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Morphomeristic Characterization of *Enteromius* Species in Small Water-bodies of the North Rift, Kenya

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Abstract

Enteromius, a diverse genus of cyprinid fish native to tropical Africa, comprises around 350 species. These species inhabit various aquatic habitats, notably in Kenya's North Rift region. Rivers and reservoirs in this area provide essential habitats but face threats from agricultural activities and habitat fragmentation. Morphometric and meristic traits help manage fisheries by offering insights into population dynamics and species identification, although misidentifications pose challenges. Conservation of *Enteromius* is crucial as these fish support local biodiversity and food security, yet they are increasingly threatened by environmental changes and human activities. The study, conducted in Kenya's North Rift sampled small water bodies, involved sampling 25 rivers and reservoirs impacted by agriculture. Fish were collected from February to July 2018 using electrofishing and seine nets. A total of 972 *Enteromius* specimens were identified, measured, and analyzed for morphometric and meristic traits. Measurements were taken with Vernier calipers, and 11 meristic counts were recorded. Unidentified samples were preserved for further identification at the National Museums of Kenya. The analysis was performed at UoE Labs following established methodologies. The results indicated that *E. paludinosus* from Kapsaina Reservoir had the highest standard length (SL) of 8.1±0.8 cm, while E. neumayeri from Ellegrin Reservoir reached 9.4±1.3 cm. Notable differences in operculum length, prepectoral length, prepelvic length, preanal length, and body depth were recorded across different reservoirs and rivers. For instance, Karara Reservoir populations showed the highest operculum length in *E. paludinosus* (28.2±4.9) and *E. neumayeri* (25.5±3.2). Meristic traits, such as lateral scales above and dorsal fin rays, also varied significantly, with Kapsaina Reservoir exhibiting the highest range for E. paludinosus. In conclusion, significant trait variations among *E. paludinosus*, *E. apleurogramma, E. neumayeri*, and *E. cercops* across habitats indicate complex genetic and environmental influences, emphasizing the need for further research to understand these adaptations and their evolutionary implications.

Keywords: *Enteromius*, small water-bodies, morphomeristic analysis, principal component analysis

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Introduction

Enteromius is a genus of small to medium-sized cyprinid fish native to tropical Africa, part of the Cyprinidae family. Cyprinids inhabit diverse aquatic habitats globally and exhibit various adaptations (Kasumyan & Isaeva, 2023; Kunal et al., 2023; Moyle & Leidy, 2023). The family likely originated in East Asia during the Late Cretaceous, later dispersing worldwide (Bănărescu & Coad,1991). Approximately 1685 cyprinid species exist, with over 475 in African freshwater systems (Kunal et al., 2023). Enteromius, with around 350 species, is the most diverse and widely distributed African cyprinid genus (Martin & Chakona, 2019). The genus Enteromius differs from other small African diploid smiliogastrin genera in dorsal-fin placement, number of dorsal-fin rays, paired nostrils, eye size, and pigmentation patterns (Mipounga et al., 2019; Martin & Chakona, 2019). It is considered monophyletic, sharing a common ancestor (Young et al., 2015). In terms of conservation status of Enteromius species, the species are classified as of Least Concern in the IUCN categories (IUCN, 2018). However, many species under the genera remains undescribed, poorly describe or misidentified since these habitats may be isolated or understudied, making them potential hotspots for discovering new species (Mbewe et al., 2016). The process of misidentification is further exacerbated due to fragmentation and isolation in small water bodies such as headwater streams, rivers and reservoirs. North Rift is one such region with several rivers and man- made reservoirs that flow from the high land's region of Kenya, providing water resource for agricultural activities and supporting the local economy (Harrison et al., 2020).

Rivers and reservoirs offer diverse habitats such as riffles and pools, which are ideal for fish colonization (Cantonati et al., 2020). Flow variations, seasonal changes, and floods are essential for fish migration and spawning, however, activities like channelization and excessive sedimentation disrupt these habitats, leading to a decline in fish populations due to altered turbidity, dissolved oxygen, and nutrient balance (Siddha & Sahu, 2023; Okoyen et al., 2020). In Kenya, Enteromius species, such as E. neumayeri, E. paludinosus, E. cercops, and E. apleurogramma, are prevalent in headwater streams, rivers, and lakes, providing significant economic and ecological benefits (Masese et al., 2017; 2020). These species contribute to biodiversity and are crucial for food security in rural areas (Kajee et al., 2023; Okechi, 2022; Larsen et al., 2022).

Morphometric and meristic traits are vital for managing African inland fisheries, providing insights into population structure, health, and dynamics (Jawad et al., 2020; GonzalezMartinez et al., 2021). These traits help distinguish fish stocks and assess the impact of fishing and environmental factors (Bryndum-Buchholz et al., 2021; Nneji et al., 2020; Labidi et al., 2021). Morphological similarities among Enteromius species create classification challenges and misidentifications, leading to inaccurate data on ecological roles and habitat preferences (Nagelkerke, 1997; Chakona et al., 2022; Hoban et al., 2020). This misidentification complicates our understanding of species distributions and adaptations, hindering conservation strategies (Hatch, 2021; Stapley et al., 2015). Habitat fragmentation and agricultural expansion in Kenya's North Rift further threaten Enteromius species by isolating populations and reducing genetic diversity (Mlewa & Osuka, 2007). Reservoirs disrupt river flow, exacerbating isolation. Seasonal fluctuations and overexploitation of fisheries resources add to the stress, decreasing population sizes and reproductive success (Balirwa et al., 2003; Sumaila & Tai, 2020; Correa et al., 2015). This has necesiitated to carry out the study to determine the morphomeristic intraspecies variations among population of Enteromius species in small water bodies in North Rift, Kenya.

Materials and Methods

Study area

The study was undertaken in Uasin Gishu County in North Rift region, Kenya. Dominated by agriculture and pastoralism, the area features.

Fish collection and measurement

Sampling in the North Rift targeted rivers and reservoirs, totaling 25 sites, selected based on their unique features. Guided by county fisheries officers, sampling aimed to represent water bodies impacted by agriculture. Fish sampling took place from February to July 2018 using an electrofisher and seine net, each site sampled for approximately 30 minutes. Fish were identified using Froese and Pauly's (2011) keys, with 972 Enteromius samples measured for various parameters. Unidentified samples were preserved in 70% ethanol for later identification at the National Museums of Kenya. Specimens were analyzed at UoE Labs for morphometric and meristic differences. A total of 972 specimens were examined, and various measurements were taken using a Vernier caliper (Helios, 0.05 mm). In addition to the measurements, 11 meristic counts were made, following the methodology described in Bamba et al. (2011).

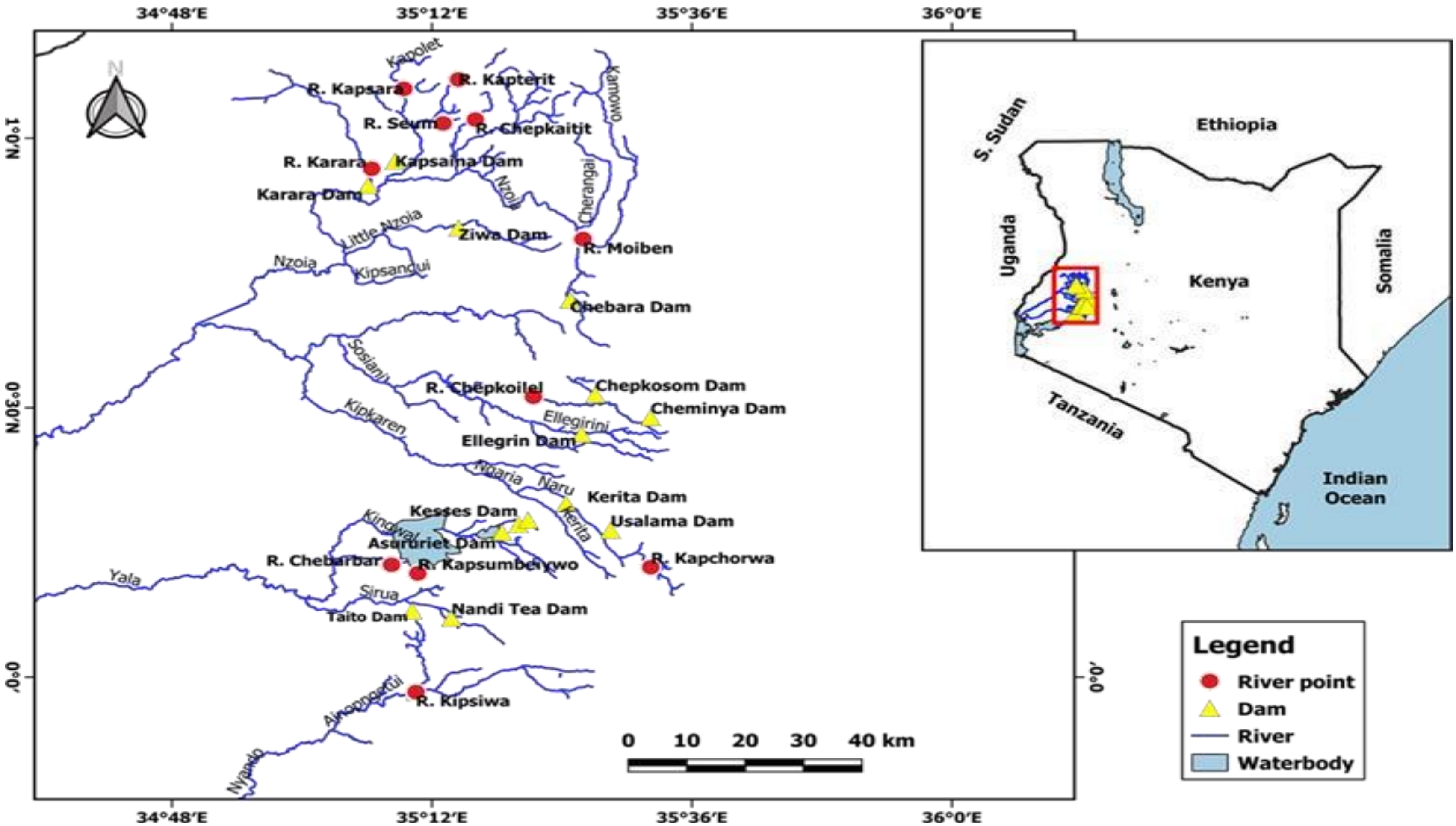

Figure 1: Study area map showing sampling points of rivers and reservoirs in Uasin Gishu County

Table 1: Morphometric characters of *Enteromius sp*. used in the current study

Morphometric	Acronym	Description
Total weight	TW	Measurement of total wet mass
Total length	TL	Maximum elongation from end to end
		The measurement taken from the tip of the snout to the base of the caudal fin.
Standard length	SL	
Operculum length	OPL	Measurement from the lower part to the upper part of the operculum.
Prepectoral length	PPECL	Measurement extending from the rostral tip of the upper jaw to the foremost point of the pectoral fin base
Preanal length	PPELL	Distance from the fish's snout to the end of the pelvic fin
		Measurement spanning from the rostral tip of the upper jaw to the foremost point of the anal fin base
Predorsal length	PAL	
Pectoral fin length	PDL	Measurement from the snout's tip to the base of the caudal fin
Pelvic fin length	PECFL	Measurement from the tip of the snout to the base of the caudal fin
PrePelvic Length	PELFL	The length of the ray originating at the base of the pelvic fin
Anal fin length	AFL	Measurement between the foremost and rearmost points of the anal fin
Dorsal fin length	DFL	Measurement between the foremost and rearmost points of the dorsal fin
Head length	HL	Distance between the snout and the posterior edge of the opercular bone
		The length of the eye, extending from its foremost to rearmost points within the orbit.
Eye diameter	ED	
Mouth width	MW	The distance between the dorsal and ventral surfaces of the head, running perpendicularly through the rear angle of the mouth.
		Vertical depth of the body between points near the front origins of the dorsal fin and pelvic fin.
Body depth	BD	
Operculum width	OPW	The distance from the back part of the orbit to the end of the operculum
		The distance from the foremost part of the body to the front margin of the orbit.
preorbital length	POL	

Eleven meristic counts made on the samples include lateral scales, dorsal fin length, lateral line scales, caudal fin scales, caudal fin rays, circumpendicumlar scales, anal fin rays, scales below lateral lines, pelvic fin rays, pectoral fin rays, predosal scales and dorsal fin spines (Table 1).

Results

Morphometric measurements of specimens of *E. paludinosus* examined from six reservoirs and one river in North Rift region, Kenya

The highest Standard length (SL) of 8.1±0.8 in cm was recorded in Kapsaina reservoir with the lowest recorded in Karara River population ($F_{0.05\ (6,\ 53)} = 5.0$, $p<0.001$). Largest Operculum length was recorded Karara reservoir (28.2±4.9) while the lowest was recorded in Usalama reservoir populations ($F_{0.05\ (6,\ 53)} = 3.6$, $p=0.005$). For the Prepectoral length the highest was recorded in Karara reservoir (30.5±4.3) and the lowest in Kesses reservoir (20±0.0) population with as significant difference ($F_{0.05\ (6,\ 53)} = 4.0$, $p=0.002$). The assessed PrePelvic Length was highest in Karara reservoir (56.7±8.5) and Karara River (56.2±6.0) and lowest in Kesses reservoir population ($F_{0.05\ (6,\ 53)} = 4.1$, $p=0.002$). The largest Preanal length was recorded in Karara reservoir (78.2±6.2) and Chebara reservoir (78.4±8.9) and lowest in Kesses reservoir (60±0.0). The largest Predorsal length was recorded in Karara reservoir population (57.0±10.1) with the lowest recorded in Kesses reservoir population ($F_{0.05\ (6,\ 53)} = 2.6$, $p=0.028$). The Largest Pectoral fin length and Pelvic fin length were recorded in Kesses reservoir and Usalama reservoir (20.0±0.0) with the lowest in Kapsaina reservoir populations ($F_{0.05\ (6,\ 53)} = 1.5$, $p=0.190$). The longest anal fin length and dorsal fin length were recorded in Kapsaina reservoir and Karara reservoir each with 57.5±77.7 while the shortest were recorded in Kapsaina reservoir. The largest eye diameter (47.6±10.9) and Mouth width (48.6±10.9) % of HL were recorded in Karara River and with the smallest recorded in Kesses reservoir populations both having 22.2±0.0 with no significant difference ($F_{0.05\ (6,\ 53)} = 2.5$, $p>0.05$). The largest Body depth of SL was recorded in Kesses reservoir (27.5±0.0) followed in Kapsaina reservoir (26.0±1.5) with the smallest recorded in Karara reservoir (20.7±2.8) populations with a significant difference ($F_{0.05\ (6,\ 53)} = 3.0$, $p=0.014$). The largest Operculum width (OPW) and preorbital length (POL) as % of HL were recorded in Chebara reservoir (105.2±20.4), followed in Kapsaina reservoir (104.5±18.5),and lowest in Karara reservoir (77.8±0.0) populations with no significant difference ($F_{0.05\ (6,\ 53)} =1.6$, $p=0.169$) as illustrated in Table 2.

The assessed meristic characters included lateral scales above (LASC), Dorsal fin rays (DFR), lateral line scales (LLS), Caudal fin rays (CFR), circumprndicular scales (CIRSC), anal fin rays (AFR), Below lateral scales (LBSC), Pelvic fin rays (PVFR), pectoral fin rays (PFR), Predorsal scales and dorsal fin spines (DFS). Among the Meristic characters examined *E. paludinosus* for samples collected from six reservoirs and one river in North Rift region, Kenya, only lateral scales above (LASC) differed significantly among the populations (KW=13.26, $p=0.039$) with Kapsaina Reservoir having the highest range of 4-7 and a median of 4.5 while Kesses Reservoir had the lowest of 3-3 and a median of 3 as illustrated in Table 3.

Table 3: Meristic characters examined *E. paludinosus* for samples collected from six reservoirs and one river in North Rift region, Kenya

Water_body	Kesses Reservoir (1)	Kapsaina Reservoir (10)	Chebara Reservoir (4)	Ziwa Reservoir (35)	Karara River (4)	Karara Reservoir (4)	Usalama Reservoir (1)		
	Range (median)	Range (median)	Range (median)	Range (median)	Range (median)	Range (median)	Range (median)	*K-W*	Asymp. Sig.
lateral scales above (LASC)	3-3(3)	4-7(4.5)	3-5(4)	3-7(4)	3-4(4)	4-4(4)	4-4(4)	13.26	0.039
Dorsal fin rays (DFR)	8-8(8)	8-9(8.5)	7-9(8)	79(8)	7-8(8)	8-8(8)	8-8(8)	6.192	0.402
lateral line scales (LLS)	19-19(19)	26-32(29)	24-32(28)	24-32(28)	28-30(29)	28-30(30)	28-28(28)	5.148	0.525
Caudal fin rays (CFR)	16-16(16)	17-24(19.5)	18-24(18)	16-24(18)	18-20(19)	16-20(20)	16-16(16)	9.722	0.137
circumprndicular scales (CIRSC)	2-2(2)	3-3(3)	2-33)	2-3(3)	3-3(3)	3-3(3)	3-3(3)	9.836	0.132
anal fin rays (AFR)	6-6(6)	6-8(7)	6-8(6)	6-8(7)	6-8(6)	6-7(6)	7-7(7)	4.78	0.572
Below lateral scales (LBSC)	3-3(3)	4-6(4.5)	4-5(5)	4-6(4)	5-5(5)	4-5(5)	4-4(4)	8.603	0.197
Pelvic fin rays (PVFR)	8-8(8)	7-8(8)	7-8(8)	7-8(8)	7-8(7.5)	7-8(7)	8-8(8)	7.91	0.245
pectoral fin rays (PFR)	12-12(12)	10-16(12)	12-15(12)	10-6(12)	12-15(14.5)	11-15(15)	11-11(11)	5.789	0.447
Predorsal scales	10-10(10)	10-11(10.5)	9-14(10)	9-14(10)	10-14(10.5)	10-10(10)	10-10(10)	6.209	0.400
dorsal fin spines (DFS)	1-1(1)	1-4(3)	2-3(2)	1-3(2)	1-3(2.5)	1-3(2)	33(3)	6.536	0.366

Morphometric measurements of specimens of *E. apleurogramma* examined from two reservoirs and one river in North Rift region, Kenya

The study assessed morphological and meristic traits of E. apleurogramma from various reservoirs and a river in North Rift region, Kenya, revealing significant differences among populations. The highest Standard Length (SL) was found in Kapsaina and Chebara reservoirs (4.6±0.2 cm), while the lowest was in Kesses River (3.2±0.3 cm) ($F_{0.05\ (6,\ 53)}$ = 66.4, p<0.001). The highest Operculum Length (OL) was in Kesses River (29.8±3.4%), with the lowest in Chebara reservoir (20.8±1.3%) ($F_{0.05\ (6,\ 53)}$ = 26.3, p<0.001). Kesses River had the highest Prepectoral Length (PPECL) (29.8±3.4%) and Preanal Length (PAL) (63.5±6.0%), while Kesses reservoir recorded the highest Body Depth (BD) (30.4±3.7%) ($F_{0.05\ (6,\ 53)}$ = 162.2, p<0.001). The largest Predorsal Length (PDL) was in Kesses River (54.1±8.8%), and the highest Prepelvic Length (PPELL) was in Kapsaina reservoir (54.1±8.8%) ($F_{0.05\ (6,\ 53)}$ = 9.6, p<0.001). Kesses River had the longest Anal Fin Length (AFL) and Dorsal Fin Length (DFL) (24.7±3.1%) ($F_{0.05\ (6,\ 53)}$ = 13.2, p=0.046). Meristic traits showed significant differences, with the highest Lateral Scales Above (LASC) in Kesses reservoir (range 3-5, median 4) (KW=22.015, p<0.001), and the highest Dorsal Fin Rays (DFR) in Kesses reservoir (range 6-11, median 9) (K-W=47.081, p<0.001). Kesses River recorded the highest number of Lateral Line Scales (LLS) (range 24-30, median 26) and Caudal Fin Rays (CFR) (range 14-26, median 20) (K-W=54.469, p<0.001). Predorsal scales did not vary significantly among the populations (p>0.05).

Table 4: Morphometric measurements of specimens of *E. apleurogramma* examined from three reservoirs and one river in North Rift region, Kenya. The ample size is in parenthese

	Kesses reservoir	Kesses River	Kapsaina reservoir	Chebara reservoir		
Morphometric measurements	Mean (n=27)	Mean (n=35)	Mean (n=3)	Mean (n=8)	F	Sig.
SL in cm	3.6±0.3	3.2±0.3	4.6±0.2	4.6±0.2	66.4	<0.001
OL % SL	28.4±2.6	29.8±3.4	21.0±1.6	20.8±1.3	26.3	<0.001
PPECL % SL	29.0±5.3	25.5±4.2	19.5±1.3	19.7±1.1	12.2	<0.001
PPELL % SL	51.1±5.7	51.0±4.0	39.1±0.5	39.2±0.4	22.2	<0.001
PAL % SL	68.2±5.0	63.5±6.0	42.8±1.0	42.8±0.9	63.8	<0.001
PDL % SL	52.2±11.1	54.1±8.8	36.9±3.8	37.3±3.4	9.6	<0.001
PECFL % SL	21.0±3.8	21.7±3.9	15.3±2.5	15.2±2.3	8.8	<0.001
pelvic fin length	21.0±3.8	21.7±3.9	15.3±2.5	15.2±2.3	8.8	<0.001
AFL % SL	21.6±3.4	24.7±3.1	17.2±5.0	16.7±4.4	13.2	<0.001
DFL % SL	21.7±3.4	24.7±3.0	16.2±5.0	16.7±4.4	13.2	<0.001
HL % SL	1.0±0.1	0.9±0.1	0.9±0.1	0.9±0.1	15.8	<0.001
ED % HL	28.7±3.2	35.8±14.2	34.7±2.4	34.9±2.2	2.5	0.063
MW % HL	28.7±3.2	33.5±5.3	26.8±5.8	27.4±5.0	7.9	<0.001
BD % SL	30.4±3.7	27.4±2.5	7.9±1.0	8.1±0.8	162.2	<0.001
OPW	66.2±12.0	58.3±7.4	65.8±9.7	67.1±8.0	3.2	0.025
POL % HL	65.2±12.0	58.3±7.4	65.8±9.7	67.1±8.0	3.3	0.025

Table 5: Meristic characters examined from *E. apleurogramma* samples collected from three reservoirs and one river in North Rift region, Kenya

	Kesses Reservoir (27)	Kesses River (35)	Kapsaina Reservoir (3)	Chebara Reservoir (8)		
Meristic	Range	Range	Range	Range	*K-W*	Asymp.
characters LASC	(3median-5(4))	(3median-4(3))	(3median-3(3))	(3median-3(3))	22.01	Sig.<0.001
DFR	6-11(9)	6-8(7)	5-6(6)	5-6(6)	47.08	<0.001
LLS	19-26(22)	24-30(26)	20-22(20)	20-22(20)	54.46	<0.001
CFR	14-26(20)	14-20(16)	12-16(12)	12-16(12)	30.47	<0.001
CIRSC	2-3(2)	3-3(3)	2-2(2)	2-2(2)	64.69	<0.001
AFR	5-10(6)	6-8(6)	5-6(5)	5-6(5)	20.80	<0.001
LBSC	3-6(4)	3-5(4)	4-4(4)	4-4(4)	16.03	0.001
PVFR	6-10(8)	6-8(7)	5-6(6)	5-6(6)	42.82	<0.001
PFR	6-14(10)	10-12(11)	8-10(8)	8-10(8)	15.15	0.002
Predorsal scales	9-11(10)	9-11(10)	10-10(10)	10-10(10)	4.976	0.174
DFS	1-3(2)	1-4(1)	1-2(2)	1-2(2)	16.44	0.001

Morphometric measurements of specimens of *E. neumayeri* examined from eight reservoirs and eleven rivers in North Rift region, Kenya

The highest Standard length (SL) of 9.4±1.3, 8.4±0.8 and 8.0±1.2 in cm of *E. neumayeri* were recorded in Ellegrin reservoir, Usalama Reservoir and Suem river populations respectively with the lowest recorded in Cheplelach River population (4.8±0.9) with a significant difference in the populations ($F_{0.05\ (18,\ 602)}$ = 13.2, p<0.001). Operculum length (OL) as the % SL was recorded Karara Reservoir (25.5±3.2), Karara River (24.2±2.6) and Kapsumbeiywo River population (25.4±2.7) while the lowest was recorded in Ellegrin reservoir (16.6±1.6) and Kerita reservoir populations (16.0±1.7) with a significant difference ($F_{0.05\ (18,\ 602)}$ = 32.6, p<0.001). For the Prepectoral length (PPECL) % SL, the highest was recorded in Ellegrin reservoir population (39.6±3.5) and the lowest in Taito reservoir population (24.8±2.6) with as significant difference ($F_{0.05\ (18,\ 602)}$ = 28.5, p<0.001). The assessed PrePelvic Length (PPELL) as % of SL was highest in Karara reservoir populations (51.3±5.5) followed in Taito reservoir population (50.2±6.6) with the lowest recorded in Kapsumbeiywet River population (42.7±4.0) with a significant difference ($F_{0.05\ (18,\ 602)}$ = 4.5, p<0.001). The largest Preanal length (PAL) as % of SL was recorded in Usalama reservoir population (74.2±3.4), followed in Chebarbar River population (72.1±8.5), Kapchorwa River population (72.8±4.3), Karara River population population (72.5±7.3) and Kipsiwa River population (72.4±4.5) with the lowest recorded in Cheplelach River population (49.6±4.1) with a significant difference ($F_{0.05\ (18,\ 602)}$ = 37.7, p<0.001). The largest Predorsal length (PDL) % SL was recorded in Kapsumbeiywo River population (55.7±11.2) followed in Kipsiwa River population (54.1±4.0) with the lowest recorded in kapsumbeiywet River population (41.2±4.4) with a significant difference ($F_{0.05\ (18,\ 602)}$ = 8.8, p<0.001). the highest Pectoral fin length (PECFL) as % of SL was recorded in Moiben River (19.6±6.6) and Cheplelach River (19.1±2.3) with the lowest in Karara Reservoir populations

(15.7±4.4) and Chepkaitit River(15.7±1.1) with a significant difference ($F_{0.05\ (18,\ 602)}$ = 2.6, p<0.001). Largest Pelvic fin length was recorded in Moiben (19.6±6.6) and Cheplelach River (19.1±2.3) and lowest in Karara Reservoir (15.7±4.4) and Chepkaitit River populations (15.7±1.1). The longest anal fin length (AFL) % SL as well as dorsal fin length (DFL) % SL were recorded in Moiben River(19.9±6.0) and Cheplelach River (19.2±2.6) while the shortest were recorded in Karara Reservoir (15.7±4.4) and Chepkaitit River (15.7±1.1) populations with a significant difference ($F_{0.05\ (18,\ 602)}$ = 1.6, p-0.046). The largest head length (HL) as % of SL was recorded in Ellegrin reservoir (2.4±0.4) and the smallest in Chepkaitit River (1.0±0.3) populations with a significant difference ($F_{0.05}$ (18, 602) =15.0, p<0.001). The largest eye diameter (ED) and Mouth width (MW) % HL as % of HL was recorded in Kapchorwa River (53.2±5.8) and 52.9±8.9 respectively with the smallest recorded in Ellegrin reservoir (22.3±3.0) populations for both eye diameter and Mouth width significant difference ($F_{0.05\ (18,\ 602)}$ = 12.2, p<0.001). the largest Body depth (BD) as % of SL was recorded in Nandi Tea Reservoir(26.4±2.3) and Moiben River (26.2±5.7) with the smallest recorded in Cheplelach River (21.2±2.0) populations with a significant difference (F0.05 (18, 602) = 5.9, p<0.001). The largest Operculum width (OPW) and preorbital length (POL) as % of HL were recorded in Kapsumbeiywo River (101.4±22.1), Kapchorwa River(102.2±29.1) and Nandi Tea Reservoir (102.9±17.7) and lower in Ellegrin reservoir (54.7±7.2) populations with a significant difference ($F_{0.05\ (18,\ 602)}$ =15.0, p<0.001) as illustrated in Table 6.

There were nineteen site where meristic characters of *E. neumayeri* samples were collected and examined. These were; Kapsaina Reservoir, Chebara Reservoir, Cheplelach River, Ellegrin Reservoir, Kapsara River, Kerita Reservoir, Moiben River, Kapsum-beiywet River, Seum river, Karara River, Karara Reservoir, Chebarbar River, Chepkaitit River, Kapchorwa River, Kipsiwa River, Taito Reservoir, Kapsumbeiywo River, Nandi Tea Reservoir and Usalama Reservoir. Lateral scales above (LASC) was high Kapsaina Reservoir and Chebara Reservoir each with a range of 4-7 and a median of 5 while Kerita Reservoir and Chepkaitit

River had the lowest of 3-4 and a median of 4 in each with a significant difference (KW=213.9, p<0.001). Similarly, Dorsal fin rays (DFR) numbers were high in Kapsaina Reservoir and Chebara Reservoir with a range of 6-10 and a median of 8 while Moiben River had the lowest with a range of 5-10 with a median of 8 in each with a significant difference (K-W=60.5, p<0.001). For number of lateral line scales (LLS), Kapsara River recorded the highest range of 24-36 with a median of 30 while both Kapsaina Reservoir recorded the lowest of 19-31 with a median of 26 differing significantly (K-W=70.6, p<0.001). In number of Caudal fin rays (CFR), Chepkaitit River recorded the highest range of 10-24 with a median of 20 while both Moiben River recorded the lowest of 18-20 with a median of 20 differing significantly (K-W=65.9, p<0.001). In number of circumprndicular scales (CIRSC), Ellegrin Reservoir recorded the highest range of 2-24 with a median of 18 while majority recorded the lowest of 2-3 with a median of 2 differing significantly (K-W=33.1, p<0.001). In number of anal fin rays (AFR), Chebara Reservoir recorded the highest range of 6-10 with a median of 7 with a significant difference from other populations (K-W=75.9, p<0.001).

Table 6: Morphometric measurements of specimens of *E. neumayeri* examined from eight reservoirs and eleven rivers in North Rift region, Kenya

Karara River(26)	Karara Reservoir (4)	Chebarbar River (47)	Chepkaitit River (3)	Kapchorwa River (31)	Kipsiwa River (31)	Taito Reservoir (31)	Kapsumbeiywo River (31)	Nandi Tea Reservoir (21)	Usalama Reservoir (4)		
Mean±sd	Mean±sd	Mean±sd	Mean±sd	Mean±sd	Mean±sd	Mean±sd	Mean±sd	Mean±sd	Mean±sd	F	Sig.
6.9±1.3	6.2±1.0	7.2±1.3	6.8±1.2	7.2±1.2	7.1±1.6	6.9±1.2	7.4±1.7	7.5±0.9	8.4±0.8	13.2	<0.001
24.2±2.6	25.5±3.2	22.7±3.4	22.3±2.0	23.5±2.3	22.7±1.6	21.7±2.6	25.4±2.7	22.5±1.7	21.7±6.6	32.6	<0.001
28.5±6.1	27.3±2.5	25.8±3.2	25.3±1.9	26.2±2.2	25.5±1.8	24.8±2.6	28.0±3.4	25.6±1.7	27.1±1.2	28.5	<0.001
49.4±*8.5*	51.3±5.5	48.1±8.3	47.9±2.0	49.3±3.8	47.8±8.0	50.2±6.6	48.9±7.8	48.7±2.7	48.0±7.1	4.5	<0.001
72.5±7.3	69.0±6.5	72.1±8.5	67.9±1.8	72.8±4.3	72.4±4.5	71.6±5.6	71.1±10.4	71.3±4.6	74.2±3.4	37.7	<0.001
51.5±8.4	53.0±4.6	53.2±8.2	52.0±2.8	52.3±4.8	54.1±4.0	50.0±3.3	55.7±11.2	51.9±3.7	52.6±3.3	8.8	<0.001
17.4±2.1	15.7±4.4	18.9±10.6	15.7±1.1	17.7±2.6	16.5±2.6	17.7±1.9	17.1±4.7	16.2±2.0	18.3±2.0	2.6	<0.001
17.4±2.1	15.7±4.4	18.9±10.5	15.7±1.1	17.7±2.5	16.5±2.6	17.7±1.9	17.1±4.8	16.2±2.0	18.3±2.0	2.6	<0.001
16.3±2.4	16.0±1.8	19.3±23.4	12.7±0.6	16.4±2.3	15.8±2.3	17.1±2.3	14.5±4.4	14.6±1.5	17.6±1.7	1.6	0.046
16.3±2.4	16.0±1.8	19.3±23.4	12.7±0.6	16.4±2.3	15.8±2.3	17.1±2.3	14.5±4.4	14.6±1.5	17.6±1.7	1.6	0.046
1.0±0.2	1.3±2.0	1.1±0.3	1.0±0.3	1.1±0.2	1.1±0.3	1.1±0.2	1.2±0.3	1.2±0.2	1.3±0.1	15.0	<0.001
40.8±5.6	40.9±8.4	40.8±11.1	42.8±6.3	53.2±5.8	40.3±7.0	46.3±9.4	40.2±6.7	40.4±6.7	34.8±4.8	12.2	<0.001
41.3±5.8	40.9±8.4	40.8±11.1	42.8±6.3	52.9±8.9	41.0±7.1	46.3±9.4	40.4±6.5	40.8±6.3	34.8±4.8	12.3	<0.001
23.0±2.5	24.3±3.0	23.9±3.3	23.6±1.2	23.9±3.1	25.1±2.2	23.9±2.0	25.4±2.4	26.4±2.3	22.6±0.9	5.9	<0.001
98.4±16.9	99.4±26.1	94.5±28.4	98.3±12.4	102.2±29.1	97.9±15.0	99.0±18.7	101.4±22.1	102.9±17.7	81.3±8.1	34.4	<0.001
98.4±16.9	99.4±26.1	94.5±28.4	98.3±12.4	102.2±29.1	97.9±15.0	99.0±18.7	101.4±22.1	102.9±17.7	81.3±8.1	34.4	<0.001

Water body	Kapsaina reservoir (37)	Chebara reservoir (30)	Cheplelach River (4)	Ellegrin reservoir (35)	Kapsara River(77)	Kerita reservoir (35)	Moiben River (4)	kapsumbeiywet River (15)	Suem river (42)
Morphometric measurements	Mean±sd	Mean±sd	Mean±sd	Mean±sd	Mean±sd	Mean±sd	Mean±sd	Mean±sd	Mean±sd
Standard length (SL) in cm	6.8±1.2	7.1±1.2	4.8±0.9	9.4±1.3	7.3±1.2	7.6±1.3	7.3±2.2	7.7±1.2	8.0±1.2
Operculum length (OL) % SL	18.0±2.2	17.4±1.9	22.8±3.1	16.6±1.6	19.2±3.0	16.0±1.7	18.9±5.2	17.0±2.5	23.1±2.0
Prepectoral length (PPECL) % SL	31.8±5.8	33.4±5.4	26.1±5.2	39.6±3.5	28.1±4.2	34.1±5.2	35.9±8.6	31.9±4.8	25.5±2.9

PrePelvic Length (PPELL) % SL	43.9±4.9	44.9±4.9	43.3±4.0	48.3±3.1	46.0±4.6	44.9±5.2	48.6±10.3	42.7±4.0	49.7±3.6
Preanal length (PAL) % SL	52.7±3.7	53.5±3.2	49.6±4.1	55.3±4.1	64.7±10.3	51.4±2.9	59.3±14.2	53.0±3.5	70.8±8.4
Predorsal length (PDL) % SL	43.3±6.1	45.2±5.1	45.2±5.4	48.2±3.1	49.2±6.4	45.6±6.1	49.1±11.1	41.2±4.4	51.7±6.4
Pectoral fin length (PECFL) % SL	17.5±2.9	17.8±3.0	19.1±2.3	16.0±1.8	16.1±2.6	16.5±2.6	19.6±6.6	17.2±2.9	17.1±2.6
pelvic fin length	17.5±2.9	17.8±3.0	19.1±2.3	16.0±1.8	16.1±2.6	16.5±2.6	19.6±6.6	17.2±2.9	17.1±2.6
anal fin length (AFL) % SL	17.4±3.0	18.0±3.0	19.2±2.6	16.9±1.6	16.3±3.5	18.1±2.4	19.9±6.0	17.5±3.1	16.9±2.1
dorsal fin length (DFL) % SL	17.4±3.0	18.0±3.0	19.2±2.6	16.9±1.6	16.3±3.5	18.1±2.4	19.9±6.0	17.5±3.1	16.9±2.1
head length (HL) % SL	1.6±0.3	1.7±0.3	1.1±0.2	2.4±0.4	1.4±0.2	1.7±0.3	1.7±0.4	1.7±0.3	1.3±0.2
eye diameter (ED) % HL	24.3±2.9	23.9±3.1	27.3±5.4	22.3±3.0	32.4±8.1	25.6±3.1	26.3±5.1	24.9±2.6	42.1±8.7
Mouth width (MW) % HL	24.4±2.9	23.8±3.1	27.2±5.4	22.3±3.0	32.4±8.1	25.6±3.1	26.3±5.1	24.9±2.6	40.9±5.4
Body depth (BD) % SL	24.6±3.1	25.0±3.3	21.2±2.0	23.5±1.8	24.2±2.8	23.2±2.4	26.2±5.7	24.5±3.5	22.3±1.7
Operculum width (OPW	70.6±11.0	69.6±11.6	58.0±8.7	54.7±7.2	75.0±16.6	58.1±9.6	59.5±13.4	74.1±13.0	86.1±10.7
preorbital length (POL) % HL	70.6±11.0	69.6±11.6	58.0±8.7	54.7±7.2	75.0±16.6	58.1±9.6	59.5±13.4	74.1±13.0	86.1±10.7

Table 7: Meristic characters examined from *E. neumayeri* samples collected from eight reservoirs and eleven rivers in North Rift region, Kenya

	Kapsaina Reservoir (37)	Chebara Reservoir (30)	Cheplelach River (35)	Ellegrin Reservoir (35)	Kapsara River (77)	Kerita Reservoir (35)	Moiben River (70)	Kapsum-beiywet River (15)	Seum river (42)	Karara River (26)
Water body	Range (median)	Range (median)	Range (median)	Range (median)	Range (median)	Range (median)	Range (median)	Range (median)	Range (median)	Range (median)
lateral scales above (LASC)	4-7(5)	4-7(5)	3-4(4)	3-5(4)	3-6(4)	3-4(4)	3-6(4)	4-7(8)	3-7(4)	3-6(4)
Dorsal fin rays (DFR)	6-10(8)	6-10(8)	6-8(7)	6-9(8)	6-9(8)	7-9(8)	5-10(8)	6-9(6)	7-9(8)	7-9(8)
lateral line scales (LLS)	19-31(26)	20-31(27.5)	26-30(28)	24-34(28)	24-36(30)	26-32(28)	24-32(29)	19-31(28)	24-32(28)	24-32(30)
Caudal fin rays (CFR)	10-28(22)	10-28(22)	15-2(18)	12-24(18)	16-24(20)	17-2(18)	10-24(20)	10-28(2)	16-4(19.5)	16-22(20)
circumprndicular scales (CIRSC)	2-3(3)	2-3(3)	2-3(3)	2-24(18)	2-3(3)	3-3(3)	2-4(3)	2-3(3)	2-3(3)	2-3(3)
anal fin rays (AFR)	6-10(7)	6-10(7)	5-6(6)	6-8(7)	5-10(6)	6-8(7)	4-10(6)	6-8(8)	6-8(6)	6-8(6)
Below lateral scales (LBSC)	3-6(5)	3-6(5)	4-5(4)	4-5(5)	4-6(5)	4-5(4)	4-6(5)	4-6(5)	4-6(5)	4-5(5)
Pelvic fin rays (PVFR)	8-12(10)	8-12(10)	5-7(7)	6-12(8)	7-12(8)	7-8(7)	6-10(8)	8-10(10)	7-8(8	7-8(7)
pectoral fin rays (PFR)	10-14(12)	10-14(12)	10-5(12)	10-16(12)	8-16(12)	11-6(12)	10-5(12)	10-14(12)	10-16(12	11-16(15)
Predorsal scales	9-12(10)	9-12(10)	9-1(10)	9-14(11)	9-15(10)	10-12(11)	9-11(10)	10-12(10)	9-14(10	9-14(10)
dorsal fin spines (DFS)	1-3(2)	1-3(2)	1-4(1)	1-3(2)	1-3(2)	1-4(1)	1-8(2)	1-3(2)	1-4(3	1-3(2)

Karara Reservoir (26)	Chebarbar River (3)	Chepkaitit River (3)	Kapchorwa River (31)	Kipsiwa River (25)	Taito Reservoir (31)	Kapsumbeiywo River (31)	Nandi Tea Reservoir (21)	Usalama Reservoir (4)		
Range (median)	Range (median)	Range (median)	Range (median)	Range (median)	Range (median)	Range (median)	Range (median)	Range (median)	K-W	Asymp. Sig.
3-7(4)	3-5(4)	3-4(4)	3-7(4)	3-5(4)	3-7(4)	3-7(4)	3-7(4)	4-5(4)	213.9	<0.001
7-9(8)	7-9(8)	7-8(8)	7-9(8)	7-9(8)	7-9(8)	6-9(8)	7-9(9)	8-8(8)	60.5	<0.001
24--32(30)	24-32(30)	28-30(30)	24-32(28)	26-32(30)	24-32(30)	24-32(30)	24-32(28)	28-32(30)	70.6	<0.001
18-24(20)	16-24(20)	18-20(20)	16-24(18)	16-24(20)	16-24(18)	16-24(20)	16-24(18)	16-20(17)	165.9	<0.001

2-3(3)	2-3(3)	3-3(3)	2-3(3)	2-3(3)	2-3(3)	2-4(3)	2-3(3)	3-3(3)	33.1	0.016
6-8(6)	6-8(6)	6-8(6)	6-8(6)	6-8(6)	6-8(6)	6-8(7)	6-8(7)	7-8(7)	75.9	<0.001
4-6(5)	4-5(5)	5-5(5)	4-6(5)	4-5(5)	4-6(5)	4-6(5)	4-6(4)	4-5(4.5)	97.6	<0.001
7-8(7)	7-8(7)	7-8(7)	7-8(8)	7-8(7)	7-8(8)	7-10(8)	7-8(8)	8-8(8)	218.3	<0.001
10-1515)	10-16(14)	14-15(15)	10-15(14)	10-15(12	10-16(14)	10-16(12)	10-16(12)	11-16(11.5)	73.3	<0.001
9-14(10)	9-14(10)	10-14(10)	9-14(10)	10-14(10)	9-14(10)	9-14(10	9-14(10)	10-11(10)	58.1	<0.001
1-3(3)	1-3(3)	1-3(3)	2-3(3)	1-4(2)	1-3(3)	1-4(2)	1-4(3)	1-3(2.5)	75.3	<0.001

In number of Below lateral scales (LBSC), Kapsara River, Moiben River, Kapsumbeiywet River, Seum river, Kapchorwa River, Taito Reservoir, Kapsumbeiywo River and Nandi Tea recorded the highest range of 4-6 with a significant difference from other populations (KW=97.6, p<0.001). In number of Pelvic fin rays (PVFR), Kapsaina Reservoir and Chebara Reservoir recorded the highest range of 8-12 with a median of 10 while both Cheplelach River recorded the lowest (5-7) with a significant difference (K-W=218.3, p<0.001). In number of pectoral fin rays (PFR), Chepkaitit River recorded the highest range of 14-15 with a median of 15 while Kapsara River recorded the lowest of 8-16with a median of 12 differing significantly (K-W=73.3, p=0.002). Number of Predorsal scales was high in Kapsumbeiywet River with a range of 10-12 and median of 10 differing significantly (K-W=58.1, p=0.001). Number of dorsal fin spines (DFS), was high in Moiben River with a range of 1-8 and median of 2 also differing significantly with the rest (K-W=75.3, p=0.001) as illustrated in Table 7.

Morphometric measurements of specimens of *E. cercops* examined from Chepkosom reservoir in North Rift region, Kenya

The morphometric measurements of *E. cercops* was determined from the Chepkosom reservoir (Table 8).

Table 8: Morphometric measurements of specimens of *E. cercops* examined from Chepkosom reservoir in North Rift region, Kenya

Morphometric measurements	N	Mean±sd
Standard length (SL) in cm	30	5.0±0.5
Operculum length (OL) % SL	30	23.7±2.8
Prepectoral length (PPECL) % SL	30	20.6±6.6
PrePelvic Length (PPELL) % SL	30	36.7±7.0
Preanal length (PAL) % SL	30	47.7±5.9
Predorsal length (PDL) % SL	30	37.8±7.9
Pectoral fin length (PECFL) % SL	30	16.7±2.6
pelvic fin length	30	16.7±2.6
anal fin length (AFL) % SL	30	18.3±2.6
dorsal fin lenghth (DFL) % SL	30	18.3±2.6
head lenghth (HL) % SL	30	1.0±0.1
eye diameter (ED) % HL	30	30.5±5.4
Mouth width (MW) % HL	30	30.5±5.4
Body depth (BD) % SL	30	22.9±3.6
Operculum width (OPW	30	75.8±17.4
preorbital length (POL) % HL	30	75.8±17.4

The standard length was 5.0±0.5 cm. Operculum length (OL) % of SL was 23.7±2.8, Prepectoral length (PPECL) as % of SL was 20.6±6.6. PrePelvic Length (PPELL) as % of SL was 36.7±7.0, Preanal length (PAL) as % of SL w, as 36.7±7.0, Predorsal length (PDL) as % of SL was 47.7±5.9. Pectoral fin length (PECFL) as % of SL was16.7±2.6, pelvic fin length % of SL was 16.7±2.6, anal fin length (AFL) as % of SL was18.3±2.6, dorsal fin length (DFL) % of SL was 18.3±2.6. Head length (HL) % of SL was 1.0±0.1, eye diameter (ED) % of HL was 30.5±5.4, Mouth width (MW) % of HL was

30.5±5.4, Body depth (BD) % SL of was 22.9±3.6, Operculum width (OPW) was 75.8±17.4, while preorbital length (POL) as % of HL was 75.8±17.4 (Table 8).

For meristic characters, lateral scales above (LASC) for *E. cercops* samples collected from Chepkosom reservoir in North Rift region, Kenya ranged from 3-5 with a median of 4 as illustrated in Table 4.10. Dorsal fin rays (DFR) ranged from 8-15 with a median of 10 while lateral line scales (LLS) ranged from 20-34 with a median of 25.

Table 9: Meristic characters examined from *E. cercops* samples collected from Chepkosom reservoir in North Rift region, Kenya

Meristic characters	N	Range	Median number
lateral scales above (LASC)	30	3-5	4
Dorsal fin rays (DFR)	30	8-15	10
lateral line scales (LLS)	30	20-34	25
Caudal fin rays (CFR)	30	20-34	24
circumperperndicular scales (CIRSC)	30	2-3	3
anal fin rays (AFR)	30	4-12	8
Below lateral scales (LBSC)	30	3-6	4.5
Pelvic fin rays (PVFR)	30	7-17	10
pectoral fin rays (PFR)	30	8-18	12
Predorsal scales	30	6-12	10
dorsal fin spines (DFS)	30	1-10	3

D Caudal fin rays (CFR) ranged from 20-34 with a median of 24 while circumperperndicular scales (CIRSC) ranged from 2-3 with a median of 3. Anal fin rays (AFR) ranged from 4-12 with amedian of 8 while Below lateral scales (LBSC) ranged from 3-6 with a median of 4.5. Pelvic fin rays (PVFR) ranged from 7-17 with a median of 10 while pectoral fin rays (PFR) ranged from 8-18 with a median of 12. For Predorsal scales and dorsal fin spines (DFS) the range was between 6-12 and 1-10 with a median of 10 and 3 respectively (Table 9).

Discussion

Meristic characters of *E. paludinosus* populations varied across different reservoirs and a river in the North Rift region. Predorsal scales showed little variation, suggesting strong genetic control or minimal environmental influence. This aligns with previous research indicating certain meristic characters are more genetically determined. For instance, Smith et al. (1997) found scale counts highly conserved within populations due to genetic factors. Kesses Reservoir exhibited higher lateral scales above (LASC) compared to Kapsaina and Chebara Reservoirs, possibly due to environmental factors like habitat complexity and predator abundance. Studies by Winemiller et al. (2015) support the influence of habitat conditions on morphological traits. The higher dorsal fin rays (DFR) in Kesses Reservoir might be due to genetic factors or selective pressures enhancing swimming performance or predator avoidance. The lateral line scales (LLS) in Kesses River were higher, likely due to differences in water flow and habitat structure, aiding in navigation and predator detection. The higher caudal fin rays (CFR) in Kesses River might enhance maneuverability and swimming performance. The higher circumprndicular scales (CIRSC) in Kesses River could be an adaptation to predator avoidance or enhanced prey capture. Bell and Foster (2017) highlighted the role of habitat complexity in the development of anti-predator adaptations. The higher anal fin rays (AFR) in Kesses Reservoir could be linked to habitat conditions or reproductive strategies, aiding in swimming control and courtship displays, as explored by Wong and Rosenthal (2006). The pectoral fin rays (PFR) in Kesses River might improve movement control and prey capture efficiency.

Morphometric measurements of *E. apleurogramma* from two reservoirs and one river showed significant differences due to ecological and genetic factors. Variations in resource availability, habitat structure, and predation pressure influenced morphological traits. Genetic factors, such as limited gene flow, contributed to morphometric divergence. Studies by Brown (2012) support these findings, while Jones et al. (2018) suggest additional influencing factors. Ecological differences among habitats, including food availability and predation pressure, influenced meristic characters. For instance, higher LASC in Kesses Reservoir compared to Kapsaina and Chebara Reservoirs might be due to habitat structure or predator abundance. Genetic factors also played a role, with limited gene flow and natural selection driving phenotypic differences.

Morphometric measurements of *E. neumayeri* from eight reservoirs and eleven rivers varied due to ecological, genetic, and anthropogenic factors. Differences in food availability, habitat structure, and predation pressure influenced growth and development. Genetic factors, such as limited gene flow and natural selection, contributed to morphometric variation. Anthropogenic influences, including habitat alteration and pollution, also played a role. Studies by Brown (2012) align with these findings. Meristic characters of *E. neumayeri* varied due to ecological and genetic factors. Higher LASC in Kapsaina and Chebara Reservoirs compared to Kerita Reservoir and Chepkaitit River were attributed to habitat structure and resource availability. Genetic drift and natural selection further influenced meristic variation, supporting findings by Brown (2012).

Morphometric measurements of *E. cercops* from Chepkosom Reservoir indicated a small standard length. This could be influenced by limited food resources, environmental factors like water quality, and genetic factors. Comparative studies by Smith et al. (1997) highlighted the influence of resource availability and environmental conditions on body size. Meristic characters of *E. cercops* showed variability, influenced by genetic and environmental factors. Genetic variation and environmental conditions, such as food availability and habitat structure, played roles in the development of meristic traits. Studies by Smith et al. (1997) support these findings.

Conclusion and Recommendations

In conclusion, the meristic and morphometric analyses of *E. paludinosus*, *E. apleurogramma*, *E. neumayeri,* and *E. cercops* revealed significant variations in their traits across different habitats, indicating a complex interplay of genetic, environmental, and ecological factors in shaping their morphology. Genetic control appeared to influence certain meristic characters, such as predorsal scales, while environmental factors like habitat complexity and predation pressure seemed to affect others, like lateral scales. The morphometric differences observed were largely attributed to body size variations, highlighting the importance of overall body size and proportions in determining morphological diversity. The results emphasize the need for further research to understand the specific mechanisms driving these adaptations and their implications for the evolutionary trajectories of these species.

References

Balirwa, J. S., Chapman, C. A., Chapman, L. J., Cowx, I. G., Geheb, K., Kaufman, L., ... & Ogutu-Ohwayo, R. (2003). Biodiversity and fishery sustainability in the Lake Victoria basin: an unexpected marriage? BioScience, 53(8), 703-716.

Bănărescu, P., & Coad, B. W. (1991). Cyprinids of Eurasia. In *Cyprinid Fishes: Systematics, biology and exploitation* (pp. 127-155). Dordrecht: Springer Netherlands.

Bell, A. M., & Foster, S. A. (2017). The evolutionary biology of the threespine stickleback. Oxford University Press.

Bryndum-Buchholz, A., Tittensor, D. P., & Lotze, H. K. (2021). The status of climate change adaptation in fisheries management: Policy, legislation and implementation. *Fish and Fisheries*, *22*(6), 1248-1273.

Cantonati, M., Poikane, S., Pringle, C. M., Stevens, L. E., Turak, E., Heino, J., ... and Znachor, P. (2020). Characteristics, main impacts, and stewardship of natural and artificial freshwater environments: consequences for biodiversity conservation. *Water*, *12*(1), 260.

Chakona, A., Jordaan, M. S., Raimondo, D. C., Bills, R. I., Skelton, P. H., & van Der Colff, D. (2022). Diversity, distribution and extinction risk of native freshwater fishes of South Africa. *Journal of Fish Biology*, *100*(4), 1044-1061.

Correa, S. B., Araujo, J. K., Penha, J. M., da Cunha, C. N., Stevenson, P. R., & Anderson, J. T. (2015). Overfishing disrupts an ancient mutualism between frugivorous fishes and plants in Neotropical wetlands. *Biological Conservation*, *191*, 159-167.

Gonzalez-Martinez, A., De-Pablos-Heredero, C., González, M., Rodriguez, J., Barba, C., & García, A. (2021). Morphological Variations of Wild Populations of Brycon dentex (Characidae, Teleostei) in the Guayas Hydrographic Basin (Ecuador). The Impact of Fishing Policies and Environmental Conditions. *Animals*, *11*(7), 1901.

Harrison, I. J., Green, P. A., Farrell, T. A., Juffe-Bignoli, D., Sáenz, L., & Vörösmarty, C. J. (2016). Protected areas and freshwater provisioning: a global assessment of freshwater provision, threats and management strategies to support human water security. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *26*, 103-120.

Hoban, S., Bruford, M., Jackson, J. D. U., Lopes-Fernandes, M., Heuertz, M., Hohenlohe, P. A., ... & Laikre, L. (2020). Genetic diversity targets and indicators in the CBD post-2020 Global Biodiversity Framework must be improved. *Biological Conservation*, *248*, 108654.

IUCN. (2018). The IUCN Red List of Threatened Species. Version 2018-2. Retrieved from http://www.iucnredlist.org.

Jawad, L. A., Ibáñez, A. L., Kiki, M., and Gnohossou, P. (2020). Determination of body shape and meristic characters variations in wild and cultured populations of cichlid fish, Oreochromis niloticus, from the Republic of Benin, West of Africa. Fisheries and Aquatic Life, 28(3).

Jones, M. R., Mills, L. S., Alves, P. C., Callahan, C. M., Alves, J. M., Lafferty, D. J., ... & Good, J. M. (2018). Adaptive introgression underlies polymorphic seasonal camouflage in snowshoe hares. *Science*, *360*(6395), 1355-1358.

Kajee, M., Henry, D. A., Dallas, H. F., Griffiths, C. L., Pegg, J., Van der Colff, D., ... and Shelton, J. M. (2023). How the Freshwater Biodiversity Information System (FBIS) is supporting national freshwater fish conservation decisions in South Africa. *Frontiers in Environmental Science*, *11*, 303.

Kasumyan, A. O., and Isaeva, O. M. (2023). Taste Preferences of Cyprinid Fishes (Cyprinidae). A Comparative Study. *Journal of Ichthyology*, *63*(1), 119-146.

Kunal, K., Garima, and Ganie, P. A. (2023). Fishery Resources and Ichthyofaunal Diversity in the Temperate Himalayas. In *Fisheries and Aquaculture of the Temperate Himalayas* (pp. 11-23). Singapore: Springer Nature Singapore.

Losos, J. B. (2011). *Convergence, adaptation, and constraint. Evolution: Education and Outreach*, 4(3), 489-495.

Mbewe, G., Mutondo, M., Maseka, K., & Sichilongo, K. (2016). Assessment of heavy-metal pollution in sediments and tilapia fish species in Kafue River of Zambia. *Archives of environmental contamination and toxicology*, *71*, 383-393.

Moyle, P. B., & Leidy, R. L. (2023). Endangered freshwater fishes: does California lead the world.

Okoyen, E., Raimi, M. O., Oluwatoyin, O. A., & Williams, E. A. (2020). Governing the environmental impact of dredging: Consequences for marine biodiversity in the niger delta region of Nigeria. *Okoyen E, Raimi MO, Omidiji AO, Ebuete A W. Governing the Environmental Impact of Dredging: Consequences for Marine Biodiversity in the Niger Delta Region of Nigeria. Insights Mining Science and Technology*, *2*(3), 555586.

Siddha, S., & Sahu, P. (2023). Integrating GIS and irrigation water quality index approaches for identifying groundwater irrigation potential zones in Central Gujarat, India. *Environmental Monitoring and Assessment*, *195*(9), 1082.

Smith, T. B., Wayne, R. K., Girman, D. J., & Bruford, M. W. (1997). A role for ecotones in generating rainforest biodiversity. *Science*, *276*(5320), 1855-1857.

Stapley, J., Garcia, M., & Andrews, R. M. (2015). Long-term data reveal a population decline of the tropical lizard Anolis apletophallus, and a negative affect of El Nino years on population growth rate. *PLoS One*, *10*(2), e0115450.

Sumaila, U. R., & Tai, T. C. (2020). End overfishing and increase the resilience of the ocean to climate change. *Frontiers in Marine Science*, *7*, 523.

Winemiller, K. O., Fitzgerald, D. B., Bower, L. M., & Pianka, E. R. (2015). Functional traits, convergent evolution, and periodic tables of niches. *Ecology letters*, *18*(8), 737-751.

Wong, B. B., & Rosenthal, G. G. (2006). Female disdain for swords in a swordtail fish. *The American Naturalist*, *167*(1), 136-140.