MORPHOLOGICAL CHARACTERIZATION OF NATURAL POPULATIONS OF
Sarotherodon galilaeus (LINNAEUS, 1758) FROM THREE SELECTED RESERVOIRS IN SOUTH WESTERN, NIGERIA

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ABSTRACT

Morphological characterization of *Sarotherodon galilaeus* (Linnaeus, 1758) from Opa, Asejire and Ero reservoirs in southwest, Nigeria was carried out with a view to determining the morphological heterogeneity or homogeneity among the three different populations and to determine whether there are morphotypes of this species in the selected study areas. Twenty five morphometric measurements and six meristic counts were recorded on 150 specimens; fifty from each reservoir population. Principal Component Analysis (PCA) and Canonical Variate Analysis (CVA) were performed on the morphometric and meristic data using PAST software. All the clusters produced by the PCA and CVA analyses on the morphometric and meristic data overlapped widely; indicating a low level of morphological differentiation among the three populations of *Sarotherodon galilaeus*. The study concluded that the *Sarotherodon galilaeus* populations from Opa, Asejire and Ero reservoirs are morphologically similar and phenotypically inseparable.

Keywords: Morphometric, Meristic, Morphological differentiation, Reservoirs in south-western Nigeria, *Sarotherodon galilaeus*

INTRODUCTION

One of the major forces that drive the evolution of new species is the formation of different morphotypes within a population; which is induced by both biotic and abiotic conditions of the environment. The degree of speciation can be assessed directly by quantifying the morphological traits both morphometric and meristic characters of individuals within the population (Bailey, 1997). Morphometric characters are external features that are quantified using metric measurements in form of size; they can also be quantified geometrically in form of shape; while meristic characters are quantified using serial body counts.

It has been documented in several species that there is a strong correlation between morphology and habitat specialization; as morphological traits that are well suited to the conditions in one environment may be ill-suited to those in others (Bolnick *et al.,* 2003; DeWitt and Scheiner, 2004; Webster *et al.*, 2011). Little variation in body shape has been seen to correlate with fitness parameters such as body condition, foraging success, growth rate etc. Lindsey (1988) noted that morphology is particularly dependent on environmental conditions especially, during early life history stages. The prevailing environmental conditions during the early developmental stages of an organism, shapes and influences largely the morphology and phenotype of that organism (Tudela, 1999; Pinheiro *et al.*, 2005). Morphological characteristics can show high flexibility in response to differences in environmental conditions (Swain and Foote, 1999) which may lead to adaptive selection. This implies that organisms in a population may adjust their morphological features to meet the peculiarities and demand of their ecological conditions (Swain and Foote, 1999). Stearns (1983) noted that fishes exhibit some degree of phenotypic plasticity which allows them to respond adaptively to environmental changes.

In fisheries biology, morphometric and meristic characters have been commonly used as powerful tools for measuring discreteness and relationships among various taxonomic categories (Ihssen *et al.,* 1981). They are also used to identify fish stocks (Turan *et al.*, 2006; Suneetha and Damayanthi, 2008) and for determining the evolutionary linkages between fish fauna (Deesri *et al.*, 2009). Information on morphological variation among

populations can serve as a basis for studying population structure, and may be useful for studying short-term, environmentally- induced variations directed towards effective management of fisheries. Intra-specific morphological variations corresponding to differences in habitat and resource use have been documented in different animal groups, including gastropods (De Witt *et al.,* 2000), insects (Johansson and Wahlstrom, 2002); amphibians (Dayton *et al.*, 2005); reptiles (Phillips and Shine 2004); birds (Price, 1987) and mammals (Smartt and Lemen, 1980). In fishes, intraspecific morphological variation within and among populations with similar and different environmental conditions including water chemistry, substrate type and water depth has been reported by several authors (Lattuca *et al.*, 2007; Spoljaric and Reimchen, 2007; Oladimeji *et al.*, 2015; Solomon *et al.*, 2015; Oladimeji and Olaosebikan, 2017). Although, reports have suggested that the morphological characteristics of fish are determined by an interaction between both genetic and environmental factors (Tudela, 1999), it has been observed that morphological variability among populations may not necessarily reflect population differentiation at the molecular level (Tudela, 1999). At the intra-specific level, phenotypic differences observed in morphological characters are not directly under the influence of genes, but is subjected to environmental modification (Khayyami *et al.*, 2015).

Sarotherodon galilaeus, is native to Africa and Middle East, but is widely distributed also in Europe and some parts of America. It has been introduced to several Asian countries such as Japan and China for aquaculture purposes (Froese and Pauly, 2014). *S. galilaeus* is largely found in Nigerian waters; it is widely cultivated and appreciated by consumers because of its excellent taste and being a good and affordable source of protein. There is paucity of information on the morphological characterization of wild populations of *S. galilaeus* in southwestern Nigeria and there is need to determine whether there are morphotypes of these species especially in the selected study areas where large and indiscriminate harvest of this fish is done on daily basis. This information will contribute to knowledge on the taxonomy of this fish species and by extension; ensure its effective management, sustainable yield and conservation.

MATERIALS AND METHODS
STUDY AREA

The fish samples were collected from three reservoirs located in three different states (Osun, Oyo, and Ekiti States) in the southwestern part of Nigeria. The reservoirs are Opa reservoir in Osun state, Asejire reservoir in Oyo state and Ero reservoir in Ekiti state. These three reservoirs represent some of the major water bodies in southwestern Nigeria, where large harvest of this fish species is done on daily basis. The Opa Reservoir Basin was established in 1978 by the impoundment of Opa River which took its source from Oke-Opa Hills. It is geographically located in Ile-Ife, Osun state, Nigeria. The reservoir has a catchment area of close to 116 square kilometres. It extends from longitude $4°31'$E to $4°39'$ E and from latitude $7°21'$N to $7°35'$ N (Figure 1). The surface area of the reservoir is about 0.95 square kilometres, while the capacity at peak level is about 675 m^3. The minimum depth is 0.95 m while the maximum depth is 6.4 m. The mean annual temperature of the area is 27 $°C$ (Akinbuwa and Adeniyi, 1996).

Asejire Reservoir is located in Oyo State, in the southwestern part of Nigeria. It is the impoundment of the Osun River, about 30 kilometres east of Ibadan (Figure 2). It lies between latitude $7°21'45"$N and longitude $4°08'00"$E. It has a catchment area of about 23.42 km^2 (2,342 hectares), a normal pool elevation of 150 m and maximum flood elevation of 152.4 m. The surface area is about 24 km^2 (Ayodele, 1979). The reservoir provides water to the Asejire and Osegere water treatment plants in Ibadan. It has a capacity of about 80 million litres per day, of which 80% is used for domestic purposes.

Ero Reservoir, established in 1983, is located in Ikun-Ekiti, Ekiti state, Nigeria. It is the impoundment of the Ero River which lies between latitude $7°59'$N and longitude $5°12'$E, covering a distance of about 11 km (Figure 3). The impoundment area is about 4.5 km^2 while the water surface area is about 450 hectares with a maximum capacity of about 20.9 million cubic

metres. The dam supplies over one hundred towns and villages in the state with pipe borne water   (Omoniyi and Basorun, 2013).
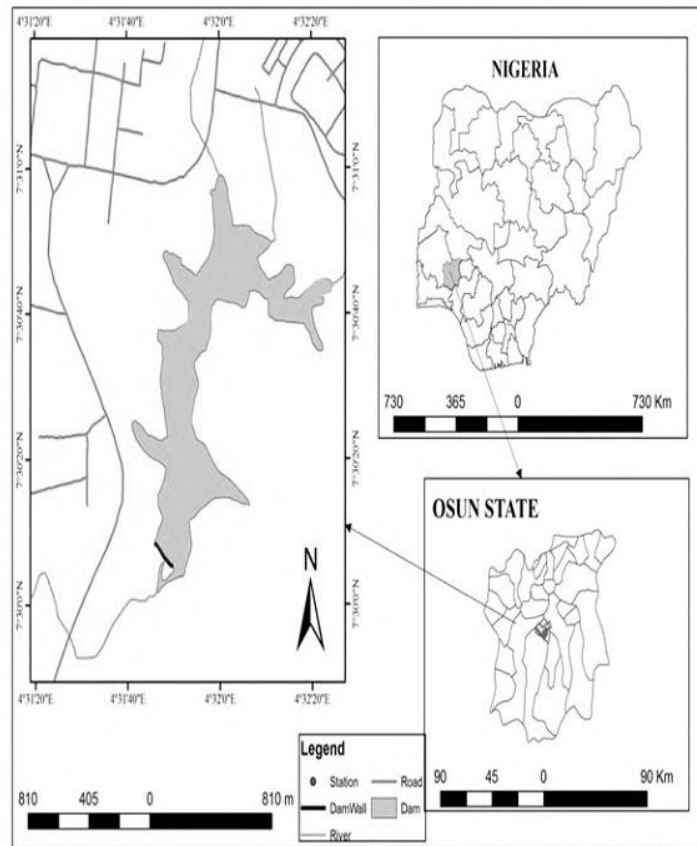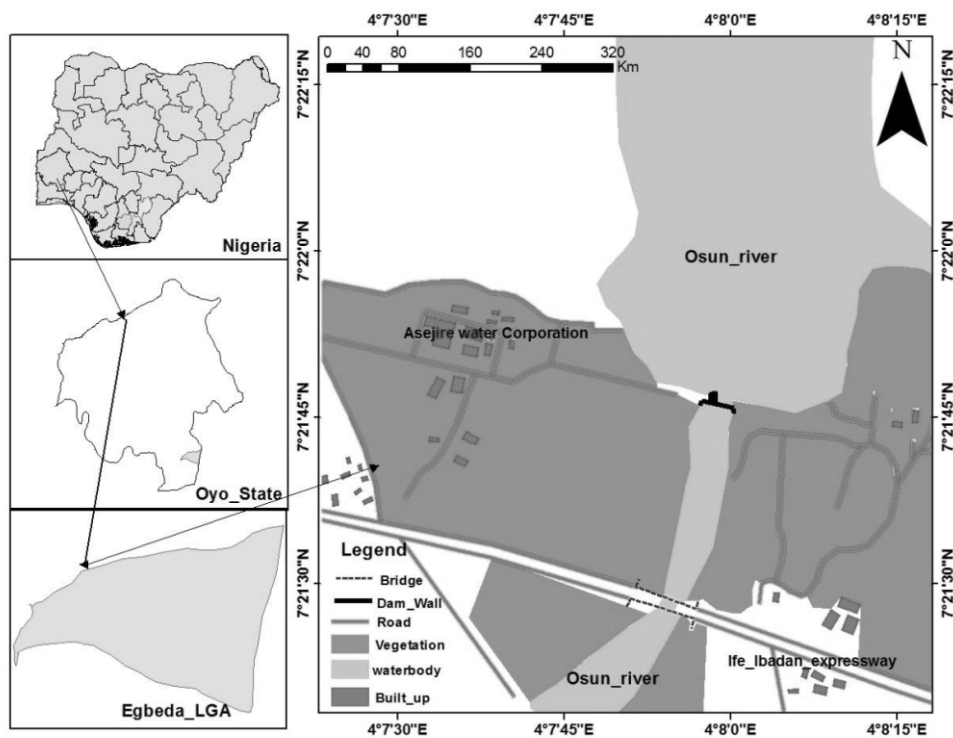

Figure 1: Map of Opa Reservoir in Osun State, Nigeria

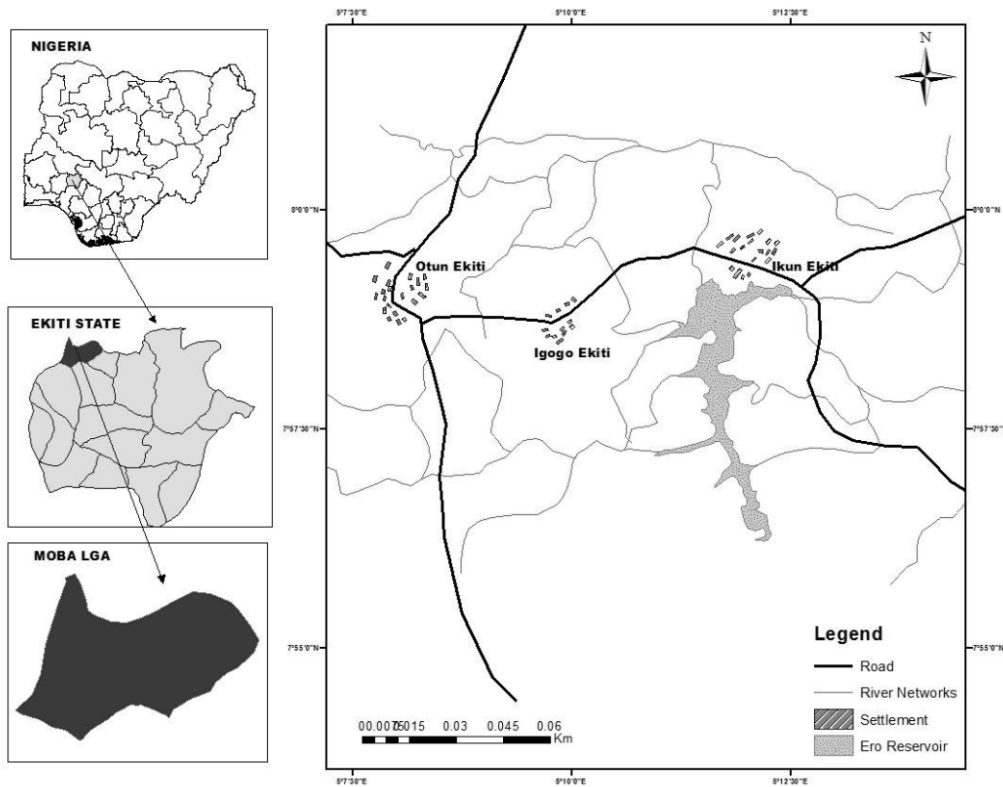**Figure 2:** Map of Asejire Reservoir in Oyo State, Nigeria

Figure 3: Map of Ero Reservoir in Ekiti State, Nigeria

Sampling

Fifty samples of *S. galilaeus* were randomly collected from each reservoir; making a total of 150 samples. The fish samples were collected from landings of commercial fishermen at each study site and then brought to the Fish Culture Laboratory in the Department of Zoology, Obafemi Awolowo University. The fish samples were identified using standard identification key prepared by Paugy *et al.* (2003). Twenty five morphometric measurements [Total length (TL), Standard length (SL), Head length (HL), Body depth (BD), Snout length (SNL), Cheek depth (CHD), Eye length (EYL), Dorsal fin length (DFL), Anal fin length (AFL), Length of last dorsal spine (LDS), Length of third anal spine (LTAS), Pelvic fin length (PFL), Pre-dorsal distance (PDD), Upper lip length (ULL), Lower jaw length (LJL), Lower lip width (LLW), Lower lip length (LLL), Pectoral fin length (PECFL), Pre-orbital distance (POD), Caudal peduncle length (CPL), Caudal peduncle depth (CPD), Lower jaw width (LJW), Pelvic spine length (PSL), Pre-anal distance (PAD) and Distance of lower jaw to pelvic fin (PELD)] as in Dunz and Schliewen (2010) and were recorded in 50 individuals in each population using digital Vernier calliper (NEIKO 01407A). Six meristic counts: number of scales on lateral line, number of dorsal spine, number of dorsal ray, number of gill rakers, number of anal fin rays and number of anal fin spines were also recorded. Principal Component Analysis and Canonical Variate Analysis were carried out separately on the morphometric measurements and meristic counts because morphometric characters are continuous while the meristic characters are discontinuous. Furthermore, the meristic characters are fixed early in development while the morphometric characters are more prone to environmental changes (Allendorf *et al.*, 1987). Measurements of each morphometric character were standardized for fish size (SL) in accordance with Reist (1985) using percentage standard length as follows:

$Mn = (Mo/SL) \%,$

where: Mo is the original measurement; and SL is the standard length.

This was done in order to remove the varying effect of size on each of the fish samples.

Size-corrected morphometric data were analysed by multivariate method using Principal Component Analysis (PCA) and Canonical Variate Analysis (CVA) on Paleontological

Statistics (PAST) software (Hammer *et al.*, 2001). Canonical Variate Analysis was done specifically to test for intraspecific variation within the populations. Factor loadings based on Eigen values from Principal Component Analysis (PCA) were used to determine the morphometric character with the highest variation that can discriminate among the three populations. The meristic data were also subjected to Principal Component Analysis while factor loadings based on Eigen values was also used to identify the meristic character that differed most among the three populations.

RESULTS

The descriptive statistics of each morphometric and meristic characters recorded on the *S. galilaeus* samples are shown on table 1. The PCA showed a wide overlap of data among the morphometric measurements of *S. galilaeus* from the three

reservoirs (Figure 4). Canonical Variate Analysis (CVA) plot also showed a marked overlap of morphometric data among members in Ero, Opa and Asejire reservoir respectively, however there is a slight dispersion from the cluster by members occupying Opa reservoir (Figure 5). Factor loadings based on Eigen values from the PCA showed that dorsal fin length was the morphometric character that varied most among the three populations and hence can be used to delineate the populations. The PCA based on the six meristic counts of *S. galilaeus* from Opa, Asejire and Ero reservoirs in Osun, Oyo and Ekiti states respectively showed homogeneity as the meristic characters largely overlapped among the three populations (Figure 6). However, factor loadings based on Eigen values on the PCA was able to identify number of gill rakers as the meristic character most responsible for variation among the studied populations (Figure 7).

Table 1: Descriptive Statistics of the Morphological Traits Recorded on _Sarotherodon galilaeus_ from Ero, Opa and Asejire Reservoirs in South-western Nigeria

Morphometric and Meristic parameters	Mean	Std. Deviation	95% C.I. of mean	Max.	Min.
TL ERO	11.758	1.791	0.509	16.90	9.20
OPA	18.120	4.902	1.393	30.90	11.40
ASEJIRE	13.906	1.618	0.460	0.50	10.50
SL ERO	9.092	1.524	0.433	13.70	6.90
OPA	14.688	4.263	1.212	24.90	8.80
ASEJIRE	11..078	1.346	0.382	17.00	8.50
HL ERO	3.446	0.677	0.192	5.00	2.20
OPA	4.710	1.054	0.300	8.40	3.40
ASEJIRE	3.832	0.463	0.131	5.60	3.00
BD ERO	4.006	0.757	0.215	5.60	2.80
OPA	6.578	1.884	0.535	11.90	4.20
ASEJIRE	4.482	0.514	0.146	6.50	3.60
SNL ERO	1.060	0.384	0.109	2.30	0.40
OPA	2.074	3.190	0.907	24.00	0.90
ASEJIRE	1.224	0.196	0.0558	1.90	0.80
CD ERO	1.372	0.513	0.146	3.40	0.60
OPA	2.106	2.225	0.632	17.00	1.00
ASEJIRE	1.584	1.658	0.471	13.00	1.00
EL ERO	1.214	1.440	0.409	11.10	0.40
OPA	1.126	0.265	0.0753	1.90	0.50
ASEJIRE	1.008	0.110	0.0314	1.20	0.70
DFL ERO	6.094	0.734	0.208	9.30	5.00
OPA	8.894	7.516	2.136	58.00	1.60
ASEJIRE	4.726	0.877	0.249	7.60	3.00
AFL ERO	1.424	0.337	0.0958	2.30	0.40
OPA	2.716	0.881	0.250	4.80	1.20
ASEJIRE	1.932	0.327	0.0930	2.90	1.40
LDS ERO	1.812	0.245	0.0698	2.50	1.30
OPA	2.740	2.861	0.813	22.00	1.40
ASEJIRE	1.412	0.340	0.0967	2.10	0.70
LAS ERO	1.150	0.320	0.0908	2.00	0.50
OPA	1.722	0.505	0.144	2.70	0.60
ASEJIRE	1.652	0.219	0.0622	2.30	1.20
PFL ERO	2.544	0.556	0.158	4.30	1.60
OPA	4.634	1.500	0.426	8.10	2.30
ASEJIRE	3.232	0.462	0.131	5.00	2.00
PDD ERO	3.822	0.765	0.217	5.70	2.50
OPA	6.198	5.479	1.557	43.00	3.20
ASEJIRE	4.462	0.500	0.142	6.40	3.30
ULL ERO	0.934	0.228	0.0649	1.50	0.60
OPA	1.232	0.358	0.102	2.00	0.40
ASEJIRE	1.062	0.155	0.0441	1.60	0.80
LJL ERO	2.158	0.251	0.0977	2.80	0.70
OPA	2.112	0.925	0.263	3.60	0.60
ASEJIRE	1.508	0.344	0.0713	3.20	1.60
LLW ERO	0.968	0.300	0.0852	1.60	0.50
OPA	1.228	0.267	0.0760	1.80	0.70
ASEJIRE	1.008	0.158	0.0448	1.50	0.80
LLL ERO	0.594	0.174	0.0495	1.10	0.30
OPA	0.846	0.28	0.081	1.80	0.30
ASEJIRE	0.504	0.0925	0.0263	0.70	0.30
PcFL ERO	0.780	0.236	0.0672	1.30	0.30
OPA	1.296	0.377	0.107	2.20	0.50
ASEJIRE	0.780	0.156	0.0445	1.40	0.70
POD ERO	3.616	1.022	0.290	6.20	1.60
OPA	5.040	1.478	0.420	8.90	2.30
ASEJIRE	4.070	0.508	0.144	6.10	3.20
CPL ERO	0.814	0.245	0.0696	1.70	0.40
OPA	1.320	0.419	0.119	2.40	0.60
ASEJIRE	1.216	0.527	0.150	4.40	0.80
CPD ERO	1.590	0.385	0.109	2.80	0.90
OPA	2.456	0.846	0.240	4.20	1.10
ASEJIRE	2.110	0.260	0.0738	3.00	1.50

Morphometric and Meristic parameters		Mean	Std. Deviation	95% C.I. of mean	Max.	Min.
LJW	ERO	1.744	1.511	0.429	12.00	1.00
	OPA	2.766	3.036	0.863	23.00	0.90
	ASEJIRE	1.744	0.225	0.0639	2.60	1.40
PSL	ERO	1.520	0.233	0.0662	2.30	1.10
	OPA	2.144	0.639	0.182	3.60	0.90
	ASEJIRE	1.794	0.222	0.0630	2.40	1.10
PAD	ERO	6.916	1.392	0.396	10.70	5.00
	OPA	11.006	3.189	0.906	18.50	6.80
	ASEJIRE	7.930	0.934	0.265	11.80	6.20
PelD	ERO	3.842	0.816	0.232	6.10	2.30
	OPA	6.056	1.645	0.467	10.40	3.40
	ASEJIRE	4.488	0.656	0.186	6.80	3.20
SLL	ERO	28.740	2.877	0.818	34.00	19.00
	OPA	28.560	2.697	0.766	33.00	24.00
	ASEJIRE	31.000	1.884	0.536	35.00	26.00
DsS	ERO	16.200	0.452	0.128	17.00	15.00
	OPA	15.900	0.364	0.104	17.00	15.00
	ASEJIRE	16.280	0.454	0.129	17.00	16.00
DsR	ERO	11.880	0.558	0.159	17.00	11.00
	OPA	11.880	0.961	0.273	15.00	10.00
	ASEJIRE	11.580	1.052	0.299	13.00	11.00
GlR	ERO	19.460	3.632	1.032	25.00	10.00
	OPA	24.140	2.356	0.670	31.00	18.00
	ASEJIRE	22.860	1.485	0.422	29.00	18.00
AFR	ERO	11.000	0.000	0.000	11.00	11.00
	OPA	10.840	0.468	0.133	12.00	10.00
	ASEJIRE	10.840	0.738	0.210	13.00	8.00
AFS	ERO	3.000	0.000	0.000	3.00	3.00
	OPA	3.000	0.000	0.000	3.00	3.00
	ASEJIRE	3.000	0.000	0.000	3.00	3.00

Abbreviations:

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TL=	Total length	PECFL=	Pectoral fin length
SL=	Standard length	POD=	Pre-orbital distance
HL=	Head length,	CPL=	Caudal peduncle length
BD =	Body depth,	CPD=	Caudal Peduncle Depth
SNL=	Snout length	LJW=	Lower jaw width
CD=	Cheek depth	PSL=	Pelvic spine length
EL =	Eye length	PAD=	Pre-anal distance
DFL =	Dorsal fin length	PELD=	Distance of lower jaw to pelvic fin
AFL=	Anal fin length	SLL=	No. of scales on lateral line
LDS=	Length of last dorsal spine	DsS=	No. of Dorsal spine
LAS=	Length of third anal spine	DsR=	No. of Dorsal ray
PFL=	Pelvic fin length	GlR=	No. of Gill rakers
PDD=	Pre-dorsal Distance	AFR=	No. of Anal fin ray
ULL=	Upper lip length	AFS=	No of Anal fin spine
LJL =	Lower jaw length,		
LLW=	Lower lip width		
LLL=	Lower Lip Length		
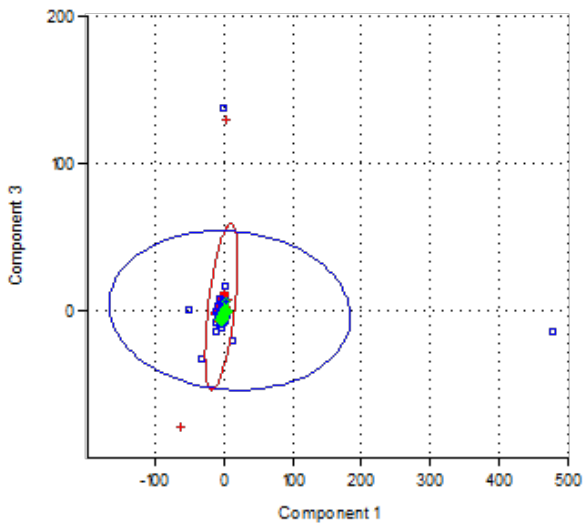
Figure 4: Principal Component Analysis Based on Morphometric Measurements of *Sarotherodon galilaeus* showing Overlap of Characters among the Three Populations

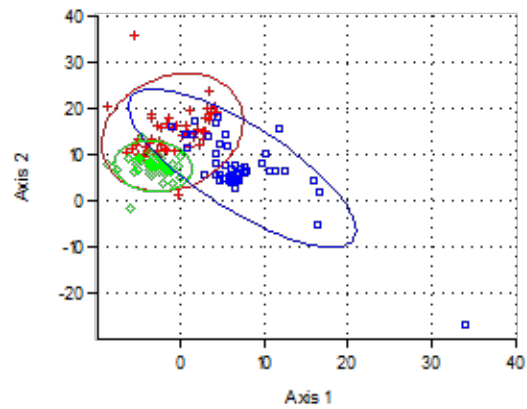**Note:** Opa Reservoir (blue), Asejire Reservoir (green) and Ero Reservoir (red).

Figure 5: Canonical Variate Analysis (CVA) Based on Morphometric Measurements of *Sarotherodon galilaeus*

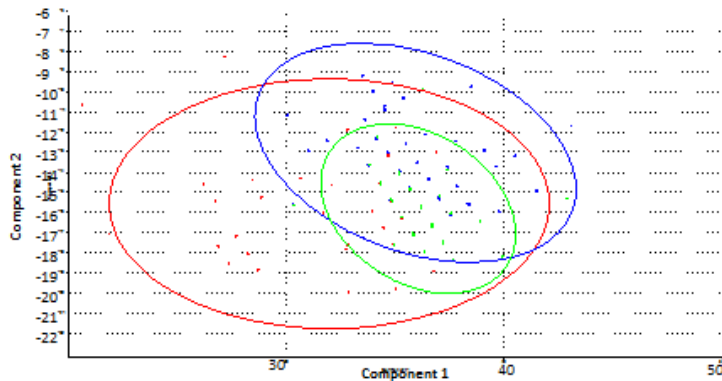**Note**: Ero Reservoir (red), Opa Reservoir (blue) and Asejire Reservoir (green)

Figure 6: Principal Component Analysis based on 6 Meristic Counts of *Sarotherodon galilaeus* from the Three Populations

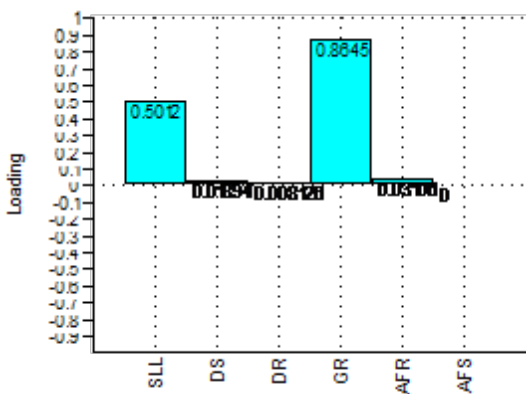**Note:** Ero Reservoir (red), Opa Reservoir (blue) and Asejire Reservoir (green)

Figure 7: Respective *Sarotherodon galilaeus* Meristic Counts and their Loadings on Component1 of the Principal Component Analysis

Abbreviations:

SLL= Scales on lateral line   DS= Dorsal spine
DR= Dorsal ray   GR= Gill rakers
AFR= Anal fin ray   AFS= Anal fin spine

DISCUSSION

Measurements of morphometric characters and meristic counts were employed in this study because they are considered to be dependable tools to characterize and identify fish species especially on the field where more detailed diagnostic tools such as biochemical and molecular markers are not available. Also, morphometric and meristic measurements are considered dependable tools because they are sensitive to environmental changes (Fryer and Iles, 1972).

The wide overlap of data observed among the morphometric measurements of *S. galilaeus* from the three reservoirs of study (Opa, Asejire and Ero) as revealed by the PCA implies that there are no statistically significant differences in the morphometric measurements of *S. galilaeus* across the three different reservoirs. Canonical Variate Analysis, however, was able to identify variants in the morphometric characters of some *S. galilaeus* species inhabiting Opa reservoir only; thus revealing intra-specific variation within the Opa reservoir population of *S. galilaeus*. Also, factor loadings based on Principal Component analysis identified dorsal fin length and number of gill rakers as the morphometric and meristic character respectively, which varied most among the three populations.

This may be a reflection of the difference in feeding environment, availability of different food types and prey in the different study areas. Also, the fish fauna in the three different reservoir varies; which means that the predators that the fishes are exposed to will also vary in the different environments. This observation can be justified by the fact that fishes are more susceptible to environmentally-induced morphological variation and they show greater variation in morphological characters both within and among populations than any other group of vertebrates (Winberger, 1992; Turan *et al.*, 2006). Similarly, the intraspecific morphological variation observed in the Opa reservoir population of *S. galilaeus* as revealed by the Canonical Variate Analysis (CVA) confirms the report of Smith and Skulason (1996) that intra-population variation exist in fish species which could correlate with habitat choice as well as availability of food resources.

A general overlap of morphometric and meristic characters of *S. galilaeus* was observed in the three reservoirs of study, Opa, Asejire and Ero reservoirs (Osun, Oyo and Ekiti states respectively). The observed overall morphological relatedness may be as a result of similar climatic conditions in these three reservoirs. This is consistent with the report of Carvalho (1993) that if localized populations inhabit similar environments, they may fail to display great heterogeneity in phenotypic or genetic traits. The findings of this study is in contrast to that of Oladimeji and Olaosebikan (2017) who reported that *Tilapia zillii* population from Ero and Asejire reservoirs were morphologically different, while the *T. zillii* population from Opa reservoir shares some morphological similarities with both Ero and Asejire reservoirs.

Similarly, Omoniyi and Agbon (2008) reported morphometric and meristic variations in *Sarotherodon melanotheron* collected from brackish and fresh water habitats in southwestern, Nigeria. They suggested that the morphological variations could be as a result of difference in the temperature, salinity and substratum in the two water bodies. Olopade *et al.* (2018) also reported significant morphological differences between a freshwater and brackish water population of *Coptodon guineensis* in Rivers state, Nigeria and concluded that the two populations are phenotypically separable. Solomon *et al.* (2015) noted that morphological variations among different populations of the same species of fish are usually indicative of adaptations to prevailing environmental conditions which may be unique to each population. Chukwuka *et al.* (2019) reported large morphological differences between *Sarotherodon galilaeus* and *Oreochromis niloticus* in Lake Geriyo, northeastern Nigeria. They noted that the observed morphological differences are an indication that the species had adapted to different spatial and vertical distributions within the lake.

In conclusion, morphological similarities were observed among *S. galilaeus* populations occupying Opa, Asejire and Ero reservoirs. These results established homogeneity in morphology among populations of *S. galilaeus* inhabiting the three different reservoirs. This implies that the

populations are phenotypically inseparable and there are no morphotypes of this species in the selected study areas.

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