**Population dynamics of *Labeo senegalensis* (Valenciennes, 1842)** **from Roseries reservoir**

**Abstract**:

Fishery stock assessments and management provide valuable insights into various aspects, including fish growth patterns, recruitment, mortality rates, exploitation rates, and stock biomass. This study estimated the population dynamics parameters of *Labeo senegalensis* using FiSAT II software and analyzed length-frequency data collected from four sites in the Roseries Reservoir, Sudan. The von Bertalanffy growth model was applied to analyze growth patterns. Key parameters include asymptotic length L∞ and growth coefficient K derived from the von Bertalanffy growth function. The relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) were calculated as exploitation functions to determine biological reference points. The exploitation rates at the maximum exploitation rate (Emax) were derived for 0.1 (E0.1) and 0.5 (E0.5) of the virgin biomass (E0) using the Knife-edge option. Structured virtual population analysis was conducted using FiSAT II software, incorporating parameters such as L∞, K, M, and F. The von Bertalanffy growth parameters were determined, with an asymptotic length (*L*∞) of 54.60 cm and a growth coefficient (*K*) of 0.260 yr.⁻¹. The recruitment patterns indicated a peak from April to August, coinciding with the rainy season. The annual rates of total mortality (Z), natural mortality (M), and fishing mortality (F) were calculated as 1.06 yr.⁻¹, 0.59 yr.⁻¹, and 0.47 yr.⁻¹, respectively, reflected an exploitation rate (E) of 0.45; while the maximum sustainable exploitation rate (E*max*) was identified as 0.5. These findings indicate that *Labeo senegalensis* in the Roseries Reservoir exceeds the exploitation edge, highlighting the need for reduced fishing pressure to ensure sustainability. Early harvesting practices and gear selectivity pose risks to the long-term sustainability of the population. Implementing size limits, seasonal closures, and effort regulations may enhance yield while safeguarding the stock.

**Keywords**: Growth, Mortality, Recruitment, *Labeo senegalensis*, and Exploitation rate.

**Introduction**:

The population dynamics parameters are useful in evaluating the well-being of any fish population including *Labeo* spp. *Labeo senegalensis* is an economically important fish in Sudan, thus, the population parameters studies generated information essential for its sustainable management (Abdalla et al., 2021). The *Cyprinidae* family is widely distributed across major African drainages such as the Nile, Niger, Zaire, and Zambezi (Skelton *et. al*., 1991). In Sudan, the Roseries Reservoir ranks as the third richest region in terms of fish diversity, accounting for 36% of the total inland fish species (Abdalla and Adam, 2024); the family Cyprinidae is represented by 22 species (Mahmoud *et*. *al*., 2024). Understanding population dynamics, especially population growth rates of aquatic species, is crucial to implementing restorative conservation strategies for European river biodiversity. For instance, by identifying endemic species in decline or monitoring trends in invasive species. Identification of geographical patterns in population trends can also provide scientific evidence to define region-specific environmental management and conservation planning, setting priorities where it is most needed and for the most vulnerable species (Santos et al., 2022).

Studies on fishery stock assessments and management provide valuable insights into various aspects, including fish growth patterns, recruitment, mortality rates, exploitation rates, and stock biomass (Maunder *et. al*., 2023 & Pervin and Mortuza, 2008). According to King (2007), effective management of inland fisheries requires a comprehensive plan to conserve sustainable fish stocks. Accurate stock assessments rely on thorough studies of growth, recruitment, and mortality.

The present investigation aims to provide a detailed population dynamics of *L. senegalensis* in the Roseries Reservoir. Information on these aspects is essential for the effective management of this economically significant *Cyprinidae* species and its future exploitation.

**Materials and Methods**:

**Study area**:

The Roseires Dam is situated on the Blue Nile River in Sudan, serving water storage for agricultural irrigation and hydroelectric power generation. Approximately 550 kilometers from Khartoum, the dam's first construction phase was completed in 1966. Subsequently, the second phase raised the dam's height from 68 meters to 78 meters, which enhanced its storage capacity from 3.0 billion cubic meters to 7.3 billion cubic meters. This expansion of the reservoir has transformed it into a crucial source of fish resources, supporting local communities by providing essential livelihoods, employment opportunities, and income. Fish samples were systematically collected from four designated sites within the reservoir as detailed in Table 1. This dam not only plays a vital role in regional water management but also significantly contributes to the socioeconomic development of the surrounding areas.



Fig. 1. Roseires Dam in Sudan, Africa (11°47′53″N 34°23′15″E﻿ / ﻿11.79806°N 34.38750°E﻿ / 11.79806; 34.38750). From Ayn network (https://3ayin.com/en/sudan-authorities-support-while-affected-communities-fear-africas-largest-dam/).

Table 1. Shows the coordinates of the fish sampling sites in Roseires Reservoir (Blue Nile, Sudan) and the distance from the Damazin City Site.

|  |  |  |  |
| --- | --- | --- | --- |
| Site | Distance (km) | Coordinate | Elevation (m) |
| Awal Bab  | 4 | 11°45'14"N 34°21'51"E | 487 |
| EL Regiba  | 16 | 11°38'39"N 34°20'51"E | 497 |
| Kirma  | 43 | 11°41'09"N 34°30'35"E | 506 |
| Wad EL Mahi  | 80 | 11°25'27"N 34°40'17"E | 507 |

**Samples collection:**

A total of 555 fish specimens were collected monthly from four sites from January to December 2022, as outlined in Table (1). To facilitate sampling, gillnets with stretched bar mesh sizes of 2 cm, 4 cm, 6 cm, and 8 cm were employed. These nets varied in length from 50 m to 100 m and in depth from 2 m to 4.5 m, as detailed in Table (2). Fish identification was conducted following the Neumann *et. al*., (2016) and Bailey (1994). The total length of each fish was measured to the nearest 1.0 mm from the tip of the snout to the end of the upper lobe of the caudal fin (left side) utilizing a standard measuring board. Additionally, fish body weight was recorded to the nearest 1.0 g using a digital balance model FRUIT 2000B.

Table 2. Specifications of gillnets used to collect fish samples.

|  |  |  |  |
| --- | --- | --- | --- |
| Gear No. | Length (m) | Depth (m) | Mesh size (cm) |
| 2 | 50 | 2 | 2 |
| 12 | 90 | 4 | 4 |
| 12 | 95 | 4 | 6 |
| 12 | 100 | 4.5 | 8 |

**Growth Parameters:**

The von Bertalanffy growth model was applied to analyze growth patterns. Key parameters include asymptotic length *L∞* and growth coefficient *K* derived from the von Bertalanffy growth function:

*Lt* =*L∞* (1-e-k(t-t0)).

The theoretical age at zero length t0​ was calculated as:

log10 (−*t*0) = − 0.3922 − 0.2758 × log10 *L∞*− 1.038 × log10 *K*. (Pauly, 1979).

Longevity T*max*​ was estimated as 2 × log *L∞* + log *K*​. The growth performance index was calculated as:

3 /*K* + *t*0. (Moreau *et. al*., 1986)

**Mortality Parameters:**

The total annual instantaneous mortality rate Z was estimated using length-converted catch curves. Natural mortality M was calculated as:

log10M = - 0.0066 - 0.279 × log10*L*∞+ 0.6543 × log10K + 0.4634 × log10T. Pauly (1980).

Where: M = instantaneous natural mortality, *L∞* asymptotic length, “T” mean surface temperature (24.5 °C), and “*K*” = growth rate.

**Fishing mortality (F)** was derived from:

F = Z – M. Beverton & Holt, (1957).

**The exploitation rate (E)** was obtained using:

E = F/Z. Gulland (1971).

### Relative Yield and Biomass per Recruit:

The relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) were calculated as exploitation functions to determine biological reference points. The exploitation rates at the maximum exploitation rate (E*max*) were derived for 0.1 (E0.1) and 0.5 (E0.5) of the virgin biomass (E0) using the Knife-edge option. The model developed by Pauly and Soriano (1986) was employed to predict Y'/R based on previous values of M/K, *L∞*, and *Lc*. The relative biomass per recruit was estimated as described by Gayanilo *et. al*., (2005). This approach enables assessing sustainable fishing levels and informs management strategies for fishery resources.

**Length at First Capture**:

Length at first capture, *Lc*, ​ was determined using Beverton and Holt's equation. The ELEFAN I method was used to estimate age at first capture, *tc*​.

*Lc* = *L̄*-*K* × (*L∞* - *L̄*) ÷ Z. Beverton & Holt, (1957).

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

**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 set at:

⅔×M (Patterson, 1992).

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

0.4×M (Pauly, 1984).

**Virtual Population Analysis:**

Structured virtual population analysis was conducted using FiSAT II software, incorporating parameters such as *L∞*​, *K*, M, and *F*. Biological reference points were estimated through Beverton and Holt’s model (1992).

**length at optimum cohort biomass** calculated as:

*Lopt*= *L∞* × (3÷3 + M÷*K*).

**Data Analysis:**

Microsoft Excel was used to organize data, while population parameters were estimated using FiSAT software (Gayanilo *et. al.*, 1996, and Pauly and Morgan, 1987).

**Results**:

A total of 555 specimens of *Labeo senegalensis* were collected from four sites in the Roseries reservoir, as shown in Table (1), during January and December 2022. The total length varied between 8.8 and 52 cm, computed an average of 25.982 ± 6.791 cm.

Growth parameters were calculated according to the von Bertalanffy function as follows: an asymptotic length (*L*∞) of 54.60 cm, a growth curvature (*K*) of 0.260 yr.⁻¹ and a theoretical age at length zero (*t*0) of -0.264 yr.⁻¹. The growth performance index (Φ') based on the *L*∞ and *K* parameters of the von Bertalanffy growth function (vBGF) was estimated at 2.889 while longevity (T*max*) was determined to be 11.27 years, as shown in Fig. (2), and Table (3). The von Bertalanffy growth function was derived accordingly:

*Lt* = 54.60 × 1-exp(-0.260×(t+0.264)).



Fig. (2): Von Bertalanffy growth curve of *Labeo senegalensis* by ELEFAN I based on length-frequency distribution (*L∞* 54.60 cm and *K* 0.260 yr -1).

In this investigation, instantaneous mortality was estimated for total (Z), natural (M), and fishing (F) mortality as follows: 1.06 yr. -1, 0.59 yr. -1, and 0.47 yr. -1, respectively. Reflecting the exploitation rate (E) of 0.45, as shown in Fig. (3) and Table (3).



Fig. (3): Total, natural, fishing mortality, and exploitation rate using length-converted catch curve from FiSAT output.

The probability of capture for this species indicated that the length at first capture (*Lc*) was 8.8 cm. The lengths at which 25%, 50%, and 75% of the fish were vulnerable to capture were 20.6 cm, 25.97 cm, and 31.35 cm, respectively, as shown in Fig. (4) and Table (3).



Fig. (4): Probability capture of *L. senegalensis* in the reservoir.

In this investigation, *L. senegalensis* showed one round of recruitment with a peak extended from April to August, coinciding with the rainy season as appears in Fig. (5).



Fig. (5): Annual recruitment of *Labeo senegalensis* from the Roseries reservoir.

The maximum relative yield per recruit (Y/R) was achieved at an exploitation rate (E*max*) of 0.5. The exploitation rates corresponding to 10% and 50% of the maximum Y/R (E01 and E05) were estimated at 0.418 and 0.312, respectively. Additionally, *Lc*/*L∞* was 0.261, and the probability distribution of length *M*/*K* was 1. The calculated length at optimum cohort biomass (*Lopt*) was 31.09 cm, as appears in Fig. (6 & 7) and Table (3).



Fig. (6): Beverton and Holt's relative yield per recruitment (Y/R) and biomass per recruit (B/R) of *Labeo senegalensis* in the Roseries reservoir.



Fig. (7): Length of structured virtual population analysis of *Labeo senegalensis.*

Table (3): Bio-parameters of *L. senegalensis* from Roseries reservoir.

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Calculated value | Parameter | Calculated value |
| *L*∞ | 54.60 | E | 0.45 |
| *K* | 0.260 | E01 | 0.418 |
| *t*0 | -0.264 | E05 | 0.312 |
| Phi (Փ') | 2.889 | E*max* | 0.5 |
| Z | 1.06 | *L*25 | 20.60 |
| M | 0.59 | *L*50 | 25.97 |
| F | 0.47 | *L*75 | 31.35 |
| T*max* | 11.27 | *Lopt* | 31.09 |
| F*max* | 0.210 | *Lc* | 8.8 |
| F*limit* | 0.393 | *L*c/*L*∞ | 0.261 |
| F*opt* | 0.236 | *M*/*K* | 1 |
| *tm50* (yr.-1) | 0.97 | *Lm50* (cm) | 31.09 |

**Discussion:**

The present study examined the population dynamics of Labeo senegalensis in the Roseries reservoir, with a total of 555 specimens collected. The total length (TL) ranged from 8.8 to 52 cm, with a mean of 25.982 ± 6.791 cm. Slightly similar findings were reported by Abdalla *et. al*., (2024), who recorded comparable lengths (8.8 – 40.5 cm) for the same species in the Khashm El-Girba reservoir (Sudan); While Shuaib *et. al*., (2025) in the Upper Atbara and Setit complex dam (Sudan), they reported TL ranged between 21.2 and 47.5 cm (mean 27.7 ± 10.91 cm). The variations in size distribution may be attributed to differences in fishing pressure and gear selectivity across study locations.

This study's von Bertalanffy growth parameters (*L*∞ = 54.60 cm, *K* = 0.260 yr ⁻¹, and *t*0 = -0.264 yr⁻¹, Φ' = 2.889) differed from those reported in other regions. Shuaib *et. al*., (2025) found a lower symptomatic length (47.5 cm) but higher growth curvature (0.86 yr.⁻¹) and *t0* (-0.786 yr⁻¹) for L. senegalensis in Upper Atbara and Setit complex dam, Sudan, while Abdalla *et. al*., (2024) reported even lower values (*L*∞ = 42 cm, *K* = 0.490 yr.⁻¹). Conversely, El-Kasheif *et. al*., (2007) documented a higher *L*∞ (72.99 cm) for Labeo niloticus (syn. L. senegalensis) in the Nile River (Egypt). Variations in growth parameters were also observed in other Labeo species, such as L. rohita (*L*∞ = 83.3 cm, *K* = 0.56 yr⁻¹) and L. calbasu (*L*∞ = 61.2 cm, *K* = 0.28 yr⁻¹) in India (Dwivedi, 2009), and L. dussumieri (*L*∞ = 41.7 cm, *K* = 0.52 yr⁻¹) in Sri Lanka (Athukorala & Amarasinghe, 2010). Montchowui *et. al*., (2011) noted that hydrological conditions, species-specific traits, and environmental factors could influence differences in growth rates.

The longevity (T*max*) of L. senegalensis in this study was estimated at 11.27 years, which was higher than the values reported by Abdalla (2018) (5.604 years) and Abdalla *et. al*., (2024) for the same species in Khashm El-Girba reservoir (Sudan), Montchowui *et. al*., (2011) (10.0 years), and El-Kasheif *et. al*., (2007) (8.3 years). These discrepancies may be linked to variations in mortality rates, exploitation levels, and habitat conditions.

Total mortality (Z = 1.06 yr⁻¹), natural mortality (M = 0.59 yr⁻¹), and fishing mortality (F = 0.47 yr⁻¹) in this study were lower than those reported by Shuaib *et. al*., (2025) (Z = 2.29 yr⁻¹, M = 1.38 yr⁻¹, F = 0.91 yr⁻¹); Abdalla *et. al*., (2024) documented mortality levels of *L. senegalensis* in Khashm El-Girba reservoir (Z = 1.41 yr⁻¹, M = 0.98 yr⁻¹, F = 0.43 yr⁻¹). Similar with slight variations were observed in other Labeo species, such as L. calbasu (M = 1.11 yr⁻¹, F = 3.48 yr⁻¹) in Bangladesh (Alam *et. al*., 2000) and L. rohita (F = 2.73 yr⁻¹, M = 0.94 yr⁻¹) in India (Dwivedi, 2009). These differences likely stem from varying fishing pressures and ecological conditions across study sites.

The growth performance index (Φ' = 2.889) in this study was slightly similar to those reported by Abdalla *et. al*., (2024) (Φ' = 2.937) and Montchowui *et. al*., (2011) (Φ' = 2.99), but within the range (2.61–3.50) documented for other Labeo species (Athukorala & Amarasinghe, 2010; Ahmed *et. al*., 2005). The length at first sexual maturity (*Lm*50 = 31.09 cm) was similar to El-Kasheif *et. al*., (2007) (30.0 cm), but slightly lower than reported by Abdalla *et. al*., (2024) (25.26 cm), possibly due to differences in environmental conditions affecting maturation.

The exploitation rate (E = 0.45) was close to the maximum sustainable yield (E*max* = 0.5), indicating that the stock is near full exploitation. This finding aligns with those of Abdalla *et. al*., (2024) and Montchowui *et. al*., (2011), and the exploitation rate (E = 0.4) reported by Shuaib *et. al*., (2025). The length at first capture (*Lc* = 8.8 cm) was aligned with Abdalla *et. al.,* (2024), but lower than that recorded by Shuaib *et. al*., (2025) (24.02 cm), suggesting differences in fishing gear selectivity.

Recruitment patterns showed a single peak from April to August, coinciding with the rainy season, similar to findings by Shuaib *et. al*., (2025) and Montchowui *et. al*., (2011). However, Abdalla *et. al*., (2024) reported a peak in July, while Alam *et. al*., (2000) observed recruitment in August–October for L. calbasu. These variations may reflect species-specific spawning behaviors and environmental triggers.

The estimated fishing reference points (F*max* = 0.210, F*limit* = 0.393, F*opt* = 0.236) were lower than those reported by Shuaib *et. al*., (2025) (F*max* = 0.81, F*limit* = 0.92, F*opt* = 0.55), indicating regional differences in stock resilience and fishing pressure.

Recommendations for managing *L. senegalensis* fishery in Roseries reservoir:

F*limit* (0.393 yr.-1): Absolute upper limit to prevent overfishing.

F*opt* (0.236 yr.-1): Target for sustainable yield.

F*max* (0.210 yr.-1): Theoretical maximum effort (risky).

Overall, the observed variations in growth, mortality, and recruitment parameters highlight the influence of environmental conditions, fishing practices, and species-specific traits on L. senegalensis populations. Management strategies should consider regional differences to ensure sustainable exploitation.

## **Conclusion**:

This research delivers an in-depth analysis of the population dynamics of *Labeo senegalensis* within the Roseries Reservoir. The growth parameters reveal an asymptotic length of 54.60 cm and a growth coefficient of 0.26 yr⁻¹. The instantaneous mortality rate indicates moderate levels, suggesting a significant exploitation rate. Capture probability data illustrate that the species is susceptible to fishing at relatively small sizes, which are below the length at first maturity. Nonetheless, early harvesting practices and gear selectivity pose risks to the long-term sustainability of the population. Implementing size limits, seasonal closures, and effort regulations may enhance yield while safeguarding the stock.

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2.

3.

**Reference**:

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