the level of a species, the stock can grow faster (K relatively high) when it is made of young individuals, but slower when old (K relatively low) [32]. Hence, growth comparison must be approached from a multivariate perspective in which both L∞, K and above *Φ'* (because *Φ'* incorporate the two preceding parameters) are taken into consideration [33]. According to Moreau *et al.* [34] and Dadzie *et al.* [35], *Φ'* values should be equal or roughly similar between different stocks of the same species in a normal distribution. In this study, the Shapiro-Wilk test done on values presented on Table 1 shows that the distribution is normal and there is no significant difference between them (W = 0.98, p = 0.97, N = 9).

Consequently, the overall growth of *O. niloticus* in Lake Toho is as performant as elsewhere. The *Φ'* values of African fish usually ranged between 2.65 and 3.32 [36]. This indicates their low growth performance. The *Φ'* value (2.70) determined in this study indicates the low growth performance of *O. niloticus* in Lake Toho and in other lakes and reservoirs [20, 34, 36-49].

Mortality and growth parameters are antagonistic factors in the dynamic of populations. Capture related mortality (F) and natural mortality (M) contribute to total mortality (Z = M + F). Their ratio is a good indicator of the prevalent one. The relevance of the estimated M value is established through M/K. The ratio which should be comprised between 1.5 and 2.5 for the majority of fish is 2.5 for *O. niloticus* in this lake [50]. Thus, M which is 0.74 year^{-1} is largely higher than that of F. As a general rule, if Z/K ratio < 1, the population is growth-dominated, if it is >1, then it is mortality-dominated; if it is equal to 1, then the population is in equilibrium where mortality balances growth [51]. In the present study, Z/K ratio = 3.7. This means that there is a mortality-dominated situation in Lake Toho. It still suggests that there is overfishing. But as E-value obtained (E = 0.33) in the present study is less than 0.5, fishing effort is slow with a dominance of small size individuals in the captures. Thus, the fishing system used in Lake Toho does not allow the majority of fish the ability to reproduce themselves at least once before being captured. This is growth overfishing [52]. In such conditions, an increase in the mesh size of fishing gears should go along with that of fishing effort. And this is in agreement with the fact that current E is lower than E_{max} (0.65).

Table 1: Asymptotic length (L∞), growth coefficient (K) and growth performance index (*Φ'*) of *O. niloticus* from various regions.

Lakes / Reservoirs, Countries	L∞	K (year⁻¹)	Φ'	References
Lac Toho, Benin	42.3 cm TL	0.29	2.70	Present study
Lac Kainji, Nigeria	53.2 cm TL	0.29	2.92	[37]
Lake Nasser, Egypt	52.1 cm SL	0.26	2.77	[34]
Opa Reservoir, Nigeria	56.7 cm TL	0.26	2.93	[38]
Nyanza Gulf of Lake Victoria, Kenya	61.3 cm TL	0.39	3.12	[39]
Lake Ayame I, Cote d'Ivoire	35.3 cm TL	0.40		[40]
Minneriya Reservoir	43.5 cm TL	0.32		[41]
Adawalawe Reservoir	44.0 cm TL	0.49		[41]
Victoria Reservoir, Sri Lanaka	38.2 cm TL	0.60		[41]
Kaptai Reservoir, Bangladesh	55.6 cm TL	0.39		[42]
Bontanga Reservoir, Ghana	23.6 cm SL	0.58		[43]
Shallow Irrigation Reservoir, Sri Lanka	50.7 cm TL	0.64		[44]
Lake Coatetelco, Mexico	17.9 cm SL	0.34		[45]
Nyanza Gulf of Lake Victoria, Kenya	58.8 cm TL	0.59	3.31	[20]
Nyanza Gulf, Lake Victoria, Kenya	64.6 cm TL	0.25	3.02	[46]
Gbedikere Lake, Nigeria	43.8 cm TL	0.32	2.79	[47]
Lake Volta, Ghana	33.5 cm SL	0.55		[48]
Lake Volta, Ghana	33.5 cm SL	0.35	2.59	[49]

5. Conclusion

In Lake Toho, There is growth-overfishing of *O. niloticus*. It is expected that the present results will contribute to the proper management of this resource. An increase in the mesh size of fishing gears should go along with that of fishing effort to preserve the population on the species.

6. Acknowledgements

This study was financed by British Ecological Society (BES) through the Program of Research Grants. We sincerely thank Dr Neil Springate and Dr Dominic Burton, Administrators of the BES. We also thank Jean Marc Gnonlonfoun for his assistance.

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