Genetics & Biodiversity Journal
Journal homepage: https://journals.univ tlemcen.dz/GABJ/index.php/GABJ
ISSN : 2588-185X

OPEN ACCESS

Original Research Paper

Impoundment impact on the morphology of *Brycinus macrolepidotus* (Characiformes: Alestidae) Populations in the Osun River, Nigeria.

OLADIMEJI Tofunmi Elizabeth[1*], ADEWOLE Henry Adefisayo[1], OLAGUNJU Sodiq Damilola [1] and OGUNRIBIDO Ayokunle Olamide[1]

[1]*Department of Zoology, Obafemi Awolowo University Ile-Ife, Nigeria;*

***Corresponding Author**: Oladimeji Tofunmi Elizabeth; Department of Zoology, Obafemi Awolowo University Ile-Ife, Nigeria **Email**: *toladimeji@oauife.edu.ng.* (+2348033092964)

Article history: Received: November 9th 2022; Revised: july 1st 2023; Accepted: July 16th 2023

Abstract

River impoundment has constituted a major disturbance to aquatic ecosystems worldwide by transforming rivers into reservoirs; this in turn has resulted in adaptive changes in the morphology of native species. To determine the potential effect of impoundment on the morphological characters of *Brycinus macrolepidotus*, the morphological variation between its populations associated with the river and reservoir areas along the Osun River was compared. In total, eighty (80) specimens were collected from the study areas and measured using standard procedures. Statistical procedures such as the student T-test, and principal component analysis (PCA) were performed on the morphometric and meristic data using SPSS and PAST software respectively. The T-test analyses revealed that the body depth, snout length, eye diameter, pelvic fin length, pre-anal length, pectoral-fin ray, pelvic-fin ray, and scales above the lateral line varied significantly ($P<0.05$) between the two populations. However, the PCA comparing the two populations revealed low differentiation for most characters. The observed changes in some morphological features between *Brycinus macrolepidotus* populations have implications for the adaptation of the fishes to the environmental changes imposed by the impoundment of the Osun River.

Keywords: Dam, Environmental conditions, Meristic, Morphology, River

Introduction

Brycinus macrolepidotus also known as the true big-scale tetra (Valenciennes, 1850) is located within the family Alestidae, a group of African characiforms. Like other "African characids", they were formerly included in Characidae but are more distantly related phylogenetically (Froese *et al.*, 2016). Brycinus species are commonly found in freshwater bodies and they thrive well in both lacustrine and riverine conditions; as it is common with most freshwater fishes (Olurin and Aderibigbe, 2006).

Morphological variation in fishes is completely related to many aspects of their ecology; including locomotion, space resource limitations, and foraging tactics, and it can be used to indicate the functional diversity of fish assemblages (Ignam, 2015). Fishes have been reported to exhibit different morphologies in adaptation to different environmental conditions (Agbebi *et al*., 2009; Oladimeji *et al*., 2017; Oladimeji *et al.*, 2020).

More than any other vertebrate, fishes show greater variations in morphological characteristics, both within and between populations, due to their high phenotypic flexibility (Cabral *et al.*, 2003; Hossain *et al*., 2010; Mohaddasi *et al*., 2013; Jalili *et al*., 2015). However, prevailing environmental conditions during the early life history stages of an organism have been reported to influence and/or determine largely the shape and morphology of that organism (Pinheiro *et al*., 2005; Radojkovic *et al*., 2018). Also, adaptive selection may result from flexibilities in morphological characteristics in response to different environmental conditions and ecological demands (Swain and Foote, 1999; Anvarifar *et al*., 2011; Gaston and Lauer, 2015; Silva *et al.*, 2016).

River impoundment has constituted a major disturbance to aquatic ecosystems worldwide (Dynesius, 1994; Nilsson *et al*., 2005; Downing *et al*., 2006; Santos and Araújo, 2015). It causes fundamental changes in the natural landscapes by transforming rivers into reservoirs which in turn have accompanying ecological and evolutionary effects on native species (Hendry *et al.*, 2002; Langerhans *et al*., 2003; McGuigan *et al.,* 2003; Haas *et al.*, 2010; Araújo *et al*., 2013; Franchi *et al.*, 2014). The most pronounced effects of impoundments on aquatic organisms, especially fish, are a reduction in genetic diversity and adaptive changes in the morphology of native species (Myers, 2001; Anvarifar *et al*., 2011). Continuous reduction in genetic diversity as a result of restriction to gene flow may threaten populations or in extreme cases, lead to population extinction if not properly monitored and controlled. Several studies have reported habitat-specific morphological differentiations in fish populations (Oladimeji and Olaosebikan, 2017, Ola-Oladimeji *et al*., 2017, Oladimeji *et al*., 2020); especially with regard to the impoundment of rivers (Haas *et al*., 2010; Hendry *et al.*, 2002; Langerhans *et al*., 2003). Haas *et al*. (2010) reported significant differences in the morphology of *Cyprinella venusta* inhabiting reservoirs from those inhabiting streams. They found that those inhabiting reservoirs were deeper-bodied and had a smaller head, a more anterior dorsal fin, a shorter dorsal-fin base, and a more ventral position of the eye than those in streams.

However, there is a lack of information regarding the morphological responses of *B. macrolepidotus* populations associated with its occurrence along the perturbed Osun River, which is a UNESCO world heritage site and one of the longest rivers in Nigeria, with an extension of about 267 km (Anifowose and Oyebode, 2019). The objective of this study, therefore, is to determine the morphological differences between *B. macrolepidotus* populations sampled from the Osun River and its reservoir site in Asejire, Nigeria.

Materials and Methods

Description of the study site

The study was carried out in the Osun River and Asejire reservoirs, respectively in Osun and Oyo States, Nigeria. The Osun River whose source is from Igede Ekiti, Ekiti State, Nigeria; runs through Osun groove with its mouth located at the Lekki Lagoon and was impounded at Asejire, Oyo State in the late 1960s purposely for portable water supply to the people of Ibadan and its environs. The portion of the River around Owode-Osogbo, Osun State, Nigeria, where the study was carried out is located between 07°74'81"N and 004°63'18"E whereas the Asejire Reservoir is located within 07°21'45"N and 004°80'0" E (Figure1).

Fish collection, identification, and morphometric analysis

Forty specimens of *Brycinus macrolepidotus* were collected from each sampling site using gill and cast netting methods. Specimens were identified using identification keys prepared by Paugy *et al.* (2003). Eighteen (18) morphometric characters according to Adeosun *et al*., 2019 with some modifications were measured to the nearest centimeter with digital Vernier calipers and standard meter rule in all 80 fish specimens. The measured characters include total length (Tl), standard length (Sl), head length (Hl), body depth (Bd), snout length (Snl), eye diameter (Ed), pre-anal length (Pal), pre-pectoral length (Ppl), longest dorsal-fin ray length (Ldfr), pelvic-fin length (Pfl), pectoral-fin length (Pecfl), caudal-peduncle length (Cpl), caudal-peduncle depth (Cpd), pre-dorsal length (Pdl), anal-fin base length (Afbl), dorsal-fin base length (Dfbl), caudal-fin length (Cfl) and pre-pelvic length (Ppel). Seven meristic characters were counted and recorded on each specimen. The counted meristic characters include dorsal-fin rays, anal-fin rays, pectoral-fin rays, pelvic-fin rays, number of scales on the lateral line, number of scales above the lateral line, and number of scales below the lateral line.

Statistical analysis

The morphometric measurements were standardized to fish size according to Reist (1985). This was done to remove the effect of size such that the comparative variation in morphology of the fish populations can be determined independently of size. Hence, the percentage of the standard length was used to remove the effect of size as follows:

$$Mn = \frac{Mo}{SL}\ \%, \text{ where:}$$

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

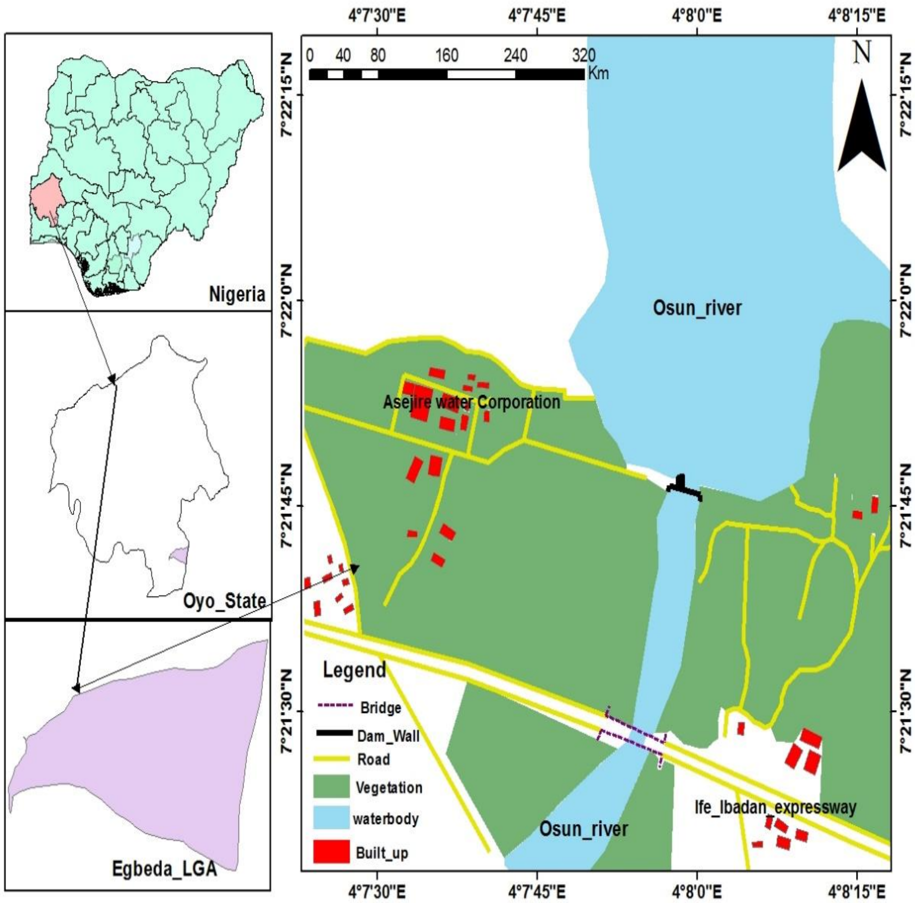

Figure1: Map of Osun River showing Asejire reservoir

The new data set obtained for each of the measurements (Mn), which excludes standard length was further transformed to a common logarithm because linearity and normality are better approximated by logarithm rather than by original variables (Hair *et al.*, 1998). The transformed data set was used for the final analysis. Data generated were expressed as mean ±SEM. The data was subjected to Kolmogrov-Smirnov and Shapiro-Wilk tests to check for the normality of the data set. T-test was carried out on the morphometric and meristic characters of the fish specimens to determine the significant variation for each trait between the two localities when $P < 0.05$. Principal Component Analysis (PCA) was also used to determine the morphological variation between the two populations. Factor loadings based on Eigenvalues in the PCA were used to determine the morphometric factors that can discriminate between the two populations. These analyses were carried out using SPSS (version 25.0) and PAST Software.

Results

The analyses performed to compare the fish specimens revealed that 5 out of the 17 analyzed morphometric characters varied significantly ($P < 0.05$) between the two localities (Table 1). The characters showing more variation, as shown in the table include the body depth (t=2.691; P=0.009), the snout length (t=6.946; P=5.33E-10), the eye diameter (t=2.278; P=0.030), pelvic fin length (t=2.568; P=0.014), and the pre-anal length (t=4.962; p=1.41E-5). Also, the counts such as the pectoral-fin rays, pelvic fin rays (t= -3.592, P=0.0009; t= 2.210, P=0.031 respectively), and the scales above lateral line (t= -4.080; P=0.00021) were found to be significantly different ($P < 0.05$) meristic characters between the two populations (Table 1). The populations of *B. macrolepidotus* examined were not grouped separately along the PCA in both the morphometric and meristic comparisons (Figure 2 and Figure 3, respectively). However, factor loadings based on the PCA showed the caudal peduncle length as the most contributing morphometric character to the variance of the fish specimens between the two populations, with the highest loading value of 0.4597.

The snout length had the second-highest loading value of 0.4107 (Figure 4). The meristic character with the highest loading value in the PCA is several lateral line scales, loading (0.7759) (Figure 5).

Table 1. Comparison of morphometric and meristic characters between *Brycinus macrolepidotus* populations from the Osun River and Asejire Reservoir

Parameter	Osun River	Asejire Reservoir	t-test	P-Value
Total Length	124.77 ±0.93	123.58 ±0.57	1.094	0.284
Head Length	24.03 ±0.46	23.05 ±0.26	1.819	0.084
Body Depth	39.92 ±0.85	28.49 ±0.31	2.691	***0.009**
Snout Length	9.10 ±0.24	7.05 ±0.16	6.946	***5.33E-10**
Eye Diameter	7.85 ±1.59	7.34 ±0.17	2.278	***0.030**
Pelvic Fin Length	20.56 ±0.32	199.58 ±0.27	2.568	***0.014**
Pectoral Fin Length	22.06 ±0.54	21.16 ±0.32	1.427	0.165
Caudal Fin Length	26.42 ±0.59	26.32 ±0.45	0.137	0.893
Pre-Pectoral Fin Length	23.94 ±0.42	24.54 ±0.35	-1.312	0.197
Pre-Pelvic Length	50.91 ±0.79	49.50 ±0.59	1.455	0.154
Pre-Anal Length	78.77 ±1.43	71.11 ±0.90	4.962	***1.41E-5**
Longest Dorsal-Fin Ray Length	19.58 ±0.46	19.83 ±0.24	-0.576	0.567
Dorsal Fin Base Length	10.75 ±0.24	10.20 ±0.16	1.768	0.083
Caudal Peduncle Length	15.89 ±0.56	15.05 ±0.61	0.917	0.366
Caudal Peduncle Depth	12.12 ±0.19	12.10 ±0.34	0.053	0.967
Anal Fin Base Length	15.01 ±0.28	14.63 ±0.27	0.966	0.339
Pre Dorsal Length	59.82 ±0.96	58.39 ±0.60	1.192	0.241
Dorsal Fin Ray	8.40±0.11	8.58±0.12	-1.0694	0.291
Anal Fin Ray	13.75±0.14	14.23±0.20	-1.910	*0.060
Pectoral Fin Ray	10.08±0.19	11.10±0.24	-3.592	***0.0009**
Pelvic Fin Ray	9.48±0.181.33	9.00±0.17	2.21	***0.03**
Lateral Line Scale	20.88±0.17	21.03±0.40	-0.349	0.728
Scales Above Lateral Line	9.48±0.16	10.3±0.16	-4.080	***0.00021**
Scales Below Lateral Line	8.60±0.15	8.93±0.19	-1.29	0.204

**P* < 0.05*

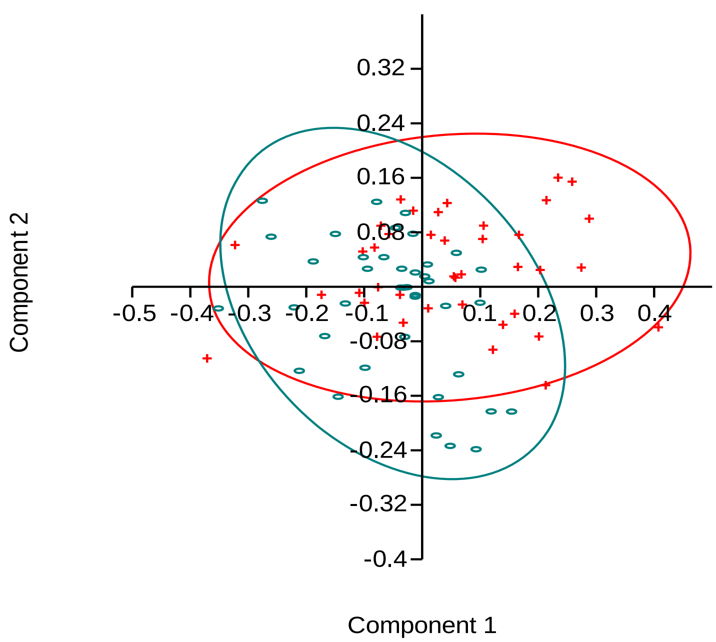

Figure 2. Principal components analyses based on 17 morphometric characters of *Brycinus macrolepidotus* showing an overlap of data from the two study locations; the Osun River (blue) and Asejire Reservoir (Red)

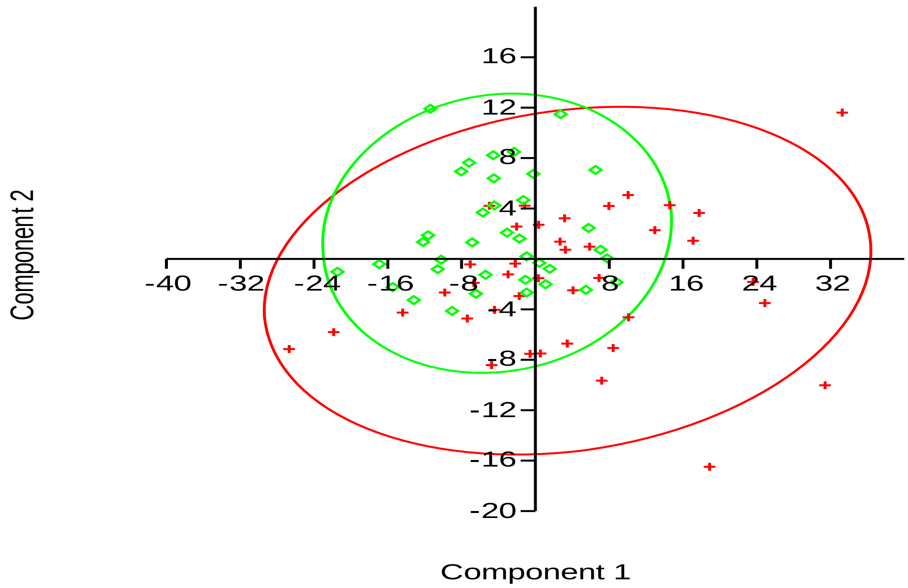

Figure 3. Principal components analyses based on seven meristic counts of *Brycinus macrolepidotus* between the two studied locations; Osun River (Green) and Asejire Reservoir (red).

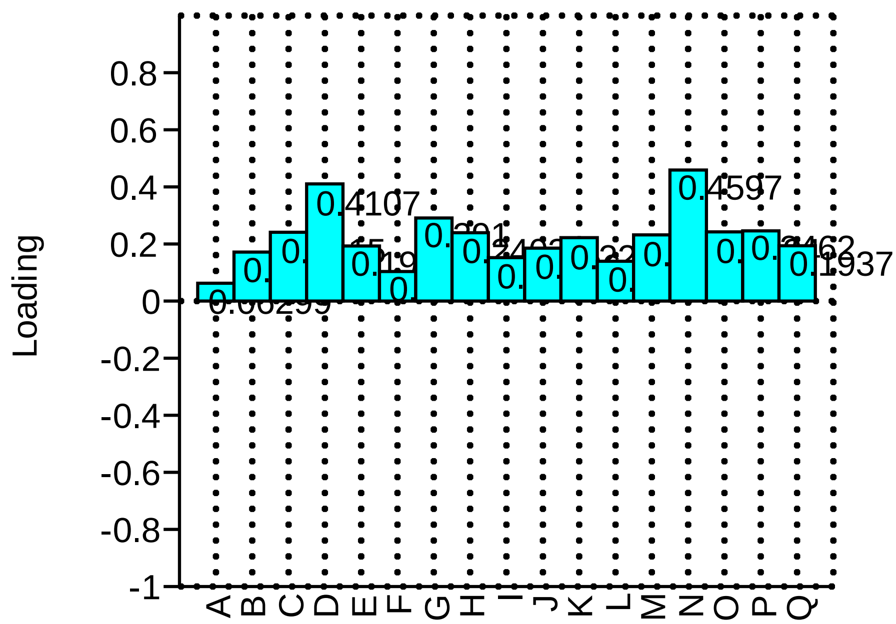

Figure 4. Respective *B. macrolepidotus* morphometric characters and their loadings on PCI of the Principal Component Analysis

Key: *A = Total length (TL), B = Head length (HL), C = body depth (BD), D =Snout length (SNL), E = Eye diameter (ED), F = pelvic fin length (PFL), G = Pectoral fin length (PEFL), H= Caudal fin length (CFL), I = Pre pectoral fin length (PPEFL), J= pre pelvic length (PPFL), K= pre anal length (PAL), L= longest dorsal fin ray length (LDFRL), M = dorsal fin base length (DFBL), N =caudal peduncle length (CPL), O= caudal peduncle depth (CPD), P = anal fin base length (AFBL), Q = pre dorsal length (PDL).*

DOI: 10.46325/gabj.v7i2.324

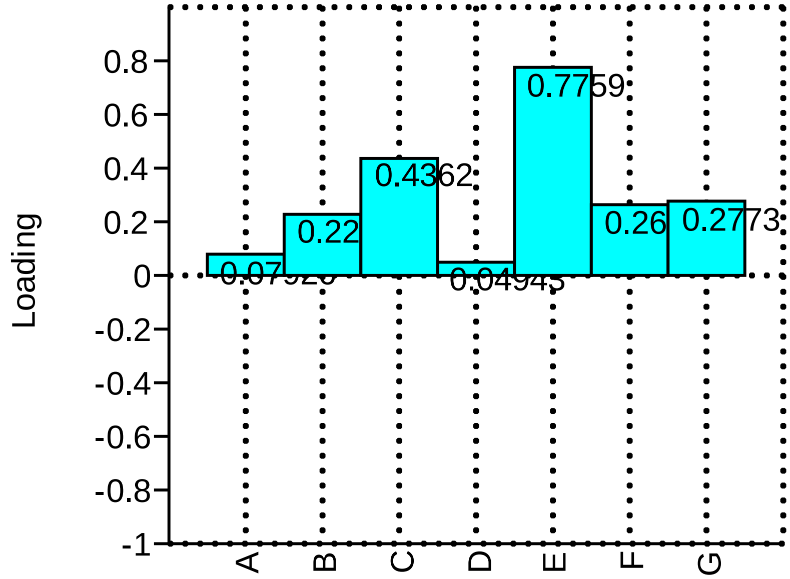

Figure 5. Respective *B. macrolepidotus* meristic characters and their loadings on PCI of the Principal Component Analysis

Key: *A= Dorsal fin rays, Anal fin rays, Pectoral fin rays, Pelvic fin rays, Number of scales on the lateral line, Number of scales above the lateral line, Number of scales below the lateral line.*

Table 2. Eigenvalues and percentage variance of morphometric data showing the distribution of variation among the components in the PCA

PC	Eigenvalue	% variance
1	120.533	53.852
2	25.8603	11.554
3	17.6107	7.8682
4	16.5204	7.3811
5	10.9314	4.884
6	7.30021	3.2616
7	5.66354	2.5304
8	3.9846	1.7803
9	3.58063	1.5998
10	3.31911	1.4829
11	2.05813	0.91955
12	1.76525	0.78869
13	1.39966	0.62535
14	1.10937	0.49565
15	0.906433	0.40498
16	0.689527	0.30807
17	0.588405	0.2628

Table 3. Eigenvalues and percentage variance of meristic data showing the distribution of variation among the components in the PCA

PC	Eigenvalue	% variance
1	5.34324	46.739
2	1.71796	15.028
3	1.53768	13.451
4	1.16543	10.195
5	0.632919	5.5364
6	0.605665	5.298
7	0.429071	3.7533

Discussion

The morphological variation of *B. macrolepidotus* from two waterbodies artificially separated along the same drainage (the Osun River and Asejire Reservoir) was investigated in this study using morphometric and meristic characters. It has been established that water impoundment poses ecological difficulties to native species that are capable of responding to the barrier (dam), which changed the condition of the waterbody from lentic to lotic (Haas *et al.*, 2010; Franssen, 2011; Foster *et al*., 2015). Studies have also shown that morphological characteristics can show high flexibility in response to differences in environmental conditions (Gianneto *et al*., 2013; Pompei *et al*., 2016; Radojkovic *et al.*, 2018). This study, adds to the existing body of knowledge that the impoundment of rivers has a significant effect on the morphology of native fish species inhabiting the water body. In this study, univariate analysis was able to identify five morphometric and three meristic characters that vary significantly between the two populations.

The morphological differences observed between the reservoir and river populations of *Brycinus macrolepidotus* correspond to characters that have a direct impact on fitness (Langerhans and Reznick 2010). This implies that the change from the lotic (flowing river) to the lentic (reservoir) condition of the water body significantly impacted the morphological characters of the fishes. The variation observed in the morphometric and meristic data agrees with the findings of Mian *et al.* (2014) and Khayyami *et al.* (2015) that partial or complete isolation of fish groups within a species can result in notable differences in morphological variables. However, the significant variation observed in the meristic counts of *B. macrolepidotus* populations disagrees with the submissions made by Murta (2000), Oladimeji *et al.* (2015), and Oladimeji and Olaosebikan (2017) that meristic characters do not show significant differences among populations when compared to morphometric characters; and thus may not be conclusively used to differentiate populations. The significant differences in the meristic characters observed in this study could be due to the differences in the prevailing ecological or evolutionary condition in the waterbody that brings about the observed changes in the studied fish populations.

Significant differences observed in the snout length and eye depth between the two fish populations could be attributed to ecological differences, primarily in fish feeding. Types of diet and availability of fish food in different habitats have been documented as a factor that influences or increases variation in the morphological characteristics of fish, such as mouth position and head size (Sapounidisa *et al.*, 2015; Radojkovic *et al*., 2018).

Also, fishes inhabiting environment with highly predatory organisms usually exhibit increased morphological changes; especially the body depth and caudal peduncle which helps to increase the chances of rapid movement or burst swimming to avoid predation (Gianetto *et al*., 2013; Santos and Araujo, 2015). Fishes from flowing waterbodies have been observed to have lower body depth and a sharper snout with a more spindle shape than fishes from the reservoir (Franssen 2011; Franssen *et al*., 2013). This body shape enables them to resist drag because a fusiform shape reduces resistance in aquatic environments, allowing effective population and maintenance of velocity at lower energy costs (Foster *et al*., 2015). Therefore, the decreased body depth observed in the reservoir population in this study is presumed to be adaptive to enhance high swimming speed and mobility relative to a more streamlined body which is more advantageous in a lotic environment. This is consistent with the report of Haas *et al*. (2010), who found significant morphological differences between the body depth and some fins of *Cyprinella venusta* inhabiting reservoirs and those inhabiting streams in the southeastern United States. Similarly, the findings of this study also conform to the findings of Cureton and Broughton (2014), who reported gross morphological changes, after the construction of a dam; in a North American stream fish, *P. vigilax* populations in each of seven different rivers. The authors observed significant changes in body depth, head shape, and fin placement in the fishes; compared to the populations that occupied the rivers before dam construction. The significant differences recorded on the fins (pelvic-fin length, pre-anal length, pelvic-fin rays and pectoral-fin rays) of *B. macrolepidotus*, in this study could be associated with adaptive changes related to locomotion.

Conclusions

The result from this study suggests that the observed differences between the fish populations from the river site and reservoir site of the Osun River could be partly attributed to river damming, which acts as a stressor and with time, may permanently alter the system, moving them into a new ecological zone.

Funding Information

No external funding was received for this study

Authors Contribution

Tofunmi Elizabeth Oladimeji conceived the study, supervised laboratory work, and wrote the original draft of the manuscript. *Henry Adefisayo Adewole* critically reviewed and edited the manuscript. *Sodiq Damilola Olagunju* obtained the samples and conducted laboratory analyses *Ayokunle Olamide Ogunribido* provided laboratory guidance and also reviewed the manuscript.

Ethics

Standard ethical considerations were followed for the fish used for this study.

Conflict of Interest

The authors declare there are no conflicts of interest.

References

Agbebi, O.T., Olufeagba, S.O., Mbagwu, I.G., Ozoje, M.O., Aremu, A. 2009. Morphological characteristics and body indices of Heterobranchus bidorsalis from three geographical locations in Nigeria. Journal of Fisheries International, 4 (4), 68–72.

Anifowose AJ. and Oyebode AW. 2019. Studies on heavy metals contents of Osun River at the pre-urban settlement and across Osogbo City, Nigeria. *Journal of Taibah University for Science*, 13 (1): 318-323. *https://doi.org/10.1080/16583655.2019.1567899*

Anvarifar H. Khyabani A. Farahmand H. Vatandoust S. AnvariFar H. Jahageerdar, S. 2011. Detection of morphometric differentiation between isolated up- and downstream populations of Siah Mahi (Capoeta capoeta gracilis) (Pisces: Cyprinidae) in the Tajan River (Iran). *Hydrobiologia* 673:41–52. *https://doi:10.1007/s10750-011-0748-7*

Allendorf FW. Ryman N. and Utter FM. 1987. Genetics and fishery management: In population genetics and fishery management, University of Washington. pp. 1-9.

Araújo FG. Santos AB. Albieri RJ. 2013. Assessing fish assemblages similarity above and below a dam in a Neotropical reservoir with partial blockage. *Brazilian Journal of Biology* 73:727-736. *https://doi.org/10.1590/S1519-69842013000400007*

Cabral HN. Marques JF. Rego AL. Catarino AI. Figueiredo J. Garcia J. 2003. Genetic and morphological variation of *Synaptura lusitanica* Capello, 1868, along the Portuguese coast. *Journal of Sea Research*. 50, 167–175. https://doi.org/10.1016/S1385-1101(03)00060-1

CuretonII JC. and Broughton RE 2014. Rapid morphological divergence of a stream fish in response to changes in water flow. *Biology Letters* 10: 20140352. https://doi.org/10.1098/rsbl.2014.0352

Downing JA. Prairie YT. Cole JJ. Duarte CM. Tranvik LJ. Striegl RG. McDowell WH. Kortelainen P. Caraco NF. Melack JM. Middelburg JJ 2006. The global abundance and size distribution of lakes, ponds, and impoundments. *Limnology and Oceanography* 51: 2388–2397. *https://doi.org/10.4319/lo.2006.51.5.2388*

Dynesius M. and Nilsson C. 1994. Fragmentation and flow regulation of river systems in the northern third of the world. Science 226:753–761. *https://doi.org/:10. 1126/science.266.5186.753*

Foster K. Bower L. Piller K. 2015. Getting in shape: habitat-based morphological divergence for two sympatric fishes. *Biological Journal of the Linnaean Society* 114:152–162. *https://doi.org/10.1111/bij.12413*

Franchi E. Carosi A. Ghetti L. Giannetto D. Pedicillo G. Pompei L. Lorenzoni M 2014. Changes in the Fish Community of the Upper Tiber River after Construction of a Hydro-Dam. *Journal of Limnology* 73(2): 2008-2014.

Franssen NR. 2011. Anthropogenic habitat alteration induces rapid morphological divergence in a native stream fish. *Evolutionary Application*. 4:791-804. *https://dx.doi.org/10.1098/rspb*

Franssen NR. Harris J. Clark SR. Schaefer JF. Stewart LK. 2013. Shared and unique morphological responses of stream fishes to anthropogenic habitat alteration. *Proceedings of Royal Society Biological Sciences* 280: 20122715.

Froese R. 2006. Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. *Journal of Applied Ichthyology* 22:241-253. *https://doi.org/10.1111/j.1439-0426.2006.00805.x*

Gaston KA. And Lauer TE. 2015. Morphometric variation in bluegill *Lepomis macrochirus* and green sunfish *Lepomis cyanellus* in lentic and lotic systems. *Journal of Fish Biology* 86:317-332. *https://doi.org/10.1111/jfb.12581*

Giannetto D. Carosi A. Ghetti L. Pedicillo G. Pompei L. Lorenzoni M. 2013. Ecological traits of *Squalus lucumonis* (Actinopterygii, Cyprinidae) and main differences with those of *Squalius squalus* in the Tiber River Basin (Italy). *Knowledge and Management of Aquatic Ecosystem* 469(04). *https://doi.org/10.1051/kmae/2013049*

Haas TC. Michael J. Blum MJ. Heins DC. 2010. Morphological responses of a stream fish to water impoundment. *Biology Letters* 6:803–806. *https://doi:10.1098/rsbl.2010.0401*

Hair JF. Black WC. Babin BJ. Anderson, RE. Tatham RL. 1998. Multivariate Data Analysis. 5(3): 207-219, Prentice Hall, Upper Saddle River.

Hendry AP. Taylor EB. McPhail JD. 2002. Adaptive divergence and the balance between selection and gene flow: lake and stream stickleback in the misty system. Evolution 56:1199–1216. *https://doi:10.1111/j.0014-3820. 2002.tb01432.x*

Hossain MAR. Nahiduzzaman M. Saha D. Khanam MUH. Alam MS. 2010. Landmark-Based morphometric and meristic variations of the endangered carp, *Kalibaus Labeo calbasu*, from stocks of two isolated Rivers, the Jamuna and Halda and a hatchery. *Zoological Studies 49*(4):556-563.

Ingram T. 2015. Diversification of body shape in Sebastes rockfishes of the North-east Pacific. *Biological Journal of the Linnaean Society* 116:805–818. *https://doi.org/10.1111/bij.12635*

Jalili P. Eagderi S. Keivany Y. 2015. Body shape comparison of Kura bleak (*Alburnus filippii*) in Aras and Ahar-Chai rivers using geometric morphometric approach. *Research in Zoology* 5(1):20-24.

Khayyami H. Zolgharnein H. Salamat, N. Movahedinia A. 2015. Morphological variability of Liza klunzingeri (Day, 1888) from Bandar Abbas Port and Qeshm Island in North-eastern Persian Gulf. *Journal of Fisheries and Aquatic Science* 10:191-198.

Langerhans RB. Layman CA. Langerhans AK. DeWitt T. Jn 2003. Habitat-associated morphological divergence in two Neotropical fish species. *Biological Journal of the Linnaean Society* 80:689–698. *https://doi:10.1111/j.1095-8312. 2003.00266.x*

Langerhans RB. and Reznick DN. 2010. Ecology and evolution of swimming performance in fishes: predicting evolution with biomechanics. In Fish locomotion: An Eco-ethological perspective (eds P. Domenici & B. G. Kapoor), pp. 200–248. Enfield, NH: Science Publishers CRC Press. *https://doi.org/10.1201/b10190*

McGuigan K. Franklin CE. Moritz C. Blows MW. 2003. Adaptation of rainbow fish to lake and stream habitats. *Evolution* 57:104–118. *https://doi:10.1554/0014- 3820(2003)057*

Mohaddasi M. Shabanipour N. Eagderi S. Yazdi A. 2013. Habitat-associated morphological divergence in four Shemaya, *Alburnus chalcoides* (Actinopterygii: Cyprinidae) populations in the southern Caspian Sea using geometrics analysis. *International Journal of Aquatic Biology* 1(2), 82-92.

Mian J. Hussain SM. Siddiqui PJA. Immink A. 2014. Haematological, biochemical and immunological changes on *Cephalus L.* shrimp head protein hydrolysate and macro-algae based diets. *World Journal of Fish and Marine Science* 6:295- 304.

Murta AG. 2000. Morphological variation of horse mackerel (*Trachurus trachurus*) in the Iberian and North African Atlantic: implications for stock identification. *ICES Journal of Marine Sciences* 57(4):1240-1248. *https://doi.org/10.1006/jmsc.2000.081*

Myers N. Knoll AH. 2001. The biotic crisis and the future of evolution. Proceedings of the National Academy of Sciences USA 98:5389–5392. *https://doi.org/10.1073/pnas.091092498*

Nilsson C. Reidy CA. Dynesius M. Revenga C. 2005. Fragmentation and flow regulation of the World's large river systems. Science 308:405–408. *https://doi:10. 1126/science.1107887*

Oladimeji TE. Awodiran MO. Komolafe, OO. 2015. Genetic Differentiation Studies among Natural Populations of *Tilapia zillii*. *Notulae Scientia Biologica* 7(4):423-429. *https://doi.org/10.15835/nsb749649*

Oladimeji TE. Olaosebikan TO. 2017. Morphological variability of *Tilapia zillii (*Gervais, 1848) from selected reservoirs in South-western, Nigeria. *Ife Journal of Science* 19(1):15-25. *https://dx.doi.org/10.4314/ijs.v19i1.3*

Oladimeji TE. Awodiran MO. Ola-oladimeji FA. 2020. Morphological characterization of natural populations of *Sarotherodon galilaeus* (Linnaeus, 1758) from three selected reservoirs in South Western, Nigeria. *Ife journal of science* 22(3):85-96. *https://dx.doi.org/10.4314/ijs.v22i3.7*

Ola-Oladimeji FA. Oso JA. Oladimeji TE. Idowu EO. Adeleke K. Urihe FO. 2017. Phenotypic diversities of four populations of *Clarias gariepinus* (Siluriformes, Clariidae) obtained from Ogun and Ondo State waterbodies in South-Western Nigeria. *Vestnik Zoologii* 51(4):285–294. *https://doi.org /10.1515/vzoo-2017-0034*

Olurin KB. and Aderibigbe OA. 2006. Length-weight relationship and condition factor of pond reared juvenile *Oreochromis niloticus*. *World Journal of Zoology* 1:82-85.

Paugy D. Leveque C. Teugels GG. 2003. The fresh and brackish water fishes of West Africa Volume I and II. IRD Editions. *Publications scientifiques.* Du museum. 457 and 815pp.

Pinheiro A. Teixeira CM. Rego AL. Marques JF. Cabral HN. 2005. Genetic and morphological variation of *Soleal ascaris* (Risso, 1810) along the Portuguese coast. *Fisheries Research* 73(1-2): 67-78.

Pompei L. Giannetto D. Lorenzoni, M. 2016. Reproductive parameters in native and non-native areas of *Padogobius bonelli* and comparison with *P. nigricans* (Actynopterigii, Gobiidae). *Hydrobiologia* 779:173-182. *https://doi.org 10.1007/s10750-016-2812-9*

Reist JD. 1985. An empirical evaluation of several univariate methods that adjust for size variation in morphometric data. *Canadian Journal of Zoology* 63:1429-1439.

Santos AB. Araújo, F. G. 2015. Evidence of morphological differences between *Astyanax bimaculatus* (Actinopterygii: Characidae) from reaches above and below dams on a tropical river. *Environmental Biology of Fishes* 98:183-191. *https://doi.org/10.1007/s10641-014-0248-5*

Sapounidisa SA. Koutrakis ET. Leonardos ID. 2015. Life history traits, growth and feeding ecology of a native species (*Barbus strumicae,* Karaman, 1955) in Nestos River, a flow regulated river in northern Greece. *North–Western Journal of Zoology* 11:331-341.

Silva JC. Gubiani EA. Parana PA. Delariva RL. 2016. Effects of a small natural barrier on the spatial distribution of the fish assemblage in the Verde River, Upper Parana River Basing, Brazil. *Brazilian Journal of Biology* 76:851-863. *https://doi:10.1590/1519-6984.01215.*

Swain DP. Foote CJ. 1999. Stocks and Chameleons: The use of phenotypic variation in stock identification. *Fisheries Research* 43:1123-1128. *https://doi.org/10.1016/S0165-7836(99)00069-7*