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Length-weight Relationships and Condition Factors of Three Commercially Important Fish Species from Roseires Reservoir, Blue Nile, Sudan

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Authors' contributions

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

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ABSTRACT

This study aimed to investigating the length-weight relationships and condition factors of three commercially important fish species in Roseires Reservoir on the Blue Nile, Sudan. A total number of 387 specimens of *Labeo senegalensis*, 285 of *Alestes dentex,* and 318 *Oreochromis niloticus*)

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were collected from four sampling sites on the Roseires Reservoir, using gillnets with varying mesh sizes (4, 8, 10, and 12 cm) from November 2015 to October 2016; The total and standard lengths of each fish were measured to the nearest 1.0 mm, using measuring board; the body weight was recorded to the nearest 1.0 gm, using a digital weighing balance, version FRUIT 2000B. The results showed that the three species exhibited negative allometric growth (b < 3) in all sites, except *Labeo senegalensis* in Wad El Mahi site which showed positive allometric growth (b' value 3.182), and moderate to high correlation coefficient (r = 0.442 - 0.998) The condition factor displayed average values ranged from 1.963- 3.751 (*Labeo senegalensis*) to 2.080 - 3.287 (*Alestes dentex*) and 2.336 - 3.287 (*Oreochromis niloticus*), indicating good health conditions and wellbeing of the three species investigated in the study area. The results of this investigation provide baseline data and valuable information on the growth pattern and health status of three fish species in the Roseires reservoir and can used as a basis for effective management measures of the three fish species in the Reservoir.

Keywords: Biological; Blue Nile; Roseires; reservoir.

1. INTRODUCTION

The Nile tilapia (*Oreochromis niloticus*, Linnaeus 1758), the Nile Robber (*Alestes dentex* Linnaeus, 1758), and the African Carp *(Labeo senegalensis,* Valenciennes 1842) are commercially crucial native fish in the freshwaters of Sudan. They are regularly exploited in the small-scale freshwater fisheries sector, as they provide a substantial, crucial, and essential source of income and a nutritive source of protein required by human health. During the past few decades, significant artisanal freshwater fisheries have been heavily exploited in the major significant African rivers, lakes, and reservoirs in significant African rivers, lakes, and reservoirs, leading to a serious severe decline in severe decline in the richness of the commercial fish species [1, 2].

The length-weight relationship (LWR) and Fulton's condition factor (FCF) are two vital tools in fishery management used to determine a fish population's growth patterns and well-being. They are widely used to provide information on the growth and condition of fish and give insight into the health of fishes and their community [3-5]. Length-weight relationships of fishes are based on the assumption that growth patterns could be isometric when length and weight increase at identical growth rates or allometric when the two morphometric traits increase at different rates [6-8]. Moreover, knowledge of fish length-weight relationships supports fishery stock assessment and management [9], fish population dynamics, distribution, mortality, and morphology of the fish species [10-13].

On the other hand, the condition factor indicates the fish's well-being, overall good health, and physiological status. This is influenced by food availability [14], environmental factors, sex, maturity stage, ecological health of the habitats, and discharges from various industries which could alter water quality and changes in exchange growth patterns [15]. The condition factor is based on the assumption that heavier fish of a given length are in better condition [16]. Different fish species usually exhibit varying condition factor values, which can indicate their adaptation and health in specific habitats. Understanding Fulton's condition factor is also crucial for assessing the physiological condition and fitness in different ecosystems. Condition factors higher than 1.0 indicate good health conditions of the fish and good adaptation to the environment [17].

This study aimed to investigate the length-weight relationship and condition factor of three crucial food fish species that are regularly captured in Roseires Dam Reservoir in the Blue Nile, Sudan, provide baseline data and useful valuable information for effective fisheries management of the three fish species in Roseires Dam Reservoir.

2. MATERIALS AND METHODS

2.1 Map of the Study Area

The Roseires Dam is built across the Blue Nile River in Sudan to store water for used for agricultural irrigation and hydroelectric power purposes. It lies about 550 kilometers from the capital Khartoum. The first stage of construction of the Dam was completed in 1966. The second stage included heightening of the Dam from 68 meters to 78 meters, and its storage capacity increased from 3.0 to 7.3 billion cubic meters.

The reservoir created as a result of construction of the Dam constituted a major source of fish that provides the local communities residing in the area with livelihood employment and income (Fig. 1).

2.2 Fish Sampling Sites

Fish samples were collected from four sampling sites in Roseires Reservoir, as shown in Table 1.

2.3 Collection of Fish Samples

Fish samples were collected monthly from November 2015 to October 2016. A total number of 287, 285 and 318 specimens of *Labeo senegalensis*, *Alestes dentex* and *Oreochromis niloticus* respectively, were collected from the four sampling sites, using multi-filament gill nets of various mesh sizes and twine numbers, as shown in (Table 2).

2.4 Measurements of Length and Weight

The total length and standard length of each fish were measured to the nearest 1.0 mm, using a standard measuring board. The body weight of sampled fish was taken to the nearest 1.0 gm, using a digital weighing balance, version FRUIT 2000B.

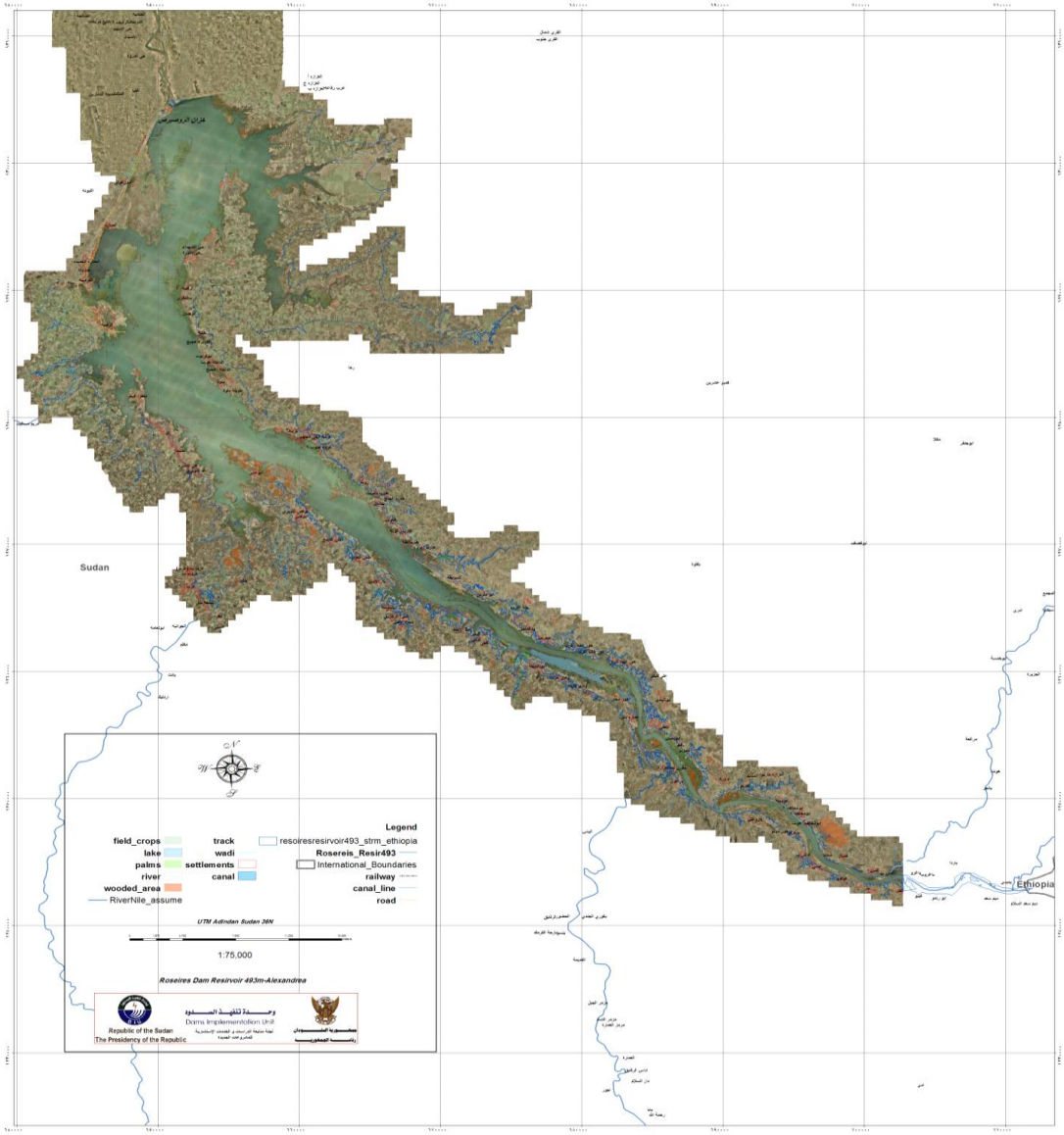


Fig. 1. Roseires Dam reservoir area (Blue Nile, Sudan)

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

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	507
Wad EL Mahi	80	11°25'27"N 34°40'17"E	507

Table 2. Specifications of gillnets used of collect fish samples

Gear No.	Length (m)	Depth (m)	Mesh size (cm)
2	50	2	4
12	90	4	8
12	95	4	10
12	100	4.5	12

2.5 Length-Weight Relationship

The relationship between the total weight and the standard length of the fish was computed using the power function according to the [18], as follows:

$$TW = a\,L^{b}$$

The LWR was also tested using the linear regression equation; Log TW = Log a + b Log SL, where: TW=Total weight (g), standard length (cm), a =constant representing the intercept on the "y" axis, and b = constant of the relationship, representing the slope of the regression line.

Excel package was used to plot the relationship curve between the standard length and total weight of the three fish species, and the liner equation was then obtained from logarithm transformation.

Condition Factor (K) or (Fulton's condition factor) (FCF):

The condition factor is usually used to compare the condition, fatness, or well-being of fish. It is calculated according to the [16] formula:

$$\mathrm{FCF} = \frac{\mathrm{w}}{\mathrm{L^b}} \times 100$$

Where W is the weight of the fish; L is the total length of the fish, and 'b' is constant.

2.6 Statistical Analysis

Statistical analysis is performed using a personal computer and the advanced computer Excel program.

3. RESULTS AND DISCUSSION

Results of the length-weight relationship of *L. senegalensis* showed that the fish exhibited a negative allometric growth pattern with growth coefficient '*b"* ranging from 1.528 to 2.508 to 2,796 in El Regiba, Awal Bab and Kirma sampling sites respectively, with moderate to high correlation *r* = 0.404 - 0.928, except Wad El Mahi site which showed positive allometric pattern (*b* = 3.18 with *r*= 0.998), as shown in (Fig. 2 and Table 3). This result is in agreement with those obtained for LWR of *L. senegalensis* in Lake Maabo, Central Africa); Khashm El-Girba reservoir, Atbara River, and Upper Atbara and Settit dam complex (Sudan) with growth exponent '*b'* ranged between 2.178 to 2.940 [19-22]. Although, [23] reported an isometric growth pattern for of *'b'* = '*b*' 3.043; and a high correlation (*r* = 0.8315 – 0.968 *L*. *senegalensis* in Dadin-Kowa lake, Nigeria; yet, [24] in Oguta Lake, Nigeria, found positive allometric growth pattern for the same species, with '*b*' = 3.840 and a high correlation *r* = 0.928; These variations in growth parameters may be due to food availability, changes in environmental factors, the ecological status of the habitats and fishing gear used in sampling.

Table (4) shows the results of the condition factor of the three fish species. It was observed that the average value of condition factor (K) of *L. senegalensis.* Ranged from 1.963 (Wad El Mahi) to 3.752 (Awal Bab), revealing this species' good condition and health status in Roseires Reservoir during the study period. This may be due to the abundance of food items and good water quality conditions of the species. The obtained value of (K) agrees with those recorded by [22] from Khashm El-Girba reservoir and Atbara River,

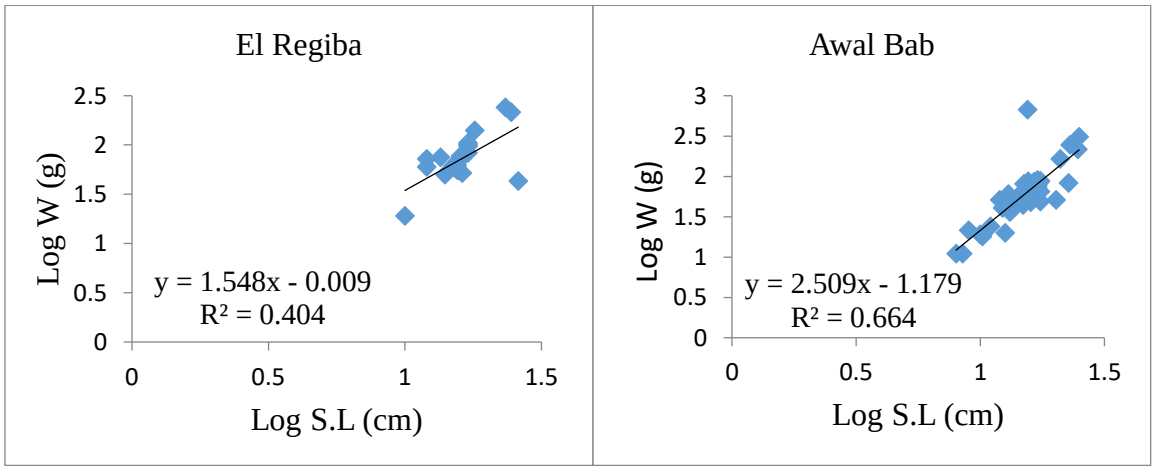
Sudan (K = 1.595 (River)) and 2.536 (Reservoir); Similar results were obtained by [24] in Lake Oguta, Nigeria, (K between 1.20 – 3.92), and [19] in Lake Maabo, Central Africa, (K = 2.341). However, [20], working in the Upper Atbara and Sittit complex dam, Sudan recorded a good condition value of K = of 3.121 for *L. senegalensis*. At the same time [25], in the Mono basin Benin and Togo, West Africa, obtained a low average condition factor of (0.085) of the same species. This may be attributed to poor water quality and environmental and geographical differentiation of the different water bodies.

The results showed that the *A. dentex* displayed a negative allometric growth pattern, with exponent '*b*' ranging between 1.477 to 2.656, and a slight moderate to high correlation (*r* = 0.442 - 0.967), Fig 3, Table 3. Similar results were recorded by [23] with exponent *b*= 2.8926, and a high correlation *r* = 0.8215. [26], investigated LWRs of the Characidae family in Jebel Aulia dam and reported growth exponent '*b*' of 2.709, *A. dentex*, indicating isometric (negative) growth patterns of this species. At the same time, [27] in Senegal, and [22] Oguta Lake, Nigeria, found isometric allometric growth of *A. dentex* with '*b*' values of 3.26 and 3.0756, with a high correlation *r*= 0.8802.

The condition factor of *Alestes dentex* varied from 2.080 at the Wad El Mahi site to 3.287 at Kirma site in the Reservoir the Wad El Mahi site to 3.287 at the Kirma site in the Reservoir, displaying good health condition and well-being of the fish (Table 4). Although, [28] in Odi River, Niger Delta, Nigeria, and [24], Oguta Lake, Nigeria, obtained low values of (K = 0.83 -1,00), and (K= 0.75) respectively, yet, [26] noted good condition factors of members of family Characidae in Jebel Aulia reservoir with the value of '*b* = 2.7096' for *A. dentex*. This variation in condition factor may be influenced by variations in food abundance, environmental factors, sex, maturity stage, and fishing gear used in sampling procedures.

Table 3. Shows the linear fit of the length-weight relationship of the three fish species

Site	Fish species	*b*	*a*	*r*
	L. senegalensis	2.509	-1.179	0.664
Awal Bab	*A. dentex*	1.477	-0.166	0.442
	O. niloticus	2.154	-0.553	0.788
	L. senegalensis	1.528	-0.009	0.404
El Regiba	*A. dentex*	2.007	-0.705	0.848
	O. niloticus	2.285	-0.710	0.808
	L. senegalensis	2.796	-1.457	0.928
Kirma	*A. dentex*	2.393	-1.807	0.931
	O. niloticus	2.648	-1.108	0.837
	L. senegalensis	3.182	-1.897	0.998
Wad El Mahi	*A. dentex*	2.656	-1.311	0.967
	O. niloticus	2.445	-0.789	0.755



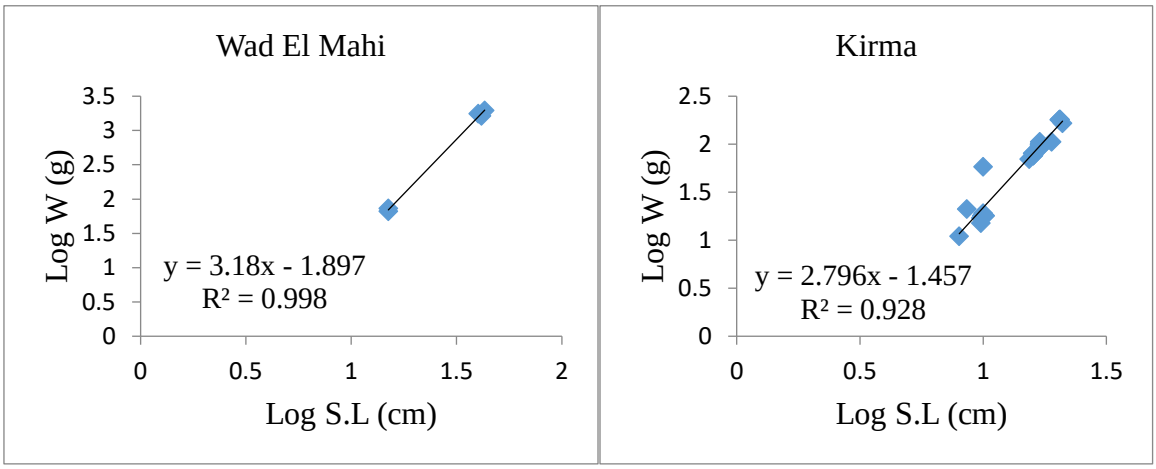


Fig. 2. Linear fit of the length-weight relationship of *L. senegalensis*

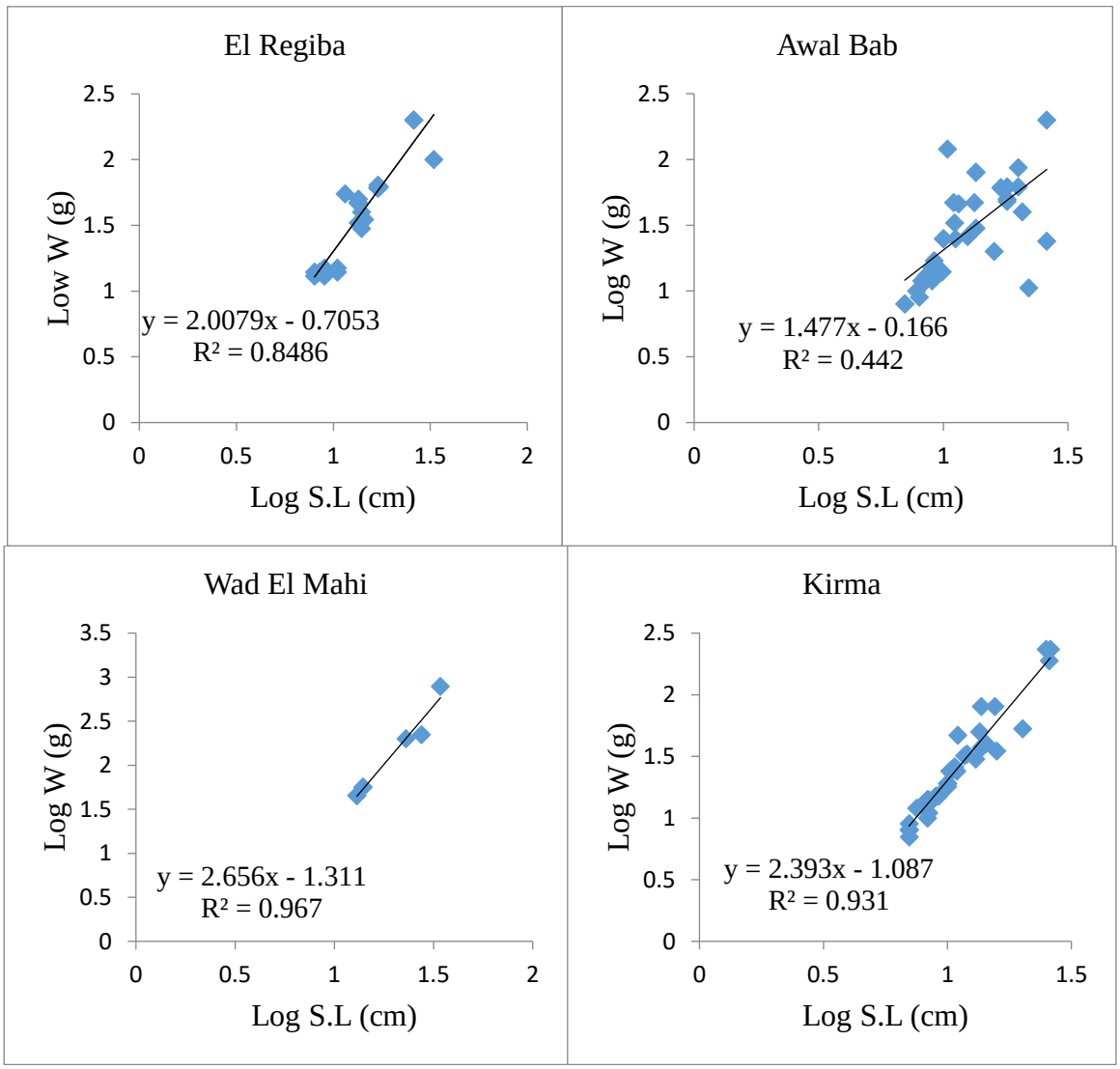


Fig. 3. Linear fit of the length-weight relationship of *A. dentex*

Table 4. Minimum and maximum monthly average of condition factor for the three fish species studied in Roseires Reservoir

Sampling site/fish species	Awal bab	Elregiba	Kirma	Wad El-Mahi
L. senegalensis	2.194±0.519 - 3.962 ±0.329	2.307±1.189 - 3.106±0.001	2.501±0.595 - 3.633±1.069	1.552±0.276 – 2.486±0.235
A. dentex	1.279±0.000 - 3.778±0.674	2.010±0.449 - 2.782±0.479	2.755±0.866 - 3.822±0.639	1.552±0.446 – 2.641±0.437
O. niloticus	2.205±0.007 - 3.601±0.248	2.169 ± 0.213 – 2.700±0.742	2.755±0.287- 3.822±0.597	2.720±0.990 – 3.769±0.869

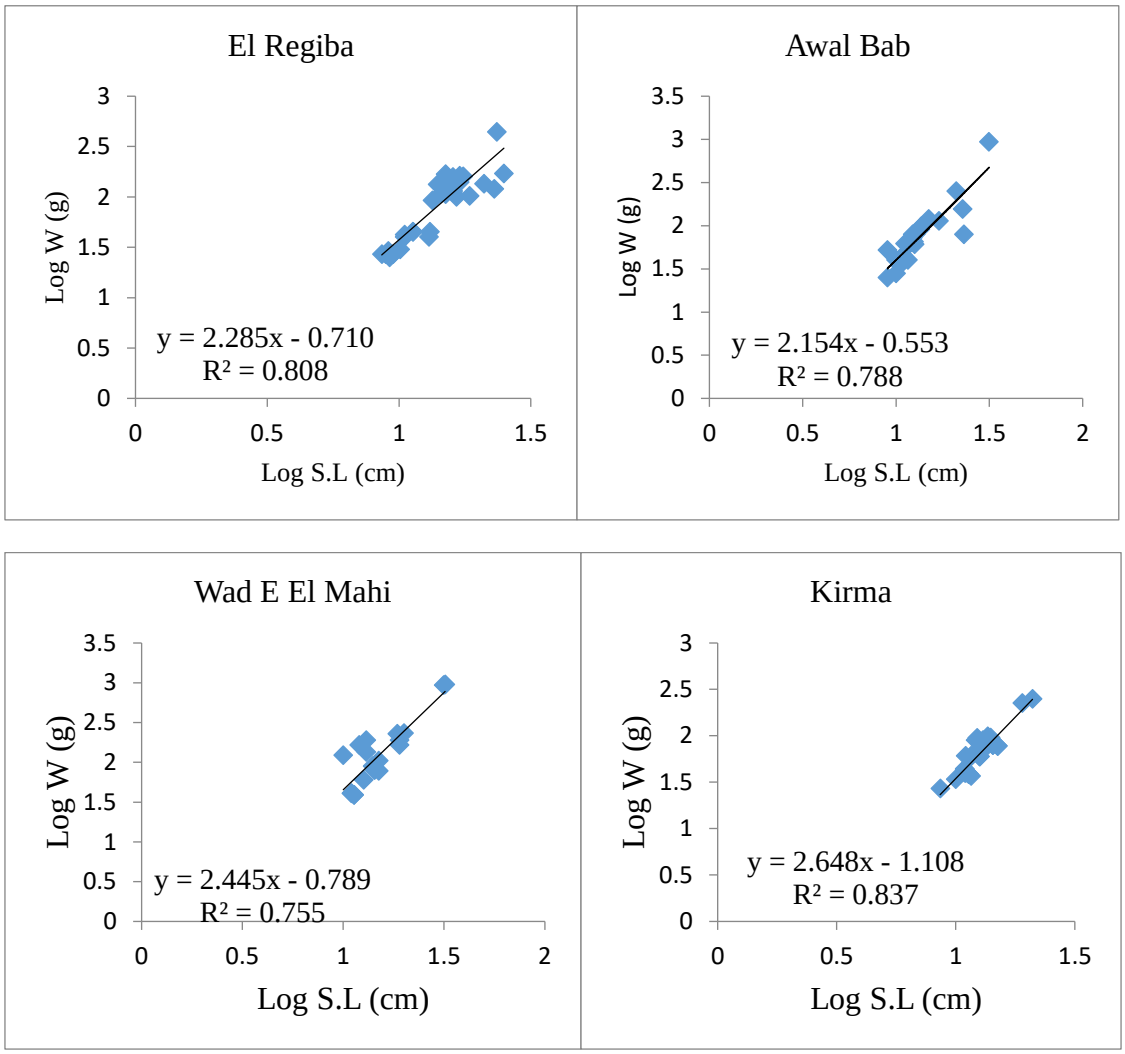


Fig. 4. Linear fit of the length-weight relationship of *O. niloticus*.

A total of 318 specimens of *Oreochromis niloticus* were collected during the study period. The results indicated that the fish exhibited a negative allometric growth pattern in all sampling sites, with growth coefficient '*b*' ranging from 2.154 – 2.648, and high correlation '*r*' = 0.755 and 0.837. This result is in agreement with '*b*' values reported for *O. niloticus* by several investigators, including [23] in Dadin-Kowa Reservoir, Nigeria; [24] in Oguta Lake, Nigeria; [19], Lake Maabo, Central Africa; [29] in Tugwi-Muskosi dam reservoir, Zimbabwe; and '*b*' = 1.60 recorded by [30] from Juba fish landing sites, White Nile, South Sudan. However, [31], found an isometric allometric growth pattern of this species from the White Nile within Sudan, with a growth coefficient '*b*' = 3.070 and a high correlation *r*= 0.981. On the other hand, [32,21,22], noted both negative and positive allometric growth of *O. niloticus* at Khashm El-Girba Dam, Atbara River, Sudan, with '*b*' ranging from 2.288 to 3.648. [33] studied the growth pattern of *O. niloticus* at two fishing sites in the Blue Nile (Sinnar) and the Main Nile (Shendi), Sudan, and found that *O. niloticus* exhibited negative, positive and isometric growth patterns, with values of '*b*' varying from 1.395 in Shendi (Main Nile), and 3.1167 in Sinnar (Blue Nile). Moreover, [34] investigated the LWRs of *O. niloticus* in selected tropical reservoirs in Southwest Nigeria, and reported both allometric and isometric growth patterns with '*b*' ranging between 2.45 to 3.20.

The results of the condition factor of *O. niloticus* exhibited a high value of (K) ranging from 2.336 (El Regiba) and 3.287 (Kirma), demonstrating that the fish enjoyed healthy conditions and well-being throughout the study period. Similar, high values of condition factor (K) *O. niloticus* were

recorded by [21] for *O. niloticus* in the Khashm El-Girba fish market (mean value of K=3.866); [22] in Khashm El-Girba Reservoir (mean K ranged from 2.441 and 3.415); [24] in Oguta Lake (Nigeria (K = 2.23); [30] in Juba fish market, South Sudan (K = 3.63); and [31] in Khashm El-Girba and Atbara River (K varied between 2.55 to 3.56); [35] in Egypt's Nile (K 1.86 - 2.10); [29] in the Tugwi-Muskosi dam, Zimbabwe, (K value 2.2); and [31], in the White Nile, Sudan, (K=1.558). However, [36], reported that *O. niloticus* exhibited poor condition factors in Lake Beseka, (Ethiopian inland water systems) with an average (K= 0.5), revealing poor health conditions of this species.

Although the condition factor of *O. niloticus* varied in most of the investigated water bodies, yet, it still lies within the healthy range of the fish, and the '*b*' values still lie within the range frequently recorded for tropical freshwater fish species.

4. CONCLUSION

From the results of the present study, it can be said that the three commercially important fish species in Roseires Reservoir, Blue Nile, Sudan, exhibited negative allometric growth pattern throughout the study period, except *L*abeo *senegalensis* at Wad El-Mahi site, which showed positive growth pattern, and high correlation coefficient.

The condition factor (K) showed high values during the period for the three species, reflecting the occurrence of abundant food items.
The finding of this study provides valuable information on the growth pattern and health condition of the commercially important fish species in Roseires Reservoir on the Blue Nile. It can inform on effective management measures of the fish population of the Reservoir, particularly after the completion and operation of the Grand Ethiopian Renaissance Dam on the Blue Nile, and subsequent changes expected to occur in the water level, water quality parameters, and fish population of the Roseires Dam Reservoir.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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