**Population dynamics of Nile Tilapia (*Oreochromis niloticus*, Linnaeus, 1758) from Roseries reservoir, Sudan**

**Abstract**:

Growth parameters are essential data points that can indicate the status of fisheries management and the extent of their exploitation. Fish growth parameters can be determined using two primary methods: direct readings from hard structures such as otoliths, spines, or vertebrae, and indirect estimates derived from length distribution data over time. This study investigated the population dynamics of Nile tilapia (*Oreochromis niloticus*) in the Roseries Reservoir, analyzing 636 specimens collected monthly from four sites, during January - December 2022. 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. The von Bertalanffy growth model was applied to analyze growth patterns. The total annual instantaneous mortality rate Z was estimated using length-converted catch curves. 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 age at first capture (tc) was determined from the estimated growth parameters (L∞, K, and t0) using the ELEFAN I method. The peak distribution occurred in September. Specimens ranged from 7 to 41.5 cm (TL), averaging 19.428 ± 6.581 cm. The length-weight relationship demonstrated a strong correlation (*r* = 0.945), indicating a negative allometric growth with a b-value of 2.804. Growth parameters were determined using the von Bertalanffy growth model, with an asymptotic length (*L*∞) of 45.15 cm, a growth coefficient (*K*) of 0.310 yr.⁻¹, and a theoretical age at length zero (*t*0) of -0.321 yr. -1. The growth performance index (Φ') was estimated at 2.801, with a maximum longevity (T*max*) of 9.36 years. Total mortality (Z) was calculated at 1.170 yr.⁻¹, natural mortality (M) at 0.70 yr.⁻¹, and fishing mortality (F) at 0.47 yr.⁻¹, resulting in an exploitation rate (E) of 0.41. *O. niloticus* exhibited one round of recruitment, peaking from April to August, coinciding with the rainy season, while the length at first capture (*Lc*) was determined to be 7 cm. The maximum relative yield per recruit (Y/R) was achieved at an exploitation rate (E*max*) of 0.499. The estimated total mortality and fishing mortality rates indicate the current fishing pressure faced by *O. niloticus*, emphasizing the need for effective management practices to ensure sustainability. The achievement of maximum relative yield per recruit at a specific exploitation rate underscores the importance of aligning fishing practices with biological data to optimize yields while preserving the fish population. Overall, this research serves as a foundational reference for future studies on Nile tilapia in Sudan and informs local and federal fisheries management strategies.

**Keywords**: Tilapia, Mortality, Population dynamics, First capture, Recruitment, Growth.

**Introduction**:

In many countries, fisheries contribute to food security and poverty reduction among populations living in coastal areas, along riverbanks, and on small islands. Inland fish play a critical role as an essential food and nutritional resource, particularly contributing to the economies of rural areas in developing countries (Ouédraogo et al., 2025). Africa is home to at least 3,300 freshwater fish species (Leveque and Paugy, 2017), representing approximately 10% of the global total (Nyboer *et. al*., 2019). Among these species, Cichlids represented 10%, as noted by Leveque and Paugy (2017). In Sudan's inland waters, Mahmoud *et. al*., (2024) recorded 134 fish species, while Abdalla and Adam (2024) reported that the Blue Nile accounts for nearly one-third of the country's freshwater fish species richness at 36%. Specifically, in the Roseries Reservoir, Mahmoud and Hagar (2020) recorded 53 distinct fish species. In fish stock assessment, the study of life history traits such as growth and mortality rates are helpful for rational fisheries resource utilization and management and predicting the future status of fishing stocks. In stock assessment, length frequency method is preferred to the direct age method to estimate the growth of fish because data on age from hard structures of fish are not easily available due to reasons like budget constraints, lack of trained manpower, and low access to technology (Yoseph et al., 2017). Understanding the length-weight relationship of fish is critical for conducting fishery stock assessments and management studies (Jellyman, 1997). This relationship provides valuable insights into fish population dynamics, including growth patterns, recruitment mortality rates, exploitation levels, and stock biomass as highlighted by Pervin and Mortuza (2008), Pauly and Morgan (1987), and Pauly (1983). The dynamics of fish populations are fundamentally based on biological processes such as reproduction, growth, maturity, mortality, and levels of exploitation (Jakobsen *et. al.*, 2016).

Growth parameters are essential data points that can indicate the status of fisheries management and the extent of their exploitation, as stated by Omitoyin *et. al*., (2013). Fish growth parameters can be determined using two primary methods: direct readings from hard structures such as otoliths, spines, or vertebrae, and indirect estimates derived from length distribution data over time, as discussed by Gayanilo *et. al*., (2002) and Panfili *et. al*., (2002). Length-based stock assessment tools are particularly advantageous in tropical and subtropical waters where seasonal variations in hard structures are subtle and often present unclear annual marks, as noted by Panhwar and Liu (2013).

This study was conducted at four fishing sites within the Roseries Reservoirs in Sudan. The primary objective was to investigate the population dynamics aspects of *O. niloticus*, including growth, mortality, recruitment, and exploration rate, in the Roseries reservoir. The results will offer valuable insights for the sustainable development, management, and exploitation of this commercially significant fish species in Sudan's freshwater ecosystems.

**Materials and Methods**:

**Study area**:

The Roseires Dam is situated on the Blue Nile River in Sudan, serving the dual purpose of water storage for agricultural irrigation and hydroelectric power generation. Approximately 550 kilometers from Khartoum, the dam's first phase of construction 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.

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 636 fish specimens were collected monthly from four sites (Table 1) from January to December 2022. 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. Details 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 |

**Length-Weight Relationship:**

The length-weight relationship for *O. niloticus* was established using the Le Cren equation:

Log (W) = log (a) + b log (L)

W represents total weight, L is total length, *a* is the intercept, and *b* is the regression coefficient.

**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:**

The length-weight relationship data were analyzed using Microsoft Excel, while population parameters were estimated using FiSAT software in accordance with methodologies of Gayanilo *et. al.*, (1996) and Pauly and Morgan (1987).

**Results**:

**Growth parameters:**

In this study, 636 specimens of *O. niloticus* were randomly collected monthly from four sites in the Roseries Reservoir (Table 1) from January to December 2022. The peak distribution of the fish occurred in September as shown in Fig. (1). The length-weight relationship exhibited a strong correlation (*r* = 0.945) indicating a negative allometric growth pattern with a b-value of 2.804 as illustrated in Fig. (2). The total length of the specimens ranged from 7 to 41.5 cm with an average of 19.428 ± 6.581 cm as shown in Fig. (3).

Fig. (1): Monthly fish distribution from the reservoir during the study period.

Fig. (2): Length-weight relationship of *O. niloticus* from the reservoir*.*

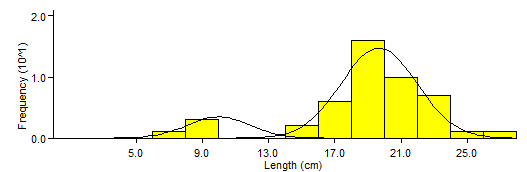


Fig. (3): Total length distribution of *O. niloticus* in Roseries reservoir.

The von Bertalanffy growth parameters were calculated as follows: an asymptotic length (*L*∞) of 45.15 cm, a growth coefficient (*K*) of 0.310 yr.⁻¹ and a theoretical age at length zero (*t*0) of -0.321 yr.⁻¹. The growth performance index (Φ') based on the *L*∞ and *K* parameters of the von Bertalanffy growth function (vBGF) was estimated at 2.801 while longevity (T*max*) was determined to be 9.36 years, as shown in Fig. (4), and Table (3). The von Bertalanffy growth function was derived accordingly:

*Lt* = 45.15 × 1-exp(-0.310×(t+0.321)).

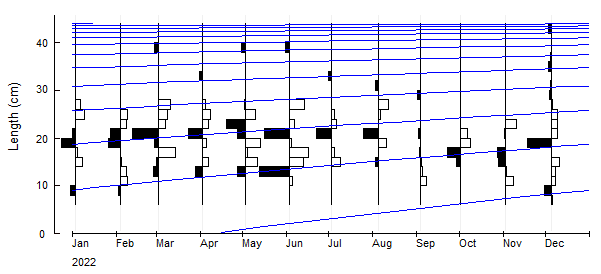


Fig. (4): Von Bertalanffy growth curve of *O. niloticus* by ELEFAN I based on length-frequency distribution (*L∞* 45.15 cm and *K* 0.310 yr -1).

The total mortality (Z) was estimated at 1.170 yr.⁻¹ natural mortality (M) at 0.70 yr.⁻¹ and fishing mortality (F) at 0.47 yr.⁻¹ with an exploitation rate (E) of 0.41 as shown in (Fig. 5 and Table 3).

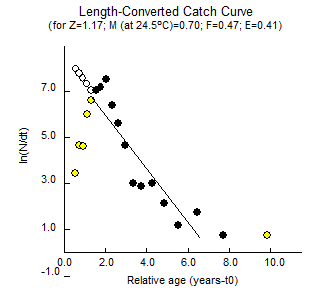


Fig. (5): Total, natural, fishing mortality, and exploitation rate using length-converted catch curve from FiSAT output.

In this investigation, *O. niloticus* showed one round of recruitment with a peak occurring from April to August, coinciding with the rainy season as appears in Fig. (6).

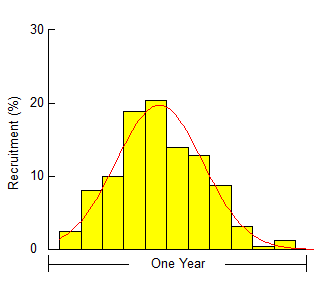


Fig. (6): Annual recruitment of *O. niloticus* from the Roseries reservoir.

The probability of capture for this species indicated that the length at first capture (*Lc*) was 7 cm. The lengths at which 25%, 50%, and 75% of the fish were vulnerable to capture were 12.27 cm, 14.12 cm, and 15.90 cm, respectively, as shown in Fig. (7) and Table (3).

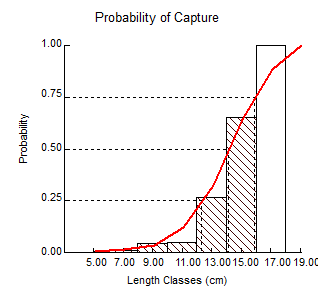
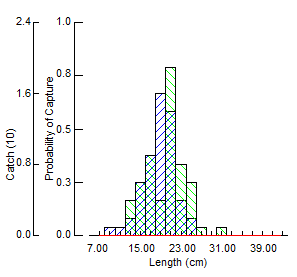


Fig. (7): Gillnet selection and the selective curve illustrate the probability of capture in the reservoir.

The maximum relative yield per recruit (Y/R) was achieved at an exploitation rate (E*max*) of 0.499. 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 0.260, and the probability distribution of length *M*/*K* was 1. The calculated length at optimum cohort biomass (*Lopt*) was 25.17 cm.

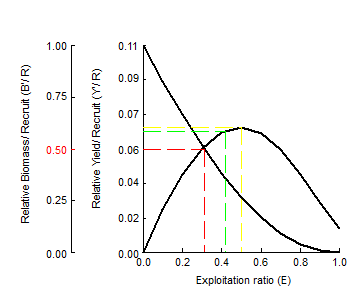


Fig. (8): Beverton and Holt's relative yield per recruitment (Y/R) and biomass per recruit (B/R) of *O. niloticus* in the Roseries reservoir.

Population analysis revealed a moderate catch-to-stock ratio in the reservoir as indicated by the yellow shading in Fig. (9), particularly within the length range of 11 to 25 cm. The highest abundance was observed in fish less than 9 cm (shown by striped green), with a gradual decline in abundance as age increased. Natural mortality was significantly high among slightly larger fish (violet shading), while fishing mortality began at 7 cm and peaked at 21.8 cm (red line) as illustrated in Fig. (9).

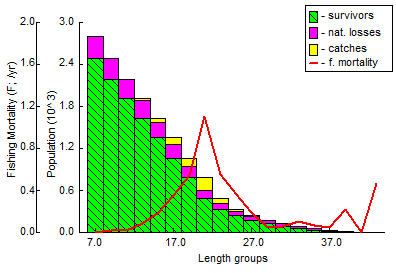


Fig. (9): Length of structured virtual population analysis of *O. niloticus.*

Table (3): Bio-parameters of *O. niloticus* from Roseries reservoir.

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | Estimated values | Parameters | Estimated values |
| *L*∞ (cm) | 45.15 | E | 0.41 |
| K yr.-1 | 0.310 | E01 | 0.418 |
| *t*0 | -0.321 | E05 | 0.312 |
| Phi (Փ') | 2.801 | E*max* | 0.499 |
| Z | 1.170 | *L*25 | 12.27 |
| M | 0.70 | *L*50 | 14.12 |
| F | 0.47 | *L*75 | 15.90 |
| *L*c/*L*∞ | 0.260 | T*max* | 9.36 |
| M/K | 1 | L*opt* | 25.17 |
| F*max* | 0.464 | F*opt* | 0.278 |
| F*limit* | 0.050 | *L*c | 7 |
| *tm50* (yr.-1) | 0.98 | *Lm50* (cm) | 11.81 |

**Discussion**:

In the current study, 636 specimens of *O. niloticus* were collected monthly from four sites in the Roseries reservoir, as shown in Table (1), between January and December 2022. The total length of the fish ranged from 7 to 41.5 cm, with an average length of 19.428 ± 6.581 cm, as shown in Fig. (3). The distribution peak occurred in September, as illustrated in Fig. (1). The straight lined equation of length-weight relationship yielded a slope (*b*) of 2.804, highly significant (*p* < 0.001), with a correlation value (*r* = 0.945), as shown in Fig. (2), indicating a negative allometric growth pattern. Similar negative allometric growth patterns have been reported for *O. niloticus* by Shuaib *et. al.*, (2024); Abdalla *et. al.*, (2023 & 2020); Abdalla (2018); Abdel Rahman (2003); Ahmed (2002); Ibrahim (2007); Ahmed *et. al*., (2011), and Hirpo (2013). These studies, conducted in Lake Nubia, Jebel Aulia reservoir (White Nile), Khashm El-Girba and Atbara River (Sudan), and Lake Beseka (Ethiopia), support the findings of this study.

The present study estimated von Bertalanffy growth parameters for *O. niloticus* with an asymptotic length (*L*∞) of 45.15 cm and a growth coefficient (*K*) of 0.310 yr.⁻¹ and a theoretical age at length zero (*t*0) of -0.321 yr.⁻¹. According to Amponsah *et. al.*, (2020) and Tessier *et. al.*, (2019), they observed that the asymptotic length falls within the range of (19.4 – 65.8 cm), as documented in Sakumo II (Ghana) and NT2 Reservoir (Lao PDR). Hence, these findings align with Shuaib and Abdalla (2024), who reported similar growth parameters with slightly lower growth curvature and theoretical age at length zero in Nubia Lake (Sudan). Comparable results were also noted in Halali Reservoir (India) and Lake Tana (Ethiopia) according to Waithaka *et. al*., (2020) and FAO (2018).

However, differences exist when comparing these findings with other studies. For instance, Abdalla *et. al.*, (2024) reported a lower asymptotic length and higher growth coefficient and theoretical age at length zero in Khashm El-Girba Reservoir (Sudan), indicating rapid growth. Similarly, lower asymptotic lengths were recorded in Lake Langeno (Ethiopia), Siombak Lake (Indonesia), Manzala Lake (Egypt), and the River Nile (Aswan, Egypt) (Tesfaye *et. al.*, 2022; Muhtadi *et. al.*, 2021; Mehanna *et. al.*, 2020; El-Kasheif *et. al.*, 2015 & El-Bokhty *et. al.*, 2014). Variations in growth parameters have also been documented in Lake Abaya and Chamo (Ethiopia) and Kaptai Reservoir (Bangladesh) (Tesfaye *et. al.*, 2021; Shija *et. al.*, 2019, and Ahmed *et. al.*, 2003). The observed differences may be attributed to factors such as fishing pressure, habitat conditions, food availability, and geographic variations influencing growth dynamics.

In this study, the growth performance index (Φ') for *O. niloticus* was estimated at 2.801, based on the *L*∞ and *K* parameters of the von Bertalanffy growth function (vBGF), as illustrated in Table (3). This result matched closely with findings from Abdalla *et. al.*, (2024) for the same species in Khashm El-Girba reservoir, and Shuaib and Abdalla (2024) in Nubia Lake (Sudan). Moreover, this study's findings agree with results documented in Lake Manzala and El-Bahar El-Faraouny (Egypt), and Lake Langeno (Ethiopia), as noted by Mehanna *et. al.*, (2020), El-Kasheif *et. al.* (2015), and Tesfaye *et. al.* (2022). However, this study's growth performance index is lower than those reported by other researchers. For instance, Shija *et. al.* (2024) in Lake Abaya (Ethiopia), and Tesfaye *et. al.* (2021) in Lake Chamo (Ethiopia). The highest value recorded was 4.44 in Wadi El-Raiyan (Mehanna, 2020), while the lowest was 2.08 in the Nam Theun 2 reservoir (Lao PDR) according to Beaune *et. al.* (2021). These variations may be attributed to differences in local environmental conditions, food availability, and fishing pressures that influence growth dynamics across different habitats.

During this study, the longevity (T*max*) of *O. niloticus* was found to be 9.36 years, as presented in Table (3). This result is higher than the T*max* recorded in Khashm El-Girba reservoir, where Abdalla *et. al*., (2024) reported a longevity of 4.62 years, suggesting that environmental factors in the Roseries reservoir may support a longer lifespan for this species. In contrast, the longevity observed in this study is lower than that reported in Nubia Lake, where Shuaib and Abdalla (2024) found a T*max* of 12.86 years, indicating potential differences in habitat conditions or resource availability that may enhance growth and survival. Additionally, the longevity results are significantly higher than those reported by Abdalla (2018), who noted an average lifespan of around 3 years for *O. niloticus* in Khashm El-Girba Reservoir and the Atbara River. This disparity may be referring to differences in environmental conditions, fishing pressures, and management practices between the study sites. Furthermore, the findings align closely with the maximum longevity of 10 years reported by Mayank and Dwivedi (2016), supporting the notion that *O. niloticus* can exhibit considerable variability in lifespan depending on local ecological factors.

The total mortality (Z) for *O. niloticus* in this study was estimated at 1.170 yr.⁻¹, with natural mortality (M) at 0.70 yr.⁻¹ and fishing mortality (F) at 0.47 yr.⁻¹, as shown in Fig. (5) and Table (3). These results indicate a moderate level of mortality for this species in the Roseries reservoir. In comparison, Abdalla *et. al*., (2024) recorded significantly higher total, natural, and fishing mortality rates of 2.38, 1.22, and 1.16 yr.⁻¹, respectively, in Khashm El-Girba reservoir, suggesting that differences in both reservoirs' environmental or fishing pressures may be influencing mortality rates in these locations. Conversely, Shuaib and Abdalla (2024) reported lower mortality rates in Nubia Lake, with total, natural, and fishing mortalities of 0.65, 0.63, and 0.02 yr.⁻¹, respectively. This disparity may reflect a more stable ecosystem or lower fishing pressure in Nubia Lake compared to the Roseries reservoir.

Further comparisons with literature indicate that total mortality rates for Nile tilapia can vary widely. For instance, rates as low as 0.8 yr.⁻¹ have been reported in Lake Naivasha (Kenya) and Kaptai reservoir (Bangladesh), as noted by Waithaka *et. al*., (2020) and Ahmed *et. al.,* (2003). Conversely, El-Bokhty *et. al*., (2014) documented a high rate of 3.64 yr.⁻¹ in the Nile River at Aswan (Egypt). Natural mortality has also shown considerable variation, ranging from 0.30 yr.⁻¹ in Nam Theun 2 reservoir (Lao PDR) to 1.44 yr.⁻¹ in Aswan, Egypt. Similarly, fishing mortality rates have been reported as low as 0.26 yr.⁻¹ in Lake Naivasha (Waithaka *et. al*., 2020). These variations in mortality rates across different studies can be attributed to several factors, including fishing practices, fishing gears and methods, and population dynamics specific to each habitat.

In the present study, the exploitation rate (E) for *O. niloticus* was calculated at 0.41 yr.⁻¹, as shown in Fig. (5) and Table (3), as derived from the formulas E = F/Z or E = F/(F+M). This result indicates that the species is experiencing a high level of fishing pressure. In comparison, Abdalla *et. al.*, (2024) reported a slightly higher exploitation rate of 0.49 yr.⁻¹ for *O. niloticus* in Khashm El-Girba reservoir, while Shuaib and Abdalla (2024) found a significantly lower rate of 0.04 yr.⁻¹ in Nubia Lake, suggesting a strong variation in fishing intensity across these locations.

The current study's exploitation rate and the estimated optimum exploitation (E*max*) of *O. niloticus* were found to be 0.41 and 0.499, respectively, indicating that the species is close to the optimum exploitation rate of 0.5. This aligns with findings from Amponsah *et. al.*, (2021) in Sakumo II (Benin) and Shija *et. al*., (2019) in Lake Chamo (Ethiopia), who reported exploitation rates of 0.29 and 0.48, respectively. However, several studies have documented higher exploitation rates than those observed in this study. Beaune *et. al.*, (2021) reported an exploitation rate of 0.79, while Mehanna (2005) indicated rates of 0.76, and other researchers, such as Shija *et. al.* (2024) and Tesfaye *et. al.*, (2022), reported rates of 0.74 and 0.67, respectively. These elevated rates suggest that the Nile tilapia stocks in those environments may be overfished, thereby raising concerns about sustainability.

Conversely, some fisheries have maintained exploitation rates below optimal levels, as seen in Lake Naivasha (Kenya), Lake Sakumo II (Ghana), and others, with rates ranging from 0.23 to 0.48, as noted by Waithaka *et. al.*, (2020) and Amponsah *et. al.,* (2020). Notably, Shija *et. al.* (2019) indicated that Lake Abaya (Ethiopia) has reached an optimal exploitation level of 0.5, while other water bodies like Lake Tana, Langeno (Ethiopia), and the Nile River at Aswan (Egypt) have reported rates exceeding optimal levels, from 0.52 to 0.78. These differences in exploitation rates can be attributed to variations in fishing practices, management strategies, and ecological conditions across different regions. This investigation suggests that the exploitation rate of *O. niloticus* in this study is a high fishing pressure; the comparison with other studies highlights significant disparities that underscore the need for careful management to ensure sustainable yields.

In the present investigation, *O. niloticus* exhibited one round of recruitment, peaking from April to August, coinciding with the rainy season, as illustrated in Fig. (6). This finding is consistent with the observations made by Abdalla *et. al.*, (2024) in Khashm El-Girba reservoir, where a similar recruitment pattern was reported. However, this result contrasts with findings from Nubia Lake, where Shuaib and Abdalla (2024) documented two rounds of recruitment for *O. niloticus*. Similarly, Amponsah *et. al.*, (2020) identified two recruitment peaks in Sakumo II (Ghana). In contrast, Assefa *et. al.*, (2019) observed a year-round recruitment pattern in Lake Tana (Ethiopia), with a peak during May and June. This variability may refer to the influence of environmental factors and regional characteristics on the reproductive strategies of this species.

In the current investigation, the capture probability analysis revealed that the length at which 50% of Nile tilapia (*O. niloticus*) are vulnerable to capture is 14.27 cm, as presented in Fig. (7) and Table (3). This finding indicates a moderate vulnerability size for this species in the study area. In contrast, Abdalla *et. al.*, (2024) reported a capture probability of 15.65 cm for Nile tilapia in the Khashm El-Girba reservoir, suggesting a slightly larger size at vulnerability in that location.

Additionally, Shuaib and Abdalla (2024) found a lower capture length of 10.07 cm in Nubia Lake, indicating that environmental conditions or fishing practices may facilitate earlier capture in that habitat. Similarly, Amponsah *et. al.*, (2020) reported an even lower capture length of 4.1 cm in Sakumo II (Ghana), which may reflect differences in the local fishing gear used or the density of juvenile fish in that area. Conversely, Assefa *et. al.*, (2019) recorded a capture probability of 18.14 cm in Lake Tana (Ethiopia), which represents a significantly larger size at vulnerability. These variations may refer to differences in the fishing intensity, species management strategies, or ecological conditions that affect growth and survival rates in different environments.

In the present study, the maximum relative yield per recruit (Y/R) was attained at an exploitation rate (E*max*) of 0.499, with corresponding values for virgin fisheries at 10% (E0.1) and complete fisheries at 50% (E0.5) of maximum Y/R recorded at 0.418 and 0.312, respectively. The optimal length for cohort biomass or pre-recruitment yield (*Lopt*) was established at 25.17 cm TL. These results are consistent with those reported by Abdalla *et. al*., (2024) and Amponsah *et. al*., (2020), who found E*max*, E0.5, and E0.1 values of 0.48, 0.35, and 0.35, respectively, indicating similar patterns in yield dynamics. However, the findings differ from those of Assefa *et. al*., (2019) in Lake Tana (Ethiopia), who reported E*max*, E0.5, and E0.1 values of 0.52, 0.45, and 0.32, respectively. This differentiation may be due to variations in geographical, stock densities, or fishing practices that influence the yield potential of *O. niloticus*. Additionally, Shuaib and Abdalla (2024) recorded E*max*, E0.5, and E0.1 values of 0.421, 0.355, and 0.278, respectively, further highlighting differences in yield dynamics across different lakes.

In terms of fishing effort, the maximum fishing effort (F*max*), precautionary limit reference point (F*limit*), and precautionary target reference point (F*opt*) in this study were calculated as 0.464, 0.050, and 0.278, respectively. In contrast, Shuaib and Abdalla (2024) reported significantly lower values for F*max* (0.18), F*limit* (0.42), and F*opt* (0.252) in Nubia Lake. This variation may reflect differences in fishing pressure and management strategies, which can greatly affect the sustainability and yield of fish stocks. Overall, while the findings of this study are consistent with some existing literature, the observed differences in exploitation and fishing effort metrics underscore the influence of environmental factors and fishing practices on the dynamics of *O. niloticus* populations across various ecosystems.

This study highlights the population dynamics of a key commercial species in Sudan, particularly during the ongoing conflict, and serves as a valuable baseline for future research on inland fish population dynamics in the region.

**Conclusion:**

This study provides valuable insights into the population dynamics of *O. niloticus* in the Roseries Reservoir. The data indicate a peak distribution in September and a strong correlation in the length-weight relationship, suggesting a negative allometric growth pattern. The observed range of total lengths and the calculated growth parameters highlight the species' adaptability and growth potential in this environment. The von Bertalanffy growth model parameters reveal important aspects of the species' life history, including an asymptotic length and growth coefficient that contribute to understanding its biological characteristics. Additionally, the estimated total mortality and fishing mortality rates indicate the current fishing pressure faced by *O. niloticus*, emphasizing the need for effective management practices to ensure sustainability.

The findings related to recruitment patterns and the probability of capture further illustrate the reproductive strategies of this species. The achievement of maximum relative yield per recruit at a specific exploitation rate underscores the importance of aligning fishing practices with biological data to optimize yields while preserving the fish population. Overall, this research serves as a foundational reference for future studies on Nile tilapia in Sudan and informs local and federal fisheries management strategies.

Disclaimer (Artificial intelligence)

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

**Reference**:

Abdalla, M. Y. M. (2018). Biological aspects of *Oreochromis niloticus* and *Labeo niloticus* from Khashm El-Girba Reservoir, Kassala State, Sudan. *M.Sc. thesis, Department of Zoology, Faculty of Science, University of Khartoum, Sudan*.

Abdalla, M. Y. M. and Adam, A. E. (2024). Diversity and distribution of ichthyofauna in the inland waters of Sudan: A Review. *Asian J. Res., Zool.,* Vol., 7(3): 1-13. DOI: <https://doi.org/10.9734/ajriz/2024/v7i3151>.

Abdalla, M. Y. M., Abdelhalim, A. I., Alawad, A. N., Shuaib, M. E. and Elhassan, M. M. (2023). Some biological parameters of the Nile Tilapia, *Oreochromis niloticus* L. 1758, from Atbara River and Khashm El-Girba reservoir, Eastern Sudan. *J. fisher., Mar., res.,* Vol., 7(3): 97-107.

Abdalla, M. Y. M., Ahmed, A. A. and Elhassan, M. M. (2020). Investigation on some biological aspects of Nile Tilapia, *Oreochromis niloticus* (L. 1758) from Khashm El-Girba fish market, Sudan: Length-weight relationship, condition factor and sex ratio. *Asian J. Res., Zool.,* Vol., 3(4): 20-26. DOI: 10.9734/AJRIZ/2020/v3i430098.

Abdalla, M. Y. M., Shuaib, M. E., Alnaiem, O., Hamid, A. M. and Adam, A. E., (2024). Population Dynamics of Nile Tilapia (*Oreochromis niloticus*, Linnaeus, 1758) from Khashm El-Girba Reservoir, Atbara River, Eastern Sudan. *Asian J. Fisher., Aquat., Res.,* Vol., 26(9): 66-79.DOI: https://doi.org/10.9734/ajfar/2024/v26i9806.

Abdel Rahman, M. M., (2003). A study on catch assessment in the northern part of Jebel Aulia reservoir. *M. Sc. Thesis, Department of Zoology, Faculty of Science, University of Khartoum. Khartoum*. Sudan.

Ahmed, K., Amin, S., Haldar, G., & Dewan, S. (2003). Population dynamics and stock assessment of *Oreochromis niloticus* (Linnaeus) in the Kaptai Reservoir, Bangladesh. *Indian Journal of Fisheries, 50*, 47–52.

Ahmed. Egbal, O. (2002). Studies on the productivity and fisheries of Khashm El-Girba reservoir in relation to annual fishing. *M.Sc. Thesis, Dept. Of Zoology, Faculty of Science, University of Khartoum*. Sudan.

Ahmed. Egbal, O., Mohammed, E. A. and Afra, A. Aziz., (2011). Length–weight relationship and condition factor of six fish species in Atbara River and Khashm El-Girba reservoir, Sudan. *Inter. J. Agri. Sci.,*3 (1):65 - 70.

Amponsah, K. K., Asiedu, B., & Failler, P. (2020). Population parameters of *Oreochromis niloticus* (L.) from a semi-open lagoon (Sakumo II), Ghana and its implications on management. *Egyptian J. Aquat., Biol., Fisher.,* Vol., 24: 195–207. DOI: [10.21608/ejabf.2020.79778](https://dx.doi.org/10.21608/ejabf.2020.79778).

Assefa, W. W., Wondie, A., & Enyew, B. G. (2019). Population dynamics and exploitation patterns of *Oreochromis niloticus* in Lake Tana, Northwest Ethiopia. *Lakes & Reservoirs: Science, Policy and Management for Sustainable Use, 24*(4), 344–353. <https://doi.org/10.1111/lre.12290>.

Bailey, R. G. (1994). A guide to the fishes of the River Nile in the Republic of Sudan. *J. Nat., Hist*., Vol., 28:937-970. DOI: <https://doi.org/10.1080/00222939400770501>.

Beaune, D., Guillard, J., Cottet, M., Kue, K., Lae, R., Chanudet, V., Descloux, S., Tessier, A. (2021). Investigating key biological parameters of Nile Tilapia (*Oreochromis Niloticus* L.) in a Large Asian Reservoir to Better Develop Sustainable Fisheries. *Hydroécol., Appl*., Vol., 21: 157–179, DOI:10.1051/hydro/2020001.

Beverton, R. (1992). Patterns of reproductive strategy parameters in some marine teleost fishes. *J. Fish Biol.,* Vol.,41, 137–160.

Beverton, R. J., & Holt, S. J. (1957). On the dynamics of exploited fish populations(Vol. 11). *Springer Science & Business Media*. ISBN 94-011-2106-0.

El-Bokhty, E.-A. E. B., & El-Far, A. M. (2014). Evaluation of *Oreochromis niloticus* and *Tilapia zillii* fisheries at Aswan region, River Nile, Egypt. *Egyptian J. Aquat., Biol., Fisher.,* Vol., 18: 79–89.

El-Kasheif, M. A., Authman, M. M., Al-Ghamdi, F. A., Ibrahim, S. A., & El-Far, A. M. (2015). Biological aspects and fisheries management of tilapia fish *Oreochromis niloticus* (Linnaeus, 1758) in El-Bahr El-Faraouny Canal, Al-Minufiya Province, *Egypt*. *J. Fisher., Aquat., Sci.,* Vol., 10: 405.

Food and Agriculture Organization (FAO). (2018). *Tilapia trade: Global and regional trends* (pp. 1–28).

Gayanilo, F. C., Sparre, P., & Pauly, D. (1996). *FAO-ICLARM Fish Stock Assessment Tools (FISAT) Software Package User’s Manual*. Food & Agriculture Organization.

Gayanilo, F., Sparre, P., & Pauly, D. (2005). *FAO-ICLARM stock assessment tools II: Revised version: User’s guide*. FAO Computerized Information Series on Fish.

Gayanilo, F., Sparre, P., and Pauly, D. (2002). FAO-ICLARM stock assessment tools (FiSAT). Software Version 1.2. 0. *FAO*. Roma.

Gulland, J. (1971). Science and fishery management. *ICES Journal of Marine Science, 33*, 471–477.

Hirpo, L. A. (2013). Reproductive biology of *O. niloticus,* in Lake Beseka, Ethiopia. *Acad.*, *J*., 7(9): 116-120.

Hoggarth, D. D., Abeyasekera, S., Arthur, R. I., Beddington, J. R., Burn, R. W., Halls, A. S., Kirkwood, G. P., McAllister, M., Medley, P., Mees, C. C., et al. (2006). *Stock assessment for fishery management: A framework guide to the stock assessment tools of the Fisheries Management and Science Programme*. Food & Agriculture Organization. ISBN 92-5-105503-3.

Ibrahim, Mahassin. A. (2007). Some Aspects of Khashm El-Girba Fisheries, Atbara River, *M. Sc. Thesis, Department of Zoology, Faculty of Science, University of Khartoum. Khartoum*. Sudan.

Kullander, S. O. (1998). A phylogeny and classification of the South American Cichlidae (Teleostei: Perciformes). Pp. 461-498, *In*: L.R. Malabarba, R.E. Reis, R.P. Vari, Z.M.S. Lucena and C.A.S. Lucena (eds.). Phylogeny and classification of Neotropical fishes. Edipucrs, Porto Alegre.

Le Cren, E. D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology*, 201–219.

Leveque, C. and Paugy, D. (2017). Freshwater Fishes in Africa. Paris: *EOLSS*; c2017.

Mahmoud, Z. N. and Hagar, E., (2020). Fish species encountered over 47 years in Lake Roseris. *EPH-Inter., J. Agricul., Environ., Res.*, Vol., 6(1): 11-14. DOI: <https://doi.org/10.53555/eijaer.v5i1.51>.

Mahmoud, Z. N., Hagar, E. A. and Abdalla, M. Y. M. (2024). Fish diversity in the Nile system and ephemeral water bodies in Sudan: Records and a review. *Inter., J. Fisher., Aquat., Stud.*, Vol., 12(4): 1-8. DOI:<https://doi.org/10.22271/fish.2024.v12.i4a.2938>.

Mayank, P., & Dwivedi, M. C. (2016). Stock assessment and population structure of alien fish species, *Oreochromis niloticus* (Linnaeus) from the lower stretch of the Yamuna River, India. *Journal of Experimental Zoology India, 19*, 163–167.

Mehanna, S. F. (2005). Population dynamics and management of the Nile tilapia *Oreochromis niloticus* at Wadi El-Raiyan Lakes, Egypt. *African Journal of Biological Sciences, 1*, 79–88.

Mehanna, S. F., Desouky, M. G., & Makky, A. F. (2020). Growth, mortality, recruitment, and fishery regulation of the Nile tilapia *Oreochromis niloticus* (Teleostei: Cichlidae) from Manzala Lake, Egypt. *Iranian Journal of Ichthyology, 7*, 158–166.

Moreau, J., Bambino, C. and Pauly, D. (1986). Indices of overall growth performance of 100 Tilapia (Cichlidae) populations. In: Maclean JL, Dizon LB, Hosillos LV, editors. The First Asian Fisheries Forum. Asian Fisheries Society; c1986. p. 201-206.

Muhtadi, A., Nur, M., Latuconsina, H., & Hidayat, T. (2021). Population dynamics and feeding habit of *Oreochromis niloticus* and *O. mossambicus* in Siombak Tropical Coastal Lake, North Sumatra, Indonesia: Population dynamics and feeding habit of tilapia. *Biodiversitas: Journal of Biological Diversity, 23*. https://doi.org/10.13057/biodiv/d230119.

Neumann, D. Obermaier, H. and Moritz, T. (2016). Annotated Checklist for fishes of the Main Nile Basin in the Sudan and Egypt based on recent specimens’ records (2006-2015). *Cybium*. Vol., 40(2):287-317.

Nyboer, E., Liang, C., and Chapman, L. (2019). Assessing the vulnerability of Africa’s freshwater fishes to climate change: A content-wide trait-based analysis. *Biol., Conserv*., Vol., 236:505-520. DOI: <https://doi.org/10.1016/j.biocon.2019.05.003>.

Omitoyin, B. Salako, A., and Eriegha, O. (2013). Some Ecological Aspects of *Oreochromis niloticus* and *Heterotis niloticus* from Ona Lake, Asaba, Nigeria. *World J. Fish., Mar., Sci*., Vol., 5: 641–648. DOI: 10.5829/idosi.wjfms.2013.05.06.7563.

Panfili, J., de Pontual, H., Troadec, H. and Wright, P. J. (2002). Manual of fish sclerochronology (pp. 464-p+). *Ifremer-IRD coedition*.

Panhwar, S.K. and Liu, Q., 2013. Population statistics of the migratory hilsa shad, *Tenualosa ilisha*, in Sindh, Pakistan. *Journal of Applied Ichthyology*, Vol., 29(5): 1091-1096. DOI: <https://doi.org/10.1111/jai.12134>.

Patterson, K. (1992). Fisheries for small pelagic species: An empirical approach to management targets. *Reviews in Fish Biology and Fisheries, 2*, 321–338.

Pauly, D. and Morgan, G. R. (1987). Editors. Length-based methods in fisheries research. ICLARM Conference Proceedings 13. ;468.

Pauly, D. (1979). Gill size and temperature as governing factors in fish growth: A generalization of von Bertalanffy’s growth formula.

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*, 175–192.

Pauly, D. (1983). Some simple methods for the assessment of tropical fish stocks. *Food & Agriculture Organization*.

Pauly, D. (1984). *Fish population dynamics in tropical waters: A manual for use with programmable calculators*. ICLARM.

Pauly, D., & Soriano, M. (1986). Some practical extensions to Beverton and Holt’s relative yield-per-recruit model. In *Asian Fisheries Society Proceedings* (pp. 491–496).

Pervin, M. R., & Mortuza, M. G. (2008). Notes on length-weight relationship and condition factor of freshwater fish, *Labeo boga* (Hamilton) (*Cypriniformes: Cyprinidae*). *University Journal of Zoology, Rajshahi University*, *27*, 97–98.

Shija, B. S. (2024). Length-based estimates of growth parameters and mortality rates of Nile tilapia (*Oreochromis niloticus*, L. 1758) in Lake Abaya, Southern Ethiopia. *East African Journal of Biophysics and Computational Science, 5*, 51–67.

Shija, B. S., Tesfaye, G., & Dadebo, E. (2019). Assessment of maximum sustainable yield and optimum fishing effort for the Nile tilapia (*Oreochromis niloticus* L.) in Lake Chamo, Ethiopia. *Journal of Agricultural and Environmental Sciences, 4*, 69–86.

Shuaib, M. E. and Abdalla, M. Y. M., (2024). Population Dynamics of Nile Tilapia (*Oreochromis niloticus*, L. 1758) in Lake Nubia, Sudan. *Asian J. Fisher., Aquat., Res.,* Vol., 26(11): 57-70. DOI: https://doi.org/10.9734/ajfar/2024/v26i11829.

Shuaib, M. E., Hamid, A. M., Khalid, A. M., Adam, A. E., Alttagi, Z. E. and Abdalla, M. Y. M. (2024). Length-weight relationships and condition factors of three commercially important fish species from Roseries reservoir, Blue Nile, Sudan. *Asian J. Fisher., Aquat., Res.,* Vol., 26(9): 1-11. DOI: <https://doi.org/10.9734/ajfar/2024/v26i9801>.

Tesfaye G, Tesfaye G, Getahun A, Tadesse Z, Workiye G. (2022). Population Dynamics of the Nile Tilapia (*Oreochromis Niloticus* L. 1758) Stock in Lake Langeno, Ethiopia. *SEJS*. Vol., 45: 174–191. DOI:10.4314/sinet.v45i2.5.

Tesfaye M, Tesfaye G, Getahun A. (2021). Growth and status of Nile Tilapia (*Oreochromis niloticus* L.) Stock in Lake Chamo, Ethiopia. Lakes & Reservoirs. Vol., 26:e12375. DOI:10.1111/lre.12375.

Tessier, A., Blin, C., Cottet, M., Kue, K., Panfili, J., Chanudet, V., Descloux, S., & Guillard, J. (2019). Life history traits of the exploited Nile tilapia (*Oreochromis niloticus* – Cichlidae) in a subtropical reservoir (Lao PDR).

Von Bertalanffy, L. (1957). Quantitative laws in metabolism and growth. *Quarterly Review of Biology,* Vol., 32: 217–231.

Waithaka, E., Yongo, E., Outa, N., & Mutethya, E. (2020). Population biology of Nile tilapia (*Oreochromis niloticus*) in Lake Naivasha, Kenya. *Lakes & Reservoirs: Research and Management, 25*, 244–249.

Jellyman, D. J. (1997). Variability in growth rates of freshwater eels (Anguilla spp.) in New Zealand. *Ecology of Freshwater Fish*, *6*(2), 108-115. <https://doi.org/10.1111/j.1600-0633.1997.tb00151.x>.

Jakobsen, T., Fogarty, M.J., Megrey, B.A. and Moksness, E. (2016). Fish reproductive biology: implications for assessment and management. 2eds. *John Wiley & Sons*.

Ouédraogo, R. B., Sanogo, S., & Compaoré, I. (2025). Population dynamics of Nile tilapia, Oreochromis niloticus (Linnaeus, 1758) in Samendéni reservoir, Burkina Faso. Fisheries and Aquatic Sciences, 28(5), 285-297.

Yoseph Tekle-Giorgis, Almken Berihun and Elias

Dadebo (2017). Assessment of sustainable yield

and optimum fishing effort for the tilapia

(Oreochromis niloticus L. 1758) stock of Lake

Hawassa, Ethiopia. Momona Ethiop. J. Sci., 9(1):

1 -21. doi.org/10.4314/mejs.v9i1.1