Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(1): 1509 – 1535 (2024)
www.ejabf.journals.ekb.eg

Assessing the Exploitation Status of *Sarotherodon galilaeus* (Linnaeus, 1758) in Samendéni Reservoir, Burkina Faso

Raogo Blaise Ouedraogo*, Souleymane Sanogo, Inoussa Compaoré

Fisheries and Wildlife Research and Training Laboratory, Institute of Rural Development (LaRFPF), Nazi Boni University, 01 BP 1091 Bobo Dioulasso 01, Burkina Faso
***Corresponding Author:** **raogoblaise2022@gmail.com**

ARTICLE INFO

Article History:
Received: Oct. 10, 2023
Accepted: Dec. 4, 2023
Online: Feb. 15, 2024

Keywords:
Samendéni Reservoir,
Sarotherodon galilaeus,
Growth,
Mortality,
Recruitment pattern,
Exploitation rate

ABSTRACT

This study examined the growth, mortality, and exploitation rate of the *Sarotherodon galilaeus* population in Samendéni Reservoir, located in the West Sudanian savannah in the Region of Hauts-Bassins, Burkina Faso. Fish samples were monthly collected from October 2021 to September 2022, and specimens measured from 9 to 32cm in total length with a mode in the interval [17;19[cm length class. Analysis of the length-frequency data of 1714 specimens using the ELEFAN method incorporated in FISAT software, indicated a growth constant (K) of 0.37 year^{-1}, and asymptotic length ($L\infty$) of 33.6cm total length for the population. The growth performance index, longevity, and theoretical age at birth (t_0) were estimated to be 2.621, 8.10 and -0.6952 years, respectively. The length at first capture (L_c=16.21cm) was lower than that at first maturity (Lm_{50} =18.717cm for males and 18.103cm for females), indicating that most of the harvested stocks were juveniles. The total mortality (Z), natural mortality (M), and fishing mortality (F) coefficients recorded 1.59, 0.93, and 0.66 year^{-1}, respectively, indicating natural mortality as a major contributor to total mortality. The recruitment pattern was a continuous model with a single peak and revealed a recruitment period in May. The exploitation rate (E= 0.25) of the population suggests underexploitation of the stock; however, increasing fishing gear mesh size and regulating fishing efforts are needed to protect the *S. galilaeus* stock.

INTRODUCTION

Global production of aquatic animals was slightly decreased from 179 million tonnes in 2018 to 178 million tonnes in 2020 **(FAO, 2021)**. Over 157 million tons were used for human consumption, and it is predicted to increase from 50 to 89% by 2030 **(FAO, 2022)**. Inland waters contribute to 66 million tonnes of this global production, and according to **Tesfaye *et al*. (2021)**, the majority of Africa's fishery production is provided by inland waters. Thus, inland waters such as reservoirs, lakes, and rivers are extremely important for food security and survival. To achieve the targets of the 2030 UN Sustainable Development Goals 2 and 14, "Zero Hunger" and "Life Below Water," respectively, ensuring the sustainability of fisheries is essential.

For effective management of fishery resources, understanding the fish population dynamics and conducting stock assessments is crucial. According to **Sparre and Venema (1992)**, stock assessments offer guidance on the optimal exploitation of aquatic living resources. However, due to data limitations, some inland fisheries have not yet been assessed.

Many African countries are facing challenges with their inland water resources due to pollution, overfishing, climate change, and eutrophication, mainly caused by human activities **(Tesfaye, 2016)**. Moreover, there is a lack of stock assessment in several freshwater fisheries, even when data collection and analysis capabilities exist **(Lorenzen *et al*., 2016; Tesfaye *et al.*, 2021)**. Thus, credible scientific evidence is necessary for effective assessment and management of fishery resources to ensure their sustainability.

In Burkina Faso, approximately 41,366 human individuals are working in fishing activities, and the domestic demand for fish has been rising in response to human population growth, rising incomes, and urbanization **(DGRH, 2021)**. Local production in 2020 was predicted to be 29752 tonnes **(Compaoré *et al*., 2023)**, with an estimation of 130,000 tonnes per year as a national demand for fish. Furthermore, the majority of reservoirs are facing some problems, such as the non-respect of the ban on fishing during the fish spawning period and the use of prohibited fishing gear by some fishermen, which could negatively impact the dynamic of different species fish populations. In addition, few studies were focused on fish stock assessment in Burkina Faso. However, **Da *et al*. (2023)** examined the growth and stock assessment of the African catfish, *Clarias anguillaris* (Linnaeus, 1758) in the Samendéni Reservoir. This reservoir has been opened for exploitation since 2018. Before, its opening to exploitation, **Minoungou *et al*. (2020)** reported 40 fish species and some Cichlidae species, such as *Sarotherodon galilaeus*, *Coptodon zillii*, and *Oreochromis niloticus*, being among the most abundant. Demographic parameters of *Sarotherodon galilaeus* in the Samandeni Reservoir was studied by **Minoungou *et al* (2021)** before its opening to exploitation; however, this study did not take into account the impact of using prohibited fishing gear, the non-respect of the ban of fishing period, and ecological changes of the reservoir due to human activities.

A high contribution of *S. galilaeus* to the total species catch has been reported in the Samendeni Reservoir by **Minoungou *et al.* (2020)**. However, since the Samendeni Reservoir was opened for exploitation by 2018, no information on *Sarotherodon galilaeus* population parameters and its stock status have been reported. Due to the non-respect of the ban fishing period June and July every year in this reservoir and the use of prohibited mesh size by some fishermen, this species is regularly exploited and could be overexploited. Thus, this situation could negatively impact their stock leading to poor fishery conditions. Therefore, assessing the population dynamics of *Sarotherodon galilaeus* is imperative to ensure fishery management in this reservoir. Thus, the main objective of this study was to estimate the population parameters of *Sarotherodon galilaeus*, including growth rate, mortality, size at first maturity, recruitment pattern, length at first capture, and stock status, using length frequency distribution data from Samendéni Reservoir.

MATERIALS AND METHODS

Study area

Samendéni Reservoir is located in the West Sudanian savannah in the region of Hauts- Bassins, Burkina Faso, and it is built on the Mouhoun River (Fig. 1). The location is between latitudes 11˚23' and 11˚19' North and longitudes 4˚34' and 4˚46' West. It ranks as the third largest reservoir in the country. This reservoir also includes catchment area and an irrigated perimeter of 21,000 hectares with a total capacity of 1.05 billion m^3. The Samendéni Reservoir area is approximatively 68,202 hectares and has a tropical savanna climate with air temperature ranging from 23.50 to 31.30℃ **(Kabré *et al*., 2023)**. Meanwhile, the mean annual rainfall was 1075.86mm from 2010 to 2020 **(Kabré *et al*., 2023)**. The Samendeni Reservoir area is characterized by two seasons: a rainy season from June to September and a dry season from October to May. The vegetation is a mix of wooded savannah, forest, and a dense semi-deciduous gallery forest. Since October 2020, the Samendéni Reservoir has been labeled as Ramsar site (number 2439) in Burkina Faso.

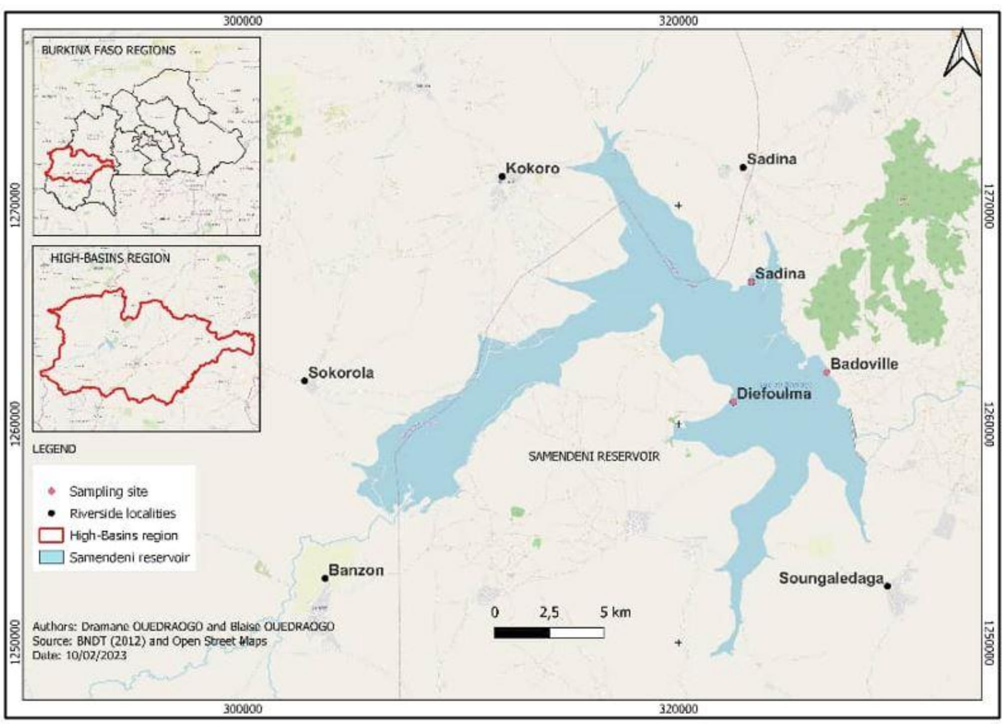

Fig. 1. Map of Samendéni Reservoir displaying the sampling areas

Data collection

Fish were randomly collected during October 2021 to September 2022 from fishermen at three sampling sites: Dioufoulma, Badoville, and Sadina in the Samendéni Reservoir. A total of 1714 specimens were sampled and sexed, and their species were identified using the relevant taxonomic keys by **Paugy *et al.* (2003)**. After sampling, all specimens were conserved in ice and transferred to the fish laboratory at Nazi Boni University for further analysis. In the laboratory, the total length (TL) of each specimen was measured from the tip of the mouth to the extended tip of the caudal fin using a fish-measuring board. A digital balance was used to measure the weight (W) of each fish to the nearest 0.1g.

Length frequency distribution and sex ratio

A histogram was used to examine the distribution of *S. galilaeus* individuals based on their total length (TL), with the length data frequency pooled at 2cm intervals. The sex ratio was computed using the following formula: sex ratio = total number of males/total number of females **(Sossoukpe *et al*., 2013)**. The chi-square test was used to check if there were statistically significant deviations from the expected 1:1 sex ratio or not **(Sokal, 1987)**.

Length-weight relationship

The relationship between length and weight was described by the equation $W = aTL^b$ **(Ricker, 1975)**. Here, W represents the total weight (g); TL is the total length (cm), and "a" and "b" are respectively the intercept and slope of the regression line of length and weight for the fish. The slope "b" was compared to 3 using student t-test to test whether *Sarotherodon galilaeus* individuals have an isometric growth in the Samendéni Reservoir. Thus, "t" value was calculated as follows: $t = |b - 3|/S_b$, where S_b is the standard error of the slope b. The t-value was compared to the t-table value for (n-2) the degree of freedom at 5% significant level **(Awasthi *et al*., 2015)**. In fact, if b=3, b<3 and b>3, it corresponds respectively to an isometric growth, negative allometric growth and positive allometric growth **(Ricker, 1975)**.

Estimation of growth parameters

Monthly collected data from October 2021 to September 2022 were analyzed using the ELEFAN I routine incorporated in FISAT software **(Gayanilo & Pauly, 1997)**. Thus, the growth of *S. galilaeus* in Samendéni Reservoir was estimated following the von Bertalanffy function (VBGF): $Lt = L_\infty (1 - e^{-K(t-t_0)})$ **(Pauly, 1979)**, with L_t,: the fish size at a specific time t, L_{∞}: asymptotic length of the fish, K growth coefficient represents the rate at which a fish attains its maximum size, t: the age of the fish, t_0: the age at which the fish length is null.

To determine t_0, the theorical age at length zero, the Pauly's empirical equation **(Pauly, 1979)** was used: $Log_{10}(-t_0) = -0.392 - 0.275 Log_{10}L_\infty - 1.038Log_{10} K$
The life-span of fish (t_{max}) was also estimated as: $t_{max} = (3/K)$ **(Taylor, 1958)**. The growth of *S. galilaeus* from Samendéni Reservoir was compared to those from previous studies by calculating the growth performance (Ø'). Thus, the growth performance Ø' was computed using asymptotic length L_∞ and growth coefficient (K) **(Munro and Pauly, 1983)**: $Ø' = Log_{10} K + 2Log_{10}L_\infty$.

Length at first sexual maturity (Lm_{50})

The size at first sexual maturity (Lm_{50}) is considered to be the size at which 50% of *S. galilaeus* individuals were mature. This size was determined during the spawning season. Gonad and oocyte maturation stages were identified following the method described by **Brown-Peterson *et al.* (2011)**. Thus, individuals at stage 1 were immature and individuals from stage 2 to 5 were mature. The data were divided into several size groups, and the percentage of mature individuals in each category was computed using logistic regression: $P = 1/ (1 + exp[-(a+bL_t)]$ with P: percentage of mature individuals, L_t: total length, a and b are the parameters of the logistic equation. The formula was transformed as follows: $ln[P/(1-P)] = a+bL_t$. Thus, by the substitution of P = 50% in the equation, $Lm_{50} = -a/b$.

Age at first sexual maturity was determined using the von Bertalanffy equation after obtaining the size at first maturity (Lm_{50}).

Estimation of mortality rate, exploitation rate, and length at first capture (Lc_{50})

A linearized length-converted curve approach was used to calculate the total mortality rate **(Pauly, 1984; Gayanilo *et al*., 2005)**. Moreover, the empirical equation was used to calculate the instantaneous natural mortality rate (M) (**Pauly, 1980)**, as follows:
$Log_{10} M = -0.0066 - 0.279*log_{10}L_\infty + 0.6543 log_{10}K + 0.463 log_{10}T$, where T = mean surface temperature (29.7℃ in this study).

The instantaneous fishing mortality rate (F) was estimated as: F = Z - M **(Beverton & Holt, 1957)**, with Z: total mortality, and M: natural mortality, moreover the exploitation ratio (E) **(Gulland, 1971)** was estimated as E = F/Z. The probability of capture was calculated by extrapolating the descending limb of the length-converted curve, and a selectivity curve was designed by applying linear regression to the ascending data points derived from a plot illustrating the relationship between the probability of capture and length. These values were then used to determine the lengths at which capture probabilities of 50, 75, and 95% occurred **(Pauly, 1987)**.

Virtual population analysis (VPA)

The method of **Jones and Zalinge (1981)** using a length convers curve procedure was used to carry out the virtual population analysis. The two constants "a" and "b" from the length weight relationship of *S. galilaeus* and the K, L_∞, M and F values of this species were used as inputs for virtual population analysis. Biomass (tons), yield (tons), total and fishing mortality, and exploitation ratio were considered as the results of this VPA analysis.

Recruitment pattern, relative yield per recruit (Y/R) and biomass per recruit (B/R)

The relative yield per recruit (Y'/R) of *S. galilaeus* was assessed using the model of **Beverton and Holt (1966)**, as follows: $Y'/R = EU^{M/K}\left[\frac{1-(3U)}{(1+m)} + \frac{(3U^2)}{(1+2m)} - \frac{(U^3)}{(1+3m)}\right]$

Where, E = F/Z exploitation rate, U = 1- (L_c /L_∞) with L_c: length at first capture, and m = (1- E)/(M/K) = (K/Z).

Using the relationship B'/R = (Y'/R)/F, biomass per recruit (B'/R) was calculated. Emax, E_{10}, and E_{50} were estimated using the first derivation of this function. E_{max} is the exploitation level, which maximizes Y/R or Y'/R; E_{10} corresponds to the exploitation level at 10% of the virgin biomass, and E_{50} is the exploitation level at 50% of the virgin biomass. The recruitment patterns were computed following the method described in the FISAT routine **(Pauly *et al*., 1996)**.

RESULTS

Length frequency distribution and sex ratio

A total of 1714 individuals of *S. galilaeus* were collected: 1340 males and 374 females (Table 1). The *S. galilaeus* population size distribution was unimodal (Fig. 2), with a modal class at [17;19[cm. There were significantly more male specimens than female specimens.

Table 1. Mean total length (TL), mean total weight (W), number of individuals (N) and sex ratio (S-R) of *S. galilaeus*

Sex	N (S-R)	Mean TL (cm) (range)	Mean W (g) (range)
Males	1340	19.6271 ± 0.10282 (9.5 - 31)	161.5832 ± 2.7008 (14 - 595)
Females	374	19.834 ± 0.2214 (9 - 32)	173.7299 ± 5.5398 (12 - 571)
Males + Females	1714 (3.582:1)	19.6721 ± 0.09377 (9 - 32)	164.2321 ± 2.4352 (12 - 595)

No significant difference was observed between the mean total lengths of males and females (t-test, d.f = 544.217, t = -0.846, $P>0.05$). However, comparatively to males, the mean body weight of females was significantly higher (t-test, *d.f* = 562.542, t = -1.971, $P<0.05$).

The sex ratio was represented by 3.582:1 (male: female). The chi square test analysis for all specimens revealed that there is a significant difference between the two sexes ($\chi^2 = 294.47$, *d.f* = 1, $P<0.05$).

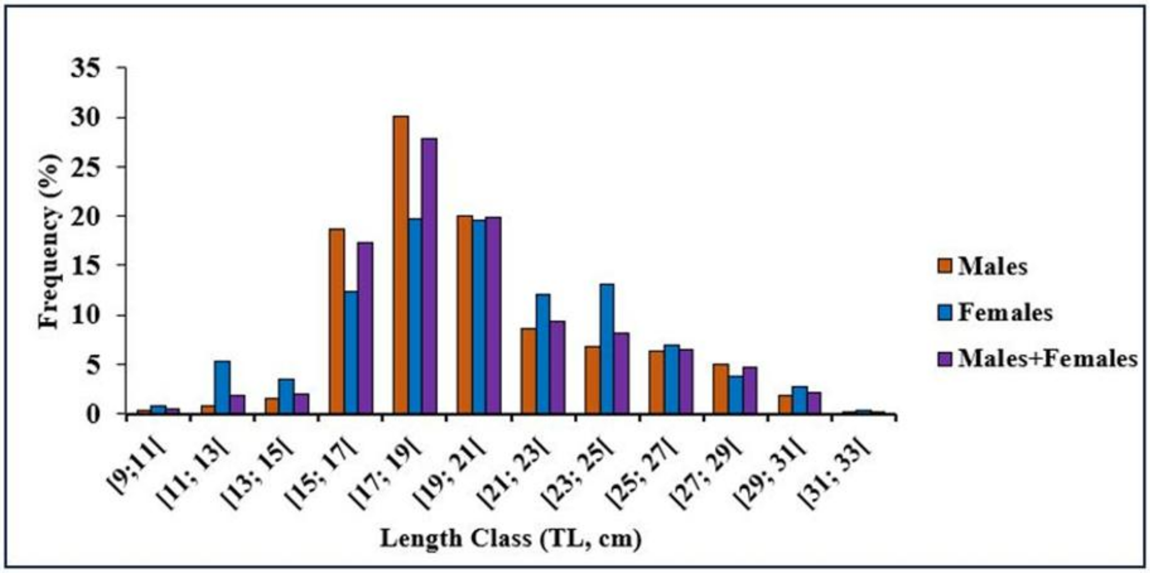

Fig. 2. Population structure of *S. galilaeus*

Length-weight relationship

The results of the length-weight relationship of *S. galilaeus* males, females, and combined sexes are displayed in Table (2) and Figs. (3, 4, 5).

Table 2. Length-weight relationship parameters of *S. galilaeus*

Sex	Effective	Total length TL (cm)	Total weight (g)	Equation	r^2
Males	1340	9.5 - 31	14 - 595	$W = 0.0325TL^{2.825}$	0.9513
Females	374	9 - 32	12 - 571	$W = 0.028TL^{2.88}$	0.962
Males +Females	1714	9 - 32	12 - 595	$W= 0.0311TL^{2.8414}$	0.9483

In this relationship, a significant difference was observed between males and females (t-test, d.f = 1710, t = 3.559, $P<0.05$). The total length and total body weight were positively correlated since the value of the pearson correlation coefficient was close to 1. The slope b was compared to 3 for males (t-test, d. f. = 1338, t = 0.245, $P>0.05$), females (t-test, d. f. = 372, t = 0.092, $P>0.05$), and pooled samples (t-test, d. f. = 1712, t = 0.253, $P>0.05$) indicated that b was not significantly different from 3 ($P>0.05$). Therefore, *S.*

galilaeus showed an isometric growth for both males, females, and combined sexes (Table 2).

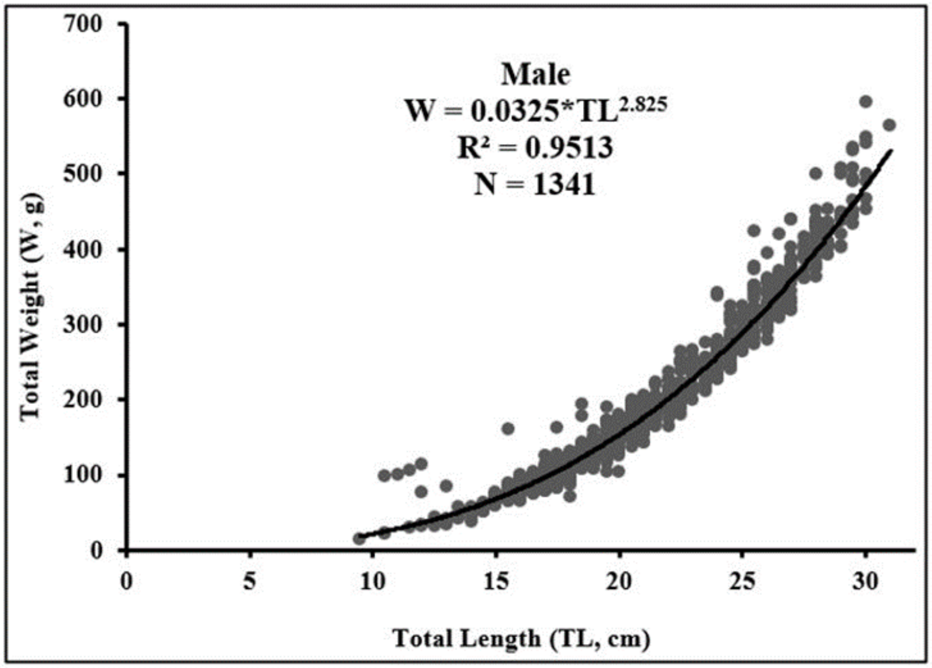

Fig. 3. Length-weight relationship of males of *S. galilaeus*

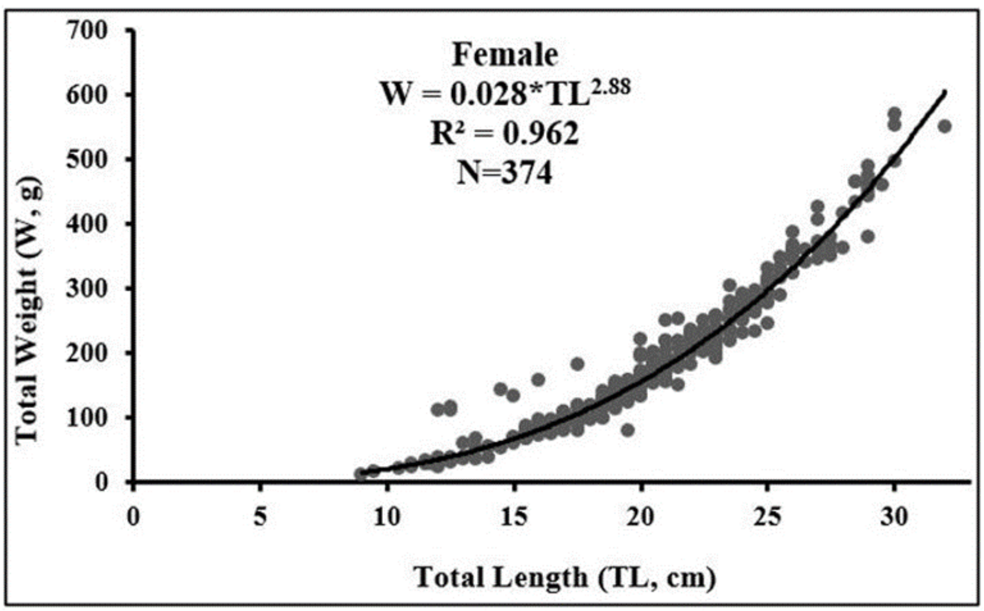

Fig. 4. Length-weight relationship of females of *S. galilaeus*

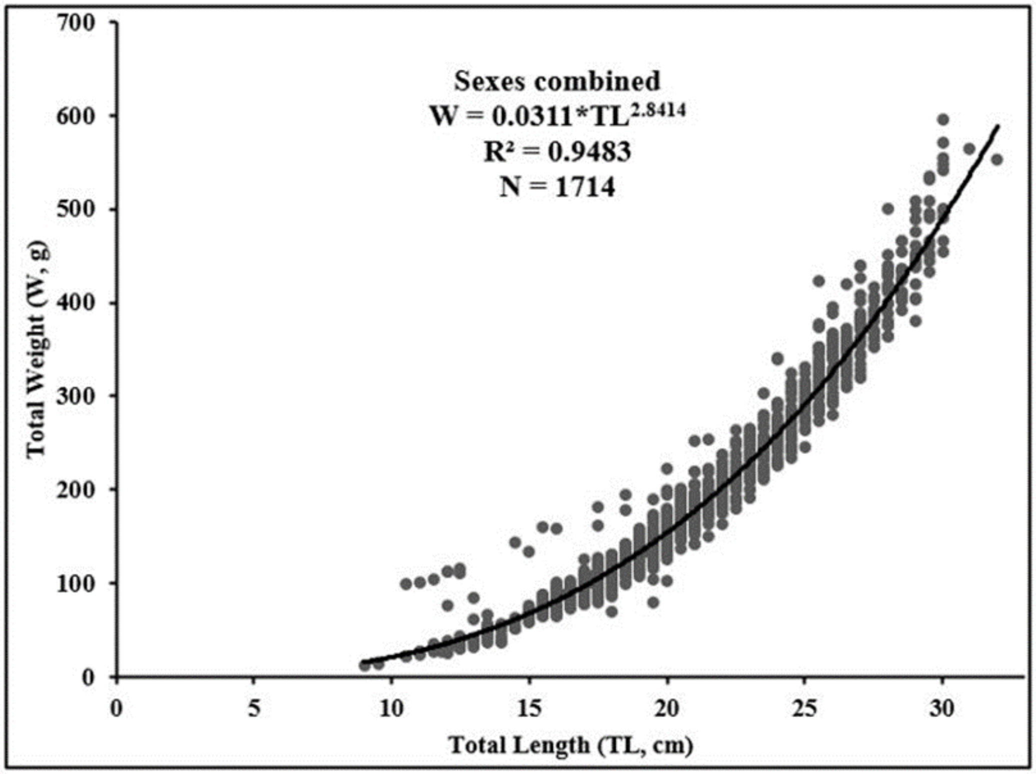

Fig. 5. Length-weight relationship of *S. galilaeus*

Growth parameters

The current results revealed an asymptotic length, growth rate and life-span of 33.6cm, 0.37 year^{-1}, and 8.10 years, respectively (Figs. 6, 7). Thus, the von Bertalanffy equation of *S. galilaeus* obtained from these parameters is written as follows:

$L_t = 33.6[1 – e^{-0.37(t+0.6952)}]$.

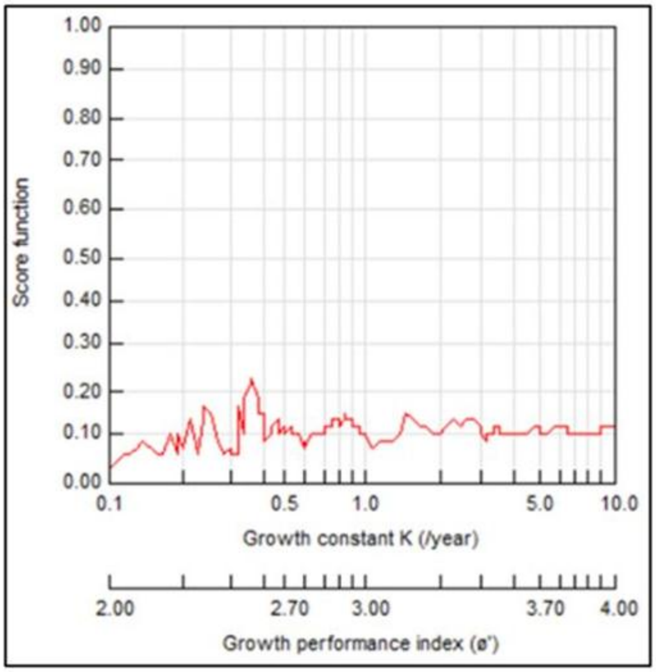

Fig. 6. ELEFAN I K-scan routine FiSAT II output for *S. galilaeus* from Samendéni Reservoir

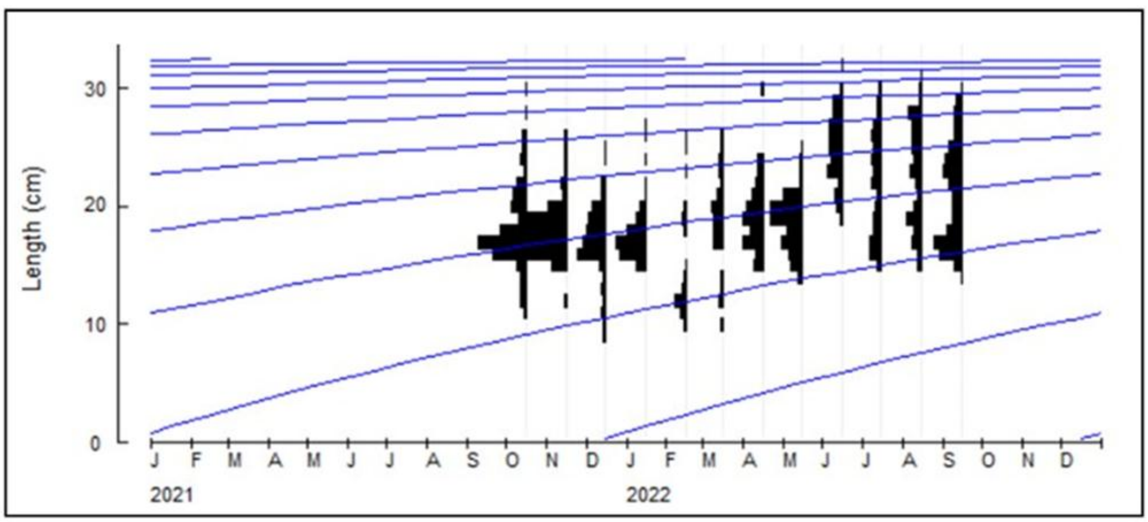

Fig. 7. Length frequency distribution output from FiSAT II with growth curve for *S. galilaeus* from Samendéni Reservoir

Furthermore, the growth performance index, the age at length zero, and the age at first sexual maturity were 2.621, -0.6952 year, and 1.4550 year, respectively (Table 3).

Table 3. Growth parameters (L_∞ and K), mortality (Z, M, F) and fishery parameters (E, L_c) of *S. galilaeus* in the Samandeni Reservoir

Description of parameters	Value
Growth and reproduction	
Asymptotic length (L_∞)	33.6 cm
Growth rate (K)	0.37 $year^{-1}$
Life-span (t_{max})	8.10 years
Growth performance index (Ø')	2.621
Age at length zero (t_0)	-0.6952 year
Mortality parameters	
Total mortality (Z)	1.59 $year^{-1}$
Natural mortality (M)	0.93 $year^{-1}$
Fishing mortality (F)	0.66 $year^{-1}$
Fishery parameters	
Exploitation ratio (E)	0.25
E_{max}	0.649
$E_{0.1}$	0.515
$E_{0.5}$	0.328
Total length at first capture L_c	16.21 cm TL

The length at first capture (L_c or $L_{50\%}$) was estimated at 16.21cm, which corresponds to an age of 1.275 year (Fig. 8).

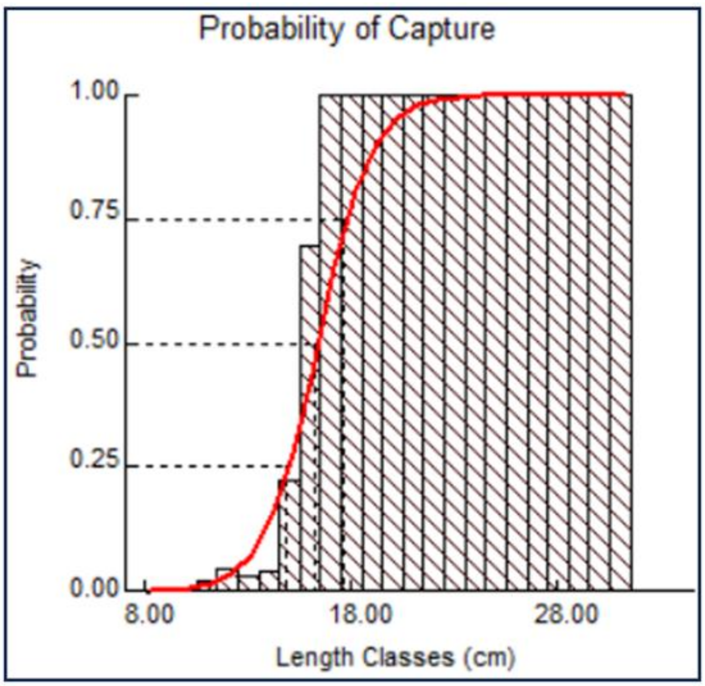

Fig. 8. Probability of capture of *S. galilaeus*

Size at first maturity

The *S. galilaeus* males and females are sexually mature at 18.717 and 18.103cm, respectively (Fig. 9). At maturity, there was no significant difference in size between males and females (t-test, d.f = 56, t = 0.054, $P>0.05$). Furthermore, the age at first maturity (tm_{50}) was 1.346 and 1.397 year for males and females, respectively.

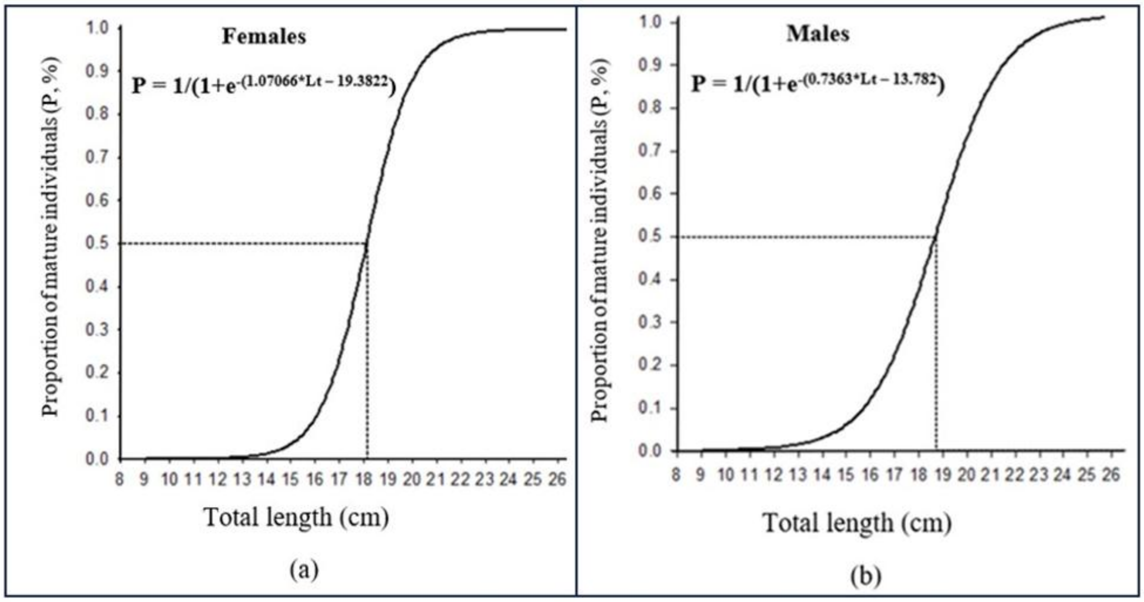

Fig. 9. Estimated size at first maturity for females (a) and males (b) of *Sarotherodon galilaeus* from Samendeni Reservoir

Recruitment pattern

Only one normal recruitment was observed per year in the Samendeni Reservoir for *S. galilaeus.* Furthermore, the main peak was observed from May to June (Fig. 10). The peak pulse produced 33.22% of the observed recruitment during the study period.

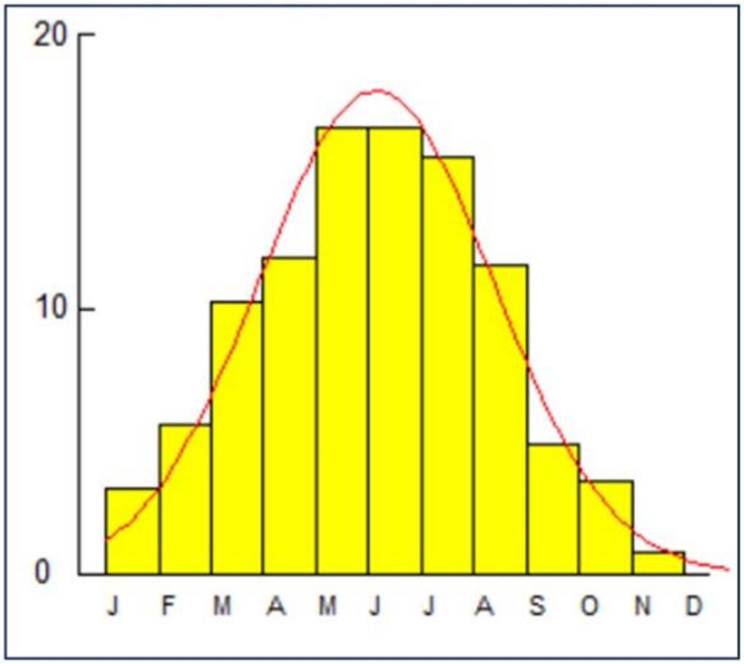

Fig. 10. Recruitment pattern output from FiSAT II for *S. galilaeus* from Samendéni Reservoir

From the length-converted catch curve, the total mortality (Z) was reported as 1.24 $year^{-1}$ (Fig. 11). Furthermore, the values obtained for fishing mortality (F) and natural mortality (M) were 0.31 and 0.93 $year^{-1}$, respectively.

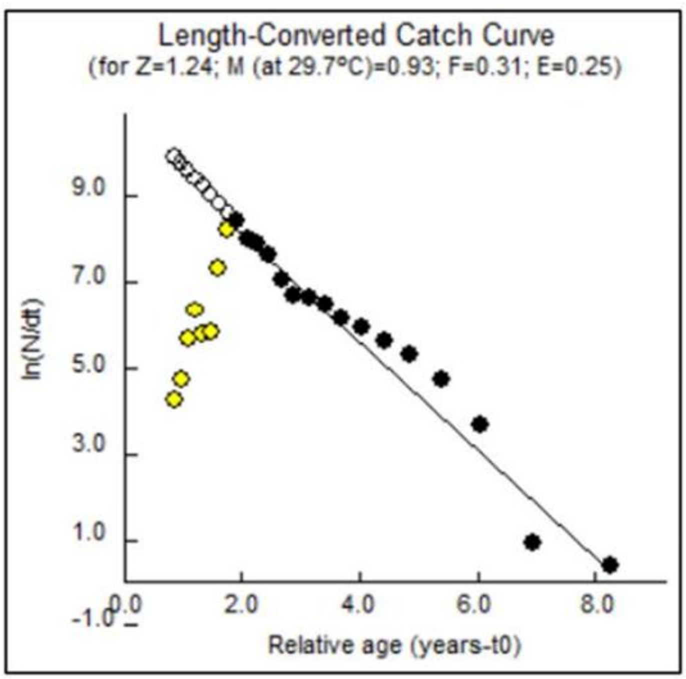

Fig. 11. Length-converted catch curve of *S. galilaeus* in the Samandéni Reservoir, Burkina Faso

The exploitation ratio (E) of 0.25 was lower than the maximum exploitation ratio (Emax) of 0.649 showing that the species *S. galilaeus* was not overexploited (Fig. 12).

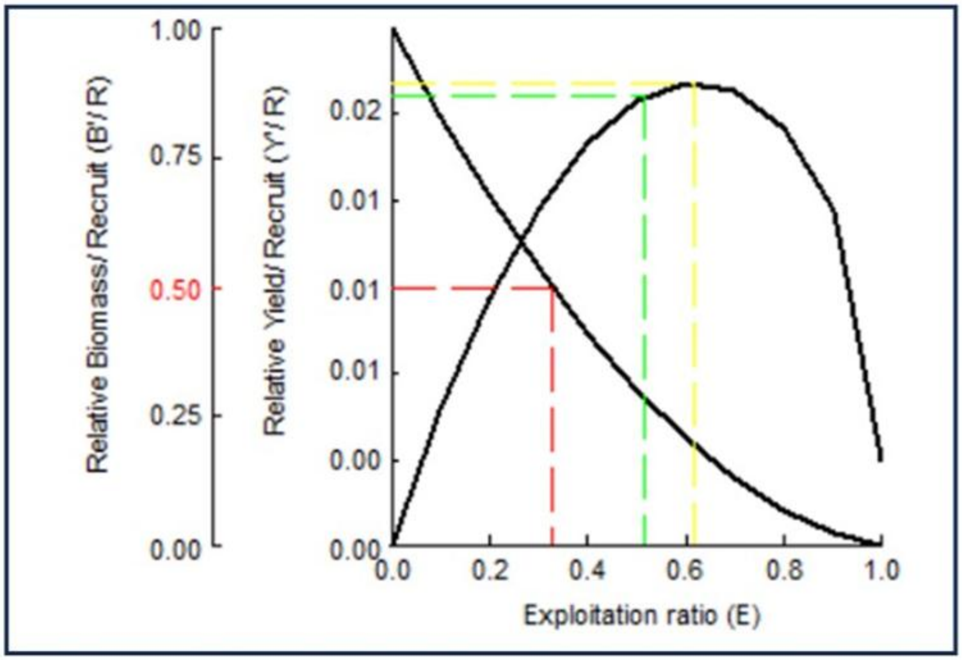

Fig. 12. Relative yield per recruit and biomass per recruit analyses for *S. galilaeus* from Samendéni Reservoir: MSY = Maximum sustainable yield

Virtual population analysis (VPA), yield-per-recruit and biomass-per-recruit

Natural causes were considered as the main reason for the mortality of *S. galilaeus* within the length range of 9- 15cm (Fig. 13 & Table 4). However, from 16cm, the fish were vulnerable to fishing gear.

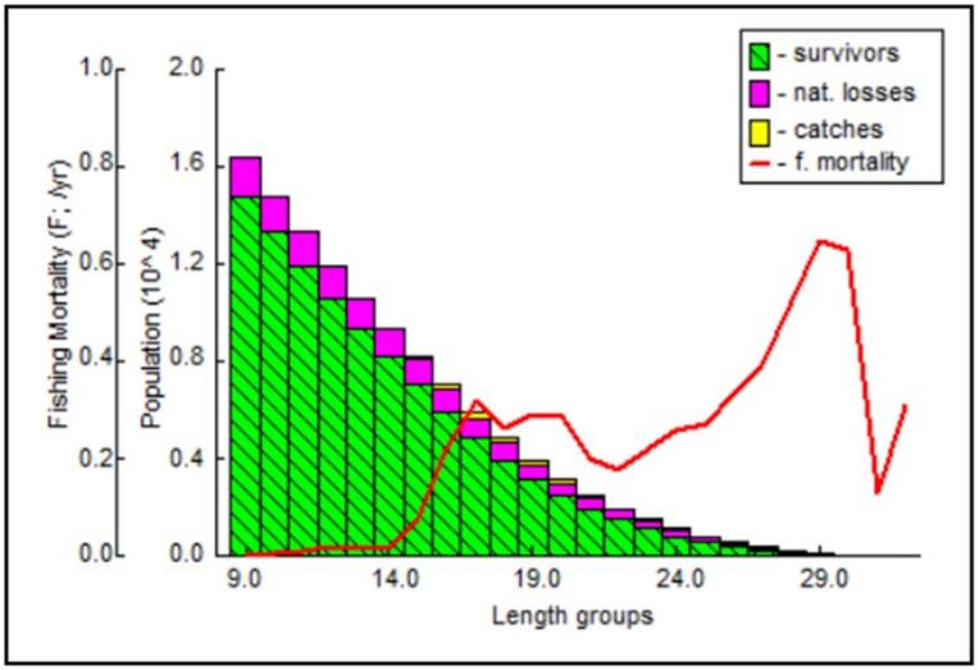

Fig. 13. Length-structured virtual population analysis of *S. galilaeus* from Samendeni Reservoir

From the length range of 16 to 20cm, fishing mortality was recorded the highest; therefore, this length group was considered the most vulnerable to fishing gear. At fish size of 9cm, there were more survivors (16391.62), whereas at size 32cm, the number of survivors was the lowest (4). The highest level of fishing mortality (F = 0.3205) was recorded at a fish size of 17cm. A variation of the steady-state biomass was observed, increasing from 17 to 20cm which corresponds to 0.09 ton, then subsequently declining to 0.00 ton at a size of 32cm (Table 4). The estimated values of $E_{0.1}$, $E_{0.5}$ and E_{max} were 0.515, 0.328 and 0.649, respectively (Fig. 12). Moreover, the maximum sustainable yield E_{max} was higher than the exploitation rate.

Table 4. FiSAT II output of virtual population analysis of *S. galilaeus* in Samandeni Reservoir

Mid-length (Cm)	Catch (In numbers)	Population (N)	Fishing mortality (F)	Steady-state biomass (tons)
9	3	16391.62	0.0018	0.03
10	5	14796.46	0.0031	0.03
11	13	13296.64	0.0086	0.04
12	27	11884.58	0.0193	0.05
13	16	10553.37	0.0123	0.06
14	18	9325.89	0.0149	0.07
15	83	8186.34	0.0750	0.08
16	218	7073.83	0.2189	0.08

17	280	5929.46	0.3205	0.09
18	200	4836.91	0.2641	0.09
19	188	3932.69	0.2884	0.09
20	159	3138.35	0.2869	0.09
21	93	2463.93	0.1980	0.08
22	70	1934.15	0.1761	0.08
23	72	1495.5	0.2178	0.08
24	69	1115.07	0.2584	0.07
25	57	797.74	0.2728	0.06
26	52	546.41	0.3317	0.05
27	43	348.63	0.3893	0.04
28	37	202.9	0.5249	0.03
29	25	100.35	0.6492	0.02
30	30	11	0.6262	0.01
31	1	12.20	0.1292	0.00
32	1	4	0.31	0.00

DISCUSSION

Length frequency distribution and sex ratio

The length-frequency distribution of *S. galilaeus* in Samendéni Reservoir was unimodal, indicating that there was probably only one cohort in the population. Before the opening of the Samendéni Reservoir for exploitation, **Minoungou *et al*. (2020)** recorded a mean size of 17.71cm for this species, which was smaller comparatively to what recorded in this study for both males (19.6271cm) and females (19.834cm). However, the mean size and length range of this study was similar, respectively, to the mean of 19.8cm and size range of 13.6 to 33.2cm in Gougan Reservoir, Benin, as mentioned by **Ahouansou *et al*. (2016)**. The size range of *S. galilaeus* from Samendéni Reservoir measured 9 to 32cm. **Da *et al*. (2018)** recorded a range size of 9.4 to 38.1cm and 7.1 to 13.6cm, respectively, at Kompienga Reservoir and Bam Lake in Burkina Faso. In the Tropical coastal estuary in Nigeria, a range size of 11 to 41cm for *S. galilaeus* was reported by **Abdul *et al.* (2019)**. Another range size of 7 to 33.3cm for the same species was also observed in Weija Reservoir in Ghana **(Ebenezer, 2010)**. **Abdul *et al*. (2010)**, upon investigating the effect of Iken brushpark on the *S. galilaeus* in the Ogun estuary, Nigeria have also reported a size range of 22 to 34cm. The size variation of *S. galilaeus* could be due to the mesh sizes of the gears used by fishermen **(Abdul *et al*., 2019)**.

The sex ratio of *S. galilaeus* was different from the expected 1:1 ratio, and there were more male individuals comparatively to females during the study period. This result is in accordance with what was reported for the same species in Lake Rudolf in northern Kenyan **(Fryer, 1972)**, and Nguru-Gashua wetlands, Northeast, Nigeria **(Ashley-Dejo *et***

***al*., 2023)**. However, a preponderance of female to male was observed at Lita Lake in Nigeria **(Fagade *et al*. 1984)**, equally predominance of *S. galilaeus* was reported at Opa Reservoir, Nigeria **(Fawole *et al*., 2000**), and at Oyan dam in Nigeria **(Olopade *et al*., 2014)**. According to **Vicentini and Araujo (2003)**, information on sex ratio is necessary to better understand the interaction between individuals, environment, and state of the population. Many factors such as reproductive behavior, food availability, environmental conditions, adaptation of population may influence the variation of sex ratio **(Brykov *et al*., 2008; Vandeputte *et al*., 2012)**. For example, the accessibility of female to resources and the environmental conditions has an impact on the reproductive success of female. However, contrary to female, the access of male to female influences the reproductive success of male, which lead to a change in the proportion of individuals of each sex in the population **(Oliveira *et al*., 2012; Qiao *et al*., 2023)**.

Length-weight relationship

Male, female, and pooled samples exhibited an isometric growth pattern, indicating that the weight and length increased at the same rate **(Tesfaye *et al*., 2021)**. Generally, "b" values may range from 2.5 to 3.5, respectively, suggesting the validation of the result of this present study **(Pauly & Gayanilo, 1997)**. This result agrees with those of other studies on *S. galilaeus* by **Abdul *et al* (2019)** in Tropical coastal estuary of Nigeria (b= 2.846 for male and 2.826 for female), and **Makkey (2021)** at Lake Manzala in Egypt (b= 3.1025). However, it disagrees with the study of **Abdul *et al*. (2010)** at Freshwater ecotype of Ogun estuary in Nigeria (b= 2.755), **Mahmoud *et al*. (2013)** at Nozha Hydrodrome in Egypt (b= 2.8951), **Adedeji *et al*. (2016)** at Lake Geriyo in Nigeria (b=3.5 for male and b=3.2 for female), **Lederoun *et al*. (2016)**, respectively, at Lake Doukon (b= 2.955) and Lake Togbadji in Benin (b=3.0545), **Da *et al.* (2018)**, respectively, at Lake Bam (b= 2.41) and Kompienga Reservoir (b=3.08) in Burkina Faso, and **Minoungou *et al*. (2020)** at Samendéni Reservoir in Burkina Faso (b= 3.15). The isometric growth pattern exhibited by *S. galilaeus* males and females in the Samendéni Reservoir may be attributed to the abundant food sources and favorable habitats **(Abdul *et al*., 2019)**.

Growth parameters

The asymptotic length obtained in this study is greater than the results from some authors such as **Moreau *et al.* (1986)**, respectively, at Lake Chad (TL_∞= 29.9cm), at Lake Chari Lagone in Tchad (TL_∞= 27.2cm), at Noussa Hydrodrome (TL_∞= 24.2cm), and at lake Manzala (TL_∞=20.1cm), **Yamaguchi *et al.* (1990)** at the High Dam Lake in Egypt (TL_∞=28.8cm), **Moreau *et al*. (1995)** at Senegal River (TL_∞= 30.1cm), **Baijot *et al*. (1997)** at Lake Ramitinga in Burkina Faso (TL_∞= 19.3cm), at Tapoa Reservoir (TL_∞= 24cm) and Loumbila Reservoir (TL_∞= 14.7cm), **Lederoun *et al.* (2016)**, respectively, at Lake Doukon (TL_∞= 26.2cm) and Lake Togbadji (TL_∞= 23.6cm), **Abobi *et al.* (2019)**, respectively, at Bontanga Reservoir (TL_∞= 17.8cm), Tono Reservoir (TL_∞= 17.8cm) and Golinga Reservoir (TL_∞=17.8 cm), and **Makkey (2021)** at Lake Manzala (TL_∞= 28.06cm). However, it was lower than those reported by **Moreau *et al.* (1986)** at Lake Kainji in Nigeria (TL_∞= 48.4cm), and Lake Nasser in Egypt (TL_∞=41 cm), **Baijot *et al*. (1997)** at Sourou Reservoir in Burkina Faso (TL_∞= 35.5), **El-Gammal and Mehanna (2003)** at Wadi El-Raiyan Lake (TL_∞= 46.64), **Du Feu (2003)** at Lake Kainji in Nigeria (TL_∞ = 45.7cm), **Ofori-Danson *et al.* (2008)** at Bontanga Reservoir (TL_∞= 36.76cm), **Mahmoud *et al.* (2013)** at Nozha Hydrodrome in Egypt (TL = 37.39cm). The lower and higher values of asymptotic length could be ascribed to some factors, such as the selectivity of the gears, the sampling methods and geographical locations, the stress of water pollution and the climatic variations **(Mansour, 2004; Wehye *et al.*, 2017; Amponsah *et al.*, 2020)**. According to **Edmond *et al* (2017)**, fish grow throughout all life, and the growth of fish can be traced back to the interaction among some factors such as endogen and exogenous factors consisting of temperature, dissolved oxygen, food availability, inter or intraspecific competition.

The growth rate (K= 0.37 $year^{-1}$) obtained from this present study is higher than the growth constant recorded in some previous studies on *S. galilaeus* by **Moreau *et al.* (1986)** with K= 0.34, 0.29 $year^{-1}$, respectively, at lake Tchad and Lake Nasser, **Baijot and Moreau (1997)** at Sourou Reservoir in Burkina Faso (K= 0.17 $year^{-1}$), **El-Gammal and Mehanna (2003)** at Wadi El-Raiyan Lake (K= 0.29 $year^{-1}$), **Offori-Danson *et al.* (2008)** at Bontanga Reservoir in Ghana (K= 0.26 $year^{-1}$), and **Mahmoud *et al.* (2013)** at Nozha Hydrodrome in Egypt (K= 0.207 $year^{-1}$). However, the growth coefficient value was inferior to the K value reported by **Moreau *et al*. (1986)** at Chari Lagone in Chad (K= 0.66 $year^{-1}$), at Noussa Hydrodrome (K= 0.98 $year^{-1}$) and Lake Manzala in Egypt (K= 0.53 $year^{-1}$), respectively, **Yamaguchi *et al.* (1990)** at the High Dam Lake in Egypt (K= 0.53 $year^{-1}$), **Moreau *et al.* (1995)** at the Senegal River in Senegal (K= 0.51 $year^{-1}$), **Baijot and Moreau (1997)** at Loumbila Reservoir (K= 1.11 $year^{-1}$), Tapoa Reservoir (K= 0.47 $year^{-1}$), and Lake Ramitinga in Burkina Faso (K= 0.64 $year^{-1}$), respectively, **Du Feu (2003)** at Lake Kainji in Nigeria (K= 0.47 $year^{-1}$), **Lederoun *et al.* (2016)** at Lake Doukon (K= 0.73 $year^{-1}$) and Lake Togbadji in Benin (K= 0.87 $year^{-1}$), respectively, **Abobi *et al*. (2019)** at Bontanga Reservoir (K= 0.79 $year^{-1}$), at Tono Reservoir (K= 0.79 $year^{-1}$) and Golinga Reservoir in Ghana (K= 0.79 $year^{-1}$), respectively, and **Makkey (2021)** at Lake Manzala in Egypt (K= 0.45 $year^{-1}$). This difference in growth rate might be caused by the variations in geographical regions, data-processing approaches, and size classes **(Amponsah *et al.*, 2016)**. According to **Wehye *et al*. (2017)** and **Amponsah *et al*. (2020)**, the growth rate K= 0.37 $year^{-1}$ ranged between 0.34 and 0.67 $year^{-1}$, which suggests that *S. galilaeus* could be considered as an intermediate growing fish species, supported by its lifespan of 8.10 years.

Baijot *et al*. (1997) recorded a growth performance of 2.34 at Sourou Reservoir, 2.43 at Tapoa Reservoir, 2.46 at Petit Bale, 2.38 at Loumbila Reservoir, and 2.13 at Ramitenga lake in Burkina Faso, respectively. Growth performance index value of 2.70 was observed at Lake Doukon and 2.68 at Lake Togbadji in Benin by **Lederoun *et al* (2016)**, 2.4 at Golinga, Tono and Bontanga Reservoirs in Ghana by **Abobi *et al*. (2019)**, and 2.462 at Noza Hydrodrome in Egypt by **Mahmoud *et al*. (2013)**. In others water bodies in Africa, a growth performance index Ø' between 2.33 to 3.04 was also reported by **Baijot *et al.* (1997)** for *S. galilaeus*, indicating a low growth performance **(Amponsah *et al*., 2020)**. The growth performance index Ø' value of 2.621 in this present study seems to be close to what was reported in the study of **Baijot *et al*. (1997)**. Thus, *S. galilaeus* could be considered as showing a low growth performance. The low growth performance seems to be induced by some ecological factors, such as low oxygen contents, extreme pH values, high turbidity, food unavailability, fluctuation in water level & reproductive activity **(Baijot *et al.*, 1997; Jimenez-Badillo, 2006; Amponsah *et al*. 2020)**.

Mortality rates (Z, M, F), exploitation rate, and length at first capture

The assessment of the mortality rate provides valuable information regarding the abundance of a fish stock, which aids in establishing catch limits that maximize benefits for all parties involved with the resource **(Sabbir *et al*., 2021)**. The total mortality in this current study (Z= 1.24 year^{-1}) is higher than that reported by **El-Gammal and Mehanna (2003)** at Wadi El-Raiyan Lake (Z= 0.8 year$^{- 1}$), and **Mahmoud *et al.* (2013)** at Nozha Hydrodrome, Egypt (Z= 0.825 year$^{- 1}$). However, this value is somewhat lower than that estimated for the same species by **Ofori-Danson *et al.* (2008)** at Bontanga Reservoir, Ghana (Z= 1.36 year^{-1}), **Lederoun *et al.* (2016)** at Lake Doukon, Benin (Z= 1.76 year^{-1}) and Lake Togbadji, Benin (Z =2.21 year^{-1}), **Abobi *et al.* (2019)** at Bontanga Reservoir, Ghana (Z= 2.66 year^{-1}) and Golinga Reservoir, Ghana (Z= 2.05 year^{-1}), and **Makkey (2021)** at the Manzala Lake, Egypt (Z= 3.28 year^{-1}). The variation of total mortality could be due to the methods used to estimate the mortality parameters, environmental conditions or the pressure of fishing activities **(Joksimovic *et al*., 2009; Amponsah *et al*., 2016)**.

The natural mortality rate of *S. galilaeus* (M= 0.93 year^{-1}) is higher compared to the values reported for the same species by **El-Gammal and Mehanna (2003)** at Wadi El-Raiyan Lake (M= 0.13 year$^{- 1}$), **El - Bokhty (2006)** at Lake Manzalah, Egypt (M= 0.71year^{-1}), **Kwarfo-Apegyah *et al.* (2009)** at Bontanga Reservoir, Ghana (M= 0.7 year^{-1}), **Mahmoud *et al.* (2013)** at Nozha Hydrodrome, Egypt (M= 0.519 year$^{- 1}$), and **Makkey (2021)** at the Manzala Lake, Egypt (M= 0.56 year^{-1}). Moreover, it is lower than the estimates reported for the same species by **Lederoun *et al*. (2019)** at Lake Doukon, Benin (M= 1.51 year$^{- 1}$) and Lake Togbadji, Benin (M= 1.74year$^{- 1}$), as well as **Abobi *et al.* (2019)** at Bontanga Reservoir, Ghana (M= 1.32 year $^{-1}$), Golinga Reservoir, Ghana (M= 1.32 year $^{-1}$) and Tono Reservoir, Ghana (M=1.32 year^{-1}).

If Z/ K ratio< 1, this indicates the predominance of growth over mortality in the population. However, if Z/ K>1, the growth is predominated by the mortality, and if Z/ K =1, an equilibrium exists between mortality and growth **(Barry, 1989)**. In this current study, Z/ K ratio was 3.35, therefore, a predomination of mortality over growth for *S. galilaeus* exists in this reservoir. According to **Pauly and Munro (1984)**, if the L_c/ L_∞ ratio is lower than 0.5, a high percentage of juveniles should be observed in the catchment composition. In our study, L_c/ L_∞ ratio recorded was 0.381. Thus, the majority of individuals in the catchment were characterized by a small size. According to **Etim and Brey (1994**), if there are no recruits from upstream, and the age at first maturity (tm_{50}) is more than one year, the stock might decline in the near future. In this study, the age at first maturity (tm_{50}) for both males and females was 1.397 and 1.346 years, respectively, which is slightly over a year, indicating the necessity to implement an appropriate management strategy to avoid a fish stock collapse. Comparatively to the fishing mortality rate (F= 0.31 $year^{-1}$), the natural mortality rate (M= 0.93 $year^{-1}$) of *S. galilaeus* was higher in Samendéni Reservoir. This suggests that natural mortality is the primary cause of *S. galilaeus* loss in Samendéni Reservoir, rather than fishing-induced mortality. These results also suggested an under-exploitation of *S. galilaeus*. This natural mortality could be attributed to the large proportion of juvenile individuals in this population. Small-sized individuals are more vulnerable to natural mortality caused by factors, such as high temperatures, predators, and climatic variations **(Amponsah *et al.*, 2020)**.

The exploitation rate of 0.25 in this study is lower than the optimal exploitation rate of 0.5 **(Pauly & Munro, 1984)**, suggesting that the stock of *S. galilaeus* in Samendéni Reservoir is currently underexploited.

Size at maturity

No significant difference was observed between the size at first sexual maturity (Lm_{50}) of *S. galilaeus* males (18.103cm) and females (18.717cm). **Ahouansou *et al.* (2016)** reported almost a same maturity size of 19cm for the same species at Gougan Reservoir of Kogbetohoue in Benin. However, **Lederoun *et al.* (2016)** reported in lakes Togbadji and Doukon that the sizes of males and females were 12.8 and 13.2cm, and 12.4 cm and 11.5cm, respectively. Additionally, no significant differences in sexual maturity were observed in both lakes and genders **(Lederoun *et al.*, 2016)**. Lm_{50} is essential for fishery management since it provides the means to avoid exploitation of young specimens and preserves the spawning stock **(Penha & Mateus, 2007)**. Thus, a mesh size which let the capture of fish with a minimum total length of 19cm may be necessary in Samendéni Reservoir. This precautionary measure will let the fish to spawn at least once before being captured by a gear.

Recruitment pattern

The period from May to June is a peak recruitment time for *S. galilaeus* in the Samendéni Reservoir and also occurs during the major spawning season for this species in the reservoir. In Burkina Faso, the period from May to August experiences higher rainfall during the rainy season, which corresponds to the main flooding period in the country. This period is characterized by more nutritional resources, which favor the recruitment of juveniles into the population. Our result is different from that of **Lederoun *et al*. (2016)** who reported a couple recruitment for *S. galilaeus*, respectively, in Lake Doukon and Lake Togbadji in Benin. According to **Pauly (1980)**, in tropical areas, fish species generally exhibit a couple recruitment pulses, which is contrary to our finding. This difference may be due to the fact that, there is only one rainy season in Burkina Faso contrary to some west African countries.

Virtual population analysis (VPA)

The main loss in the stock of *S. galilaeus* due to fishing was observed between fish size of 16 to 20cm corresponding to the size at which *S. galilaeus* is more vulnerable to fishing gear (L_c= 16.21cm). Additionally, at a size of 17cm, fishing mortality was the highest (F= 0.3205) and the length at sexual maturity for both males (18.717cm) and females (18.103cm) was greater than the current length at first capture (16.21cm) in the reservoir. This suggests that overfishing is occurring in the fishery, potentially due to the absence of a sufficient time period for young fish to mature and join the stock before being caught by current fishing gear **(Amponsah *et al*., 2016)**. As a result, increasing the mesh size of fishing gear is necessary to capture only adult individuals for management purposes, and according to **Udoh and Ukpatu (2017)**, this will allow females to participate actively in mating activities and ensure resource availability and sustainability.

CONCLUSION

This study examines the growth parameters, mortality, recruitment, exploitation rate of *Sarotherodon galilaeus* from Samendéni Reservoir, Burkina Faso. The population of this species is not overexploited. However, without strong action, the fish stock could collapse if the ban of illegal gear is not reinforced and the mesh size is increased to limit the catch of immature individuals. This action would be a great chance for *S. galilaeus* individuals for spawning at least once as the L_c and Lm_{50} are different. Otherwise, a breakdown might occur due to the lack of spawners,

REFERENCES

Abdul, W.O.; Omoniyi, T.; Akegbejo-Samsons, Y.; Agbon, A.A. and Idowu, A.A. (2010). Length-weight relationship and condition factor of cichlid, *Sarotherodon galilaeus*, in the freshwater ecotype of Ogun estuary, Ogun State, Nigeria. International Journal of Biological and Chemical Sciences, 4(4). https://doi.org/10.4314/ijbcs.v4i4.63052

Abdul, W.; Omoniyi, I.; Bashir, A.; Makinde, A.; Adekoya, E.; Owoade, T. and Oriyomi, J. (2019). Length Base Structure and Growth Parameters of *Sarotherodon galilaeus* (Pisces: Cichlidae) in Tropical Coastal Estuary, Nigeria. The Pacific Journal of Science and Technology, 20(1)**:** 289−297.

Abobi, S.M.; Mildenberger, T.K.; Kolding, J. and Wolff, M. (2019). Assessing the exploitation status of main fisheries resources in Ghana's reservoirs based on reconstructed catches and a length-based bootstrapping stock assessment method. Lake and Reservoir Management, 35(4): 415−434. https://doi.org/10.1080/10402381.2019.1616340

Adedeji, H.; Hyginus, M.; Idowu, T. and Sogbesan, O. (2016). Growth pattern and condition factor of *Oreochromis niloticus* and *Sarotherodon galilaeus* in Lake Geriyo, Adamawa State. International Journal of Life Sciences Research, 4(1): 97−99.

Ahouansou, M.S.; Lonhodé, J.; Akochéou, A.; Tokpanou, C.; Lédéroun, D. and Lalèyè, P. (2016). Détermination de maillage de filets pour une exploitation durable de *Sarotherodon galilaeus* à la retenue d'eau Gougan de Kogbétohoué au Bénin. Bulletin de la recherche agronomique du Bénin (BRAB), 85−92.

Amponsah, S.K.; Ofori-Danson, P.K. and Nunoo, F.K. (2016). Fishing regime, growth, mortality and exploitation rates of *Scomber Japonicus* (Houttuyn, 1782) from catches landed along the eastern coastline of Ghana.

Amponsah, K.S.; Asiedu, B. and Failler, P. (2020). Population parameters of *Oreochromis niloticus* (L) from a semi-open lagoon (Sakumo II), Ghana and its implications on management. Egyptian Journal of Aquatic Biology and Fisheries, 24(2): 195−207. https://dx.doi.org/10.21608/ejabf.2020.79778

Ashley-Dejo, S.S.; Abubakar, I.O.M.; Sabo, M.; Musa, M.A. and Ijabo, O.S. (2023). Length-weight relationship and condition factors of Sarotherodon galilaeus (Linnaeus, 1758) from Nguru-Gashua Wetlands, Northeast Nigeria. Jurnal Perikanan Universitas Gadjah Mada, 25 (1): 51−56. https://doi.org/10.22146/jfs.77207

Awasthi, M.; Kashyap, A. and Serajuddin, M. (2015). Length-weight relationship and condition factor of five sub-populations of *Trichogaster lalius* (Osphronemidae) of central and eastern regions of India Journal of Ichthyology, 55: 849−853. https://doi.org/10.1134/S0032945215060028

Baijot, E.; Moreau, J. and Bouda, S. (1997). Hydrobiological aspects of fisheries in small reservoirs in the Sahel region. Technical Centre for Agricultural and Rural Cooperation, Wageningen, Netherlands, 243pp.

Barry, J.P. (1989). Inferring demographic processes from size-frequency distributions: simple models indicate specific patterns of growth and mortality. Fish. Bull., 88: 13−19.

Beverton, R.J.H. and Holt, S.J. (1957). On the dynamics of exploited fish population. Chapman and Hall, London, 537pp. https://doi.org/10.1007/978-94-011-2106-4

Beverton, R.J.H. and Holt, S.J. (1966). Manual of Methods for Fish Stock Assessment, Part 2. Tables of Yield Functions, Fisheries Technical Paper, (38): 7–29.

Brown-Peterson, N.J.; Wyanski, D.M.; Saborido-Rey, F.; Macewicz, B.J. and Lowerre-Barbieri, S.K. (2011). A standardized terminology for describing reproductive development in fishes. Marine and Coastal Fisheries, 3(1): 52−70. https://doi.org/10.1080/19425120.2011.555724

Brykov, V.A.; Kukhlevsky, A.D.; Shevlyakov, E.A.; Kinas, N.M. and Zavarina, L.O. (2008). Sex ratio control in pink salmon (*Oncorhynchus gorbuscha* and *chum salmon* (O. keta) populations: The possible causes and mechanisms of changes in the sex ratio. Russian Journal of Genetics, 44: 786−792. https://doi.org/10.1134/S1022795408070053

Cazorla, A.L. and Sidorkewicj, N. (2008). Age and growth of the largemouth perch *Percichthys colhuapiensis* in the Negro River, Argentine Patagonia. Fisheries Research, 92(2-3) : 169−179. https://doi.org/10.1016/j.fishres.2008.01.016

Compaoré, I.; Sourabie, C.I. and Sawadogo, S. (2023). Effects of fish meal replacement by maggot meal in diets for Nile Tilapia fingerling (*Oreochromis niloticus* Linnaeus, 1758) in Burkina Faso. International Journal of Fisheries and Aquatic Studies, 11(5): 32−38. https://doi.org/10.22271/fish.2023.v11.i5a.2847

Da, N.; Ouédraogo, R. and Ouéda, A. (2018). Relation poids-longueur et facteur de condition de *Clarias anguillaris* et *Sarotherodon galilaeus* pêchées dans le lac Bam et le réservoir de la Kompienga au Burkina Faso. International Journal of Biological and Chemical Sciences, 12(4): 1601−1610. https://doi.org/10.4314/ijbcs.v12i4.8

Da, N.; Ouedraogo, R. and Oueda, A. (2023). Growth, and Stock Status Assessment of African Catfish, *Clarias anguillaris* (Linnaeus, 1758) from Burkina Faso Newly Man-Made Lake Samandeni. Advances in Bioscience and Biotechnology, 14(7): 346−357. https://doi.org/10.4236/abb.2023.147022

Du Feu, T. (2003). Gaining a quick overview of the Lake Kainji Fishery, Nigeria: the use of length frequency data. Fish biodiversity: local studies as basis for global inferences. ACP-EU Fisheries Research Report, 14(281).

Ebenezer, D.E. (2010). Aspect of the Biology of the Nile Tilapia *(Oreochromis niloticus)* in Weija reservoir Ghana. Ph.D. Thesis, University of Cape Coast, Ghana.

Edmond, S.; Wilfrid, A.S. and Didier, F.E. (2017). Growth, Mortality Parameters and Exploitation Rate of West African Ilisha (*Ilisha africana* Bloch, 1795, Clupeidae) off Benin Coastal Waters (West Africa): Implications for Management and Conservation. Open Journal of Marine Science, 7(3): 327−342. https://doi.org/10.4236/ojms.2017.73024

El-Gammal, F.I. and Mehanna, S.F. (2003). Fisheries management of *Sarotherodon galilaeus* (Cichlidae) at Wadi El-Raiyan lakes. Bull.Nat. Inst. Oceanogr. Fish., ARE, 29: 51−69.

Etim, L. and Brey, T. (1994). Growth, productivity, and significance for fishery of the bivalve *Egeria radiata* (Donicadae) in the Cross River, Nigeria. Archive of fishery and marine research, 42(1): 63−75.

Fagade, S.O.; Adebisi, A.A. and Atanda, A.N. (1984). The breeding cycle of *Sarotherodon galilaeus* in the IITA lake, Ibadan, Nigeria. Archiv für Hydrobiologie, 100(4): 493−500.

Fawole, O.O. and Arawomo, G.A.O. (2000). Fecundity of *Sarotherodon galilaeus* (Pisces: Cichlidae) in the Opa reservoir, Ile-Ife, Nigeria. Revista de biologia tropical, 48(1): 201−204.

FAO. (2022). The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation Rome, FAO.

Gayanilo, F.C. and Sparre, P. (2005). FAO-ICLARM stock assessment tools II: User's guide (No. 8). Food & Agriculture Org**.**

Gulland, J.A. (1971). The fish resources of the ocean, Revised edition of FAO Fish. Tech. Paper 97. Fishing News Books, Ltd., Surrey England, 225pp.

Jiménez-Badillo, L. (2006). Age-growth models for tilapia *Oreochromis aureus* (Perciformes, Cichlidae) of the Infiernillo reservoir, Mexico and reproductive behaviour. Revista de biología tropical, 54(2): 577−588.

Jones, R. and Van Zalinge, N. P. (1981). Estimates of mortality rate and population size for shrimp in Kuwait waters. Kuwait Bull. Mar. Sci, 2: 273−288.

Joksimović, A.; Regner, S. and Gačić, Z. (2009). Mortality of red mullet (*mullus barbatus* Linnaeus, 1758) on the Montenegrin shelf (south Adriatic). Archives of Biological Sciences, 61(4): A493−A499.

Kabre, F.A.; Sanogo, S.; Compaore, I. and Zongo, B. (2023). Étude du broutage et du filtrage de la microflore algale par *Heterotis niloticus* (Cuvier, 1829) et biocontrôle de la qualité de l’eau du lac de barrage hydroagricole de Samendéni au Burkina Faso. International Journal of Biological and Chemical Sciences, 17(1): 130−140. https://doi.org/10.4314/ijbcs.v17i1.10

Kwarfo-Apegyah, K.; Ofori-Danson, P. and Nunoo, F. (2009). Exploitation rates and management implications for the fisheries of Bontanga Reservoir in the Northern region of Ghana. West African Journal of Applied Ecology, 14(1). https://doi.org/10.4314/wajae.v14i1.44710

Lederoun, D.; Vandewalle, P.; Brahim, A.; Moreau, J. and Lalèyè, P. (2016). Population parameters and exploitation rate of *Sarotherodon galilaeus galilaeus* (Cichlidae) in Lakes Doukon and Togbadji, Benin. African journal of aquatic science, 41(2): 151−160. https://doi.org/10.2989/16085914.2016.1169988

Lorenzen, K.; Cowx, I.G.; Entsua-Mensah, R.E.M.; Lester, N.P.; Koehn, J.D.; Randall, R.G. and Cooke, S.J. (2016). Stock assessment in inland fisheries: a foundation for sustainable use and conservation. Reviews in Fish Biology and Fisheries, 26: 405−440. https://doi.org/10.1007/s11160-016-9435-0

Makkey. (2021). Age, Growth and mortality for management of *Sarotheradon galilaeus* (Teleostei: Cichlidae) in Lake Manzala, Egypt. International Journal of Environmental Research and Education, 1(2): 13−27.

Mahmoud, H.H.; Ezzat, A.A.; El-Sayed A.T. and El Samman, A. (2013). Fisheries management of cichlid fishes in Nozha Hydrodrome, Alexandria, Egypt. Egypt. J. Aquat. Res, 39 (4) : 283−289. https://doi.org/10.1016/j.ejar.2013.12.006

Mansour, S. A. (2004). Pesticide exposure-Egyptian scene. Toxicology, 198(1-3): 91−115. https://doi.org/10.1016/j.tox.2004.01.036

Maurya, A.K.; Radhakrishnan, K.V.; Sahu, P.; Prasad, L.; Khan, S. and Kumar, R. (2018). Length weight relationship and condition factor of *Anabas testudineus* (Bloch, 1792) from Rudrasagar Lake (A Ramsar site), Tripura. Journal of Pharmacognosy and Phytochemistry, 7(2): 1395−1398.

Minoungou, M.; Ouedraogo, R. and Oueda, A. (2021). Diversité piscicole et paramètres démographiques des principales espèces de poisson du réservoir de Samandeni, Burkina Faso. Tropicultura. https://doi.org/10.25518/2295-8010.1948

Minoungou, M.; Ouedraogo, R.; Da, N. and Oueda, A. (2020). Relation longueur-poids et facteur de condition de sept espèces de poisson du réservoir de Samandeni avant son ouverture à la pêche (Burkina Faso). Journal of Applied Biosciences, 151(1): 15559−15572.

Moreau, J.; Bambino, C. and Pauly, D. 1986. Indices of overall growth performance of 100 tilapia (Cichlidae) populations. In: "The First Asian Fisheries Forum." Maclean J.L., Dizon L.B., & Hosillos L.V. (Eds.). Asian Fisheries Society Manila, Philippines, pp 201–206.

Moreau, J.; Palomares, M.L.D.; Torres F.S.B. and Pauly, D. 1995. Atlas démographique des populations de poissons d'eau douce d'Afrique. International Center for Living Aquatic Resources Management Technical Report No. 45, Manila, 140pp.

Munro, J.L. and Pauly, D. (1983). A simple method for comparing the growth of fishes and invertebrates. Fishbyte, 1(1): 5−6.

Ofori-Danson, P.K.; Kwarfo-Apegyah, K. and Nunoo, F. (2008). An assessment of the cichlid fishery of Bontanga reservoir, Northern Ghana. W. Afr. J. Appl. Ecol, 14: 8−17.

Oliveira, M.R.; Costa, E.F.S.; Araújo, A.S.; Pessoa, E.K.R.; Carvalho, M.M.; Cavalcante, L.F.M. and Chellappa, S. (2012). Sex ratio and length-weight relationship for five marine fish species from Brazil. Journal of Marine Biology & Oceanography, 1(2). http://dx.doi.org/10.4172/2324-8661.1000103

Olopade, O.A.; Taiwo, I.A. and Emeka, C.R. (2014). Studies on some biological aspects of *Sarotherodon galilaeus* in Oyan dam, Nigeria. Academia Journal of Agricultural Research, 2(3): 93−99.

Paugy, D.; Lévêque, C. and Teugels, G.G. (2003). Poissons d'eaux douces et saumâtres de l'Afrique de l'Ouest, édition complète. Tome I & II. Edition IRD-MNHN-MRAC, Paris-Turvuren, 457+815pp.

Pauly, D. (1979). Gill size and temperature as governing factors in fish growth: a generalization of von Bertalanffy's growth formula. Berichte aus dem Institute fuer Meereskunde, Kiel University, 63: 1−156.

Pauly, D. (1980). On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. ICES Journal of Marine Science, 39(2): 175−192.

Pauly, D. and Munro, J.L. (1984). Once more on the comparison of growth in fish and invertebrates. ICLARM Fishbyte, 2: 1–21.

Pauly, D. (1984). Length-converted catch curves: a powerful tool for fisheries research in the tropics. Part III. Fishbyte, 2(3): 9–10.

Pauly, D. (1987). A review of the ELEFAN system for analysis of length-frequency data in fish and aquatic invertebrates. In ICLARM conf. Proc, 13(232): 7−34.

Pauly, D.; Moreau, J. and Gayanilo, J.F. (1996). A new method for comparing the growth performance of fishes, applied to wild and farmed tilapias. In The third international symposium on tilapia in aquaculture. ICLARM Conf. Proc. 41, pp. 433−441.

Pauly, D. and Gayanilo, J.F.C. (1997). A Bee: An alternative approach to estimating the parameters of a length-weight relationship from length frequency samples and their bulk weights. NAGA ICLARM Manila, Philippines, 22: 15−26.

Penha, J.M.F. and Mateus, L.A.F. (2007). Sustainable harvest of two large predatory Catfish in the Cuiaba river basin, northern Pantanal, Brazil. Brazilian Journal of Biology, 67(1): 81−89. https://doi.org/10.1590/S1519-69842007000100011

Qiao, Z.; Li, M.; Yu, M.; Zhang, M.; Wang, L.; Jiang, H. and Liu, S. (2023). Growth Patterns and Growth-Axis Gene Expressions in Sexual Dimorphism of *Silurus asotus* Linnaeus, 1758. Journal of Applied Ichthyology. https://doi.org/10.1155/2023/2631902

Ricker, W.E. (1975). Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can. Bull., 191: 1−382.

Sabbir, W.; Rahman, M.A.; Hossain, M.Y.; Hasan, M.R.; Mawa, Z.; Rahman, O. and Sarmin, M.S. (2021). Stock assessment of Hooghly Croaker *Panna* *heterolepis* in the Bay of Bengal (Southern Bangladesh): Implications for sustainable management. Heliyon, 7(8).

Sokal, R.R. and Rohlf, F.J. (1987). Biostatistics, second ed. Francise & Co, New York, 301pp.

Sossoukpe, E.; Nunoo, F.K.E.; Ofori-Danson, P.K.; Fiogbe, E.D. and Dankwa, H.R. (2013). Growth and mortality parameters of *P. senegalensis* and *P. typus* (Sciaenidae) in nearshore waters of Benin (West Africa) and their implications for management and conservation. Fisheries Research, 137: 71−80. https://doi.org/10.1016/j.fishres.2012.08.020

Sparre, P. and Venema, S.J.T.P. (1992). Introduction to tropical fish stock assessment part 1. Manual FAO Fisheries Technical Paper, 306(1):1–376.

Taylor, C.C. (1958). Cod growth and temperature. ICES Journal of Marine Science, 23(3): 366−370.

Tesfaye, M.; Tesfaye, G. and Getahun, A. (2021). Growth and status of Nile tilapia (*Oreochromis niloticus L.*) stock in Lake Chamo, Ethiopia. Lakes & Reservoirs: Research & Management, 26(3): e12375. https://doi.org/10.1111/lre.12375

Tesfaye, G. (2016). Population and ecosystem-based fisheries assessment of the Rift Valley Lake Koka, Ethiopia. Ph.D. Dissertation, Universität Bremen, Germany.

Udoh, J.P. and Ukpatu, J.E. (2017). First estimates of growth, recruitment pattern and length-at-first-capture of *Nematopalaemon hastatus* (Aurivillius, 1898) in Okoro River estuary, southeast Nigeria. AACL Bioflux, 10(5) : 1074−1084

Vandeputte, M.; Quillet, E. and Chatain, B. (2012). Are sex ratios in wild European sea bass (*Dicentrarchus labrax*) populations biased?. Aquatic Living Resources, 25(1): 77−81. https://doi.org/10.1051/alr/2012002

Vicentini, R.N. and Araujo, F.G. (2003). Sex ratio and size structure of *Micropogonias furnieri* (Desmarest, 1823) (Perciformes, Sciaenidae) in Sepetiba bay, Rio de Janeiro, Brazil. Brazilian Journal of Biology, 63: 559−566. https://doi.org/10.1590/S1519-69842003000400003

Yamaguchi, Y., Hirayama, N.; Koike, A. and Adam, H.A (1990): Age determination of growth of *Oreochromis niloticus* and *Sarotherodon galilaeus* in High Dam Lake, Egypt. Nippon Suisan Gakkaishi, 56(3): 437−443.