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Population Dynamics of Nile Tilapia (*Oreochromis niloticus*, Linnaeus.1758) from Khashm El-Girba Reservoir, Atbara River, Eastern Sudan

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study was conducted to assess the population parameters of Nile tilapia, *Oreochromis niloticus*, in the Khashm El-Girba Dam Reservoir in Eastern Sudan. Fish samples were collected from December 2019 to November 2020. Length-frequency data were collected from 1,671

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specimens ranging from 5.1 to 34.2 cm in total length (TL). Analysis of the population parameters was determined using the ELEFAN I routine and the FiSAT II software computer program revealed that the estimated the Von Bertalanffy growth parameters were as follows: asymptotic length (L_∞ = 36.75 cm), growth rate (K = 0.650 year $^{-1}$) and age at length zero (t_0 = -0.629) and the growth performance index (Φ') was calculated at 2.943. The instantaneous total mortality (Z), natural mortality (M), and fishing mortality (F) rates were determined using the length-converted catch curve and empirical models. The values obtained were Z = 2.38 year $^{-1}$, M = 1.22 year $^{-1}$, and F = 1.16 year $^{-1}$, respectively. The exploitation rate (E) of the Nile tilapia was calculated at 0.49 year $^{-1}$. The size at first capture (L_c) was estimated at 15.64 cm, which is slightly greater than the size at first maturity (L_m = 14.5 cm) and longevity (T_{max}) was found to be 4.62 years. These findings indicate that the stock of the Nile tilapia population in Khashm El-Girba reservoir is overexploited, and that monitoring and management practices need to be employed to maintain the stocks at the optimum exploitation level.

Keywords: Exploitation rate; FiSAT II; growth parameters; Khashm El-Girba Reservoir; Mortality rates; nile tilapia; recruitment pattern.

1. INTRODUCTION

"The study of the dynamics of fish populations is mainly based on knowledge of biological processes, such as reproduction, growth, maturity, mortality, and exploitation level. The growth parameters of fishes constitute essential data and can give an important indication of fisheries management and the level of their exploitation" [1]. "Growth parameters of fish populations can be determined through two main approaches: direct readings of hard structures (otoliths, spines, or vertebrae) and indirect estimates based on length distribution data over time" [2,3]. "The length-based stock assessment tools are relatively more useful in tropical and subtropical waters, as the seasonal differences in the hard structures of these relatively warm waters are subtle and often present unclear annual marks" [4].

"The analysis of fish stock population dynamics in tropical environments has been facilitated by the introduction of relative growth models and length-based stock assessment approaches" [5,6]. "These techniques have been employed to evaluate life-history theories and produce empirical estimates of various biological and fisheries parameters, such as longevity and length at first maturity" [5,6,7]. "Furthermore, these methods aid in forecasting fish population exploitation, which can inform the selection of appropriate management options" [8,9,10,11,12]. "Fish population biology and ecology are reflected in growth and mortality factors, which are crucial for modeling fish stock population dynamics. These metrics provide important information on the fluctuation of fish size over time and the reduction in population biomass due to fishing and/or natural causes, and are essential inputs for stock assessments" [13,14].

"All tilapias are basically herbivores or detritivores; As such they occupy an intermediate position between primary producers and piscivorous. Also, tilapia serve in the recirculation of nutrient metabolites on which primary production depends. Tilapias are so important as food fish over most of Africa, and now through much of the tropical world" [15].

Nile tilapia, *Oreochromis niloticus*, is the most commercially and ecologically important fish species in the inland waters of Sudan. The Khashm El-Girba Reservoir is considered one of the large inland water bodies in Sudan providing a vital source of livelihood, employment and income for the riparian communities residing in the vicinity of the Reservoir. However, very few information is available regarding assessing the vital population parameters of the Nile tilapia population stock in inland waters of Sudan in general and the Khashm El-Girba Dam reservoir in particular.

2. MATERIALS AND METHODS

2.1 Study Area

The Khashm El-Girba reservoir was constructed across the Atbara River, Sudan in 1964. The resulting Lake Khashm El-Girba covers a maximum area of 125 km² and extends 80 km southward from the dam wall. The lake's average depth is 6.8 m, with a maximum depth of approximately 50 m near the dam; the widest point of the lake is 4 km south of the dam [16].

2.2 Data Collection

Random samples of about 1,671 specimens of Nile tilapia fish (*O. niloticus*) were collected monthly from artisanal fishing boats using multi-filament gillnets with mesh sizes (2.5, 3, and 4 cm) during the period from December 2019 to November 2020. Samples of fish were obtained from three sampling sites (El-Remila, El-Monaba, and El-Dweih). The total length of fishes (1.0 mm) was measured in situ from the tip of the snout to the end of the upper lobe of the caudal fins, using a standard measuring board.

2.3 Growth

FiSAT II, version 1.2.2 software [17] was used to determine the growth parameters of the von Bertalanffy growth function (vBGF):

$$L_t = L_\infty\,[1\text{-}e^{-k(t-t0)}].$$

Where L_t (cm) is the length at a given time t, L_∞ (cm) is the asymptotic length, K is the rate at which L_∞ approached the asymptote; t_0 (yr) is not a direct output of FiSAT II from length-frequency data, an estimate was made independently using [18] empirical formula:

$$\text{Log}(-t_0) = -0.3922-0.2758 \times \log L_\infty - 1.038 \times \log K.$$

The growth performance index (Φ') was generated using the formula proposed by [19]:
$\Phi' = 2\log L_\infty + \log K$.
where K and L_∞ are growth parameters of the von Bertalanffy growth equation.
The longevity (also called maximum age, T_{max}) was obtained from [13] equation:
$T_{max} = 3/K + t_0$

2.4 Mortality Rates

Total mortality (Z): The instantaneous rate of total mortality (Z) was estimated using the length-converted catch curve method outlined by [13] as follows:

$$Z = \ln(dni/dti) = a + bti.$$

Where Z is the total mortality, *ni* is the number of fish in length class *i*, *dt* is the time needed for the fish to grow through length class *i*, *ti* is the age (or the relative age, computed with $t_0 = 0$) corresponding to the mid-length of class *i*, and *b* is the slope of the regression, with the sign changed, which provides an estimate of Z.

Natural mortality (M): The instantaneous rate of natural mortality (M) was calculated using [20] empirical formula using vBGF Parameters, L_∞ and K as mentioned above and the mean annual surface water temperature of 25 °C, as follows:

$$\text{Log } M = 0.0066-0.27 \log L_\infty + 0.6543 \log K + 0.434 \log T.$$

Fishing mortality (F): The instantaneous rate of fishing mortality (F) was calculated as follows:
F= Z – M [21].

Exploitation rate (E): The exploitation rate was calculated from the ratio between fishing mortality and total mortality, according to [14,21,22] as follows:

$$E = F/Z = F/M+F.$$

First maturity: First maturity (L_m or L_{50}): refers to the length at which 50% of the population reaches maturity. To estimate the L_m from the maturity stage data, fishes with maturity stages III and above were considered as mature fish. The proportion of mature fish per length class was calculated and L_m was estimated according to [23]. The relationship between the percentage of mature fish per length class and fish length was described with a logistic curve:

$$P = 1/1+e^{(b\,L + a)}$$

Where P is the proportion of mature fish at length class x, *a* and *b* are model parameters (*a*, intercept and *b*, slope of the logistic regression) estimated by the regression, and L is the length of fish. The L_{m50} was then derived from the relationship of *a* and *b*.
L_m = -a/b.

Length at first maturity (L_m): The estimates described above were used to compute the numerical percentage of specimens in the catches larger than the length at maturity (L_m). The percentage of fish between L_m and 10% of the length at optimum cohort biomass (L_{opt}) was also calculated, referred to as the L_{opt} range. Additionally, the percentage of fish beyond this L_{opt} range was calculated, referred to as mega-spawners [10]. These size-based indicators were used to evaluate the stock status.

Length at first capture (L_c): The probability of capture was estimated following [17]. length at first capture (L_c) is the length at which 50% of the fish become vulnerable to capture and is estimated from the equation of [21] which applies the growth constants of vBGF, the mean length of the fish catch ($\bar{L}$), and the total mortality parameter (Z):

$$L_c = \bar{L} - K \times (L_\infty - \bar{L}) \div Z.$$

Estimation of age at first capture (tc_{50}) was according to [21].

Recruitment pattern: The age at first capture (t_c) was determined from the estimated growth parameters (L_∞, K, and t_0) using the ELEFAN I method, which projects length-frequency data backward [24]. This routine identifies the number of seasonal recruitment pulses represented in the length-frequency data [17]. The "Percent of sample total" option in FiSAT was selected to estimate the recruitment pattern, as the samples had dissimilar sizes.

Relative yield per recruit (Y/R): Relative yield per recruit (Y/R) and relative biomass per recruit (B/R) values were calculated as a function of exploitation (E), using the estimated growth parameters and probability of capture by length (L_c) [25]. The calculations were carried out using the FiSAT software package.

Virtual Population Analysis (VPA): Estimated length structured (VPA) Analysis was carried out using the FiSAT II routine [17]. The inputs included the values of L_∞, K, M, F, a (constant), and b (exponent). The constants a and b were estimated from the length-weight relationship ($W = aL^b$).

The exploitation rates (biological reference points) at the maximum (E_{max}), ($E_{0.1}$), and $E_{0.5}$) were worked out using Beverton and Holt's model of relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R), utilizing the knife-edge selection (Ts) procedure as a function of exploitation rate (E), incorporated into the FiSAT II software [17]. The length at optimum cohort biomass or yield pre-recruitment (L_{opt}) was estimated from L_∞, K, and M, using [26] formula:

$$L_{opt} = L_\infty * (3/3 + M/K).$$

Where, L_∞, K, and M are as defined above.

3. RESULTS

3.1 Growth Parameters

Analysis of the data revealed that the length of most specimens fell between 17 – 23 cm (Fig. 1). According to the FiSAT II analysis of length-frequency data, the von Bertalanffy growth curve (vBGF) of Nile Tilapia in the Khashm El-Girba reservoir is shown in Fig. 2. The growth curve indicates the existence of eight size groups within the population. The estimated growth parameters are: L_∞ = 36.75 cm, K = 0.65 year^{-1}, and t_0 = -0.6297. The growth performance index (Φ') was calculated at 2.943, and the longevity potential of this species at 4.62 years as shown in (Table 1). The von Bertalanffy formula of growth is expressed by: $L_t = 36.75 \times [1-\exp(-0.65 \times (t+0.65))]$.

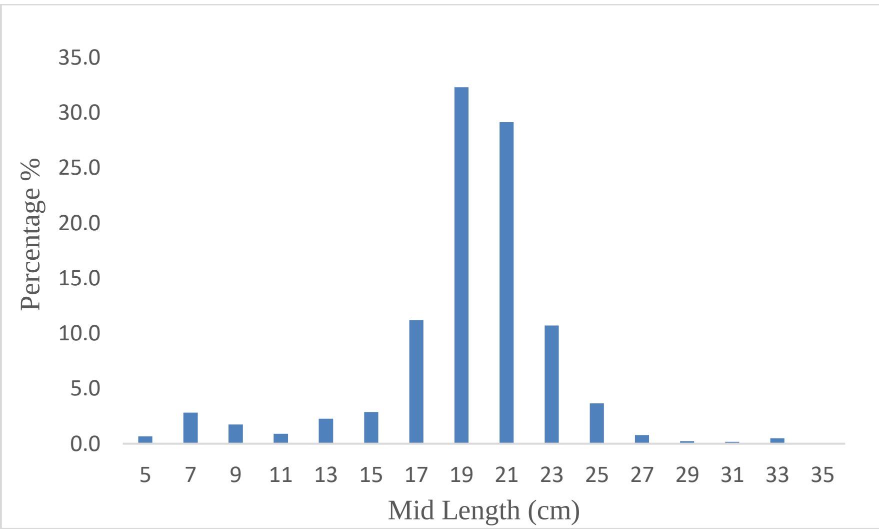

Fig. 1. Size spectrum of the Nile tilapia in Khashm El-Girba reservoir (n=1,671); Sizes are represented by the total length (cm)

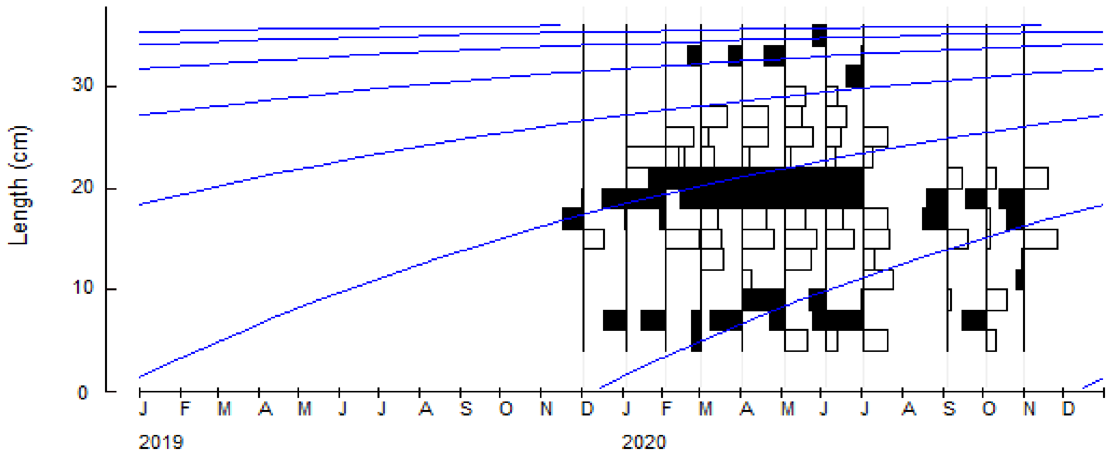

Fig. 2. Von Bertalanffy growth curve of *O. niloticus* by ELEFAN I based on length-frequency distribution (L_∞ 36.75 cm and *K* 0.65 yr $^{-1}$)

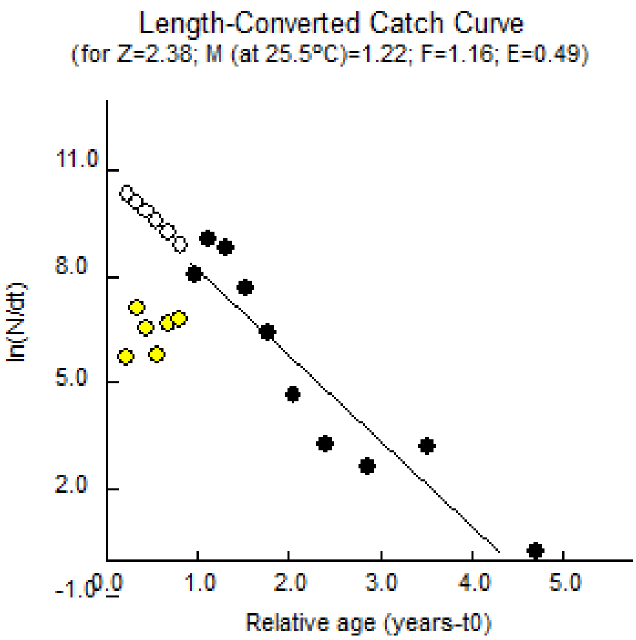

Fig. 3. Von Bertalanffy growth curve (a) (L_∞=36.75 cm; *K* = 0.650 yr $^{-1}$; on length- frequency distribution and linearized length-converted catch curve of Nile tilapia in Khashm El-Girba reservoir

Mortality rates: The instantaneous rate of total annual mortality (Z) was calculated from the linearized length-converted curve described by [13] and was determined as 2.38 year $^{-1}$. The natural mortality coefficient (M) was calculated at 1.22 year $^{-1}$, while the fishing mortality (F) was obtained by subtracting M from Z and found to be 1.16 year $^{-1}$ (Fig. 3).

Exploitation rate:The exploitation rate (E) is the fraction of deaths caused by fishing. (E) was calculated from E= F/Z; E = F/ (F+M), [27], and estimated at as 0.49 in this study (Fig. 3).

The probability of capture indicates that the length at which 50% of the fish become vulnerable to capture was 15.64 cm total length (TL). The recruitment pattern of *O. niloticus* in Khashm El-Girba exhibited a single round. It started to rise in April/May (0.33) and reached a peak during June/July (0.67 and 1.00, respectively), then declined through August (0.33), while the period from September to March witnessed no recruitment (0.00). (Figs.4 and 5, and Table 1).

Fig. 6 shows that the maximum relative yield per recruit (Y/R) was obtained at an exploitation rate (E_{max}) of 0.421. The exploitation rates corresponding to 10% and 50% of the maximum Y/R (E_{01} and E_{05}) were estimated as 0.304 and 0.278, respectively, where L_c/L_∞ = 0.050 and M/K = 1.00. The calculated length at optimum cohort biomass or yield pre-recruitment (L_{opt}) was 22.6 cm (TL).

Analysis of length-frequency data showed that the mean ± standard deviation (SD) of the asymptotic length (L_∞) of the Nile tilapia population in Khashm El-Girba reservoir was 30.00 ± 0.2 cm, and the constant growth rate (*K*) of the von Bertalanffy growth function (VBGF) was 1.5 ± 0.2 year-1. The observed extreme length of Nile tilapia was 35.00 cm, the predicted extreme length was 39.04 cm, and the range at a 95% confidence interval was 33.38 – 44.70 cm.

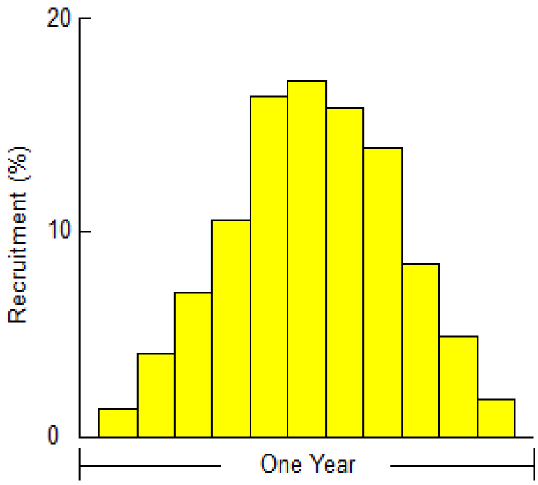

Fig. 4. The seasonal recruitment pattern

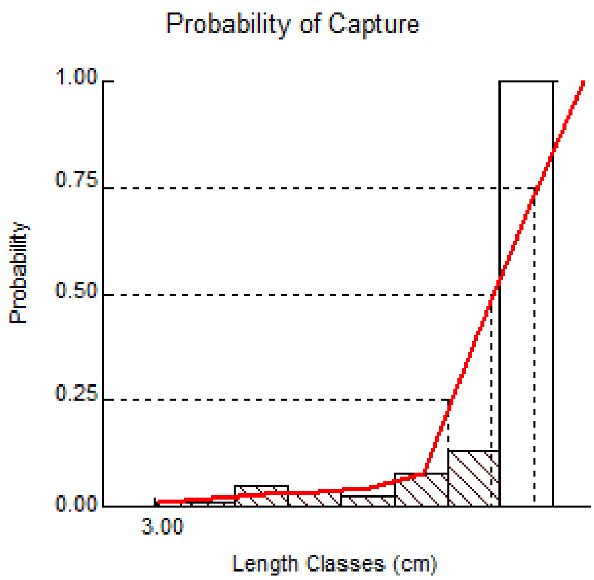

Fig. 5. The selective curve showing the probability of capture

Table 1. Fundamental information on the biological parameters of *O. niloticus* population in the Khashm El-Girba reservoir during the study period

Parameters	Estimated values	Parameters	Estimated values
L_∞ (cm)	36.75	E_{max}	0.409
K (year $^{-1}$)	0.65	E_{01}	0.304
Phi (Φ')	2.39	E_{05}	0.278
t_0 (year)	-0.65	L_c or (L_{50})	15.64 cm
T_{max} (year)	4.62	L_{25}	14.06 cm
Z (year $^{-1}$)	2.38	L_{75}	17.28 cm
M (year $^{-1}$)	1.22	L_{opt}	22.6 cm
F (year $^{-1}$)	1.16	L_m	14.5 cm

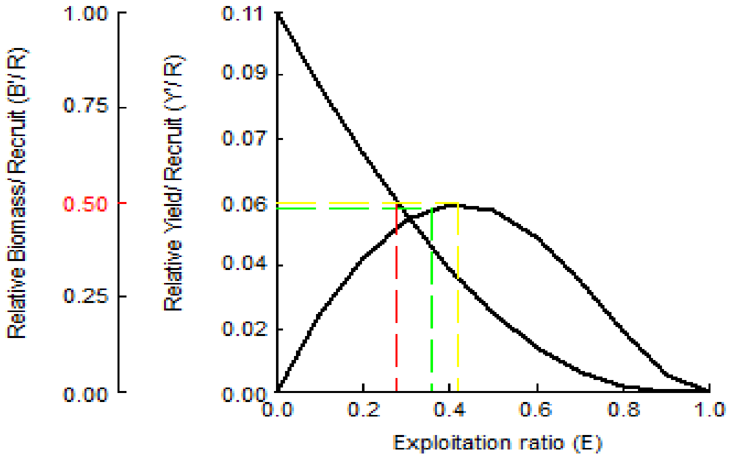

Fig. 6. Beverton and Holt relative yield per recruitment (Y/R) and biomass per recruit (B/R) of the Nile tilapia in Khashm El-Girba reservoir

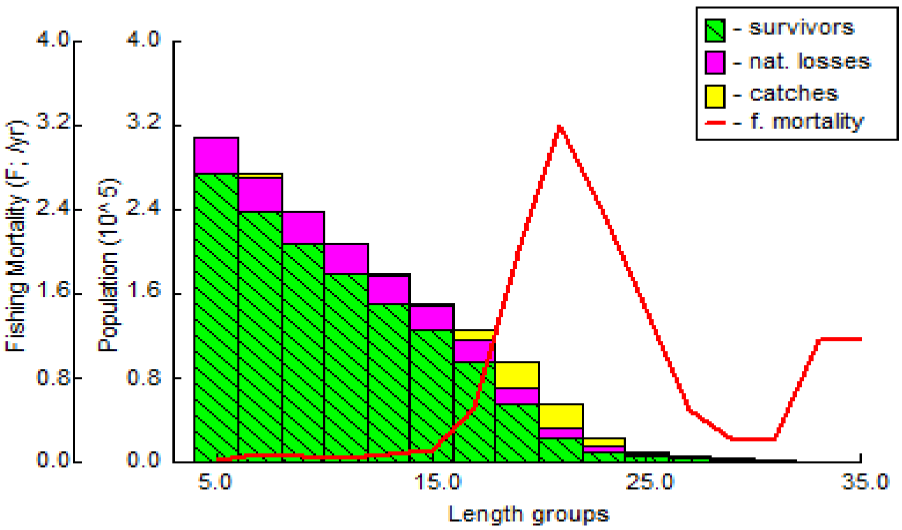

Fig. 7. Length-structured virtual population analysis of *O. niloticus* in Khashm El- Girba reservoir.

Table 2. Estimated growth parameters, mortalities' and exploitation rate ($yr.^{-1}$) and growth performance index of *O. niloticus* in various regions obtained from the literature

Location	L_∞ (cm)	K (yr^{-1})	Phi (Φ')	t_0 (yr)	Z	M	F	E	Author
Kaptai reservoir, Bangladesh	55.59	0.39	3.081	-0.13	0.80	0.59	1.39	0.42	[28]
Nam Theun 2 reservoir, Lao PDR	52.5	0.23	2.085	-	1.41	0.30	1.11	0.79	[29]
Lake Tana, Ethiopia	44.1	0.44	2.93	-0.34	2.37	0.98	1.39	0.52	[30]
River Nile (Aswan), Egypt	25.73	0.73	-		3.64	1.44	2.22	0.60	[31]
El-Bahar El-Faraouny, Egypt	37.27	0.294	2.611	-0.09	1.15	0.654	0.496	0.432	[32]
Halali reservoir, India	46.73	0.63	-	0.171	1.32	0.60	0.72	0.54	[33]
Sakumo II, Ghana	19.4	0.54	2.309	-0.34	1.84	1.30	0.54	0.29	[34]
Manzala Lake, Egypt	34.52	0.38	2.66	-0.39	2.02	0.82	1.20	0.59	[35]
Wadi El-Raiyan, Egypt	28.92 - 48.05	0.34 - 0.54	2.59 – 4.44	-0.14 to -0.26	2.59 – 4.44	0.59 – 0.97		0.77 – 0.78	[36]
Lake Toho, Benin	41.5	0.33	2.70	-0.75	1.10	0.74	0.36	0.33	[37]
Siombak Lake, Indonesia	36.04	0.59		0.087	3.04	1.24		0.59	[38]
Lake Victoria, Kenya	53.9	0.50	3.30		2.83	0.91	1.92	0.68	[39]
Nyanza Gulf, Kenya	58.78	0.59	3.31	-0.64	2.16	1.00	1.12	0.48	[40]
Garmat Ali River, Iraq	30.45	0.45	2.62	-0.313	3.26	1.03	2.24		[41]
Lake Chamo, Ethiopia	55	0.37		-0.467	1.509	0.79	0.72	0.48	[42]
Lake Abaya, Ethiopia	49.35	0.36	3.00	-0.40	1.34	0.34	1.00	0.5	[43]
Lake Langeno, Ethiopia	35.70	0.32	2.61	-0.49	2.31	0.82	1.56	0.67	[44]
Lake Chamo, Ethiopia	59.4	0.41	3.16	-0.48	2.44	0.57	1.88	0.771	[45]
NT2 reservoir, Lao PDR	65.8	0.08		-0.66					[46]
Lake Naivasha, Kenya	42	0.21	2.57		0.80	0.55	0.26	0.23	[47]

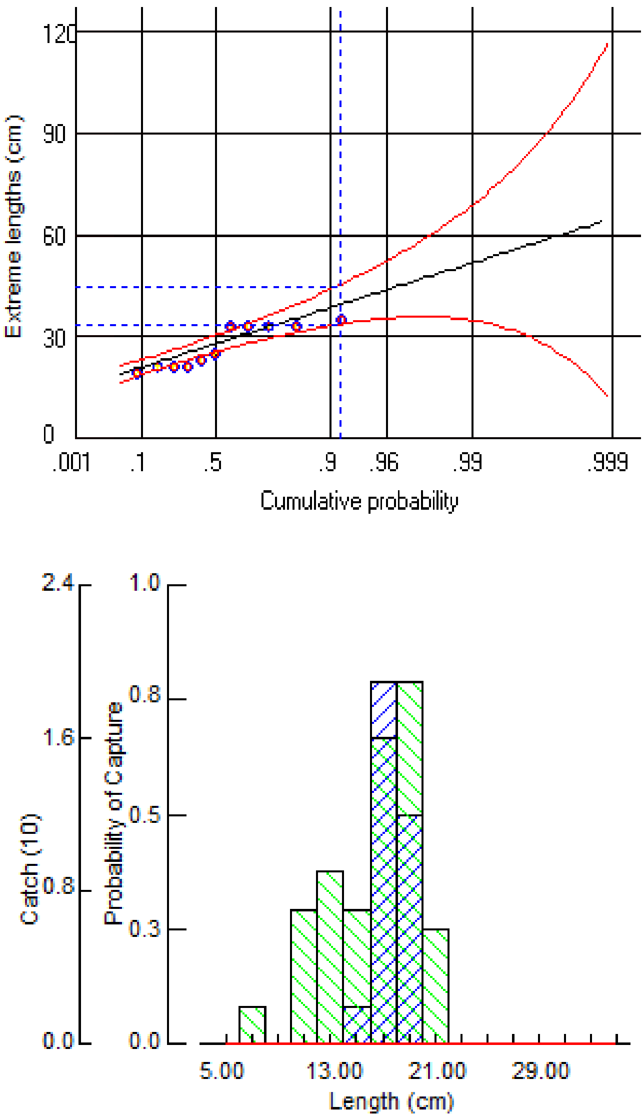

Fig. 8. Predication of a maximum of extreme length and Gillnet selection

4. DISCUSSION

In the present study, growth parameters obtained for *Oreochromis niloticus* from Khashm El-Girba Reservoir were, L_∞ =36.75 cm, K=0.65, and t_0 = -0.6297. Various researchers who worked on *O. niloticus* from different freshwater bodies, such as [27,28,44,45], reported higher values of L_∞= 55.59, 52.5, 59.4, and 65.8 cm, respectively; but lower values of K= 0,39, 0.23, 0.41 and 0,08, respectively.

Conversely, lower values of asymptotic length (L_∞ = 25.73 cm and 19.4 cm) and high values of growth constant K = 0.73 and 0.54 were recorded by [30 and 33]. [21] pointed out that the growth coefficient (K) is inversely related to the asymptotic length (L_∞) and the life span longevity. The highest value of L_∞= 65.8 cm and lowest value of (K = 0,08) of *O. niloticus* was reported by [46] NT2 reservoir, Lao PDR, Fig 2. These variations may be related to the continuous fishing of relatively smaller-sized fishes over time. The growth rate (K) of Nile tilapia in this study was 0.65 which lies within the range of 0.34 year $^{-1}$ and 0.67 year $^{-1}$, indicating that the Nile tilapia in the reservoir is moderately growing as evidenced by its short life expectancy of 4.62 years. On the other hand, the growth performance index (Φ') of several African freshwater fishes has been shown to vary between 2.65 and 3.32 indicating low growth performance [48]. The Φ' value (2.39) from the present study falls outside the range documented by [48] revealing *O. niloticus* in Khashm El-Girba Reservoir is characterized by high growth performance. However, the low growth performance index of Nile tilapia in Khashm El-Girba Reservoir differed widely from those estimated by other authors who studied the Nile tilapia in different freshwater bodies, such as [27,39,42,44] who reported value of Φ'= 3.081, 3.31, 3.30 and 3.16, respectively, indicating low growth performance. These differences in growth parameters of the *O. niloticus* population can be due to factors, like water temperature, food quantity and quality, metabolic activity, fluctuation in water level and reproductive activity, and method of sampling the fish [23,48].

Total mortality (Z) of *O. niloticus* was computed at 2.38. Natural motility (M) and fishing mortality were estimated at (1.22) and 1.16 respectively, showing that natural mortality was slightly higher than fishing mortality and that the population of this species was dominated by juvenile fishes. Similarly, high values of fishing mortality of Nile tilapia in different freshwater ecosystems were recorded by [30,38,43,44,49] with F = 2.22, 1.92, 1.56 and1.88 respectively, indicating that the populations of Nile tilapia were dominated by fishing mortality, which could be attributed to fishing mortality-induced conditions, such as high temperature, predators and fluctuations in water level. Conversely, [29,33,36] recorded low values of natural mortality of *O. niloticus* of M= 0.98, 1.30, and 0.74 respectively. Beverton et al. [21] pointed out that the natural mortality coefficient is directly related to the growth coefficient (*K*) and inversely related to the asymptotic length (L_∞) and the life span longevity, and if the Z/K ratio is1.0, the fish population is considered growth dominated, and if it is more than 2, then it is mortality dominated. The ratio of Z/K of Nile tilapia in the present study was estimated at 3.66, the Nile tilapia population is mortality-dominated.

The current exploitation rate (E) and optimum exploitation (E_{max}) of *O. niloticus* in the study area were estimated at E = 0.49 and E_{max} 0.409, revealing that this fish species was slightly under-optimum exploitation rate (0.5). Amponsah et al. [34] in Shakumo II, Benin, and [42] in Chamo Lake, Ethiopia reported an exploitation rate of *O. niloticus* of E = 0.29 and E_{max} 0.48, respectively. Gulland [27] stated that the optimal exploitation rate should be (0.50) and that the fishing rate satisfying optimal exploitation of E = 0.5 largely leads to reduced fish stocks. However, [50] suggested that a level of E = 0.4 of a fish stock should be maintained in order to ensure a sustainable yield. Higher levels of exploitation rate (E) than that obtained for *O. niloticus* in this study (E 0.49) and E_{max} 0.409), were recorded by [29] E = 0.79, E_{max} 0.594, [36] (E = 0.76, E_{max} = 0.61), [43] (E = 0.74), [44] E = 0.67 and [45], E = 0.77, showing that these exploitation rates were higher than (E = 0.5), thus Nile tilapia stocks in these water bodies had been overfished.

The estimation of size at first sexual maturity (L_{m50}) has its practical application in the determination of the minimum legal size needed to protect the spawning stock and to ensure at least one spawning for mature individuals [32]. In the present study, the probability of capture indicated that the length at which 50% of the fish become vulnerable to capture was 15.64 cm total length (TL) and the calculated ratio of (E) to the length at first capture (L_c) was (0.031), suggesting that the catch was dominated by small-sized juvenile fishes. Moreover, the length at first maturity attained by *O. niloticus* (L_m 14.5 cm) was slightly lower than the length at first capture (L_c or L_{50}), denoting that the mesh size of fishing gear used by fishermen to capture fish was comprised of small mesh sizes. The lengths at 25% and 75% capture and optimum length (L_{opt}) were estimated at L_{25}= 14.06 cm, L_{75}=17.28 cm, and L_{opt} =22.60 cm. [34], in Sakumo II, Ghana, reported that the length at first maturity (L_m 13 cm) and length of first capture L_c was 4.1 cm and length at 25% and 75% capture were 3.1 cm and 5.1 cm respectively, indicating natural mortality fishing. On the other hand, [47] in Lake Naivasha, Kenya, showed that Nile tilapia reached first maturity at L_m 28.0 cm (TL) and L_{c50} at 19.38 cm, respectively, revealing the capture of small-sized juvenile fishes.

Yield per recruit and biomass per recruit are the most common models used to describe the status of any fish stock and express the annual average biomass of survivors [41]. Analysis of the maximum yield per recruit (Y/R) of Nile tilapia in Khashm El-Girba Reservoir showed that the optimum exploitation rate (E_{opt}) was 0.421 and that (E) corresponding to 10% and 50% of the biological conservation levels (E_{01} and E_{05}) were estimated as 0.304 and 0.278, respectively. The ratio of M/K was estimated at 1.0, which falls within the normal range of 1 – 2.5 [27], while L_c/L_∞ = 0.050, and the calculated length at optimum cohort biomass (*Lopt*) was 22.6 cm (TL).

The recruitment patterns show that juveniles of *O. niloticus* in Khashm El-Girba Reservoir were first recruited in the fishery in April/May (0.33), reached a peak during June/July (0.67 and 1.00, respectively), then declined through August (0.33), while the period from September to March witnessed no recruitment (0.00). although [33], observed one round of annual recruitment reaching a peak during April in a tropical-impacted reservoir, in Central India, yet, [37] in Lake Toho, Benin, and [40] in Nyanza Gulf (Lake Victoria, Kenya) reported continuous recruitment of *O. niloticus* all year-round with one peak (May/July). Van and Ofori-Danson [51] documented that the population of Nile tilapia usually follows a bimodal form of continuous recruitment pattern, and this signifies that the population of the assessed species, in such a water body, would be far from recruitment overfishing.

5. CONCLUSION

The results of the present study revealed that the exploitation rate (E = 0.49) of *O. niloticus* in Khashm El-Girba Reservoir was higher than the maximum sustainable yield (E_{max} = 0.409), but relatively lower than the optimum exploitation rate that maintains 50% of the stock biomass unexploited (E = 0.5). The estimated length at first capture was higher than the length at first sexual maturity, implying that there is a tendency towards selective fishing mortality and high vulnerability of small-size fish for capture by small mesh-size gill nets. Furthermore, the recruitment pattern of *O. niloticus* exhibited one round of recruitment with a peak in June/July coinciding with the onset of the rainy season. Thus, the juveniles of *O. niloticus* in Khashm El-Girba Reservoir need to be regulated and protected until reaching length at first capture. The present study is considered the first of its kind regarding the study of fish population of the inland waters of Sudan by using FiSAT II, version 1.2.2 software. It is hoped to contribute to the proper management of this most commercially important fish species in the country. Moreover, it can encourage other investigators to carry out further studies on the stock assessment of other freshwater fish species occurring in the vast water bodies of the country.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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