__Original Research Article__

COMPARATIVE ANALYSIS OF MORPHOMETRIC AND MERISTIC CHARACTERS IN OREOCHROMIS NILOTICUS (NILE TILAPIA) FROM DIFFERENT ECOLOGICAL ZONES OF NIGERIA

Abstract

The present study investigated the comparative analysis of morphometric and meristic characteristics in *Oreochromis niloticus* from different ecological zones across Nigeria. A total of 347 samples (*Asejire Lake* = 62; *Oyan Lake* = 56; *Kainji Lake* = 65; *Jebba Lake* = 56; *Geriyo Lake* = 55; and *Dadin-Kowa Lake* = 53) were collected between October 2019 and September 2020. Twenty-nine morphometric characters were measured to the nearest 0.01 cm using Vernier calipersand nine meristic characters in all the collected individuals.The results of the univariate analysis of variance (ANOVA) revealed that all observed morphometric and meristic characters, except DS, DR, AS, AR, ULLS, and LLLS, were significantly different ($p<0.05$) across the study sites. Notably, *O. niloticus* from Asejire Lake had significantly higher values in all the morphometric characters. The multivariate analysis of variance (MANOVA) identified three morphometric (BW, AFL, CPL) and four meristic characters (ULLS, LLLS, right GR, and left GR) as the most discriminating traits among the studied populations.These findings align with previous research highlighting the utility of morphometric and meristic data in delineating fish populations based on habitat differences and genetic compositions. Significant differences in head-related (head length), swimming-related (anal fin length and caudal peduncle length), and feeding-related (both left and right gill raker) measurements further underscored environmental influences on morphological variation.The study suggests that ecological factors such as food availability and environmental conditions contribute to the observed variations. This research provides valuable insights into the population dynamics and adaptation strategies of *O. niloticus* in diverse aquatic environments across Nigeria

Keywords: Comparative analysis, Morphometric character, Meristic character, Ecological zones, Nile tilapia

1. Introduction

African cichlids are widely studied for their evolutionary processes, particularly due to their rapid speciation rates, adaptive radiations, and diverse speciation mechanisms (1; 2; 3). Tilapia, a significant species in aquaculture both in Africa and globally, comprises three genera; Oreochromis, Sarotherodon, and Tilapia, within the Cichlidae family. These species, originally from Africa, are now globally distributed and have significant ecological and economic roles in their native habitats (4; 5).

Over time, African cichlids have adapted to various geographical areas, displaying phenotypic variations linked to their habitats (6). Analyzing phenotypic variations through morphometric and meristic characters is a common method to differentiate fish stocks, as these characters respond to environmental changes differently across species. Such measurements provide valuable data for taxonomic classification (7). Recognizing morphometric and meristic differences is crucial for evaluating population structures and identifying stocks as documented by different authors (8; 9; 10; 11; 12; 13; 14; 15; 16). Morphomeristic studies are essential not only for taxonomy but also for understanding species health and reproduction (17).

In Nigeria, only few studies have been done on the comparative morphometric differentiation of Tilapia species such as *Tilapia zillii*, *Sarotherodonspecies*, and *Oreochromisniloticus* across different ecological zones. This research aims to compare the morphometric and meristic characters of *O. niloticus* from six water bodies in three ecological zones of Nigeria.

2. 0. Materials and Methods

2. 1. Study areas:

The study areas include six (6) lakes among the major lakes in Nigeria. These include Asejire (07°2N, 04°7˙E) and Oyan (7°15′N, 3°16′E) Lakes from the Southwestern Nigeria; Kanji (10°22′N, 4°33′E) and Jebba (9o8′N, 4o47′E) Lakes from the Northcentral of Nigeria; and Lake Geriyo (9°8′N, 12°25′E) and Dadin-Kowa (10°8′N, 11°32′E) lakes from the Northeastern Nigeria as shown in Figure 1.

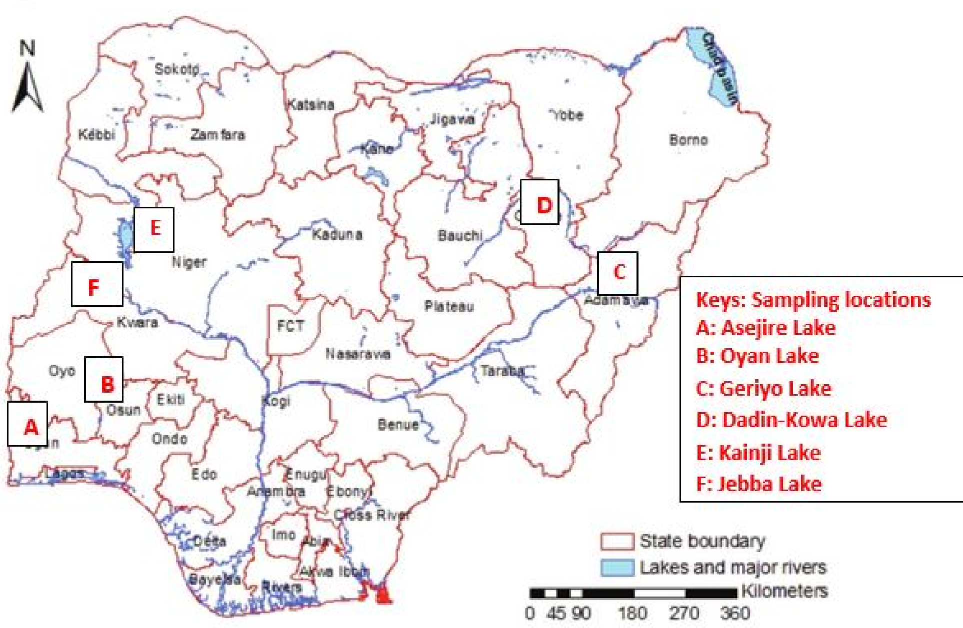

Figure I. Map of Nigeria showing the study locations

2.2. Collection of Sample

Fish samples were collected from the catches of the fishermen at landing sites in each of the study areas. Freshly collected fish samples were transported to the laboratory. Taxonomical identification of the specimens was done using the field guide to Nigerian freshwater fish by Olaosebikan and Raji (2013) and Freshwater Fishes of Nigeria by Idodo-Umeh (2003). A total of three hundred and forty-seven (347) individuals of Oreochromis niloticus were sampled (Asejire Lake = 62; Oyan Lake = 56; Kainji Lake = 65; Jebba Lake = 56; Geriyo Lake = 55; and Dadin-Kowa = 53) between October 2019 and September 2020.

2.3. Morphometric and meristic Characteristics

Twenty-nine (29) morphological measurements were made on each specimen. Morphometric characters were taken using an absolute digital caliper (Tresna Instruments, 0-150mm range) and all measurements were determined to the nearest millimetre. Measurements were made with the samples facing the left hand side. Body weight was measured using an Ohaun digital weighing balance (Mettler Instrument). The morphometric characters measured include the Total Length (TL), Standard Length (SL), Body Depth (BD), Head Length (HL), Snout Length (SnL), Eye diameter (ED) (Left And Right), Dorsal Fin Length (DFL), Anal Fin Length (AFL), Pelvic Fin Length (PvFL) (Left And Right), Pectoral Fin Length (PFL) (Left And Right), Pre orbital Length (PrOL), Caudal Peduncle Length (CPL), Caudal Peduncle Depth (CPD), Pre dorsal Length (PDL), Pre Anal Length (PAL), Lower Lip Width (LLW), Lower Jaw Width (LJW), Pelvic Distance (PD), Cheek Distance (CD), Lower Lip Length (LLL), Upper Lip Length (ULL), Pelvic Spine Length (PSL) (Left And Right), Last Dorsal Spine (LDS), Third Anal Spine (TAS).

Eight (8) meristic characteristics that were made include Dorsal spine (DS), Dorsal ray (DR), Anal spine (AP), Anal ray (AR), Lower lateral-line scale (LLLS), Upper lateral line scale (ULLS), Left gill raker (Left GR) and Right gill raker (RG)

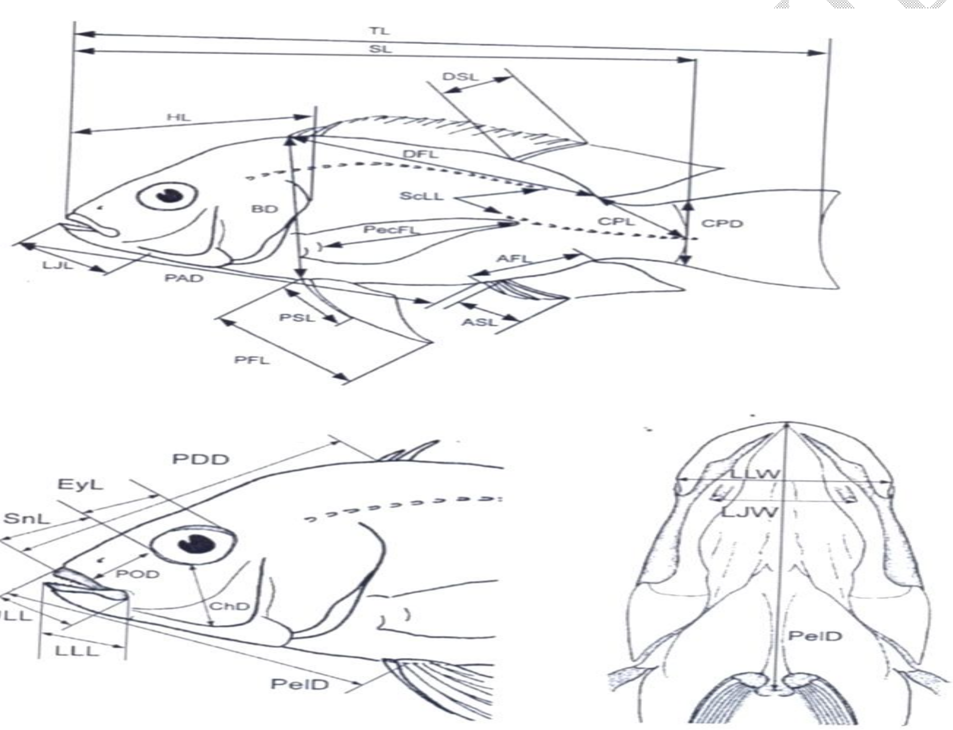

Figure 2 : Map showing the morphometrics characteristics measured

2.4. Statistical Analysis

All data were normalized by size adjustment before being subjected to statistical analysis. The standardized data were analyzed by univariate and multivariate methods. Differences among sampled populations were tested by one-way analysis of variance (ANOVA). A multivariate test of discriminant function analysis was performed to identify characters that were important in distinguishing the population groups.

3.0. Results

The results of the univariate analysis of the morphometric and meristic characteristics are presented in Table I. The results revealed that *O. niloticus* from Asejire Lake had the highest mean total weight of 255.01±125.29g, followed by 111.57±50.90g and 100.43±42.55g from Oyan Lake and Jebba Lake, respectively, while the lowest mean total weight was observed from Kainji Lake (48.23±39.58) (Table 1). Likewise, the highest mean total length (233.03±53.17cm) and standard length (187.40±43.95cm) were observed from Asejire Lake, followed by Oyan Lake with mean total length and standard length of 111.57±50.90cm and 136.50±22.24cm, respectively, while samples from Kainji Lake had the lowest mean total length (130.22±35.38cm) and standard length (130.22±35.38cm). The body depth of O. niloticus from Asejire, Oyan, Kainji, Jebba, Geriyo, and Dadin-Kowa Lakes was 75.10±14.54cm, 58.58±9.58cm, 42.96±12.34cm, 55.74±8.57cm, 53.46±2.67cm, and 51.51±9.70cm, while the head lengths were 62.03±13.66cm, 46.13±6.99cm, 36.18±9.96cm, 45.26±6.07cm, 40.74±2.94cm, and 39.10±7.41cm, respectively.

The results revealed that virtually all morphometric characteristics of *O. niloticus* from Asejire Lake were significantly higher and different (*P=.05*) from those of other lakes, which simply indicates the heterogeneity of the population, while those of *O. niloticus* from Geriyo Lake were not significantly different (p<0/05) from those of Dadim-Kowa Lake, which indicated the homogeneity of the two populations.

The results from the univariate analysis also showed that all meristcs characters observed across the studied lakes were not significantly different (*P=.05*) except the gill raker (both left and right) of *O. niloticus* from Geriyo Lake, which is significantly different from that of Asejire, Oyan, Kainji and Jebba Lakes but not significantly different from that of Dadin-Kowa Lake (Table I). The result further revealed that there is no significant difference (*P=.05*)in the gill raker counts of *O. niloticus* from Asejire, Oyan, Kainji, Jebba and Dadin-Kowa Lakes.

Table 1: Mean values of morphometric and meristic characteristics of Oreochromis niloticus from some major lakes in Nigeria.

	Asejire	Oyan	Kainji	Jebba	Geriyo	Dadin-Kowa
Characters	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
TW	255.01±125.29^{a}	111.57±50.90^{b}	48.23±39.58^{e}	100.43±42.55^{c}	66.84±13.62^{d}	73.02±44.96^{d}
TL	233.03±53.17^{a}	171.81±25.63^{b}	130.22±35.38^{d}	168.34±23.90^{b}	150.16±10.67^{c}	150.59±27.03^{c}
SL	187.40±43.95^{a}	136.50±22.24^{b}	102.91±27.84^{d}	134.45±19.37^{b}	118.55±8.77^{c}	119.84±22.76^{c}
BD	75.10±14.54^{a}	58.58±9.58^{b}	42.96±12.34^{e}	55.74±8.57^{bc}	53.46±2.67^{cd}	51.51±9.70^{d}
HL	62.03±13.66^{a}	46.13±6.99^{b}	36.18±9.96^{d}	45.26±6.07^{b}	40.74±2.94^{c}	39.10±7.41^{c}
SnL	20.67±4.82^{a}	14.85±2.37^{b}	12.46±5.02^{c}	14.37±2.41^{b}	12.54±1.49^{c}	12.34±2.86^{c}
EDL	12.64±1.87^{a}	9.71±1.28^{b}	9.11±1.36^{b}	10.22±0.99^{b}	9.41±0.64^{b}	9.12±1.12^{b}
EDR	12.71±1.84^{a}	9.88±1.50^{b}	9.13±1.39^{b}	10.30±0.75^{b}	9.52±0.69^{b}	9.38±0.98^{b}
DFL	115.54±26.27^{a}	83.87±13.61^{b}	61.22±18.24^{e}	78.14±20.20^{c}	72.29±4.97^{d}	71.46±18.83^{d}
AFL	38.19±9.78^{a}	25.02±7.63^{b}	19.38±5.45^{d}	26.88±4.02^{b}	23.28±2.27^{c}	22.93±4.77^{c}
PFLL	48.30±9.18^{a}	37.28±5.67^{c}	30.98±8.57^{d}	41.34±6.72^{b}	36.53±2.95^{c}	31.04±7.30^{d}
PFLR	49.55±8.84^{a}	37.24±5.91^{c}	31.35±8.22^{d}	41.30±6.55^{b}	35.82±2.65^{c}	30.80±7.27^{d}
PcFL	69.67±16.14^{a}	50.41±9.38^{b}	37.12±12.31^{f}	49.98±9.90^{c}	45.54±3.49^{d}	42.57±8.85^{e}
POL	11.77±3.01^{a}	7.86±1.42^{bc}	6.11±2.05^{c}	8.07±1.44^{b}	7.11±0.81^{bc}	6.80±1.78^{c}
CPL	24.46±6.31^{a}	17.38±3.70^{b}	12.18±3.66^{d}	15.87±2.21^{c}	15.85±1.74^{c}	15.33±3.43^{c}
PDL	64.65±14.53^{a}	48.41±7.28^{b}	36.49±10.52^{d}	47.68±5.76^{b}	42.01±3.41^{c}	42.71±8.15^{c}
PAL	135.04±30.57^{a}	101.42±16.53^{b}	74.73±19.56^{d}	102.15±12.99^{b}	87.52±7.13^{c}	88.68±16.97^{c}
LLW	18.14±5.10^{a}	13.41±2.80^{b}	9.26±3.44^{d}	12.54±2.57^{bc}	11.13±1.34^{bc}	10.68±2.72^{cd}
LJW	15.47±4.30^{a}	11.63±2.43^{b}	7.97±2.83^{d}	10.66±1.93^{bc}	9.14±0.88^{cd}	9.00±2.39^{cd}

PD	80.21±16.43^{a}	59.17±8.58^{b}	43.28±14.69^{e}	59.78±7.76^{b}	53.36±3.27^{c}	50.01±9.52^{d}
CD	19.62±5.12^{a}	14.07±2.53^{b}	10.37±3.62^{c}	13.65±2.16^{b}	12.37±1.15^{bc}	12.00±3.41^{bc}
LLL	12.74±3.67^{a}	9.23±1.51^{b}	7.12±2.06^{c}	8.87±1.49^{bc}	8.11±0.96^{bc}	8.26±1.62^{bc}
ULL	14.63±4.16^{a}	11.06±1.90^{b}	8.31±2.54^{c}	10.58±2.30^{b}	9.62±1.13^{bc}	9.43±1.92^{bc}
CPD	28.02±6.32^{a}	20.49±3.72^{b}	15.21±4.81^{d}	19.46±2.98^{bc}	18.58±3.20^{bc}	17.68±3.70^{c}
PSLL	26.22±5.34^{a}	20.97±2.48^{b}	17.55±5.16^{c}	21.58±2.74^{b}	19.80±1.79^{b}	16.29±2.66^{c}
PSLR	26.75±5.26^{a}	20.86±2.59^{bc}	17.72±5.39^{d}	21.90±2.60^{b}	19.46±1.43^{c}	16.44±2.64^{d}
LDS	27.15±5.43^{a}	20.77±2.84^{b}	16.09±5.25^{d}	22.12±2.67^{b}	19.41±1.55^{bc}	17.44±3.30^{cd}
TAS	28.46±5.38^{a}	21.58±2.60^{b}	16.84±5.64^{c}	21.17±2.87^{b}	20.87±1.19^{b}	17.55±3.35^{c}
Meristic characters						
DS	17.18±0.39	17.18±0.39	16.95±0.51	16.80±0.41	17.06±0.24	17.10±0.31
DR	12.06±0.24	12.12±0.60	12.25±0.64	12.35±0.49	12.24±0.56	12.70±0.47
AS	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00
AR	9.29±0.69	9.18±0.39	8.95±0.22	8.95±0.39	9.06±0.43	9.00±0.00
ULLS	22.06±0.75	21.41±0.71	21.45±0.60	22.80±0.95	22.12±0.60	22.10±0.64
LLLS	14.53±0.80	14.35±0.70	13.70±0.47	13.95±0.76	14.47±0.94	14.00±0.00
GRL	22.59±0.62^{a}	22.47±0.62^{a}	22.70±0.47^{a}	22.55±0.51^{a}	20.59±1.28^{b}	21.45±0.51^{ab}
GRR	22.71±0.47^{a}	22.53±0.51^{a}	22.60±0.50^{a}	22.50±0.51^{a}	20.94±0.97^{b}	21.45±0.51^{ab}

In the study areas, the standardized canonical discriminant function coefficient for *O. niloticus* revealed that three morphometric and four meristic characters were the most discriminating among the populations. The three discriminating morphometric characters were body weight, anal fin length, and caudal peduncle length, while the four discriminating meristic characters were the upper lateral line scale, lower lateral line scale, left gill raker, and right gill rakers (as shown in Table 2).By referring to the standardized discriminant function coefficient (Table II), we can conclude that positive coefficients indicate that higher values of the characters contribute to the discrimination between sampled species from different sites. Conversely, negative coefficients suggest that lower values of the characters are responsible for discriminating between the sampled species from different sites. Additionally, the magnitude of the coefficient represents the strength of the contribution of the characters in the species discrimination. Larger magnitude coefficients have a greater impact on group discrimination.

The standardized discriminant function coefficient (Table 2) indicates that the right gill raker (0.999) has a higher value and makes a stronger contribution to differentiating the sampled *O. niloticus* from various sites, while the body weight (-0.079) has a lower value and a weaker contribution. This is reflected in the discriminant plot (Figure 3), where sites with higher gill raker values appear on the right (positive) side of function 1, and those with lower gill raker values appear on the left (negative) side. Similarly, the plot also shows that sites with lower body weight values fall on the left side of function 1, while sites with higher body weight values fall on the right side. The standardized discriminant function coefficient indicates that body weight has a weaker contribution to the species discrimination. The canonical discriminant plot (Figure 3) also shows that the *O. niloticus* populations from Geriyo Lake and Dadin-Kowa Lake form a cluster, and similarly, the populations from Kainji Lake and Jebba Lake form another cluster on the plot.

Table 2: Standardized Canonical Discriminant Function Coefficient of Variables from *Oreochromis niloticus* from the Studied Sites

	Functions				
	1	2	3	4	5
BW	-0.079	-2.956	-0.953	0.346	0.282
AFL	0.390	1.486	0.110	1.464	0.649
CPL	-0.411	1.409	1.514	-1.518	-1.270
ULLS	0.079	-0.039	0.408	0.558	0.456
LLLS	0.124	0.319	-0.639	0.169	-0.269
GR_left	0.002	0.243	-0.206	-0.749	0.646
GR_right	0.990	-0.124	0.077	-0.018	-0.012

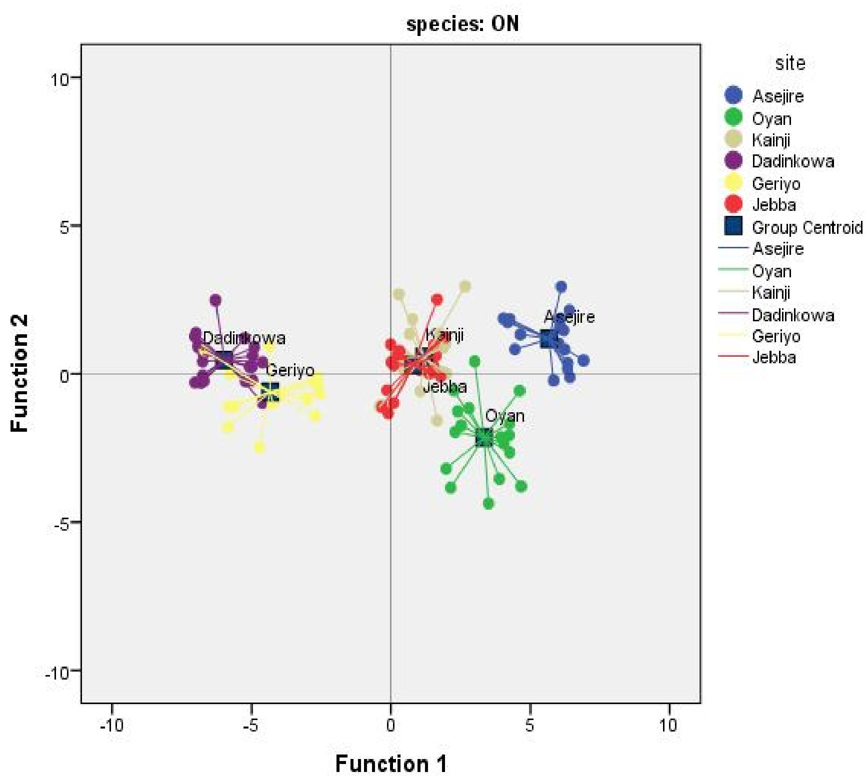

Figure 3: Canonical Discriminant Plot for *Oreochromis niloticus* from the Studied Sites

4.0. Discussion

Morphological characters including morphometric, meristic and truss network system have been widely used to delimit the various populations of fish stock from different aquatic environments (20). The observed variations in the morphometric and meristic characteristics of *O. niloticus* from the present study are similar to the reports of (14) that observed anal fin length and right gill rakers among other characters as discriminating characters in *Coptodonzilli*from some major water bodies in Nigeria. This present study also showed some level of similarities with the work of (15) who observed

Sarotherodonmelanotheron from three different Creeks in River State to be phenotypically separable population based on the variations in their body depth and caudal peduncle length.

The results from this present study also corroborate with the reports of (13) who reported significant variations in the body depth and caudal peduncle width in *Hemichromis fasciatus* from two aquatic environments (rivers and ponds) in Imo state Nigeria and the work of (11) also revealed eye diameters, caudal peduncle depth and spinous dorsal fin ray as discriminating characters in *Sarotherodongalilaeus*from three man-made lakes in Nigeria. The reports of (10) revealed body depth, caudal peduncle depth, and the number of gill rakers as discriminating characters in *Sarotherodonmelanotheron* from two lagoons, Badagry and Lagos lagoon. However, the present study is not in total submission to the work of (16) who observed caudal peduncle depth as a non-discriminating character in the racial study of *Boopsboops* from four marine stations along the Tunisia coast. There were no significant variations observed in the fin rays of *O. niloticus* from the six study areas, as they remain fairly constant which agrees with the theory of (21) that fin rays of cichlids do not vary much. Moreover, fin ray counts and vertebrae numbers were reported to have been established early in larval development and are influenced by temperature (22). Consequently, the lesser variations in the meristic characters across the studied areas may suggest that the development of the larvae experienced less distinct environmental conditions even though they are from different ecological zones.

The morphometric parameters observed in O. niloticus from Asejire and Oyan lakes were significantly higher than those of Geriyo and Dadin-Kowa lakes. This difference could be attributed to the availability of food and other environmental factors. According to (23), food availability contributes to high morphological plasticity in fish. Geriyo and Dadin-Kowa are known to be less productive (14; 24), which could result in low availability of food.In the present study, significant variations in head-related measurements were also observed between *O. niloticus* from Asejire Lake and other lakes, confirming previous reports that variations between populations of tilapia species are mostly reflected in the head region (25). (14) also observed similar variations in the head measurements of *Coptodonzillii* from five different water bodies in Nigeria. The variations observed in the morphometric and meristic characters in *O. niloticus* from the six study areas could be due to environmental factors such as temperature, salinity, geographical isolations, and genetic compositions, as established by different researchers.

There were some level of overlapping of *O. niloticus* populations observed between the populations of Geriyo and Dadin-Kowa lakes, as well as between the populations of Kainji and Jebba lakes, as shown in the canonical discriminant plot. This overlapping was due to some level of similarity or fewer variations in the studied characters, which may be attributed to the fact that both lakes are located in the same ecological zone (Sudan savannah) of Nigeria and experience the same environmental conditions, such as temperature. Even though Geriyo Lake is a natural lake and Dadin-Kowa is a man-made lake, there was no evidence of connections between the two lakes. Similarly, the overlapping between *O. niloticus*from Kainji and that of Jebba could simply be attributed to the fact that both lakes are in the same ecological zone, and there was evidence of linkage between the two lakes.

5.0. Conclusion

In summary, the current study has confirmed that differences in size and count of certain body features among populations of a species are important for evaluating the population structure. These features remain reliable tools for identifying different populations. The study identified three size-based features and four count-based features as distinguishing characteristics in *O. niloticus* from six water bodies in Nigeria. O. niloticus from Asejire Lake had significantly larger size-based features compared to the other locations, while those from Geriyo Lake and Dadin-kowa had the smallest size-based features. The observed differences in the appearance of *O. niloticus* in the studied areas may be due to factors such as temperature, food availability, geographical isolation, and genetic variation.The current study supports the idea that there is significant variation in the appearance of *O. niloticus* within different populations due to environmental factors and genetic differences.

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