The Zoologist
2025. Vol. 27: 35-42. http://dx.doi.org/10.4314/tzool.v27i1.5 Print ISSN 1596 972X, Online ISSN 2992-4030

Morphometric Variability and Biometric indices of *Oreochromis niloticus* (Linnaeus, 1758) in Ugbo and Mahin Coastal Waters, Nigeria: Implications for Fisheries Management

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Short running title: Morphometric variability of *Oreochromis*

Received: 08 May, 2025
Revised: 25 September, 2025
Accepted: 02 December 2025
Keywords: Stock assessment, Population, Conservation, Condition factor, Ecological health.

Abstract

This study assessed morphometric indices of *Oreochromis niloticus* from Ugbo and Mahin coastal waters in Ilaje, Ondo State, Nigeria. A total of 120 specimens were collected, and 25 linear measurements were recorded. Data were analyzed using Student's t-test and Principal Component Analysis (PCA). The results revealed negative allometric growth (b = 1.92–2.30), indicating slimmer body shapes with increasing length. Condition factors (1.93 ± 0.24 to 2.03 ± 0.46) suggested healthy populations. Significant morphological differences were observed in head diameter, length of anal fin base, pre-pelvic fin length, and pre-anal length ($p < 0.05$). PCA explained 76.8% of total morphometric variation, with greatest divergence in the head, body, and caudal regions, highlighting phenotypic plasticity in response to local environmental conditions. These findings provide baseline data for monitoring *O. niloticus* populations and offer practical guidance for fisheries management, including setting size limits, implementing size-selective harvesting, and prioritizing habitat conservation to maintain healthy and sustainable coastal fish populations.

Introduction

Fisheries and aquaculture play a vital role in global food security and economic development, significantly contributing to nutrition and livelihoods worldwide (FAO 2018). However, many wild fish stocks are currently overexploited or fully exploited, with some populations declining due to unsustainable fishing pressure and habitat degradation (Pham *et al* 2023). This trend highlights the urgent need for effective stock assessment and management strategies to ensure the long-term sustainability of fishery resources.

Morphometrics play an important role in fisheries science, offering reliable means of evaluating stock structure and overall fish health (Chaklader *et al* 2016). By examining body dimensions and derived indices, these approaches provide valuable insights into growth dynamics, population differentiation, and phenotypic variation (Lishchenko and Jones 2021; Rahman *et al* 2023). Biometric indices such as Length–weight Relationships (LWRs), condition factors, and form factors are widely recognized as indicators of growth efficiency, body conformation, and physiological status (Hossain *et al.* 2012). When integrated with multivariate statistical techniques, particularly principal component analysis, these methods enhance the ability to discriminate among fish populations and strengthen the scientific basis for sustainable management strategies (Siddik *et al* 2016; Hanif *et al* 2019).

In Nigeria, Nile tilapia, *Oreochromis niloticus* is one of the most economically important fish for both aquaculture and capture fisheries (Ogunji and Wuertz 2023). This species is particularly valued for its rapid growth rate, environmental adaptability, and high consumer demand (Wagaw *et al* 2024; Murillo *et al* 2025). Despite its significance, detailed morphometric data for *O. niloticus* inhabiting the Ugbo and Mahin coastal waters of Ilaje, Ondo State remain scarce.

Previous studies have primarily focused on other geographical regions, creating a critical knowledge gap for these ecologically and commercially important water bodies. Although *O. niloticus* is predominantly a freshwater species, its remarkable ecological plasticity allows it to colonize brackish coastal ecosystems, including estuaries, lagoons, and mangrove swamps, where salinity remains below 15–20 ppt (Metwaly *et al* 2025). In Ilaje coastal waters, the species' presence likely reflects either natural adaptation or anthropogenic dispersal from aquaculture systems.

The Ilaje coastal waters support diverse and productive fisheries resources that contribute substantially to local and regional food security (Ogunrayi *et al* 2025). However, increasing anthropogenic activities including overfishing, hydrocarbon pollution, and habitat modification threaten the sustainability of fish stocks in this region (Olaoye and Ojebiyi 2018; Asani Akinyode 2022; Adewale *et al*

2024). Without comprehensive baseline data and regular stock assessments, these activities may lead to irreversible declines in coastal ecosystems.

The present study investigated morphological and biometrics indices in *O. niloticus* populations from the Ugbo and Mahin coastal locations. The specific objectives were to compare morphometric characteristics of *O. niloticus* between the two locations, evaluate growth patterns through LWR, condition factor using derived biometric indices, and identify key morphometric features contributing to inter-location variations. In testing the null hypothesis that no significant differences exist in morphometric traits between these populations; the study establishes critical baseline data for *O. niloticus* in these coastal waters and provides insights relevant to sustainable management of this economically important species. While broader population-level inferences would require genetic confirmation (Lowe *et al* 2017), this morphometric assessment study offers essential preliminary information for conservation planning and fisheries management in the water bodies.

Materials and method

Collection of fish samples

A total of 120 *O. niloticus* samples were collected from the fish landing sites at Ugbo (60 samples) and Mahin (60 samples). All samples were weighed, measured, and recorded at each location to minimize handling bias

Morphometric measurement and associated indices

Twenty-six linear measurements of the morphometric characters were carried out (Table 1). All measurements were taken to the nearest 0.1cm. The body weight was measured using a digital electronic weighing balance (Adam AFP 4100l) to the nearest 0.1g.

Determination of Length-weight relationship

The length- weight relationship was determined using the mathematical model $W = aL^b$ as reported by Pauly (1993).

Where, W= Fish weight (gram), L= Fish length (cm), a = intercept, b = slope

Table 1: Morphometric description of *Oreochromis niloticus*

S/N	Abbreviation	Full Meaning	Description
1	TL	Total Length	From snout tip to tail fin tip.
2	SL	Standard Length	From snout tip to base of tail fin.
3	BW	Body Weight	Total weight of the fish.
4	BD	Body Depth	Measured as the vertical depth of the body.
5	PDL	Pre-Dorsal Length	Distance from snout tip to origin of dorsal fin.
6	PPCL	Pre-Pectoral Length	Distance from snout tip to base of pectoral fin.
7	PPVL	Pre-Pelvic Length	Distance from snout tip to base of pelvic fin.
8	PAL	Pre-Anal Length	Distance from snout tip to origin of anal fin.
9	DCP	Depth of Caudal Peduncle	The vertical height of the caudal peduncle.
10	LCP	Length of Caudal Peduncle	The horizontal length of the caudal peduncle.
11	HL	Head Length	Distance from snout tip to posterior end of operculum.
12	ED	Eye Diameter	The horizontal diameter of the eye.
13	LDFB	Length of Dorsal Fin Base	The base length of the entire dorsal fin.
14	UJL	Upper Jaw Length	Length of the upper jaw.
15	LJL	Lower Jaw Length	Length of the lower jaw.
16	CFL	Caudal Fin Length	Length of the caudal fin.
17	PVL	Pectoral Fin Length	Length of the pectoral fin.
18	PVFL	Pelvic Fin Length	Length of the pelvic fin.
19	FDFB	First Dorsal Fin Base	Length of the base of the first dorsal fin.
20	LAFB	Length of Anal Fin Base	The base length of the anal fin.
21	LDFS	Length of Dorsal Fin Spine	Length of a dorsal fin spine.
22	LAFS	Length of Anal Fin Spine	Length of an anal fin spine.
23	POL	Pre Orbital Length	Distance from snout tip to anterior eye orbit.
24	PL	Post Orbital Length	Distance from snout tip to posterior eye orbit.
25	HD	Head Depth	The vertical depth of the head.
26	SDFB	Second Dorsal Fin Base	Length of the base of the second dorsal fin.

The constants *a* and *b* were derived using least-squares linear regression of log-transformed length and weight data, as follows: log W = log a + b log L (Mehanna and Farouk, 2021).

Form factor
The form factor ($a_{3.0}$) was calculated using the following formula: $a_{3.0} = 10^{\log a - s(b-3)}$. Where a and b are regression parameters and S is the average slope (S = -1.358) of log a vs. b (Froese 2006).

Condition factor
The condition factor (K) was calculated using the formula reported by Gomiero and Braga (2005).

$$K = 100W/L^b$$

Where, K = Condition factor, W = Weight of fish in g, L = Total length of fish in cm, b = Value derived from the LWR equation.

Data analysis
Morphometric measurements were standardized to remove size-related effects following the method of Elliott *et al.* (1995), using the formula:

$$M_{adj} = M\,(Ls/Lo)^b$$

where:
M = original measurement value
M_{adj} = size-adjusted measurement
Lo = individual fish standard length
Ls = population mean standard length
b = allometric coefficient derived from regression analysis

After standardization, student t-test was used to test for differences in morphometric variables between populations at α = 0.05. Coefficient of Variation (CV) was used to expresses the extent of variability in relation to the mean of a dataset. It was calculated as the ratio of the standard deviation of the mean, and expressed as a percentage. Principal Component Analysis (PCA) was employed to reduce data dimensionality by generating weighted linear combinations of correlated variables that captured the greatest variance. The suitability of the dataset for factor analysis was further assessed using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's Test of Sphericity. To enhance interpretability, the factor matrix was rotated using the orthogonal varimax method. All statistical analyses were conducted in SPSS version 20.0.

Results

Morphometric characteristics
The morphometric features of *O. niloticus* from Ugbo and Mahin coastal waters. Fish samples from Ugbo ranged between 11.20 and 13.84 cm in length (12.35 ± 0.57 cm), while those from Mahin ranged from 9.98 to 15.01 cm (12.44 ± 0.79 cm). Although mean lengths did not differ significantly between the two locations ($p > 0.05$), body weight varied significantly ($p < 0.05$), which ranged from 36.45 ± 4.86 g to 41.80 ± 8.91 g and mean of 36.45 ± 4.86 g in Ugbo and 41.80 ± 8.9 g in Mahin.

Growth patterns and condition indices
The form factor analysis ($a_{3.0}$) revealed values of 0.00069 (Ugbo) and 0.00071 (Mahin) for *O. niloticus* (Table 2), indicating similar body shape between locations. The length-weight relationships (Figure 1) demonstrated strong linear correlations, with regression parameters showing:

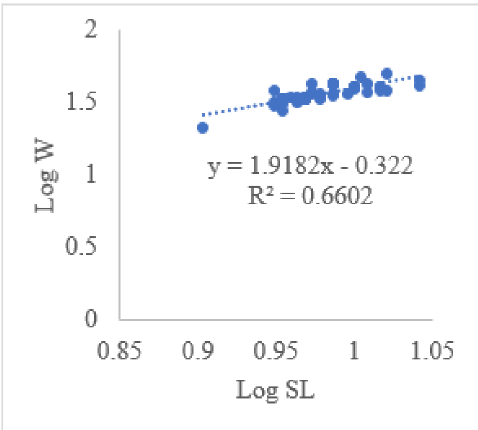
Ugbo: $W = -0.32TL^{1.92}$ ($R^2 = 0.66$) and Mahin: $W = -0.69TL^{2.30}$ ($R^2 = 0.78$)

These relationships revealed negative allometric growth patterns ($b < 3$) at both locations, with growth coefficients of 1.92 (Ugbo) and 2.30 (Mahin).

Table 2: Growth pattern, condition and form factors of *Oreochromis niloticus* from Ilaje coastal waters

Parameter	Ugbo	Mahin
b	1.92	2.30
a	-0.32	-0.69
R^2	0.66	0.78
Growth pattern	Negative Allometry	Negative Allometry
Condition factor	1.93±0.24[b]	2.03±0.46[b]
Form factor (**$a_{3.0}$**)	0.00069	0.00071

Key: b= slope, a = intercept, R^2 = coefficient of determination



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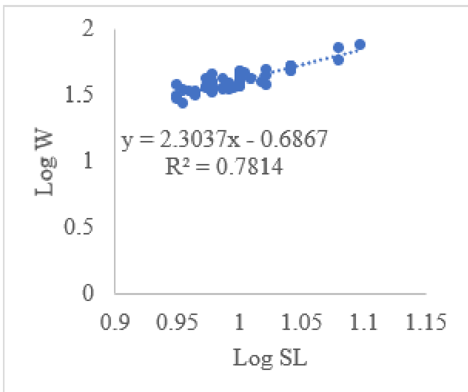

B

Figure 1. Length-weight relationship of *Oreochromis niloticus* from Ugbo (A) and Mahin (B)

Table 3: Morphometric characteristics of *Oreochromis niloticus* from Mahin coastal water

Characters	Min	Max	Mean	STD	CV (%)	Mode
Morphometry						
BD	3.50	5.70	4.16	0.44	10.58	4.50
PDL	2.70	5.60	4.66	1.05	22.45	5.50
PPCL	3.50	6.00	4.49	0.90	20.03	5.00
PPVL	3.50	6.00	4.68	0.60	12.88	5.00
PAL	7.00	10.30	8.63	0.14	1.62	9.50
DCP	2.00	2.70	2.44	0.32	13.18	2.70
LCP	1.00	1.50	1.06	0.11	10.53	1.00
HL	2.80	4.50	3.78	0.65	17.24	4.50
ED	0.80	1.90	0.96	0.26	27.54	.90
LDFB	5.50	6.20	5.85	0.21	3.66	6.00
UJL	0.50	1.00	0.79	0.25	31.33	1.00
LJL	0.50	1.00	0.79	0.25	31.40	1.00
CFL	2.50	3.60	3.26	0.43	13.09	3.60
PFL	3.30	5.00	4.04	0.46	11.50	4.00
PVFL	2.20	4.70	3.83	0.89	23.26	4.50
FDFB	3.50	5.00	4.07	0.54	13.27	5.00
LAFB	1.50	2.10	1.90	0.20	10.66	2.00
LDFS	1.00	1.80	1.47	0.19	12.94	1.50
LPVFSR	1.60	1.70	1.65	0.05	3.05	1.60
LPVFSL	1.60	1.70	1.65	0.05	3.05	1.60
LAFS	1.00	1.70	1.56	0.20	12.94	1.70
POL	1.00	1.60	1.50	0.15	9.88	1.60
PL	1.70	2.60	2.29	0.32	14.12	2.60
HD	2.00	4.30	3.56	0.88	24.59	4.30
SDFB	1.10	2.00	1. 57	0.35	20.09	2.00

BD=Body Depth, PDL=Pre-Dorsal Length, PPCL=Pre-Pectoral Length, PPVL = Pre-Pelvic Length, PAL = Pre Anal Length, DCP = Depth of Caudal Peduncle, LCP = Length of Caudal Peduncle, HL = Head Length, ED = Eye Diameter, LDFB = Length of Dorsal Fin Base, Upper Jaw Length, Lower Jaw Length, CFL = Caudal Fin Length, PVL = Pectoral Fin Length, PVFL = Pelvic Fin Length, FDFB = First Dorsal Fin Base, LAFB = Length of Anal Fin Base, LDFS = Length of Dorsal Fin Spine, LPVFSR = Length of Pelvic Fin Spine Right, LPVFSL = Length of Pelvic Fin Spine Left, LAFS = Length of Anal Fin Spine, POL = Pre-Orbital Length, PL = Post Orbital Length, HD = Head Diameter, SDFB = Second Dorsal Fin Base

Table 4: Morphometric characteristics of *Oreochromis niloticus* from Ugbo coastal water

Characters	Min	Max	Mean	STD	CV (%)	Mode
Morphometry						
BD	3.50	5.20	4.18	0.38	9.09	4.20
PDL	2.70	4.70	3.66	0.62	16.95	3.00
PPCL	3.30	4.00	3.54	0.15	4.20	3.50
PPVL	3.50	4.50	4.12	0.38	9.22	4.50
PAL	7.00	8.30	7.53	0.59	7.83	7.00
DCP	1.90	2.20	2.03	0.09	4.30	2.00
LCP	1.00	1.50	1.10	0.18	16.12	1.00
HL	2.80	4.10	3.35	0.50	15.06	2.80
ED	0.80	1.90	0.98	0.34	35.29	0.80
LDFB	5.50	6.20	5.76	0.24	4.14	5.50
UJL	0.50	1.00	0.61	0.19	31.12	0.50
LJL	0.50	1.00	0.62	0.20	31.90	.050
CFL	2.50	3.60	2.95	0.38	12.89	2.50
PFL	3.30	4.50	3.83	0.37	9.57	4.00
PVFL	2.20	3.60	2.85	0.47	16.37	2.20
FDFB	3.50	4.70	4.01	0.34	8.45	4.10
LAFB	1.50	2.10	1.77	0.22	12.54	1.70
LDFS	1.00	1.80	1.42	0.24	16.69	1.20
LPVFSR	1.50	1.70	1.63	0.06	3.52	1.60
LPVFSL	1.50	1.70	1.63	0.06	3.52	1.60
LAFS	1.00	1.50	1.40	0.16	11.46	1.50
POL	1.00	1.60	1.46	0.14	9.82	1.50
PL	1.70	2.90	2.26	0.34	15.26	2.40
HD	2.00	3.50	2.80	0.54	19.17	2.50
SDFB	1.00	2.00	1.52	0.30	19.51	1.70

BD=Body Depth, PDL=Pre-Dorsal Length, PPCL=Pre-Pectoral Length, PPVL=Pre-Pelvic Length, PAL=Pre Anal Length, DCP = Depth of Caudal Peduncle, LCP = Length of Caudal Peduncle, HL = Head Length, ED = Eye Diameter, LDFB = Length of Dorsal Fin Base, Upper Jaw Length, Lower Jaw Length, CFL = Caudal Fin Length, PVL = Pectoral Fin Length, PVFL = Pelvic Fin Length, FDFB = First Dorsal Fin Base, LAFB = Length of Anal Fin Base, LDFS = Length of Dorsal Fin Spine, LPVFSR = Length of Pelvic Fin Spine Right, LPVFSL = Length of Pelvic Fin Spine Left, LAFS = Length of Anal Fin Spine, POL = Pre-Orbital Length, PL = Post Orbital Length, HD = Head Diameter, SDFB = Second Dorsal Fin Base

Morphometric variability and differentiation

The Coefficient of Variation (CV) analysis highlighted morphological variations in *O. niloticus* from both Mahin (Table 3) and Ugbo (Table 4). In Mahin, morphometric measurements ranged from 0.25 cm (Upper Jaw Length, UJL) to 8.63 ± 1.14 cm (Pre-anal Length, PAL), with CV values between 1.62% (PAL) and 31.40% (lower jaw length, LJL). Most traits (80%) exhibited notable heterogeneity (CV>10%), although all measurements displayed unimodal distributions. For Ugbo samples, morphometric values ranged from 0.20 cm (LJL) to 7.53 ± 0.59 cm (PAL), with CVs showing wider extremes, from 3.30% (pre-pectoral fin length) to 93.60% (dorsal caudal peduncle depth), and 60% of traits demonstrated heterogeneous variation (CV>10%).

The T-test results (Table 5) revealed significant differences ($p<0.05$) in four morphological traits between the populations. These traits were Head Diameter (HD), Length of the Anal Fin Base (LAFB), Pre-pelvic Fin Length (PVFL), and PAL.

Principal components of morphometric variations

Principal Component Analysis (PCA) extracted five components with eigenvalues greater than 1, together explaining 76.80% of the total morphometric variations in *O. niloticus* from Ilaje coastal waters (Tables 6 and 7). The scree plot (Figure 2) indicated an inflection point after the third component, suggesting that the first three components accounted for the largest share of variation. PC1 explained 47.10% of the variance, followed by PC2 (12.17%), PC3 (7.12%), PC4 (5.57%), and PC5 (4.86%). The factor loadings showed that PC1 had strong positive contributions from body depth (BD, 0.648), pre-dorsal length (PDL, 0.92), pre-pectoral length (PPCL, 0.93), pre-pelvic length (PPVL, 0.76), pre-anal length (PAL, 0.911), dorsal caudal peduncle length (DCP, 0.92), head length (HL, 0.85), lower jaw length (LJL, 0.95), caudal fin length (CFL, 0.949), pectoral fin length (PFL, 0.83), first dorsal fin base (FDFB, 0.90), and length of anal fin base (LAFB, 0.84). PC2 was mainly influenced by post-orbital length (PL, 0.92) and head diameter (HD, 0.83), while PC3 showed strong contributions from lateral caudal peduncle length (LCP, 0.83), upper jaw length (UJL, 0.71), and body depth (BD, 0.12).

Table 5: T-test comparison of morphometric attributes of *Oreochromis niloticus* from study area

Characters	Ugbo		Mahin	
	Mean	Std. Deviation	Mean	Std. Deviation
BD	4.18[a]	0.38	4.16[a]	0.44
PDL	3.66[a]	0.62	4.66[a]	1.05
PPCL	3.54[a]	0.15	3.49[a]	0.90
PPVL	4.52[a]	0.38	4.68[a]	0.60
PAL	7.53[a]	0.59	8.63[b]	0.14
DCP	2.03[a]	0.09	2.44[a]	0.32
LCP	1.10[a]	0.18	1.06[a]	0.11
HL	3.35[a]	0.50	3.78[a]	0.65
ED	0.98[a]	0.34	0.96[a]	0.26
LDFB	5.76[a]	0.24	5.85[a]	0.21
UJL	0.61[a]	0.19	0.79[a]	0.25
LJL	0.62[a]	0.20	0.79[a]	0.25
CFL	2.95[a]	0.38	3.26[a]	0.43
PFL	3.83[a]	0.37	4.04[a]	0.46
PVFL	2.85[a]	0.47	3.83[b]	0.89
FDFB	4.01[a]	0.34	4.07[a]	0.54
LAFB	1.77[a]	0.22	1.90[b]	0.20
LDFS	1.42[a]	0.24	1.47[a]	0.19
LPVFSR	1.63[a]	0.06	1.65[a]	0.05
LPVFSL	1.63[a]	0.06	1.65[a]	0.05
LAFS	1.40[a]	0.16	1.56[a]	0.20
POL	1.46[a]	0.14	1.50[a]	0.15
PL	2.26[a]	0.34	2.29[a]	0.32
HD	2.80[a]	0.54	3.56[b]	0.88
SDFB	1.52[a]	0.30	1.57[a]	0.35

Means with the same superscript along the rows are not significantly different at p>0.05

BD=Body Depth, PDL=Pre-Dorsal Length, PPCL=Pre-Pectoral Length, PPVL=re-Pelvic Length, PAL=Pre Anal Length, DCP=Depth of Caudal Peduncle, LCP=Length of Caudal Peduncle, HL=Head Length, ED=Eye Diameter, LDFB=Length of Dorsal Fin Base, Upper Jaw Length, Lower Jaw Length, CFL=Caudal Fin Length, PVL=Pectoral Fin Length, PVFL=Pelvic Fin Length, FDFB=First Dorsal Fin Base, LAFB=Length of Anal Fin Base, LDFS=Length of Dorsal Fin Spine, LPVFSR=Length of Pelvic Fin Spine Right, LPVFSL=Length of Pelvic Fin Spine Left, LAFS=Length of Anal Fin Spine, POL=Pre-Orbital Length, PL=Post Orbital Length, HD=Head Diameter, SDFB=Second Dorsal Fin Base

Table 6: Eigenvalues, percentage of variance, and percentage of cumulative variance of principal components for morphometric measurements of *O. niloticus*

Components	Eigenvalues	% of Variance	Cumulative %
PC1	11.30	47.10	47.10
PC2	2.92	12.17	59.27
PC3	1.71	7.12	66.38
PC4	1.34	5.57	71.95
PC5	1.17	4.86	76.80

PC4 was defined by right and left pelvic fin spine lengths (LPVFSR, 0.837; LPVFSL, 0.402) and lateral dorsal fin base (LDFB, 0.457), whereas PC5 was associated with eye diameter (ED, 0.835) and left pelvic fin spine length (LPVFSL, 0.531).

Table 7: Principal components after varimax normalized rotation of morphometric variables of *O. niloticus*

Variables	PC1	PC2	PC3	PC4	PC5
BD	0.65	0.00	0.12	0.01	-0.02
PDL	0.92	0.01	-0.03	0.02	0.04
PPCL	0.93	-0.13	0.03	0.04	-0.05
PPVL	0.76	-0.16	0.12	-0.00	-0.21
PAL	0.91	-0.10	0.17	0.06	0.00
DCP	0.92	-0.22	0.12	0.01	-0.05
LCP	-0.06	0.07	0.83	-0.22	-0.28
HL	0.85	0.12	0.37	-0.04	-0.03
ED	-0.01	0.07	-0.12	-0.16	0.84
UJL	0.46	-0.03	0.71	0.08	0.25
LJL	0.95	0.16	0.13	0.01	-0.08
CFL	0.95	0.16	0.13	0.01	-0.08
PFL	0.83	0.15	-0.04	0.01	-0.03
PVFL	0.53	0.10	-0.22	-0.08	0.02
FDFB	0.90	-0.01	-0.00	-0.07	0.08
LAFB	0.84	-0.08	-0.14	0.17	0.02
LDFB	0.48	-0.13	-0.20	0.46	-0.31
LPVFSR	-0.09	0.30	-0.12	0.84	-0.06
LPVFSL	-0.21	-0.53	0.16	0.40	0.53
LAFS	0.22	-0.76	0.12	-0.03	0.05
POL	0.67	-0.03	0.12	0.39	-0.25
PL	-0.07	0.92	0.04	0.13	0.07
HD	0.25	0.83	0.20	0.08	0.07
SDFB	0.81	-0.44	0.04	-0.11	0.05

BD=Body Depth, PDL = Pre-Dorsal Length, PPCL = Pre-Pectoral Length, PPVL = Pre-Pelvic Length, PAL = Pre Anal Length, DCP = Depth of Caudal Peduncle, LCP = Length of Caudal Peduncle, HL = Head Length, ED = Eye Diameter, LDFB = Length of Dorsal Fin Base, Upper Jaw Length, Lower Jaw Length, CFL = Caudal Fin Length, PVL = Pectoral Fin Length, PVFL = Pelvic Fin Length, FDFB = First Dorsal Fin Base, LAFB = Length of Anal Fin Base, LDFS = Length of Dorsal Fin Spine, LPVFSR = Length of Pelvic Fin Spine Right, LPVFSL = Length of Pelvic Fin Spine Left, LAFS = Length of Anal Fin Spine, POL = Pre-Orbital Length, PL = Post Orbital Length, HD = Head Diameter, SDFB = Second Dorsal Fin Base

Discussion

Significant differences (p<0.05) were observed in pre-anal length, pelvic fin length, anal fin base length, and head diameter between the two populations of *O. niloticus*, likely influenced by both anthropogenic factors driving environmental change (Mir *et al* 2012). According to the guidelines of Lombarte *et al* (2012), factor loadings above 0.30 were considered significant, those above 0.40 more significant, and loadings of 0.50 or higher very significant. PCA revealed that the most notable morphological differences occurred in the head, body, and caudal regions. These findings align with Yakubu and Okunsebor (2011), who reported similar phenotypic divergence in *O. niloticus* in Doma Dam, Nasarawa State, Nigeria. Length–weight relationship showed a negative allometric growth pattern in both

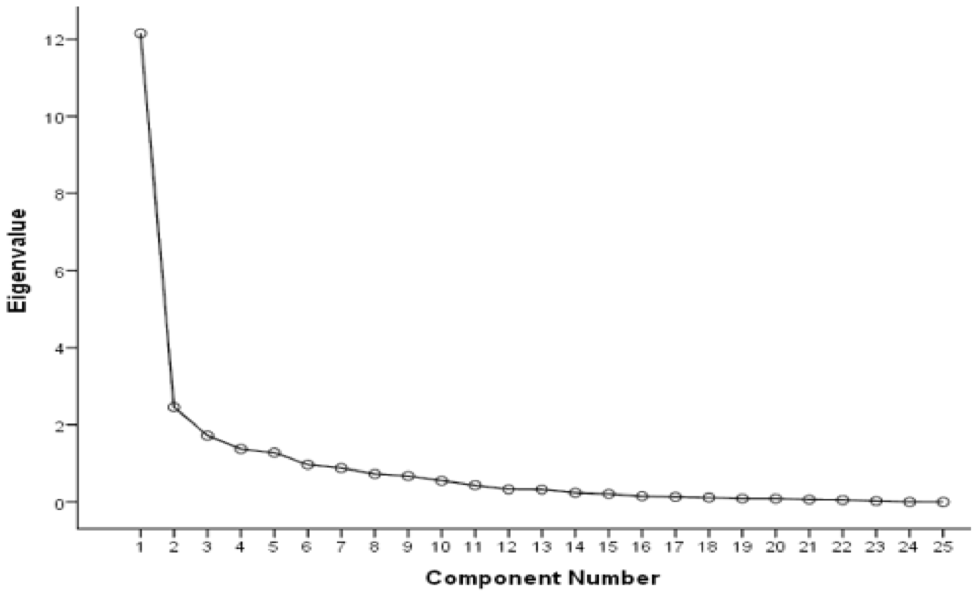

Figure 2: Scree plot for the morphometric variables of *O. niloticus*

Mahin (b=2.30) and Ugbo (b=1.92) populations, indicating that fish tend to become slimmer with increasing size.

The observed negative allometry may result from energetic trade-offs related to osmoregulation in brackish environments (Dinh *et al* 2022). Similar patterns have been documented in tilapia populations from Lake Geriyo, Yola, Nigeria (Kefas *et al.* 2020), suggesting that aquatic environments act as ecological filters shaping growth and morphology. The b values reported in the present study, corroborates the report of Kefas *et al* (2020), as well as Bala *et al* (2009) for *Coptodon* zillii in inland waters. The growth coefficient (b) for Mahin (b = 2.30) fell within the range reported for Nile tilapia (2.30–3.68) by Ahmed *et al* (2011) at the Atbara River and Khashm El-Girba Reservoir in Sudan, whereas the value for Ugbo (b = 1.92) was below this range. According to Golam and Fahad (2013), a 'b' value below 3 indicates slimmer growth, while values above 3 suggest fish become heavier.

In the present study a strong positive correlation between length and weight was recorded, indicating healthy growth and good condition of the population, consistent with the observations of Steve and Okeyo (2019), Abubakar (2006), and Abubakar and Ishaya (2000). The form factor ($a_{3.0}$), which reflects body shape differences (Hossain *et al.* 2013), ranged from 0.00020 to 0.0069. Since reference values for *O. niloticus* are scarce, these results provide valuable baseline data for future studies.

The average condition factor of *O. niloticus* which were 1.93 ± 0.24 in Ugbo and 2.03 ± 0.46 in Mahin, reflect overall good state well-being of the species and suitability of the two coastal environments (Abowei, 2010; Ighwela *et al*. 2011). Although mean value from Ugbo was slightly below the recommended range of 2.0 - 4.0 (Bagenal and Tesch, 1978), these values suggest that *O. niloticus* in both locations were in good condition. Similar findings were reported by Karrar *et al.* (2016), who recorded a condition factor of 1.56 for *O. niloticus* in Sudan's White Nile. The condition factor obtained in this study was also comparable to the values reported by Ugbomeh *et al*. (2021) for *O. niloticus* ((1.89 ± 0.43) from Eniong and Lower Cross Rivers in the Niger Delta, Nigeria.

Conclusion

This study demonstrated that *Oreochromis niloticus* populations in Ugbo and Mahin coastal waters exhibit significant morphometric differences and negative allometric growth patterns, reflecting ecological adaptation to local environmental conditions. PCA highlighted head, body, and caudal regions as the main sources of morphological variations. Positive correlations between length and weight, along with form factor and condition factor values, suggest that both populations were in good condition during the period of study, although ongoing monitoring is recommended. The findings provide valuable baseline data and emphasize the importance of habitat-specific management, including habitat protection, size-specific catch regulations, and continuous environmental monitoring, to ensure the sustainable conservation and utilization of *O. niloticus* in these coastal ecosystems.

Conflict of interest

The authors declare no conflict of interest

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