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Research Article

Sex-Based Variations in Length–Weight Relationship and Condition Factor of *Heterotis niloticus* from Kalgwai Reservoir

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ABSTRACT
The present study investigated how sex influences the length–weight relationship (LWR) and condition factor (K) of *Heterotis niloticus* inhabiting the Kalgwai Reservoir in Northwestern Nigeria from January 2022 to December 2023. A total of 120 specimens, comprising equal numbers of males and females, were randomly collected from three sampling stations using a combination of gill nets (25–50 mm mesh sizes), cast nets and longlines. Total length and body weight were recorded following established biometric procedures, and sex was identified through gonadal examination. Analysis of the log-transformed length–weight data revealed that males had *b*-values ranging from 0.35 to 1.21, with a mean of 1.21, whereas females exhibited a wider range of 0.03 to 1.95 and a higher mean value of 1.95. The combined dataset produced an average *b* of 1.42. In all cases, the regression coefficient (*b*) was below the theoretical cube value (*b* = 3), signifying negative allometric growth, where increase in length outpaces gain in weight. The Fulton's condition factor (K) differed between sexes, with males averaging 0.70 and females 1.20, while the overall mean stood at 0.90. The relatively higher K values recorded in females indicate a better physiological state, possibly linked to energy accumulation for reproduction, whereas the low values observed in some males point to potential nutritional stress. These outcomes emphasize the importance of sex in determining the growth pattern and well-being of *H. niloticus* and provide essential reference data for the management and aquaculture development of the species within the Kalgwai Reservoir.

Keywords: Condition factor; *Heterotis niloticus*; Kalgwai Reservoir; Length–weight Relationship; Sex differences

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INTRODUCTION

Inland reservoirs are vital to fisheries development and the livelihoods of people living in Nigeria's semi-arid areas. These man-made water bodies help sustain fish diversity and at the same time provide an important source of protein and income for local communities (Idris *et al.,* 2025b).

In fisheries studies, the length–weight relationship (LWR) and condition factor (K) are common tools used to understand how fish grow and adapt to their environment. The LWR helps to identify whether a species grows proportionally or not, while the

condition factor indicates how healthy and well-adjusted the fish are to their surroundings (Bagenal *et al.,* 1978; Froese, 2006). Several factors such as sex, breeding stage, water quality, and seasonal changes can influence these measurements (Getso *et al.,* 2017; Idris *et al.,* 2025b).

Different fish species in Nigeria show varying patterns of growth. For example, *Clarias gariepinus* and *Oreochromis niloticus* often display negative allometric growth in reservoir habitats (Dan-Kishiya *et al.,* 2013; Atama *et al.,* 2013), while some tilapia species have shown positive allometric patterns (Adedeji *et al.,* 2016). Growth and condition factor also tend to differ between males and females, likely because of how energy is distributed during reproduction (Muhammad *et al.,* 2025).

Heterotis niloticus, known as the African bony tongue, is one of Africa's most valuable freshwater fish. It is widely harvested across its range to meet food needs and support local markets (Akinyi *et al.,* 2018). The species grows quickly and can survive in different environmental conditions, which makes it suitable for aquaculture. Because of this, it has been introduced into several regions across Africa for culture purposes (Froese *et al.,* 2018). *H. niloticus* is found throughout tropical Africa in rivers, lakes, and floodplains, including the Nile Basin, where it contributes significantly to local and commercial fisheries (Gbaguidi and Pfeiffer, 1996).

In Nigeria, the species is common in inland waters, and water bodies like the Kalgwai Reservoir in Jigawa State offer favorable environmental conditions for fish habitation. However, despite its economic and ecological value, there is limited research on the growth and condition of *H. niloticus* in the northern part of the country (Jega *et al.,* 2024). Most studies have focused on the southern and central regions, leaving semi-arid reservoirs like Kalgwai less studied (Idris *et al.,* 2025b).

This lack of information makes it difficult to develop effective management and conservation plans for the species. Therefore, this study aims to provide basic information on the growth pattern and condition of *H. niloticus* from Kalgwai Reservoir. It examines the length–weight relationship in males, females, and combined samples, and evaluates the condition factor to reveal any differences between sexes. The results are expected to improve understanding of the species' population dynamics and support the sustainable use of freshwater resources in semi-arid areas

MATERIALS AND METHODS

Study Area and Duration

Kalgwai Dam lies about 50 meters from Kalgwai village in Auyo Local Government Area of Jigawa State, Nigeria. It was built across the Hadejia River in 1984 by the Federal Government of Nigeria as part of the Hadejia Valley Irrigation Project, which was managed by the Hadejia–Jama'are River Basin Development Authority (H.J.R.B.D.A). The reservoir covers an estimated area of about 3,800 km² (Soloman *et al,* 2018) (Figure 1). Geographically, the site is positioned between latitude 12°35'N – 10°7'E and longitude 12.230°N – 10.022°E.

The dam serves as a storage reservoir across the Hadejia River. Water inflow is mainly from the upstream Challawa and Tiga Dams located in Kano State. It is distributed through control gates into irrigation canals that supply water to farmlands and nearby communities for agricultural and household use.

The area has a tropical climate with an average annual temperature of about 37°C. There are two distinct seasons — a wet season from May to September and a dry season from October to April (Edegbene, 2018). During the dry season, the harmattan period occurs between November and February, bringing cooler temperatures that can drop to around 10°C, especially in December and January (Edegbene, 2018).

The dam reaches its maximum water level toward the end of the rainy season, usually in September, and gradually declines until the lowest level is recorded around June, just before the next rains begin. The extent of flooding changes each year depending on the amount of rainfall, which directly affects the water volume (Benthem, 1990). As a result, fish production varies from season to season, and fishing activities increase when the water level is high. Communities around the dam depend heavily on these seasonal fishing opportunities for their livelihood.

This research was carried out over a period of 24 months, from January 2022 to December 2023.

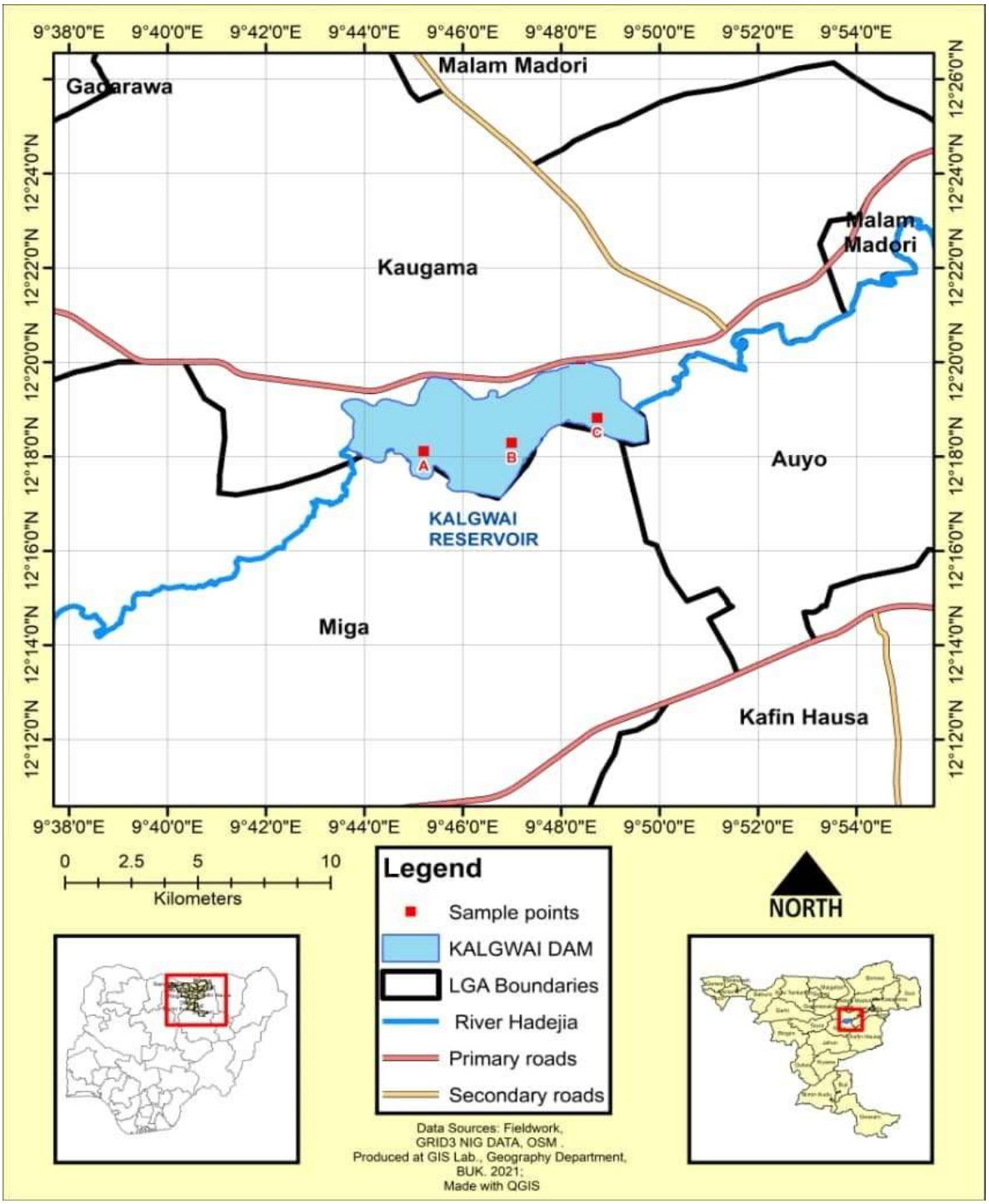

Figure 1. Map of Jigawa Showing Kalgwai Reservoir and the Sample Points

Fish Sampling and Biological Measurement

A total of 120 specimens of *Heterotis niloticus* were obtained from the Kalgwai Reservoir using a combination of artisanal and conventional fishing gears. The fishing gears comprised gill nets of varying mesh sizes (25–50 mm), cast nets, longlines, and non-baited fish traps, all of which are commonly employed by local fishermen within the area. Gill nets were typically set in the evening and retrieved early in the morning to capture active species, while cast nets were operated manually along shallow sections of the reservoir. Longlines, equipped with multiple baited

hooks, were positioned at different depths to target larger individuals, whereas traps were placed near vegetated or sheltered zones where fish congregate.

From the total catch, 60 males and 60 females were randomly selected to provide a balanced and representative dataset for subsequent analysis. Each specimen was carefully handled to avoid physical damage and immediately placed in containers packed with ice to preserve freshness during transportation to the laboratory.

Sex identification was conducted through dissection and direct observation of the gonads, following the method outlined by Jega *et al*. (2024). The total length (TL) of each specimen was measured to the nearest 0.1 cm using a measuring board, while body weight (BW) was recorded to the nearest 0.01 g using an electronic balance.

Length–Weight Relationship and Condition Factor

The length–weight relationship (LWR) was determined using the general equation:

W=aLbW = aL^bW=aLb

where *W* represents body weight (g), *L* is total length (cm), *a* is the regression intercept, and *b* denotes the growth exponent. The parameters *a* and *b* were obtained through logarithmic transformation of the data, followed by linear regression using the model:

logW=loga+blogL\log W = \log a + b \log LlogW=loga+blogL

The coefficient of determination (R^2) was used to evaluate the degree of association between length and weight. A *b*-value greater or less than 3 indicated allometric growth, whereas a value approximately equal to 3 reflected isometric growth (Froese, 2018).

The condition of individual fish was assessed using Fulton's Condition Factor (K), which was calculated as:

K=100×WL3K = \frac{100 \times W}{L^3}K=L3100×W

This index was applied to determine the general well-being and physiological state of the fish (Bagenal and Tesch, 1978).

Statistical Analysis

All statistical analyses were carried out using Microsoft Excel and SPSS (Version 25.0). Descriptive statistics were computed, and regression analyses were performed separately for male, female, and pooled datasets. Differences in LWR parameters and condition factors between sexes were evaluated using Analysis of Covariance (ANCOVA) at a 5% significance level

RESULTS

The length–weight relationship of *Heterotis niloticus* from Kalgwai Reservoir is summarized in Table 1. A total of 120 specimens were examined, consisting of male, female, and pooled (combined) samples.

For the male specimens, the *b* values ranged from 0.3536 to 0.5959, with an average of 1.2135. The corresponding *a* value varied between 0.4915 and 0.802, while the coefficient of determination (R^2) ranged from 1.000 at the minimum and maximum ends, with an average of 0.6321. The mean condition factor (*K*) recorded for males was 0.70, with observed values ranging between 0.63 and 4.61.

Among the female specimens, the *b* values ranged from 0.028 to 0.5464, with an average of 1.949. The values were between 0.7881 and 0.847, while the R^2 values also reached 1.000 at both the minimum and maximum limits, with a mean of 0.7568. The condition factor for females ranged from 0.75 to 1.90, with an average of 1.20.

When both sexes were combined, the *b* values ranged from 0.028 to 0.5959, with a mean of 1.4196, while *a* value varied between 0.802 and 0.847 and had an average of –0.1414. The R^2 values remained 1.000 at the extremes, with an average of 0.6607. The overall condition factor ranged between 0.63 and 1.90, with an average value of 0.90.

Generally, the R^2 values indicated a strong relationship between length and weight in both sexes and in the combined samples. However, variation in the *b* values suggests differences in growth response between males and females. The findings also show that male *H. niloticus* exhibited a slightly lower mean condition factor compared to females, implying better body condition and possibly higher energy reserves among the latter during the study period.

Interpretation of Growth Pattern

The variation in the length–weight relationship parameters indicates that *Heterotis niloticus* from Kalgwai Reservoir did not follow a uniform growth trend across sexes. The males showed relatively lower *b* values, suggesting a tendency toward negative allometric growth, where the fish increases in length faster than in weight. In contrast, females recorded higher *b* values, pointing to positive allometric growth, which implies that weight increases at a slightly faster rate than length. The combined data for both sexes reflected a near-balanced condition, showing an intermediate growth pattern.

These differences may be linked to biological and environmental factors such as sex-related energy allocation, feeding intensity, and reproductive activities. Females often accumulate more body reserves during the breeding period, which can explain their higher condition factor values. On the other hand, males may invest more energy in activities such as territorial defense or courtship, resulting in lower body condition during certain seasons. Overall, the results suggest that the growth of *H. niloticus* in Kalgwai Reservoir is influenced by both environmental conditions and biological factors, leading to sex-based variations in growth performance and body condition.

Table 1. Length-weight Relationship and Condition Factor of *Heterotis niloticus* from Kalgwai Reservoir

Specie	Sex		b	a	R2	Growth Pattern	K
Heterotis niloticus	Male	Minimum	0.3536	0.4915	1	NA	4.61
N = 120		Maximum	0.5959	0.802	1	NA	0.63
		Average	1.2135	0.0953	0.6321	NA	0.70
	Female	Minimum	0.028	0.847	1	NA	1.90
		Maximum	0.5464	0.7881	1	NA	0.75
		Average	1.949	-0.734	0.7568	NA	1.20
	Combined	Minimum	0.028	0.847	1	NA	1.90
		Maximum	0.5959	0.802	1	NA	0.63
		Average	1.4196	-0.1414	0.6607	NA	0.90

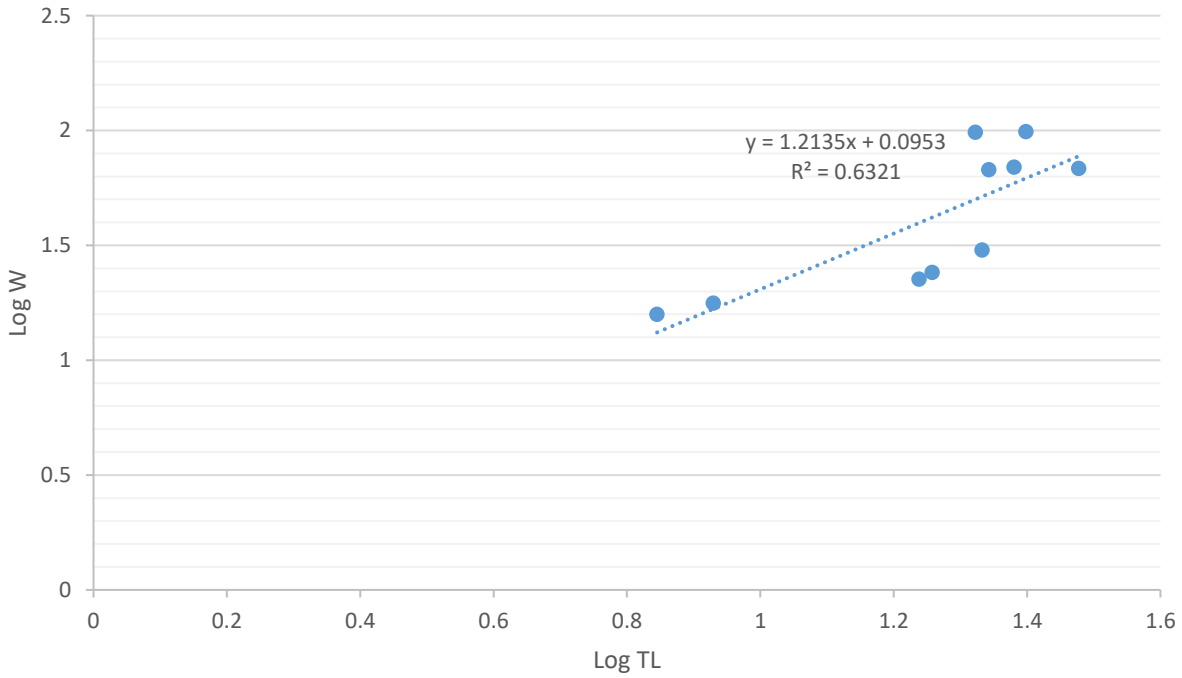

Figure 2. Length-weight Relationship of *Heterotis niloticus* Male (average) from Kalgwai Reservoir

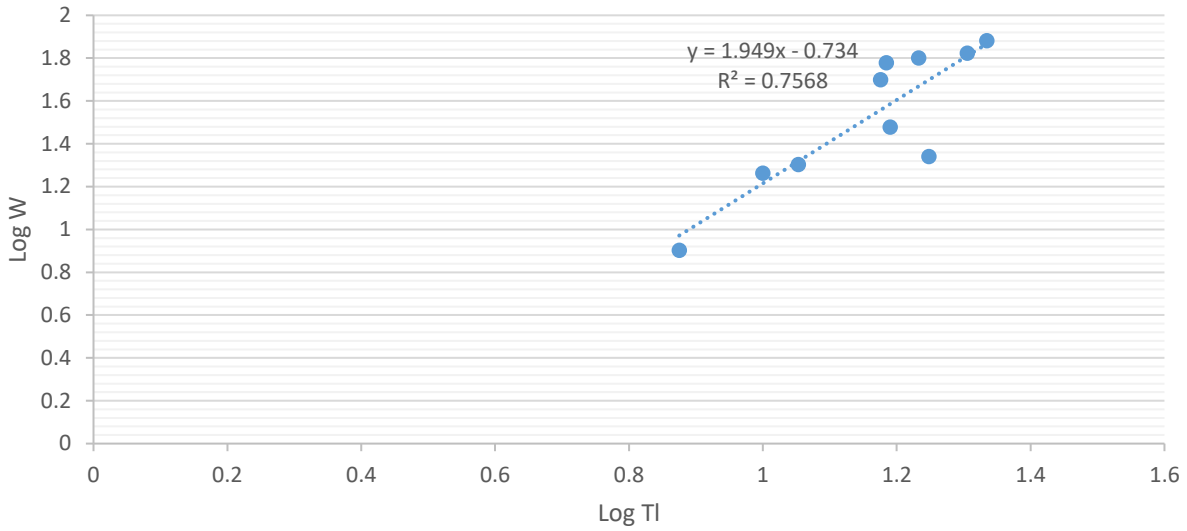

Figure 3. Length-weight Relationship of *Heterotis niloticus* Female (average) from Kalgwai Reservoir

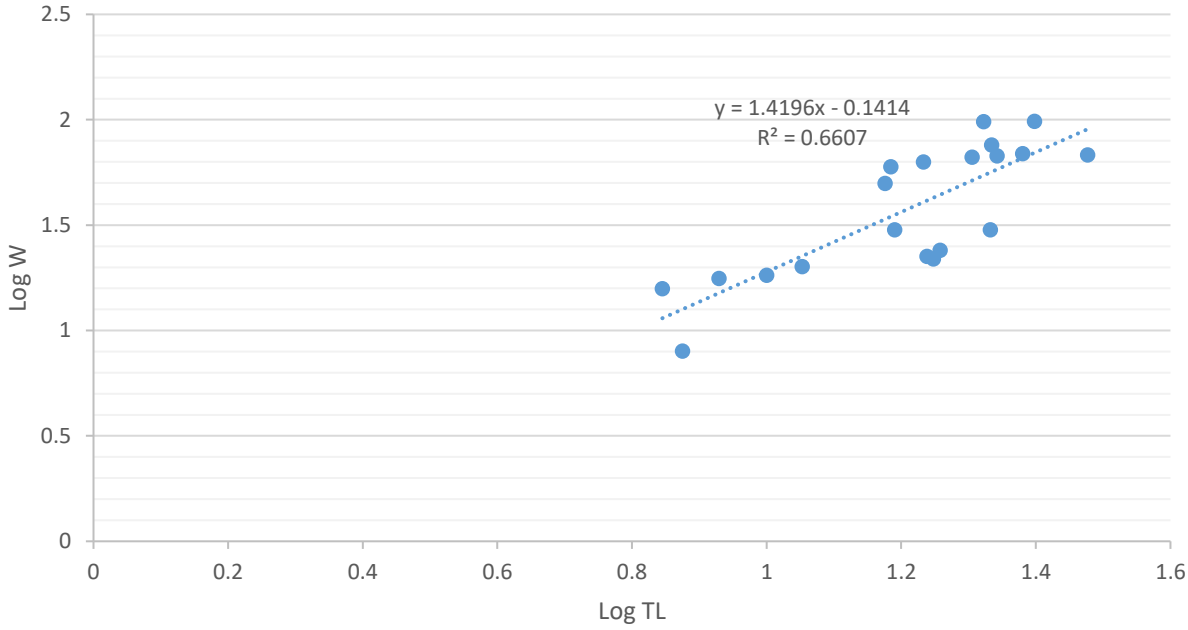

Figure 4: Length-weight relationship of *Heterotis niloticus* combined (average) from Kalgwai reservoir

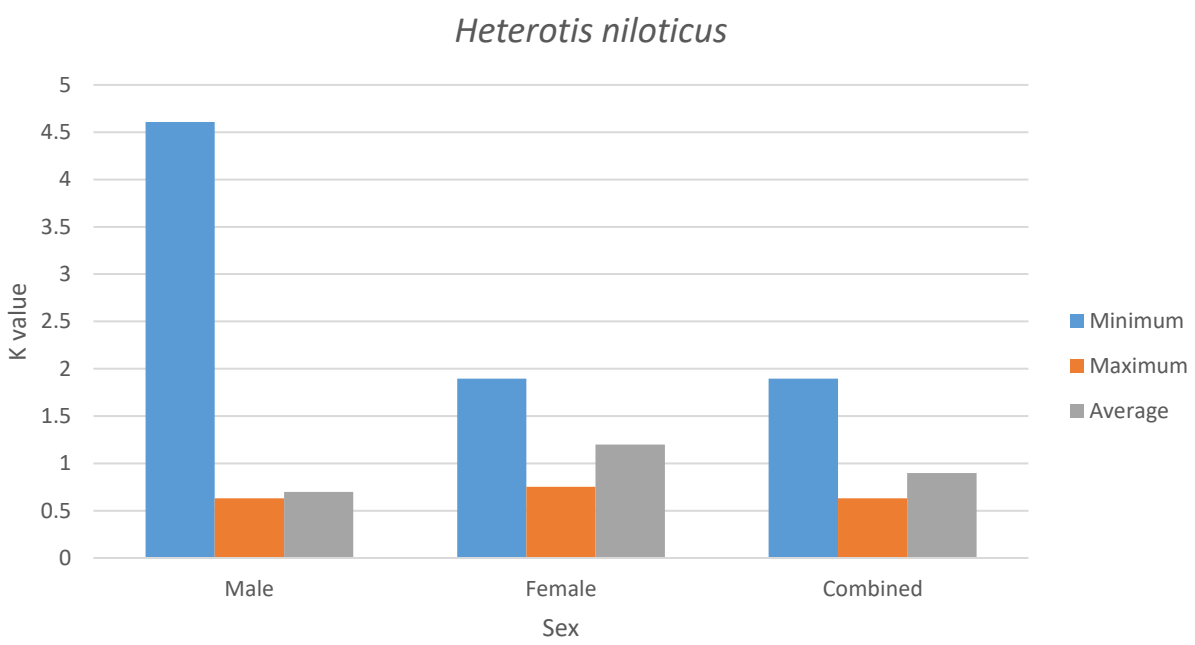

Figure 5. The Bar Chart Showing the Condition Factor (K) of *Heterotis niloticus* from Kalgwai Reservoir

DISCUSSION

According to (Khairenizam and Norma-), *b*-values below 3 indicate negative allometric growth, where fish increase in length more rapidly than in weight, while values above 3 imply positive allometry. In the present study, all *b* values were less than 3, suggesting that *H. niloticus* in Kalgwai Reservoir predominantly exhibited negative allometric growth, allocating more energy to body elongation rather than mass gain. This finding agrees with earlier reports from Nigerian freshwater ecosystems, where similar patterns of negative allometry were observed (Froese 2018; Getso *et al.,* 2017; Idris *et al.,* 2025b; Imam *et al.,* 2010; Dan kishiya *et al.,* 2013. (Atama *et al.,*2013; Alex *et al.,* 2021; Muhammad *et al.,*2025) reported sex-related variation in *Clarias gariepinus* from Zuru Dam, with males showing isometric growth and females positive allometry. In contrast, (Adedeji *et al.,* 2016) documented positive allometric growth in female *Oreochromis niloticus* from Lake Geriyo, Yola. The higher mean *b* value in females observed in this study indicates a greater tendency for weight gain at comparable lengths relative to males. This difference may be linked to reproductive physiology, as females generally store more energy reserves during gonadal development.

Condition Factor (K)

The condition factor (K) also varied with sex (Table 1; Figure 5). The average K value was 0.70 for males, while females recorded a higher mean of 1.20. When sexes were combined, the mean condition factor was 0.90. Values above 1 are typically considered indicative of favorable habitat conditions and healthy physiological status (Bagernal, and tesch 1978).

The higher condition factor values in females suggest a comparatively better state of well-being and robustness, which is likely associated with reproductive energy accumulation. Figure 4 highlights this difference, with females consistently outperforming males in terms of K. A similar observation was made by Egbal *et al.* (2011) in Juba, South Sudan, where *O. niloticus* females (1.95) had slightly higher condition factors than males (1.93). Likewise, (Idris *et al.,* 2025b) reported higher condition values for female *Clarias gariepinus* (1.14) compared to males (0.73). Conversely, (Adedeji *et al.,* 2016) recorded a K value of 1.95 for *Sarotherodon galilaeus* across both sexes, suggesting good environmental conditions in Lake Geriyo.

Some male specimens from this study recorded very low K values (minimum = 0.63), possibly reflecting nutritional stress or reduced feeding during certain periods, this differs with the work of (Muhammad et

al., 2025) reporting (K) value of 0.99 for Male *Clarias gariepinus* in Zuru Dam

Authors' Contributions

Idris S. designed the study, carried out field sampling, analyzed the data, and drafted the initial manuscript. A. A. Adam, M. U. Sambo, F. Sambo, and A. Abubakar assisted in data collection, specimen identification, and laboratory analysis. Y. Chiroma contributed to statistical interpretation and literature review. Bichi A. H. and Joel Umaru provided technical guidance, supervised the research process, and reviewed the manuscript for accuracy and clarity. A. Umar contributed to editing, referencing, and final proofreading. All authors read and approved the final version of the manuscript before submission.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper. All authors participated voluntarily and have no financial or personal relationships that could have influenced the outcomes of this study.

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