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A Review of Morphomeristic Characterization and Classification of Genus *Enteromius spp* in Africa

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Abstract

Enteromius is currently represented by 350 valid species, making it the most speciose and widely distributed cyprinid genus on the African continent. The Enteromius represents one of the most common genera occurring in almost all river systems across the continent, these fishes are generally difficult to identify because of their very similar body morphology and color pattern, coupled with the lack of revision within the group. Despite this, there are many challenges to adequately conserve the Enteromius because of unsatisfactory taxonomic knowledge of important portions of the genus. In this review, distinctive morphometric characteristics, general characterization and classification of the genus Enteromius occurring in Africa was analyzed. It was established that many species under the genera Enteromius have been mis-identified giving a false impression among the taxa richness. Genus Enteromius is distinguished from other small African diploid smiliogastrin genera distributed in African water bodies (Barboides, Clypeobarbus Barbopsis) based on differences in morphomeristic characteristics. Most occurring differences among Enteromius species are dorsal-fin placement in comparison to anal-fin origin, number of dorsal-fin rays, number of paired nostrils on either side of the snout, eye size, placement in the orbital rim and pigmentation pattern, shape and pattern of mid-lateral scale row. Isolated studies with focusing on a single geographical location resulting to double identification. Since fish under the genera Enteromius spp are sensitive to habitat quality and occurs mostly in small water bodies and headwater streams, the need to conserve catchments to enhance biodiversity.

Keywords: Morphomeristics, *Enteromius* spp., Classification, Conservation

INTRODUCTION

The taxonomy of species of *Enteromius* is to date insufficiently known, resulting to difficulties in identifications and incomplete inventories of the species (Sonet et al., 2019). It also hampers further studies on phylogenetic relationships, which are still obscure among species of genera *Enteromius* despite being widely distributed in Afrotropic regions of Africa (Makaure & Stewart, 2022). Currently, more than 350 species under the genus *Emteromius* are thought to be valid with many others waiting for description and classification. However, African river catchment scale, land use and land cover changes have been linked with modified flow regimes, deterioration in water and habitat quality, changes in nutrient cycling, organic matter processing and basal food resources for aquatic communities, leading to biodiversity loss and general impairment of ecological integrity of streams and rivers (Lubanga et al., 2021). This has led to fears that most migratory fish species such as *Enteromius* spp. ends up in fragmented habitats that pause a risk of extinction before identification and conservation takes place.

Previous years of classification placed most fish in the genus *Enteromius* in the genus *Barbus* representing diverse group broadly categorized as small *Barbus (*Tan & Armbruster, 2018). Because of uncertainties, fish in the genus *Enteromius* were placed under the collective genus name *Barbus sensu lato* which referred to the large small-scaled tetraploid Euro-Mediterranean and West Asian species. Yang et al. (2015) elevated *Enteromius* to accommodate all African diploid barbs that are presently considered small *Barbus*. This decision was criticized for a number of reasons most notable was the evidence that *Enteromius* was a non-monophyletic group. Since Yang et al. (2015), authors have disagreed on how best to address the ongoing taxonomic issue of small Barbus. Recent taxonomic efforts within the group are not accepted universal (Hayes & Armbruster, 2017). Because of stalemates in identification of the genera, some authors accepted *Enteromius* (Schmidt, Bart & Nyingi, 2018; Truter et al., 2020; Kambikambi, Kadye & Chakona, 2021; Prokofiev, Levin & Golubtsov, 2021) while others preferred to retain *Barbus* until stable monophyletic genera can be elevated from the group. Hayes & Armbruster (2017) formally recognized *Enteromius*, re-described the genus, and provided a list of the taxa included in *Enteromius*. Tan & Armbruster (2018), Levin et al. (2019), Mipounga et al. (2019), and Levin et al. (2021) opposed to assigning African small barbs to *Enteromius* was previously noted with some authors noting that the molecular phylogenetic evidence proved otherwise.

Another issue complicating the resolution of the *Enteromius* problem is the immense size of the group. Most of the estimated species remain undescribed and many of the described species have only a few specimens available for study (Popoola et al., 2022). One solution to this problem is conducting detailed review that brings on board all *Enteromius* species described in to one collection and review the morphometric characteristics distinguishing each species (Decru et al., 2022). Recent collection efforts throughout Africa are providing material for these types of studies, resulting in revisions and descriptions of new species. Currently, evidence on fish in the genus *Enteromius* are distinguished from other small African diploid *smiliogastrin* genera distributed in African water bodies, *Barboides*, *Clypeobarbus Barbopsis*, using several morphometric characteristics (Hayes, 2020). The most outstanding differences are in dorsal-fin placement in comparison to anal-fin origin, number of dorsal-fin rays, number of paired nostrils on either side of the snout, eye size, placement in the orbital rim and pigmentation pattern, shape and pattern of mid-lateral scale row (Schmidt & Bart, 2015). A number of morphological, physiological, behavioral and biochemical characteristics can also be used in identification and classification of *Enteromius* fishes. High preference is on homologous characters that show variation across taxa because they assess interrelationship and distinguish taxa easily (Rahel & McLaughlin, 2018). The effort to identify and characterize *Enteromius* has placed the genera in headwater streams and small water bodies making it among the most common genus occurring in almost all river systems across Africa.

Despite *Enteromius* being among the most common genus inhabiting most rivers across Africa (Kambikambi et al., 2021), fish under the genus *Enteromius* is generally difficult to identify because of their very similar body morphology and color pattern, coupled with the lack of revision within the group (Martin & Chakona, 2019). As a result, a number of fishes within *Enteromius spp* are currently considered to have wide geographic ranges across multiple river systems (Kambikambi, 2020). Such distribution patterns are unexpected for freshwater restricted taxa as their dispersal is limited by terrestrial and marine barriers, and they reflect the incomplete systematic and taxonomic knowledge of freshwater fishes in the region (Rennie, 2021). This taxonomic impediment handicaps basic research in biological sciences and biodiversity conservation

(Raphahlelo, Přikrylová & Matla, 2020). The use of morphometric and meristic characters is essential to identify fish species and their habitat uniqueness as well as ecological criteria in any water body. This review forms part of the effort to describe the spatial patterns, morphometric characteristics and conservation status of the fish species under genus *Enteromius* (small *Barbus)* in Africa.

Spatial Patterns of *Enteromius* Fish Species

In Kenya, Research done by Masese et al. (2020) shows that *Enteromius spp.* mostly dominates low-order streams (first to third order) in headwaters of rivers in Lake Victoria basin are species-poor. Most fishes of this genera are endemic to rivers, and species turnover across river basins was found to be low order stream**.** The abundance of the small *Barbus* lowers as you move down the stream where low dissolved oxygen and high turbidity exist (Turyahabwe et al., 2022). Most of the species were found at the upper ridges of the low order streams accounting for up to 60% of the total biomass of *Enteromius Spp* sampled while the lower parts of the river had no occurrence of the species (Masese et al., 2020). The upper reaches of Lake Victoria fish species confines individuals in the rivers as percentage *E. neumayeri* (6.2%) *Enteromius nyanzae* (5.6%), *Enteromius cercops* (2.9%), *E. paludinosus* (1.2%) and *Enteromius kerstenii* (1.2%) (Masese et al., 2020). Most species occurred in small numbers, with 19 species forming a combined <1% of all individual collected as shown in figure 1.

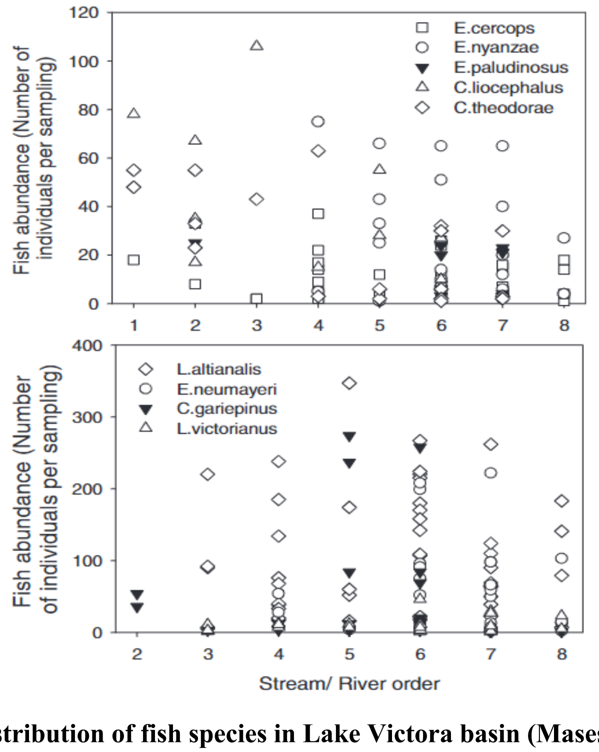

Figure 1: Distribution of fish species in Lake Victora basin (Masese et al., 2020).

The species showed sensitivity to dissolved oxygen, turbidity and nutrients related pollution that happens in downstream rivers. *Enteromius* ssp. was also found in the localities within the Athi River drainage include the swamps of Amboseli National Park, Kiambogo River, and Mzima Springs (Mipounga et al., 2019). *Enteromius amboseli* was described from the swamps in Amboseli National Park but is considered a junior synonym of *E. apleurogramma*. Following the discovery of genetic divergences among populations of the red-finned barb, a morphometric analysis was undertaken. Table 1 shows fish from the Genus *Enteromius* characterised and the locality in Kenya.

Table 1: Distribution of Fish of genera *Enteromius* in Kenya (adopted from Mipounga et al., 2019)

Species	Locality	Drainage	Voucher No	Catalog No	Accession No Cyt*b*	Accession No GH intron 2	Accession No RAG1
E. apleurogramma	River Oromba at Ombei Bridge, Nyando River System	Lake Victoria	1534	NMK FW/2248/1-10	KX178088	KX177984	
E. apleurogramma	River Oromba at Ombei Bridge, Nyando River System	Lake Victoria	1535	NMK FW/2248/1-10	KX178089	KX177985	
E. apleurogramma	Lake Victoria at Ogenya Beach	Lake Victoria	1570	NMK FW/2261/1-24	KX178093		
E. apleurogramma	Lake Victoria at Ogenya Beach	Lake Victoria	1571	NMK FW/2261/1-24	KX178094	KX177991	
E. apleurogramma	Mbogo River at Muhoroni-Nandi Hills Road, River Nyando System	Lake Victoria	1583	NMK FW/2269/1-3	KX178098	KX177995	KX274691
E. apleurogramma	Mbogo River at Muhoroni-Nandi Hills Road, River Nyando System	Lake Victoria	1586	NMK FW/2269/1-3	KX178099		
E. apleurogramma	Lake Kanyaboli at Kanyaboli Beach	Lake Kanyaboli	1610	NMK FW/2278/1-3	KX178102	KX177997	MH616629
E. apleurogramma	Lake Kanyaboli at Kanyaboli Beach	Lake Kanyaboli	1611	NMK FW/2278/1-3	KX178103	KX177998	MH616630
E. apleurogramma	River Kuja, Keera Area, Nyamira County	Lake Victoria	1669	NMK FW/2314/1-3	KX178116	KX178009	KX274718
E. apleurogramma	River Kuja, Keera Area, Nyamira County	Lake Victoria	1670	NMK FW/2314/1-3	KX178117		
E. apleurogramma	River Kipsonoi, Sondu River system, at Chebilat-Sotik Road Bridge	Lake Victoria	1675	NMK FW/2315/1-68	KX178120		
E. apleurogramma	River Kipsonoi, Sondu River system, at Chebilat-Sotik Road Bridge	Lake Victoria	1676	NMK FW/2315/1-68	KX178121		
E. amboseli	Ol dare Swamp inside Amboseli National Park	Athi River	10122	NMK FW/2694/1-38	KX178165		
E. amboseli	Ol dare Swamp inside Amboseli National Park	Athi River	10127	NMK FW/2702/1-7	KX178166	KX178028	KX274725
E. amboseli	R. Kiambogo at Kimana, Loitoktok, Emali Rd. Bridge	Athi River	10128	NMK FW/2738/1-59	KX178167		MH616631

Enteromius fish species displayed spatial variability in abundance, diversity and taxon richness in response to changes in water quality and nutrients in the various reservoirs (Ahmed & Turchini, 2021). In made-made fragmented dams of the rift valley, five species of genera *Enteromius* were found to inhabit dams in rift valley. The low abundance was attributed to deterioration in the environmental conditions and ever-increasing fishing effort resultant from population growth and lack of alternative livelihood (Seara et al., 2022). Owing to the small sizes of the *Enteromius* fish, there is a likelihood of recruitment overfishing of the slightly large-bodied ones due to the market preference of large-sized fish. Studies on other species such as that by Gichuru et al. (2019) noted that the *Oreochromis niloticus* fishery in Uasin Gishu small water bodies was driven by market preferences of large-sized *Oreochromis niloticus*. These large-sized fish are primarily spawners, potentially resulting in recruitment overfishing in the reservoir thus resulting to lack of reproduction hence low abundance and reduced diversity. Introducing new fish species in a water body is problematic if they compete for the same niche with native and non-native fish which are ecologically more versatile.

Recent study by Englmaier et al. (2020), on ongoing *Enteromius* species identification from the Ethiopian valley found a new species, *E. yardiensis,* with the general appearance of silvery in color and no barbells. The species was found in shallow waters with the velocity ranging from 1.5 m/s to 2 m/s with high oxygen concentration (Englmaier, Tesfaye & Bogutskaya, 2020). Morphometric measurements showed distinctive difference that separated the species from the five-existing species in the Ethiopian valley as shown in Figure 3. The Ethiopian rift valley lakes have shown high abundance of *Enteromius* fish that have not been described.

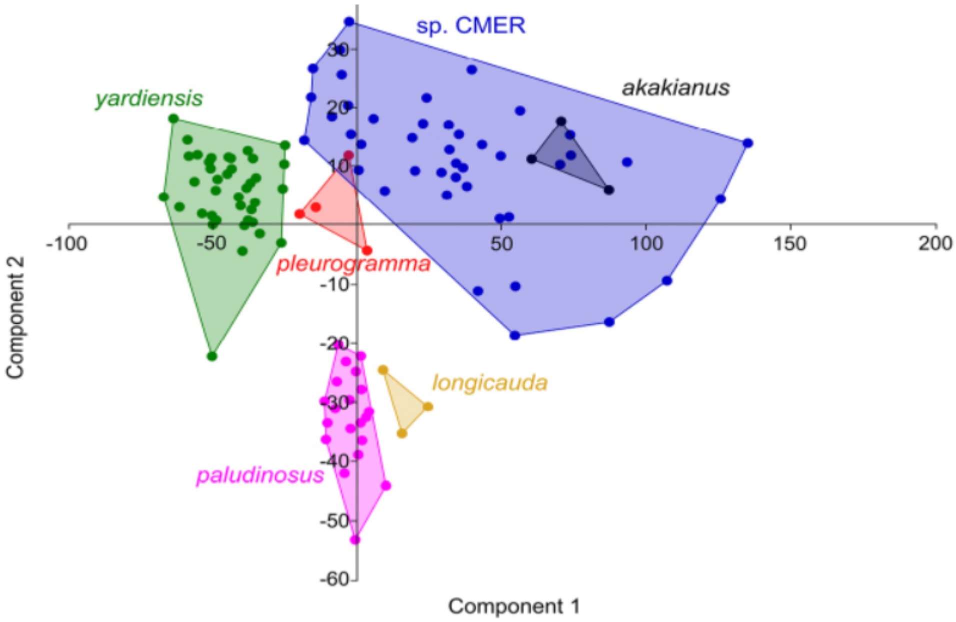

Figure 2: Morphomeristic distinction of genera *Enteromius* from Ethiopian valley by Englmaier, Tesfaye & Bogutskaya (2020).

The most dominant morphometric measurement that dominates the Ethiopian Fish of genus *Enteromius* in headwater streams is the presence and absence of barbells, color, eye position osteology and sensory canals, proved to be very productive for taxonomy in this group of fishes (Prokofiev et al., 2021). *Enteromius akakianus* was found as a resurrected valid species including populations from the Central Main Ethiopian Rift (basins of lakes Langano, Ziway, and Awasa). Since some of the species characterized in Ethiopia rift are restricted to the valley, the need for conservation arises.

South Africa exhibit mostly 38 species of *Enteromius* that are recognized and described, they are found mostly at the headwater streams and rivers characterized by high dissolved oxygen and low velocity (Mashego & Matlou, 2018) as illustrated in table 2. Due to their sensitivity of pollution and low tolerance levels, the population drastically reduces as the river's changes to mid order levels (Lo et al., 2020). Of the 38 currently recognized species of this genus in southern Africa, 20 are endemic to South Africa. Skelton (2016) divided some of these species into two broad groups, the chubby head and the goldie barb groups, based on unique morphological characteristics and the development of distinctive golden coloration pattern during the breeding season. The chubby head barb group is represented by four species, the chubby head barb *Enteromius anoplus* (Weber, 1897), the red tail barb *Enteromius gurneyi* (Gunther, 1868), the Amatola barb Enteromius amatolicus (Skelton, 1990) and the Marico barb *Enteromius motebensis* (Van & Basson, 1984). Three species belonging to this group have narrow geographic ranges, with *E. anoplus* being the only exception as its range extends from coastal systems in the south to the Limpopo River system in the north, making it the most widely distributed freshwater fish in South Africa.

Table 2: Spatial distribution of *Enteromius spp*. in South Africa river system by Mashego & Matlou (2018)

System	River	lineage	Catalogue and field number	Latitude	Longitude	Morphology sample size (*n*)	DNA san size (*n*)
Orange	Stormbergspruit	*E. oraniensis*	MK19AL17	−30.776	26.422	13	1
Orange	Stormbergspruit	*E. oraniensis*	SAIAB 209737	−30.858	26.418	20	1
Orange	Bossielaagtespruit	*E. oraniensis*	SAIAB 209736	−30.799	27.077	20	2
Olifants	Olifants	*E. cernuus*	SAIAB 135553	−31.610	18.746	5	
Olifants	Olifants	*E. cernuus*	SAIAB 135483	−32.564	18.996	5	
Olifants	Olifants	*E. cernuus*	SAIAB 200351	−32.441	18.959		2
Olifants	Olifants	*E. cernuus*	SAIAB 135479	−32.144	18.873	5	
Olifants	Breekrans	*E. cernuus*	RUSI 65417	−32.559	19.299	8	
Gouritz	Buffels	*E. anoplus* ss	SAIAB 200353	−33.189	20.858		2
Gouritz	Gamka	*E. anoplus* ss	SAIAB 186167	−33.469	21.734		2
Gouritz	Nels	*E. anoplus* ss	SAIAB 186161	−33.467	21.735		2
Gouritz	Buffels	*E. anoplus* ss	SAIAB 200353	−33.189	20.858	10	
Gouritz	Buffels	*E. anoplus* ss	SAIAB 130195	−33.432	21.416	10	
Great Fish River	Tarka	*E. mandelai* sp. n	SAIAB 209734	−32.218	25.929	5	4
Great Fish River	Pauls	*E. mandelai* sp. n	MK19AL03	−32.035	25.521	10	4
Great Fish River	Great Fish River	*E. mandelai* sp. n	SAIAB 209732	−31.899	25.210	20	4
Great Fish River	Koonap	*E. mandelai* sp. n	Koonap b	−32.395	26.512		4
Great Fish River	Eyre	*E. mandelai* sp. n	Eyre 1	−32.507	26.792		4
Great Fish River	Eyre	*E. mandelai* sp. n	Eyre 3	−32.531	26.790		2
Great Fish River	Balfour	*E. mandelai* sp. n	Balfour 2	−32.575	26.655		1
Great Fish River	Balfour	*E. mandelai* sp. n	Balfour 3	−32.567	26.620		2
Great Fish River	Balfour	*E. mandelai* sp. n	Balfour 4	−32.535	26.677		2
Great Fish River	Fairbairn	*E. mandelai* sp. n	Fairbairn 1	−32.509	26.709		3
Keiskamma	Rabula	*E. mandelai* sp. n	Rabula 1	−32.749	27.097		3
Keiskamma	Rabula	*E. mandelai* sp. n	Rabula 2	−32.758	27.134		2
Keiskamma	Rabula	*E. mandelai* sp. n	Rabula 3	−32.749	27.132		2
Keiskamma	Keiskamma	*E. mandelai* sp. n	MK19AL09	−32.718	27.010	13	
Keiskamma	Amatele	*E. mandelai* sp. n	MK19AL10	−32.717	27.009	6	4
Buffalo	Yellowwoods	*E. mandelai* sp. n	MK19AL12	−32.807	27.470	7	2
Buffalo	Yellowwoods	*E. mandelai* sp. n	MK19AL15	−32.725	27.489	11	2
Buffalo	Yellowwoods	*E. mandelai* sp. n	MK19AL21	−32.758	27.488	6	2
Buffalo	Izele	*E. mandelai* sp. n	SAIAB 209733	−32.771	27.389	12	3

In West Africa, the most dominant species is *Enteromius trispilos* species of ray-finned fish in the genus *Enteromius* which forms part of the 16 species of *Enteromius* fully described (Ren, 2015). In Gabon, a new species (*Enteromius pinnimaculatus sp. nov*.) was recently distinguished from all other Gabonese *Enteromius* by the presence of several distinct spots on the dorsal fin in combination with three or four round spots on the flanks (Mipounga et al., 2020). In Africa, it is superficially similar to *Enteromius walkeri* and with which it shares an unusual allometry in that the proportional length of the barbells decreases as the fish grows (Weyl et al., 2017). Nevertheless, one can distinguish these species by vertebral number, maximum standard length, the length of the anterior barbells, the length of the caudal peduncle and in most specimens, the number of lateral-line and circumpeduncular scales (Mipounga et al., 2020). These two species also inhabit widely separated drainages, with *E. walkeri* occurring in coastal drainages of Ghana including the Pra and Ankobra Rivers and the new species occurring in tributaries of the Louetsi and Bibaka Rivers of Gabon, which are part of the Ogowe and Nyanga drainages, respectively (Mipounga et al., 2019). Despite extensive collections in those drainages the new species is known from only two localities, suggesting the importance of conservation of its known habitat.

Distribution pattern of *Enteromius spp* is closely related to the habitat quality with most species found in the headwater streams and rivers (Schmidt & Barrientos, 2019). As the land use change continues to impact on the quality of the ecosystem, more likely some species will get extinct before they are identified.

Speciation Processes in *Enteromius* spp

Most of *Enteromius* species occurs in isolated ecosystem, this may have caused significant variations in morphology and not genes (Schmidt et al., 2019). The wide distribution ranges of the species on the one hand, and the often much narrower distribution ranges of the putative new species detected through DNA barcoding on the other, may be a reason most *Enteromius spp* were not detected as different species. The majority of earlier studies on ichthyofaunal diversity concern collections from small areas and even individual rivers, the studied specimens are often identified as one of the morphologically similar species presumed to occur in the studied region (Kambikambi, 2020). Unfortunately, these identifications rarely imply detailed comparisons with specimens from other regions, let alone type specimens. In addition, the allopatric lineages within each of these species were morphologically sufficiently similar to remain grouped for as long as they were not subjected to comparisons based on multivariate morphometric methods (Voet et al., 2022). Although minor morphological differences can be interpreted as intraspecific geographic variation among different populations, the detected morphological and genetic differences among the most examined specimens of *Enteromius*, suggests that these populations probably represent separate, undescribed species. Although DNA barcodes allowed for the clustering of putative conspecifics, the obtained tree does not necessarily reflect the phylogenetic relationships within the genus *Enteromius*.

A review of the phylogeny would not only require a comprehensive sampling of all species of *Enteromius spp* but also the inclusion other groups (Decru et al., 2022). Nevertheless, some scenarios can be proposed concerning their evolutionary history. As in each of the geographically isolated river stretches studied distinct putative species appear to occur, allopatric speciation may well have been the main mode of speciation in this genus. However, the phylogenetic relationships among the species remain largely unresolved, as there is a lack of resolution in several parts of the family tree. While it is possible that the lack of resolution is due to incomplete taxon sampling and to the small number of characters, plausible cause which often results in difficulties in resolving phylogenetic patterns (Folk et al., 2018). The unresolved phylogenies would in that case be the result of an almost concurrent differentiation between populations from different river stretches on a short evolutionary timescale. The fact that in this scenario adaptation to different niches has not been necessary, could thus be the cause that only minor morphological differences exist, which were only detected after multivariate exploratory techniques.

The example of *Enteromius* species unresolved phylogenies is *E. atromaculatus* and *E. Pellegrini* as illustrated in figure 3, the populations from the Ituri River and its most important right-bank affluent, the Epulu River, have a slightly different color pattern, which seems to support the scenario of allopatric speciation (Petrosino et al., 2022). The case would be the result of an almost concurrent differentiation between populations from different river stretches on a short evolutionary timescale. The fact that in this scenario adaptation to different niches has not been necessary, could thus be the cause that only minor morphological differences exist, which were only detected after multivariate exploratory techniques.

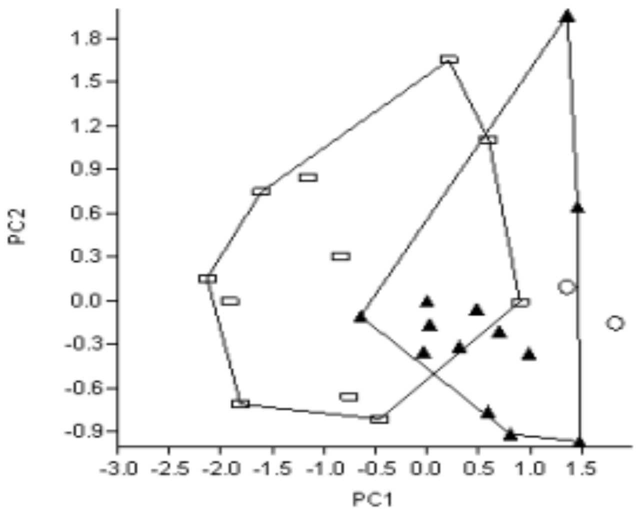

Figure 3: Scatterplot of PC2 against PC1 for a PCA on 10 meristics (n = 36) of *E. atromaculatus* Epulu 2 (▲), and Ituri 8 (.) Also shown are the type specimens of *E. atromaculatus* adopted from (Prokofiev Levin & Golubtsov, 2021).

However, for *E. atromaculatus*, there was only a genetic divergence of 1.75% between these populations, and even no divergence for *E. pellegrini*. Also based on counts and measurements, both populations of *E. atromaculatus* and *E. pellegrini* overlap (Prokofiev et al., 2021). These two instances could be examples of intraspecific geographical color variation rather than of two separate species in each of the two groups. This conclusion is unexpected, since even morphologically very similar populations were found to represent separate putative species in almost every individual river stretch. The observation that the populations from the Ituri and the Epulu cannot be distinguished based on the multivariate analyses and do not appear to be genetically distinct, is even more surprising since these two river stretches are isolated. Indeed, the discussed populations are separated from each other by the presence of two waterfalls, one on the Epulu, just upstream of its confluence with the Ituri, and one on the Ituri itself. The falls could form important barriers for fish species and populations, at least for upstream dispersal. However, this hypothesis does not appear to be supported by our results (Prokofiev et al., 2021). The distribution patterns, in combination with morphological (dis)similarities and the unresolved phylogenetic relationships, indicate that multiple allopatric speciation events on a short evolutionary timescale is a plausible mode of speciation for the examined species of Enteromius. Such allopatric divergences can occur in river systems when hydrological changes cause (simultaneous) disconnections of river stretches. Remarkably, some morphologically similar putative species occur however in sympatry.

DISCUSSION

Morphometric Characteristics Distinguishing genus *Enteromius*

A study done in Ethiopia showed that Ethiopian *Enteromius* species with a serrated dorsal-fin ray are distant from the true *E. paludinosus*, *E. longicauda* as and one called *E. paludinosus* complex involves several supposedly valid species with two distinct species occurring in the Main Ethiopian Rift area (Englmaier et al., 2020). A new species, *Enteromius yardiensi* ssp, was described from the Afar Depression in the north-eastern part of the Northern Main

Ethiopian Rift. *Enteromius akakianus* is resurrected as a valid species including populations from the Central Main Ethiopian Rift (basins of lakes Langano, Ziway, and Awasa) (Englmaier et al., 2020). No genetic data were available for *E. akakianus* from its type locality. *Enteromius yardiensis* is clearly distant from *E. akakianus* from the Central Main Ethiopian Rift by CO1 and cytb barcodes: pairwise distances between the new species and the Ethiopian congeners were 5.4% to 11.0% (Englmaier et al., 2020). Morphologically, the new species most clearly differs from all examined Ethiopian congeners by three specializations which are unique in the group: the absence of the anterior barbel, the absence of the medial branch of the supraorbital sensory canal, and few, 1-3, commonly two, scale rows between the lateral line and the anus. Studies done by Emily et al. (2017) on morphological characterization of *Barbus altianalis* within the Lake Victoria basin revealed intra specific variation

Study done by Prokofiev & Golubtsov (2021) on Juba river system around bale mountain in Ethiopia identified a new species *Enteromius baleensis* that differs from all other *Enteromius* with having the last unbranched dorsal-fin ray soft and flexible, scales moderately small (34-37 in lateral series), and incomplete lateral line (Prokofiev & Golubtsov, 2021). The deeper relationships between these taxa are unresolved, meaning sister-group relationships are not understood based on the research done so far however, examination of the resulting well-supported clades (posterior probability .95%) furthers the case of the practical utility of a taxon such as Enteromius.

Taxonomic challenges of *Enteromius*

Much work is needed to resolve the taxonomy of *Enteromius*. Resolution of the relationships between *Enteromius* Clade I and *Enteromius* Clade II is needed, but will come only with increased taxon sampling and additional loci. Hemigrammopuntius is an available name for Clade II; however, it is unclear if this clade is diagnosable and what species would belong in it. Major barriers to inferring relationships across Cyprinidae are also barriers to clarifying the relationships among members of *Enteromius*: incomplete taxon sampling due to inaccessibility of samples, multiple genome duplication events, few loci analyzed, and homoplasious morphological characteristics (Tsigenopoulos et al., 2002; Chen & May-den, 2009; Yang et al., 2015). Although these small minnows have a pan-African distribution, accessibility into countries of interest and to field sites is limited, often due to political instability (Williams & Kniveton, 2011; Day et al., 2013). This low accessibility, as well as few professional curators and taxonomists across the continent, makes voucher specimens, and especially tissue samples, rare (Skelton & Swartz, 2011). In addition to the rarity of specimens, an uninformative and confusing taxonomy has halted forward progress for the African cyprinids. The polyphyletic arrangement of *Barbus*. has been recognized since Myers (1960:213) decried this ‘‘monstrous aggregation,’’ and molecular work since the 1990s has continued to verify the fact that the small African barbs are not closely related to *Barbus*, despite bearing the name (Berrebi et al., 1996; Tsigenopoulos et al., 2002; Wang et al., 2007; Pethiyagoda et al., 2012). Although the monophyly of the *Enteromius* group remains unclear, morphological characteristics and ploidy level unite these taxa and distinguish them from other historical members of the genus. There are three certainties about the small African diploid ‘*Barbus*’: they are not *Barbus*, they are not closely related to *Barbus*, and they will never be placed back in *Barbus*. Rather than reverting into an uninformative genus as proposed by Schmidt & Bart (2015), we use *Enteromius* to reflect those diploid taxa which bear radial striae on their scales and possess seven to eight branched dorsal rays until a more complete examination of the group is possible. Although *Enteromius* is non-monophyletic, recognizing *Enteromius* as a valid genus is the more taxonomically sound choice than to continue to use a genus name known to be incorrect. We provide a list of the species which should be considered *Enteromius*, and do not advocate at this time disturbing the taxonomic rankings of genera whose distinctiveness is sufficiently described based on morphological and molecular data (*Barboides, Barbopsis, Caecobarbus, Clypeobarbus, and Pseudobarbus*). Combined with Vreven et al. (2016), there is finally a list of species in each of the African barb genera, and ichthyologists can now better handle future taxonomic revisions.

Mis-identification and Unrecognized Diversity

There exist to large extend, mis-identification of fish in the genus *Enteromius* existing in different parts of African basins. This to some extend have led to unappreciated diversity of Cyprinids in different parts due to previous categorization under the genus *Barbus*. For instance, Rokel River Basin of Sierra Leone, West Africa reported by Tesema et al. (2022) some species were misidentified as morphospecies of *Labeo barbus* which were confirmed by using Cytb gene-based phylogenetic analyses utilizing BI and ML approaches. The identification of four species (Labeobarbus wurtzi, L. sacratus, Prolabeo batesi, and Raiamas scarciensis) was confirmed (Kanu et al., 2022). *Raiamas steindachneri* was placed under a taxonomic uncertainty however more data is needed to ascertain the species. However, two species of Labeo from the RR basin are demonstrated to be currently misidentified, and so are four species of *Enteromius*.

Hayes (2020) also reported new species, *E. alberti* and *E. mimus*, were previously considered conspecific, respectively, with *E. perince* and *E. stigmatopygus* in West Africa. Decru et al. (2013) also reported deep divergence among four morphology-based species of *Enteromius* from the northeastern part of the Congo River basin, and their reported genetic divergence was greater than 5% and even up to 20% between lineages of morphologically similar specimens, clearly surpassing the 2% threshold (Decru et al., 2013). Taxonomic revisions of fish in the upper Guinean ecoregion suggest the likely discovery of new species in the Fouta Djallon Highlands. Integrative analyses applied to the African mountain catfish (Amphilius spp.) of Fouta Djallon Mountain resulted in the discovery of at least nine new species of Amphilius and small barbs (Kanu et al., 2022). Only 11 morphospecies of cyprinid fish from the Rokel River basin were investigated here in a molecular phylogenetic context, but seven of them were shown to be misidentified or of taxonomic uncertainty (Kanu et al., 2022). If this level of scrutiny is extrapolated to all morphospecies collected from the Rokel River basin, it is likely that new species and even more endemic species may be discovered.

Conservation Status of *Enteromius spp.*

The revelation of unrecognized diversity of genus *Enteromius* fish from the Rokel River and many other basins in this review suggests important implications for the conservation of biodiversity (Kanu et al., 2022). Inaccurate taxonomy on purely morphological or molecular grounds only leads to an underestimation of species richness and endemism, which can misdirect conservation efforts (Lean, 2019). However, our DNA molecular approach used is not enough to identify species for conservation efforts, and combining DNA data with a morphological approach gives a better understanding of species diversity.

An integrative taxonomic revision of genus *Enteromius* from different basin in the future is likely to confirm many existing species under the genus *Enteromius* (Binta et al., 2019). Species such as *L. parvus*, *L. coubie, E. ablabes, and E. macrops*, from Siera Leon basin are not listed as target species for conservation planning and priority, probably due to the underestimated level of endemism and the overestimated level of widely distributed populations due to mis-identification (Kanu et al., 2022). Most Afrotropical ecoregion are presently not listed among the priority freshwater Key Biodiversity or Areas Biodiversity Hotspot due to mis-identification (Harvey et al., 2021). Unveiling this undetected diversity for example, Rokel River basin fish might warrant reconsideration for conservation priorities.

There are two species of *Enteromius* (*E. foutensis and E. liberiensis*), placed under endemism in upper Guinean region, which are listed Endangered (EN) (Kanu et al., 2022). The two putative species have a narrower distribution than previously identified morphospecies and hence need to review the classification. Some fish in the genus *Enteromius* have shown serious extent to which they are under threat is more severe than presently supposed due to the occurrence under small geographical area (Acosta et al., 2020). As fish under genus *Enteromius* keeps classified appearing isolated habitats with varying conditions, the need for characterization before they are extinct. Fragmentation of habitats like man-made dams, isolated pools and land use change in headwater streams threatens the biodiversity and identification if fish under the genera *Enteromius*.

CONCLUSION

The future of genera *Enteromius spp.*, (the small, diploid Asian barbs) represents a model for examining the small, diploid African barbs. The use of morphomeristic measurements to characterize fish species give an insight towards those species that remains poorly characterized. Management of aquatic resources in the Afrotropics, biological assessment has not been widely used to evaluate the level of degradation of streams and rivers. The evidence of most unidentified species under the genera *Enteromius*, provides the need for morphomeristic studies to evaluate the spatial distribution of *Enteromius spp*. Following the low diversity of fish species in the headwaters of many rivers in the Afrotropics, it is important to hasten identification in order to model management practices before most species extinct. The review demonstrates the need for morphological studies resolve relationships among *Enteromius* and related taxa, and provide the framework for these future taxonomic decisions.

RECOMMENDATION

clear insight in the number of species within genera *Enteromius spp*. is urgently needed to address conservation issues. When the number of species is highly underestimated, the decline of species may also be far worse than initially detected. Therefore, using morphomeristic measurements can be of key importance for traditional taxonomy in accelerating the pace of species detection and description. By applying molecular in combination with multivariate analyses of morphometric data to several *Enteromius* populations from the Afrotropic and the relevant type specimens, the number of species under genera *Enteromius spp.* identified will increased from current status. Considering the fact that some species are endemic to specific locality, imply a high variability in morphomeristic measurements that may increase of the number of species within this genus when extrapolated to the entire African continent.

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