**On the population dynamics of *Labeo senegalensis* (Valenciennes, 1842) in upper Atbara and Settit Dam complex, Eastern Sudan.**

**Abstract**:

In the present study, 500 specimens of *Labeo senegalensis* were collected from artisanal fishing boats during the period from September 2019 to January 2020. The total length of the collected specimens ranged from 21.2 to 47.5 cm with a mean of 27.7 ± 10.91 cm. The maximum length was 45.0 cm, while the maximum predicted length at the 95% confidence limit was 46.18 cm. The length-weight relationship was highly correlated (*r* = 0.947), with a b-value of 2.847, indicating negative allometric growth. Growth parameters estimated from the von Bertalanffy growth model were: *L∞* = 47. 5 cm, *K* = 0.86 yr⁻¹, and theoretical age at zero length “*t*0” was -0.786 yr⁻¹. The relative longevity (T*max*), was 2.7 years; and the growth performance index at 3.28. The total, natural, and fishing mortality rates were estimated as 2.29 yr⁻¹, 1.38 yr⁻¹, and 0.91 yr⁻¹, respectively, which gives an annual exploitation rate of 0.4 yr⁻¹. The exploitation levels at 10%, 50%, and maximum sustainable exploitation (E*max*) were calculated as 0.355, 0.278, and 0.421, respectively. The capture lengths at 25%, 50%, and 75% were estimated as 16.56 cm, 20.39 cm, and 24.14 cm, respectively. Maximum, limit, and optimum fishing levels of fishing (F*max*, F*limit,* and F*opt*) were found to be 0.81, 0.92, and 0.55, respectively. The asymptotic length of *L*. *senegalensis* population “*L∞*“in this study was calculated at 30 cm, while the growth coefficient “*K”* was found to be 1.5 yr⁻¹. The length of catch at 50% and 75% was estimated at 9.5 and 12 cm, respectively. This investigation was important for monitoring and managing fisheries resources to enhance sustainability and conservation efforts of the stocks of *L senegalensis*, one of the most important commercial fish species in the upper Atbara and Settit Dam Complex.

**Keywords**: *Labeo senegalensis*, Upper Atbara and Settit Dam Complex, growth parameters, exploitation level, mortalities, recruitment.

**Introduction**:

Family Cyprinidae is considered the largest family of freshwater fishes. Fishes belonging to this family are widely distributed worldwide, with an overall number of about 3,000 [species](https://en.wikipedia.org/wiki/Species) of which only 1,270 of these species remain extant (Li *et. al.,* 2021). Globally, the genus *Labeo* Cuvier 1817, consists of at least 80 species representing about 16.4% of the African cyprinid ichthyofauna (Reid, 1985). About 134 fish species occur in the freshwaters of Sudan of which 22 species belong to the family Cyprinidae (Mahmoud *et. al.,* 2024). *Labeo senegalensis* (Valenciennes, 1842) is the most prevalent and abundant species in the country and has gained special significance for their good taste and high market value. Most species of the genus *Labeo* are commercially important and contribute significantly to the fisheries resources of African countries (Weyl and Booth 1999; Delaney *et al;* 2007; Skelton *et. al.,* 1991).

The study of the length-weight relationship of fish forms the basis for fishery stock assessments and management studies. It provides insights into fish population dynamics, such as growth patterns, recruitment, and mortalities, exploitation rate, and stock biomass (Pervin and Mortuza, 2008; Pauly and Morgan, 1987, and Pauly, 1983). Recent studies of the population dynamics and stock assessment of *Labeo senegalensis* have been conducted by several researchers including Abdalla *et. al.,* (2024); Olufeagba and Okomoda (2016); Montchowui *et. al.,* (2011), and El-Kasheif *et. al.,* (2007).

The present study was conducted on fishing sites located on two seasonal rivers; the Upper Atbara River at Rumela site and the Settit River at Burdana site on the eastern part of Sudan. The study's main objective is to investigate aspects of the population dynamics of *L. senegalensis* in the two water bodies. The findings of this research will provide valuable information in relation to the sustainable development, management, and exploitation of this commercially important fish species in the freshwaters of Sudan.

**Material and Methods**:

**Study area**:

The study area included two small dams built at Rumela on the Upper Atbara River and Burdana on the Settit River in eastern Sudan. It lies at latitude 14º16'36" N and longitude 35º53'49" E, about 20 kilometers upstream from the convergence of the Atbara and Settit rivers, and approximately 80 kilometers south of the Khashm El-Girba Dam. The two dams are interconnected and have a total length of 13.0 kilometers. The joined reservoir has a storage capacity of about 3.7 billion cubic meters, and at an elevation at maximum filling of 517.5 meters above sea level (Adam and Hamad, 2021).

Although the construction of the two dams served multiple purposes, such as the provision of irrigation water for agricultural production, hydroelectric power generation, socioeconomic development, and supply of drinking water, yet, it also served as a vital fishery resource for increasing fish production from the artisanal fisheries in the eastern part of Sudan.

**Data collection**:

Random samples of about 500 specimens of African carp (*L. senegalensis*) were collected monthly from artisanal fishing boats during the period from September 2019 and January 2020. Fish were identified to the species level following Neumann *et. al.,* (2016). The total length of the fish was measured to 1.0 cm, from the tip of the snout to the end of the upper lobe of the caudal fins using a standard measuring board. Fish body weight was measured to the nearest 1.0 g using a digital weighing balance, model FRUIT 2000B.

**Length-weight relationship**: The relationship between the length and weight of *L. senegalensis* was calculated according to the equation:

W = aL b

When the relationship is converted into the logarithmic form it gives a straight-line relationship graphically represented as log W = Log a + b log L

Where: W=total weight; L=Total length, and “a” is the intercept, and “b” is the slope (regression coefficient).

**Growth parameters**:

The asymptotic length (*L∞*), and growth coefficient (*K*) were estimated according to the von Bertalanffy growth function (vBGF), following (Pauly, 1979):

Lt =*L∞* (1-e-k(t-*t*0))

The theoretical age at zero length (*t*0) was determined following (Pauly, 1979):

log10 (−*t*0) = − 0.3922 − 0.2758 × log10 *L∞* − 1.038 × log10 *K*.

**Longevity** (T*max*) was calculated as 3/K + *t*0.

**The growth performance index** was estimated using the Moreau *et. al.,* (1986) expression:

2 × log *L∞* + log *K*.

**Mortality parameters**:

**The total annual instantaneous mortality rate** (Z) was estimated using the length-converted catch curve.

**The natural mortality rate** (M) was ascertained following Pauly (1980):

log10M = - 0.0066 - 0.279 × log10*L∞* + 0.6543 × log10*K* + 0.4634 × log10T

Where, M = instantaneous natural mortality, *L∞* asymptotic length, “T” mean surface temperature (26 °C) and “*K”* = growth rate.

**The fishing mortality rate** (F) was calculated according to Beverton and Holt (1957) equation:

F = Z – M

**Exploitation rate (E)**:

Exploitation rate (E) was obtained using Gulland (1971) relationship:

E = F/Z

**Relative yield per recruit** (Y'/R) and **relative biomass per recruit** (B'/R). The relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) were calculated as a function of exploitation to obtain biological the reference points. Further, the exploitation rate at the maximum exploitation rate (E*max*), at 0.1 of the virgin biomass (E0.1), and E0.5 and the exploitation rate at 0.5 of the virgin biomass were worked out by applying the Knife-edge option. The model of Pauly and Soriano (1986) was used to predict the relative yield per recruit (Y'/R) using the previous of values of M/K, *L∞*and*L*c. The relative biomass per recruit (B'/R) was estimated by B'/R= (Y'/R)/F (Gayanilo *et al.,* 2005).

**The length at first capture (*L*c)**: Length at first capture was determined following Beverton and Holt (1957) equation:

*L*c = L̄-*K* × (*L∞* - L̄) ÷ Z

Where: L̄=mean length of the fish catch; *K*= growth coefficient; *L∞*= asymptotic length and Z= the total mortality.

**First maturity (*Lm* or *L*50)**: The *Lm* from the mature fish (stages III+) data per length class was calculated based on Gunderson and Sample (1980) as follows: P = 1÷1+e (b L + a)

Where: P=the proportion of mature fish at length class x, a= intercept, and b=slope.

The *Lm*50 was then derived from the relationship of “a” and “b” as follows: *Lm* = -a÷ b.

**The length at first maturity (*Lm*)**:

Based on first maturity (above) the percentage of specimens in the catches larger than the length at maturity (*Lm*); the percentage of fish between *Lm* and 10% the length at optimum cohort biomass (*Lopt*=) and the percentage of fish beyond this *Lopt* range (mega-spawners) were determined following Froese (2004).

**The recruitment pattern**:

The age at first capture (*tc*) was determined from the estimated growth parameters (*L∞*, *K*, and *t*0) using the ELEFAN I method following (Gayanilo *et. al.,* 2005). The "Percent of sample total" option in FiSAT was used to estimate the recruitment pattern when the samples had dissimilar sizes.

**Maximum fishing effort (F*max*)** was determined as:

0.67×K/0.67-Lc (Hoggarth *et. al.,* 2006).

**The precautionary limit reference point (F*limit*)** was determined as:

⅔×M (Patterson, 1992).

**The precautionary target reference point (F*opt*)** was calculated as:

0.4×M (Pauly, 1984).

**The estimated length of structured virtual population analysis (VPA)**:

The length-structured Virtual Population Analysis (VPA) was carried out based on previously produced growth parameters (*L∞*, *K*, *t*0, M, F, the intercept “a” and the slope “b”, in accordance with the FAO FiSAT-II software program, following Gayanilo *et al*., (2005).

**Biological reference points** were estimated 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 procedure as functions of exploitation rate, incorporated into the FiSAT II software (Gayanilo *et. al.,* 2005). The length at optimum cohort biomass or yield pre-recruitment (*Lopt*) was estimated from *L∞*, *K*, and M using the Beverton (1992) formula:

*Lopt* = *L∞* × (3÷3 + M÷*K*)

**Data analysis**:

Excel spreadsheets from Microsoft Office (2016) were used to determine the length-weight relationship. Following Gayanilo *et. al*., (1996) and Pauly and Morgan (1987), the FAO-ICLRAM Stock Assessment Tool (FiSAT) software was used to estimate population parameters.

**Results**:

In the current study, 500 specimens of *L. senegalensis* were randomly collected monthly from artisanal fishermen's boats between September 2019 and January 2020. The total length of the fishes ranged from 21.2 cm to 47.5 cm, as shown in Fig. (1).



Fig. (1). Total length distribution of *Labeo senegalensis* in Upper Atbara and Settit Dam complex.

Length-weight relationship of *L. senegalensis* exhibited a strong correlation (*r*= 0.947), indicating a negative allometric growth pattern with a b-value of 2.847, as shown in Fig (2).

Fig. (2). Length-weight relationship and correlation of *Labeo senegalensis* from Upper Atbara and Settit dam complex.

The von Bertalanffy growth parameters were calculated as follows: asymptotic length (*L∞*) of 47.5 cm, a growth coefficient (*K*) of 0.86 yr⁻¹, and a theoretical age at length zero (*t*0) of -0.786 yr -1 (Fig. 3 and Table 1). Total mortality (Z) was estimated at 2.29 yr⁻¹, natural mortality (M) at 1.38 yr⁻¹ and fishing mortality (F) at 0.91 yr⁻¹; with an exploitation rate (E) of 0.4 yr⁻¹ as shown in (Fig. 4 and Table 1).



Fig. (3) von Bertalanffy growth curve



Fig. (4). Von Bertalanffy growth curve (a) (*L∞*= 47.5 cm; *K* = 0.86 yr-1; on length-frequency distribution and linearized length-converted catch curve of *L. senegalensis* in Upper Atbara and Settit Dam complex.

The growth performance index, the phi-prime (Փ'), is based on both the *L∞* and *K* parameters of the von Bertalanffy function (VBGF), estimated according to Vakily (1988):

Փ' = log *K* + 2 \* log *L∞*

In the present investigation, *Labeo senegalensis* exhibited one round of recruitment with a peak from Jun to August, which coincided with the rainy season as shown in Fig. (5).



Fig. (5). The seasonal recruitment pattern of *L. senegalensis* in Upper Atbara and Settit Dam complex.

The probability of capture of this species indicated that the length at first capture (*L*c) was 24.02 cm, and the length at vulnerable catch at of 25%, 50%, and 75% was 16.56 cm, 20.39 cm, and 24.14 cm respectively, as presented in Fig. (6) and Table (1).



Fig. (6). The selective curve shows the probability of capture.

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 (E01 and E05) were estimated as 0.355 and 0.278, respectively; whereas *L*c/*L∞* = 0.05 and the probability distribution of length M/K = 1. The calculated length at optimum cohort biomass (*Lopt*) was 30.78 cm (TL).



Fig. (7). Beverton and Holt's relative yield per recruitment (Y/R) and biomass per recruit (B/R) of the *L. senegalensis* in the Upper Atbara and Settit Dam complex.



Fig. (8). Length-structured virtual population analysis of *L. senegalensis* in Upper Atbara and Sittit Dam complex.

Analysis of length-frequency data showed that the mean ± standard deviation (SD) of the asymptotic length (*L∞*) of the Nile carp population in the Upper Atbara and Settit Dam complex was 30 ± 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 *L. senegalensis* was 45 cm, the predicted extreme length was 46.18 cm, and the range at a 95% confidence interval was 39.11 –53.25 cm (Fig. 9).



Fig. (9). Predict a maximum of extreme length and Gillnet selection.

Table (1): shows the biological parameter of *L. senegalensis* from Upper Atbara and Settit D

am complex.

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | Estimated Values | Parameters | Estimated values |
| *L∞* (cm) | 47.5 | E | 0.40 |
| *K* (year-1) | 0.86 | E*max* | 0.421 |
| Phi (Փ') | 3.28 | E01 | 0.355 |
| *t*0 (year) | -0.786 | E05 | 0.278 |
| T*max* (year) | 2.70 | *L*50 (cm) | 20.39 |
| Z (year-1) | 2.29 | *L*25 (cm) | 16.56 |
| M (year-1) | 1.38 | *L*75 (cm) | 24.14 |
| F (year-1) | 0.91 | *L*opt (cm) | 30.78 |
| *L*c / *L∞* | 0.05 | Z/K | 2.66 |
| M/K | 1.0 | F*opt* | 0.55 |
| F*max* | 0.81 | *Lm* (cm) | 23.36 |
| F*limit* | 0.92 | *Lc* (cm) | 24.02 |

**Discussion**:

In the present study, the total length of the samples of *L. senegalensis* varied from 21.2 cm to 47.5 cm. These measurements are notably larger than those recorded in the Khashm El-Girba reservoir for the same species (Abdalla *et. al.,* 2024). The length-weight relationship of this speciesexhibited a strong correlation with *r* = 0.947 denoting negative allometric growth with a b-value of 2.847. Almost similar results were obtained by Abdalla *et al.,* (2021) on *Labeo senegalensis* from Khashm El-Girba Reservoir and Atbara River (Sudan), with a highly significant correlation of (*p*<0.001), (*r*=0.966), slope’ b’= 2.178; Brahim *et al.,* (2023) from Lake Maabo (Chad) of (*p*<0.001), (*r*=0.966), slope’ b’= 2.178 and Adam and Hamad (2021) from Upper Atbara River and Settit Dam Complex (Sudan); b= 2.832 and *r* = 0.975 respectively, indicating negative allometric growth pattern of this species. However, Olufeagba *et al*; (2016) studied the Length-weight relationshipof *Labeo senegalensis* from lower River Benue (Nigeria), and reported an isometric growth pattern for both sexes with’ b’= 3.04 for females and ‘b =3.07 for males, while Hossain *et. al*., (2015) investigated *Labeo boga* in the Padma River northwestern, Bangladesh, and recorded positive allometric growth pattern for this species with b for males= 3.008, b for females = 3.114 and b for combined sexes =3.113, respectively, and *r*2 ranging from 0.954 - 0.962. These differences in length-weight relationship may be related to variations in water in terms of temperature, dissolved oxygen, water turbidity, water flow, and type of substrate, which may induce spatial and temporal changes in the distribution and abundance of the fish assemblages in different water bodies.

In the current study,the growth parameters obtained from the von Bertalanffy growth model for *L. senegalensis* were calculated as follows; asymptotic length (*L∞*) of 47.5 cm, growth coefficient (*K*) of 0.86 yr⁻¹, and theoretical age at length zero (*t*0) of -0.786 yr. However, low values of growth parameters were recorded for *L. senegalensis* by Abdalla *et al.,* (2024) from the nearby Khashm El-Girba reservoir, Sudan, with *L∞* = 42 cm, *K* = 0.490 year-1 and *t*0 -0.518 year-1. El-Kasheif *et. al*., (2007) studied *Labeo niloticus* (renamed *Labeo senegalensis*) from the Nile River (Egypt) and derived a high value of *L∞* = 72.99 cm and K of 0.55 year-1 for this same species. Variations in growth parameters across different *Labeo* species were observed by several workers including Dwivedi, (2009) who studied *L. rohita* and *L. calbasu* in the Paisuni River (India), and found values of *L∞* = 83.3 and 61.2 cm and *K* = 0.56 yr⁻¹ and 0.28 yr⁻¹ for the two species respectively*.* Athukorala and Amarasinghe (2010) estimated the growth parameters for *Labeo dussumieri* in the Udawalawe River basin, Sri Lanka, and reported *L∞* at 41.7 cm and *K* at 0.52 yr⁻¹ with an isometric growth pattern of *b* = 3.02, and a highly significant correlation (*p* < 0.001, *r* = 0.997). Montchowui *et. al.,* (2011) studied *Labeo parvus* in the Oueme River in Benin and reported growth parameters of *L∞* of 57.0 cm and *K* of 0.30 yr⁻¹. He ascribed these variations in growth parametersoffishesto a range of factors, including the mean water level, water flow fluctuation, and each species' inherent traits.

In this study, the total mortality Z of *L. senegalensis* was estimated at 2.29 per year, natural mortality M = 1.38 per year, and fishing mortality F = 0.91 per year, with an exploitation ratio E = 0.4 per year. Conversely, low mortalities values were reported by Abdalla *et. al.,* (2024) for *L. senegalensis* from Khashm El-Girba reservoir (Sudan), with total mortality Z = 1.41 yr⁻¹; fishing mortality F = 0.43 yr⁻¹, natural mortality M = 0.98 yr⁻¹, and El-Kasheif *et. al.,* (2007) for the same species from the River Nile who estimated total, natural, and fishing mortality rates at 1.30 yr⁻¹, 0.64 yr⁻¹, and 0.66 yr⁻¹ respectively. However, several workers studied the mortality parameters of different *Labeo* species, such as Alam *et. al.,* (2000) on *Labeo calbasu* in the Sylhet basin, Bangladesh, and recorded annual rates of natural and fishing mortality of 1.11 yr⁻¹ and 3.48 yr⁻¹, respectively. Dwivedi, A. (2009) estimated F, M, and Z of *L. rohita* in Vindhyan River, India*,* at 2.73 yr⁻¹, 0.94 yr⁻¹, and 3.67 yr⁻¹, respectively. Athukorala and Amarasinghe, (2010), in the Walawe River basin, Sri Lanka, estimated Z = 2.93 yr⁻¹, M = 1.07 yr⁻¹, and F = 1.86 yr⁻¹ for *L. dussumieri* and Montchowui *et. al.,* (2011) investigated *L. senegalensis* in Queme River, Benin and presented values of fishing mortality F = 0.79 yr⁻¹; natural mortality M = 0.68 yr⁻¹, and total mortality Z = 1.47 yr⁻¹. These dissimilarities in mortality rates may be due to the impact of ecological factors and the use of different fishing techniques on the growth of different species found within the freshwater ecosystem.

The growth performance index (Փ') of *L. senegalensis* was found to be 3.28, which is higher than that reported by Abdalla *et. al.,* (2024) for *L. senegalensis*; Montchowui *et. al.,* (2011) for *L. dussumieri* with Փ' values of 2.937, 2.99. Athukorala and Amarasinghe (2010) stated that growth performance indices (Փ') of *L. senegalensis* in African lakes and rivers ranged from 2.61- 3.12, whereas Ahmed *et. al.,* (2005) found values of Փ' *L. fimbriatus* and *L. rohita* varied in Indian rivers between 2.98 to 3.23 and 3.46 to 3.50 respectively. According to Pullin *et. al.,* (2007), the growth performance indices of fishes usually range from 3,19 to 3,26. These variations in the values of growth performance indices in different freshwater bodies may be attributed to different traits of fish species as well as to different geographical locations of freshwater ecosystems.

The length at first sexual maturity (*Lm*) of *L. senegalensis*, was determined at 23.36 cm. This value is slightly less than that obtained by Abdalla *et. al.,* (2024) and El-Kasheif *et. al.,* (2007), who reported *Lm* at 25.26 cm, and 30.0 cm respectively.

In the current investigation, *L senegalensis* showed a single recruitment peak occurring from June to August, coinciding with the rainy season. Montchowui *et. al.,* (2011) noted that *L. senegalensis* exhibited a single recruitment peak from June to September, while Abdalla *et. al.,* (2024) reporteda single recruitment peak in July at the Khashm El-Girba reservoir, Sudan, and Alam *et. al.,* (2000) declared that a recruitment peak occurred from August to October of *L. calbasu* in the Sylhet basin, Bangladesh. However, Amin *et. al.,* (2001) recorded two recruitment peaks for *L. rohita,* onein April-June and the other in October-November. These differences in the recruitment peaks of fish reveal that the timing of recruitment is influenced by the type of fish species and the environmental biological factors affecting the fish population in the particular freshwater ecosystem.

Analysis of the probability of capture indicated that the length at first capture (*L*c) of *L. senegalensis* was 24.02 cm, with vulnerable lengths at 25%, 50% and 75% of the catch being 16.56 cm, 20.39 cm, and 24.14 cm, respectively. The maximum relative yield per recruit (Y/R) was observed at an exploitation rate (E*max*) of 0.421, whereas the exploitation rates corresponding to 10% and 50% of the maximum Y/R (E01 and E05) were estimated at 0.355 and 0.278, respectively.

The calculated exploitation rate of this species was 0,40 which is consistent with the findings of Abdalla *et al*., (2024) and Montchowui *et. al.,* (2011), but less than the maximum exploitation rate of 0.50. Generally, an exploitation rate of a fish exceeding a value of 0.50 reveals that the fish stock is considered overfished, and there is an urgent need for effective management measures to prevent overfishing of the stock of the target species.

In this study, *L*c/*L∞* and M/K were estimated at 0.05 and 1.0 respectively, and the calculated length for optimal cohort biomass or yield prior to recruitment (*Lopt*) was 30.78 cm (TL). The potential longevity for *L. senegalensis* was estimated at a T*max* of 2.7 years, which is nearly similar to the age of *L. niloticus* reported by Abdalla (2018) from the Khashm El-Girba reservoir, almost half the value recorded for the same species(5.604 years) by Abdalla *et. al.,* (2024) in Khashm El-Girba reservoir and less than one-third of the value recorded by Montchowui *et. al.,* (2011) for *L. senegalensis* (10.0. years) and 8.3 years recorded by El-Kasheif *et. al.,* (2007) for *L. niloticus* from El-Kanater El-Khyria, (Egypt). These differences in longevity can be explained by species-specific traits, level of exploitation, and various biological and ecological factors.

**Conclusion**:

In view of the results of this study, it may be concluded that the biometric growth parameters assessed for *L. senegalensis* from the Upper Atbara and Settit Dam Complex are more or less in optimal condition with a normal growth pattern. There is a strong correlation of length-weight relationship (*r* = 0.947), showing a negative allometric growth, although some future changes of these values may occur due to increasing fishing pressure and changing hydrobiological conditions. Moreover, the findings of this study showed that the natural mortality rate was higher than fishing mortality, suggesting significant losses which may be related to natural environmental causes. The recruitment pattern exhibited a single peak from June to August, coinciding with the rainy season, reflecting the influence of environmental factors on the fish populations. The maximum relative yield per recruit (Y/R) was achieved at an exploitation rate (E*max*) of 0.421, whereas the estimated exploitation rate of this fish species was 0.4.0, which is slightly below the optimum sustainable yield of 0.50, suggesting that the fish stock in the study area is still underexploited. This study provides some important baseline data for the management of the stocks of this commercially important fish species in the Upper Atbara and Settit Dam Complex. It can also stimulate future research programs aimed at the effective management and exploitation of other commercially valuable fish stocks in the freshwater resources of the country.

**List of Abbreviations**:

|  |  |
| --- | --- |
| Abbreviation | Meaning |
| *L*∞ | Asymptotic length  |
| *K*  | Growth coefficient |
| Phi (Փ') | Growth performance index |
| *t0* | Theoretical age at zero length |
| T*max* | Longevity |
| Z  | Total mortality |
| M | Natural mortality |
| F | Fishing mortality |
| *Lc* | The length at first capture |
| *Lm* | The length at first maturity |
| F*max* | Maximum fishing effort  |
| F*limit* | The precautionary limit reference point  |
| F*opt* | The precautionary target reference point |
| E | Exploitation rate |
| E*max* | Maximum exploitation rate |
| E01 | The virgin biomass  |
| E05 | Exploitation rate at 0.5 of the virgin biomass |
| *L50* | The length of the vulnerable catch is 50% |
| *L25* | The length of the vulnerable catch is 25% |
| *L75* | The length of the vulnerable catch is 75% |
| *Lopt* | Length at optimum cohort biomass |
| *r* | Correlation coefficient |
| *b*-value | The slope of the regression coefficient of LWR |
| log | Logarithm |
| T | Mean surface temperature |
| Y'/R | Relative yield per recruit |
| B'/R | Relative biomass per recruit  |

**Ethical Issues**: Ethics approval and consent to participate, consent for publication, and availability of data and materials are not applicable.

Disclaimer (Artificial intelligence)

Option 1:

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 the writing or editing of this manuscript.

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