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Research Article

Diversity and Morphometric Characteristics of Some *Labeobarbus* Species in the Gumaro River, in Lake Tana Sub-Basin, North-Western Ethiopia

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This study explored the distribution, diversity, and morphological characteristics of some *Labeobarbus* species in the Gumaro River from August 2021 to January 2023. A total of 348 specimens, belonging to 12 species, were collected from three sites. Catches were dominated numerically (85.5% of the total catch) by *Labeobarbus nedgia*, *Labeobarbus intermedius*, *Labeobarbus beso*, and an unidentified species that appeared to be a potential hybrid. Abundance, distribution, and Shannon diversity values differed between sites, possibly due to the presence of natural barriers. To characterize the potential hybrid species, 28 morphometric and 13 meristic characteristics were measured and compared with most closely related species, including *L. nedgia* and *L. beso*. Principal component analysis (PCA) was used to compare the morphometric characteristics of these three groups only for fresh specimens. Morphometric characterization of the unidentified species showed that some characteristics had a common identity with both *L. nedgia* and *L. beso*, indicating potential hybridization. However, some morphometric characteristics, particularly the head and mouth profiles, indicated a significant difference between *L. nedgia*, *L. beso*, and the putative hybrid species. Most meristic characteristics were similar between the known and unidentified species. Therefore, this potentially hybrid species needs molecular characterization to confirm its genotypic identity. An expanding presence of instream barriers within the Lake Tana tributaries may be leading to increased potential for hybridization among its endemic *Labeobarbus* species.

Keywords: abundance; fish diversity; hybrid species; *Labeobarbus* species; phenotypic characterization

1. Introduction

Ethiopia has abundant freshwater fish species, including more than 206 fish species, of which 38 are endemic to the country [1]. Lake Tana is the largest lake in Ethiopia and one of the top 250 lake regions in the world for its contribution to biological, ecological, and conservation values [2] and is recognized as a UNESCO Biosphere Reserve site due to its rich biodiversity [3]. The lake and its tributaries are home to an estimated 28 fish species from six genera (*Clarias, Enteromius, Garra*, *Labeobarbus*, *Nemacheilus,* and *Oreochromis*) [4, 5]. Lake Tana contains 17 *Labeobarbus* species, at least half of which are endemic to the country [4, 6]. In Ethiopian highland rivers, adaptive radiation is common in most cyprinid fish [7], and adaptive speciation and radiation have occurred within the Lake Tana *Labeobarbus* species flock for the last 10,000–25,000 years [8].

Cyprinidae are the most diverse and predominant freshwater fish globally [9] and are characterized by a diversity of body sizes, shape, and biological traits. Changes in trophic resources are considered the main force behind the differentiation of various species in cyprinid fishes, such as the diversification of mouth polymorphism in some lacustrine and riverine *Labeobarbus* assemblages [6]. Some unique morphometric traits of fish alter with changing dietary adaptations due to ecological diversification and environmental degradation [6, 10].

Lake Tana *Labeobarbus* species flocks are characterized by low genetic divergence, speciation, and hybridization, which makes it difficult to distinguish these species genetically [4, 7, 11]. *Labeobarbus* species have distinct features that encompass various morphometric characteristics, including head and body morphology, barbel structure, mouth shape, eye size, head profile, and upper and lower lip structures [4, 12]. Through a combination of molecular and ecomorphological approaches, evolutionary changes have been detected in Lake Tana *Labeobarbus* due to the specific and divergent selectivity of food types [6]. Morphometric measurements, including digital caliper methods, image-based digital geometric methods, and different taxonomic techniques were used to explore the phenotypic variation, evolutionary adaptations, and relationships of different fish species [13–15].

Over the last 3 decades, the taxonomy, nomenclature, reproductive biology, and ecology of the Lake Tana *Labeobarbus* species flock have been described by a number of studies [4, 12, 16–19]. Reproductive isolation between lacustrine and riverine species, along with spatial and temporal segregation during spawning migration in nine of the 17 species [20, 21], are thought to have contributed to the development of distinct morphometric features [21–23]. Furthermore, the combinations of differences in habitat preference and diet, including for piscivores, molluscivores, detritivores, herbivores, zooplanktivores, and insectivores, were used as an indicator for the distinct variations in morphometric features between the *Labeobarbus* flock in Lake Tana [4, 6, 12].

More than half of Lake Tana *Labeobarbus* species are migratory during their reproduction season to upstream tributary rivers, and some species are lacustrine. However, some studies indicated that lacustrine species were found in upstream tributary rivers during the reproductive season, as well as some riverine species, including *Labeobarbus intermedius, Labeobarbus nedgia*, and *Labeobarbus beso* were found both in lacustrine and riverine habitats [24, 25]. This highlights a lack of clear distinction in the reproductive traits and habitat preferences between some species. Furthermore, there is no clear information why different phenotypes within the same genotypes occur, which comes either due to the presence of speciation or shallow genetic divergence in the Lake Tana *Labeobarbus*, which needs further studies [11]. The overall genetic differentiation among the Lake Tana *Labeobarbus* spp. is by far limited while several studies explored the presence of morphometric and genetic differentiation [8, 11].

Moreover, the diversity and distribution of fish in the Gumaro River have not been studied by any prior researchers, which is noteworthy. Gumaro River is one of the small tributary rivers of Lake Tana. As such, this study aims to explore this novel habitat and its fish diversity and distribution of *Labeobarbus* species and determines the morphological characterization of the unidentified fish species, to aid in future conservation of threatened *Labeobarbus* species.

2. Materials and Methods

2.1. Ethical Statement. This research was carried out under permission from the Addis Ababa University graduate research ethics approval committee and the Department of Zoological Science ethical committee.

2.2. Study Area. The Gumaro River is a small tributary of Lake Tana. It is situated at 12° 23′ 2.4″ north and 37° 33′ 0″ east with an elevation of 1901.23 m above sea level (asl) (Figure 1). The upstream location of the riverbank is characterized by deep valleys (50–80 m) from the tip of the riverbank to the water surface, narrow and steep banks, a riverbed consisting predominantly rocky and gravel, and the shoreline is covered by shrubs and grass. In contrast, the downstream riverbed is pooled and with high sediment and characterized by gully erosion in the riverbank. This downstream region of this river is highly exploited for intensive irrigation activities both in pump-based and small irrigation weirs, and small-scale riverine fisheries. The climate condition of the Gumaro River is dominated by dry season between October and April, and the rainy season is from May to September. The maximum and average flow rates of the Gumaro River record in August were 51.49 and 10.94 m/s, respectively (Source: Abbay Basin Authority).

2.3. Sampling Technique. Three sampling sites were selected based on the suitability of the riverbed for spawning of *Labeobarbus* species and their appropriateness for net setting, including pooled water, sandy, and gravel substrates: (1) a large waterfall site at an altitude of 1890.5 m asl, (2) a small waterfall site at an altitude of 1871 m asl, and (3) a third site at an altitude of 1855 m asl, which is situated downstream of the two upstream sites. However, fish were collected from triplicate sites from each of the three main sites. Fish samples were collected monthly from August 2021 to January 2023, apart from during the peak time of spawning migration in September, during which sampling occurred twice per month. Fish specimens were collected using multifilament and monofilament gillnets with 6 and 8 cm mesh sizes.

2.4. Fish Identification and Morphometric Measurements. Specimens were identified to species level using the keys developed by Nagelkerke [16] and Nagelkerke and Sibbing [4], and species abundance was recorded per main sampling site. After identification and collecting enough samples for each size, some live specimens were released immediately into the water in order to minimize fish death. The unidentified specimens were described based on visual detection and measuring the morphometric characteristics and compared with *L. beso* and *L. nedgia*. These species were selected purposefully, as they show similar characteristics with the

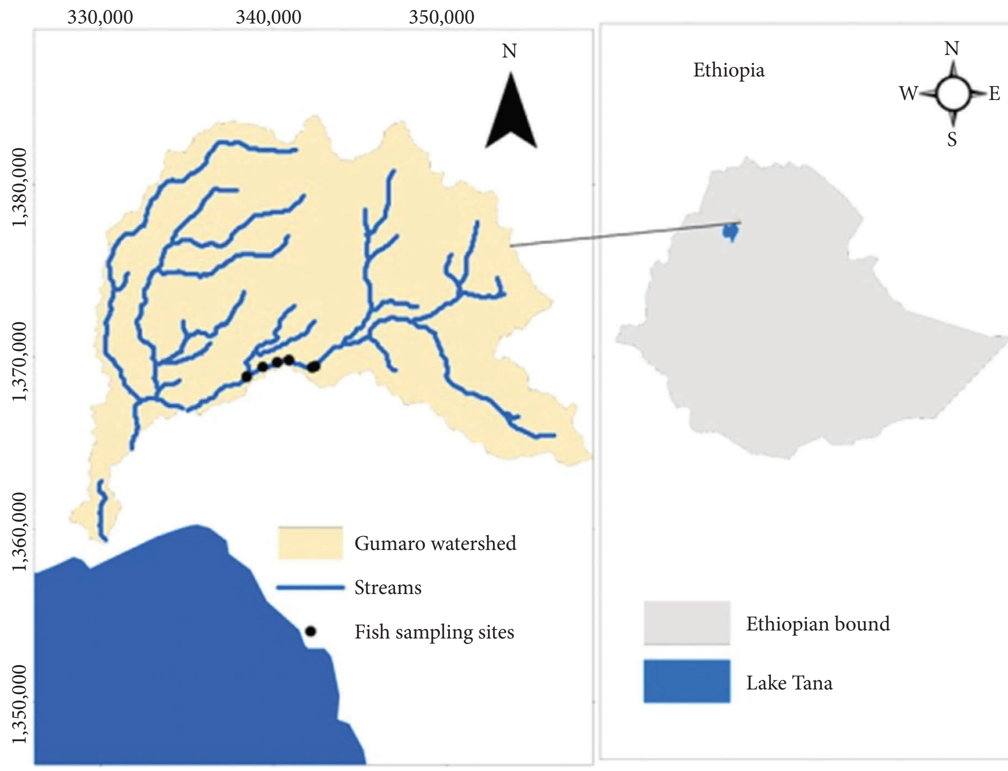

Figure 1: Location of Ethiopia, Lake Tana, and the Gumaro River watershed and fish sampling sites.

unidentified species, including head profile, upper and lower jaws, and lip structures. A total of 28 morphometric and 11 meristic characteristics were measured on fresh specimens for *L. beso* (15 specimens), *L. nedgia* (12 specimens), and *Labeobarbus* hybrids (37 specimens) (Table 1). However, we used only 25 fresh hybrid specimens to compare with other known *Labeobarbus* species because fresh specimens are more reliable to characterize morphological descriptions [26]. A graduated digital caliper was used for measuring morphometric characters with 0.1 mm precision, and a magnifier lens was used to count the meristic variables. Some unidentified specimens were preserved in 80% alcohol and transported to the Bahir Dar Fish and Other Aquatic Life Research Center for further studies.

2.5. Data Analysis. The data of the distribution pattern of each species were plotted using bar graph using Microsoft Excel. Shannon diversity index and species richness were computed using Primer software and compared between the three different sites along the Gumaro River. First, all measured morphometric characteristics were divided by standard length to minimize the size difference effect [13, 27]. Descriptive statistics such as mean, minimum, maximum, and standard deviation were calculated for all morphometric and meristic characteristics of each species. One-way ANOVA was applied for mean comparison of all morphometric characteristics between three species groups. Principal component analysis was used to plot an ellipse based on the morphometric variation between species, using R version 4.2.

3. Results

3.1. Diversity, Abundance, and Spatiotemporal Distribution of Labeobarbus Species. A total of 348 specimens, included 12 species, were sampled from three different sites across the Gumaro River (Figure 2). All species were in the Family Cyprinidae, apart from *Clarias gariepinus* (Clariidae). In total, four dominant species contributed 85.5% of the total specimens, including *L. nedgia* ($N = 103$, 29.6%), *L. beso* (87, 3%), *L. intermedius* (58, 16.7%), and *L.* hybrid (50, 14.4%) (Figure 2). However, seven *Labeobarbus* species, including *Labeobarbus brevicephalus* (25), *Labeobarbus gorgorensis* (10), *Labeobarbus truttiforms* (5), *Labeobarbus tsanensis* (3), *Labeobarbus surkis* (2), *Labeobarbus crassibarbis* (1), and *Labeobarbus platydorsus* (1) were found rarely.

The temporal distribution of *Labeobarbus* species indicated that more abundant and diverse species were sampled during the months of September and October. *L. nedgia* and *L. intermedius* were predominant species in all the study months (Table 2).

The highest Shannon diversity index was found at the small waterfall site, followed by high waterfall site (Table 3). No fish specimens were caught from upstream sites, due to the large waterfall site, which blocked upstream spawning migratory species.

3.2. Phenotypic Description of the Unidentified LabeobarbusSpecies (Labeobarbus hybrid). The phenotypic characteristics of the hybrid specimens were described after investigation of a unique mouth profile compared

Table 1: Morphometric and meristic parameters to compare the hybrid *Labeobarbus* species with *Labeobarbus beso* and *Labeobarbus nedgia*.

Morphometric characteristic	Code	Meristic characteristic	Code
1. Total length	TL	1. Dorsal fin spines/simple	DFS
2. Fork length	FL	2. Dorsal fin rays	DFR
3. Standard length	SL	3. Anal fin spines (simple)	AFS
4. Body depth	BD	4. Anal fin ray (branched)	AFR
5. Body width	BW	5. Pectoral fin (total)	PF
6. Head length	HL	6. Ventral fin (total)	VF
7. Head width	HW	7. Lateral line scales	LLS
8. Eye diameter	ED	8. Predorsal scale	PDS
9. Preorbital	Pre-OL	9. Scales from dorsal fin to lateral line	SDFLL
10. Postorbital	POL	10. Scales from ventral fin to lateral line	SFVL
11. Snout width	SW	11. Scales from anal fin to lateral line	SAFL
12. Snout length	SL		
13. Orbit diameter	OD		
14. Predorsal fin	PDFL		
15. Dorsal fin length	DFL		
16. Dorsal fin base	DFBL		
17. Pectoral fin length	PFL		
18. Pelvic-ventral length	PVL		
19. Pelvic fin length	PFL		
20. Ventral-anal length	VAL		
21. Pre-ventral length	PVL		
22. Anal fin length	AFL		
23. Anal fin base length	AFBL		
24. Preanal length	PAL		
25. Caudal peduncle length	CPL		
26. Caudal peduncle depth	CPD		
27. Caudal fin length	CFL		
28. Tail height	TH		

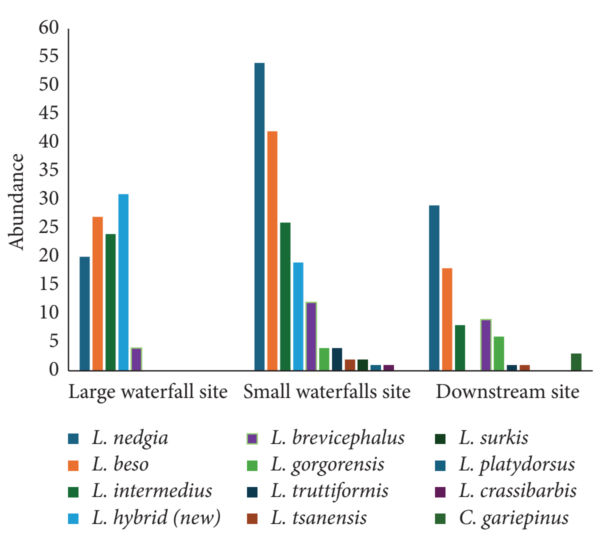

Figure 2: Abundance and distribution of all species sampled at three different sites across the Gumaro River.

with the previously described *Labeobarbus* species (Figure 3). The general head morphology of *L. hybrids* resembles that of *L. nedgia* and *L. beso*, which had a slightly convex head profile, and no nuchal hump. However, the lower and upper lip characteristics of the *L. hybrid* were different from those of the *L. nedgia* and *L. beso* species.

The analysis of morphometric characteristics revealed that *L. hybrid* had similarities and separate morphometric characteristics with *L. beso* and *L. nedgia* (Figure 4). In the second axis of PCA, some of the morphometric characteristics, including PDFL, DFLH, PFL, SL, ED, and PVL, were more pronounced characters for *L. nedgia*. In the first axis of PCA, both *L. nedgia* and *L. hybrid* showed common morphometric characteristics, including HW, BW, HW, DFBL, BD, PVL, CPL, AFBL, and SW.

The analysis of some of the morphometric characteristics, including body depth, head length, head width, eye diameter, predorsal fin length, dorsal fin length, and tail height, showed significant differences between *L. nedgia, L. beso*, and *L. hybrid* (Table 4).

The meristic characteristics of *L. hybrid*, *L. nedgia,* and *L. beso* showed less distinct features. While meristic characteristics were a better tool for phenotypic classification, there was no major difference between the new hybrid species and other *Labeobarbus* species (Table 5). The mean value of the number of scales from anal fin to lateral line and from ventral fin to lateral line and the number of simple and branched dorsal fins were different between *L. hybrid, L. beso,* and *L. nedgia*.

4. Discussion

Over the past 30 years, extensive research has been done on the reproductive biology and spatiotemporal assemblage

Table 2: Temporal distribution of all fish species sampled from the Gumaro River in 2021–2023.

Study month	Sampling	*L. beso*	*L. brevicephalus*	*L. crassibarbus*	*L. gorgorensis*	*L. intermedius*	*L. nedgia*	*L. platydorsus*	*L. surkis*	*L. truttiformis*	*L. tsanensis*	Putative *L. hybrid*	*C. gariepinus*
March	1	10	0	0	0	5	0	0	0	0	0	9	0
August	2	10	6	0	3	7	9	0	0	1	0	0	0
September	3	11	11	0	4	5	8	1	2	1	0	2	0
September	4	19	3	1	2	16	24	0	0	1	3	6	0
October	5	7	5	0	1	8	33	1	0	1	0	13	3
November	6	6	0	0	0	14	13		0	0	0	8	0
January	7	24	0	0	0	3	16	0	0	0	0	12	0

Table 3: Shannon diversity index and species richness of the pooled fish species sampled from three different sites along the Gumaro River.

Sample	Species richness (D)	Species evenness (J′)	Shannon–Weaver index (H′)
Large waterfall site	6.585	0.990	3.264
Small waterfall site	8.170	0.981	3.517
Downstream site	6.228	0.982	3.121

Figure 3: Pictures for the morphological comparison of the head and mouth profile of the *Labeobarbus beso, Labeobarbus nedgia*, and putative *Labeobarbus hybrid* specimens sampled from the Gumaro River.

structure of *Labeobarbus* species across tributaries of Lake Tana [4, 16, 18, 19]. However, this study revealed the spatiotemporal distribution and phenotypic characteristics of the *Labeobarbus* species in the Gumaro River, which is a newly investigated river that has not been previously studied. Among the 12 species collected from the Gumaro River, *L. nedgia* was the most dominant, followed by *L. beso* and *L. hybrid*. Other studies also found these dominant species in different tributary rivers of Lake Tana, apart from *L. hybrid* [17, 19, 20, 28]; however, *L. intermedius* and *L. brevicephalus* were the predominant catch in most tributary rivers of Lake Tana [19, 23, 24].

This study revealed that the Gumaro River is the main spawning grounds of Lake Tana migratory *Labeobarbus* species, while natural waterfall barriers influenced the upstream migration and assemblage structure of fish. Additionally, the presence of anthropogenic pressures, including fishermen, sand mining, and irrigation activities may influence the distribution pattern of fish in the Gumaro River. Other studies have also reported similar findings from different tributary rivers of Lake Tana [29, 30]. In the current study, the Shannon diversity index (H′) was higher in the Gumaro River, ranging from 3.12 to 3.5; particularly more abundant and diverse *Labeobarbus* species were found at the small waterfall site. In comparison with other Lake Tana tributaries, higher fish diversity is found in the Gumaro River, which might be due to the presence of different habitats and anthropogenic pressures [19, 31]. In addition to the anthropogenic pressures, the diversity and distribution of fish in the Lake Tana tributaries were influenced by different morphological and ecological variability of the river [32].

The temporal variation of fish in the Gumaro River was influenced by different seasons, which influence the river flow rate and volume. During the dry season, the flow rate totally stopped, and only pooled water was available for fish. In line with the several other studies, we found that most of the migratory *Labeobarbus* species found more abundant in September and October. Similar studies were reported that more abundant and diverse species found in the rainy and

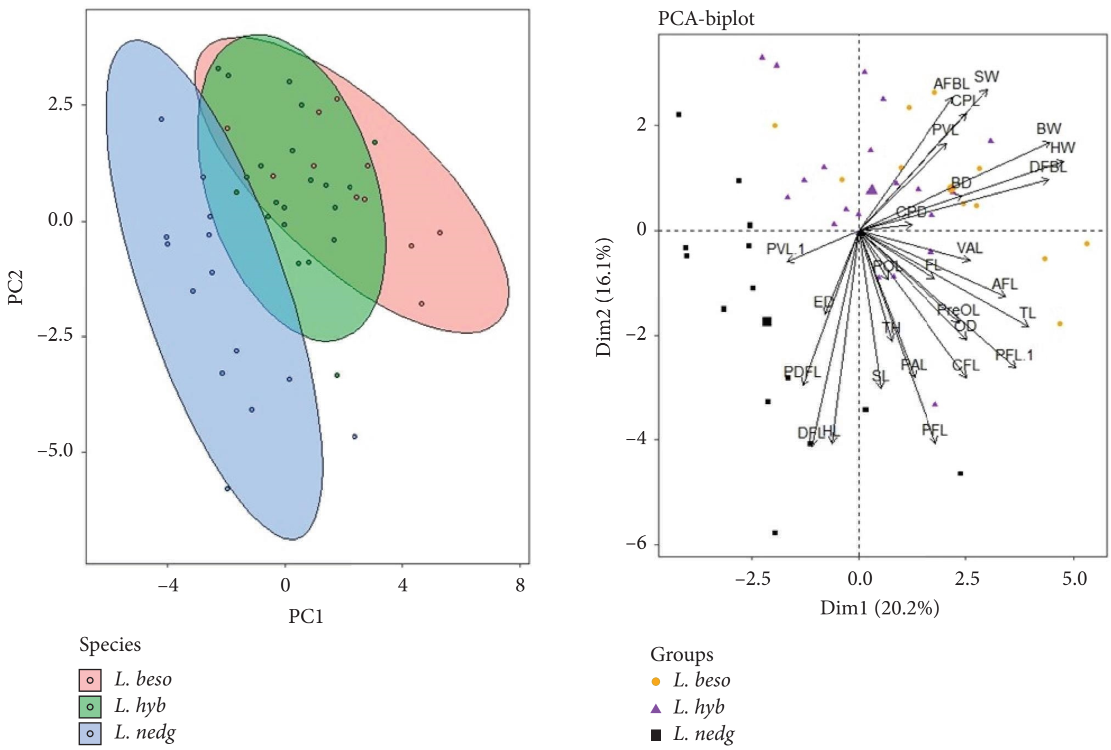

Figure 4: Principal component analysis of morphometric variation between *Labeobarbus* hybrid, *Labeobarbus beso*, and *Labeobarbus nedgia*.

postrainy seasons [23–25]. *L. nedgia, L. beso,* and *L. intermedius* were found dominant in both the rainy and dry seasons. Similar to other studies, these species were found both in riverine and lacustrine habitats [6, 18, 19], which could be the potential cause for their dominance in both seasons.

The characterization of the morphometric and meristic characteristics of the new unidentified *Labeobarbus* species indicated that there could be a potential hybrid species between *L. beso* and *L. nedgia*. In particular, the presence of distinct features, especially the head and mouth profiles, suggest that it may be a new species. However, further investigations, both molecular and laboratory cross breeding tests are necessary to confirm new or hybrid species as the Lake Tana *Labeobarbus* population is known for its distinct and elastic phenotypic features [11].

Lake Tana *Labeobarbus* species showed less genetic differentiation but are morphologically different, which indicates the variation comes due to being influenced by ecological functions or adaptive radiation [11]. Some of the *Labeobarbus* hybrid specimens had a less developed upper lip, such as *L. nedgia* (although some hybrids did not have an upper lip) but had no lower lips in the lower jaw, unlike *L. nedgia*. The lower jaw is continuous, which is consistent with *L. beso;* however, the strength and shape differ. Furthermore, *L. hybrid* has no lobe lip unlike *L. nedgia* and *Labeobarbus degeni* (Figure 4). The mouth size of *Labeobarbus* hybrid was similar to those of *L. intermedius*, while it was smaller than *Labeobarbus megastoma* and *Labeobarbus macrophtalmus*. Similarly, the size of eye was larger than *L. megastoma* and smaller than *L. macrophtalmus*. Moreover, the head profile was no big unlike *Labeobarbus longissimus and Labeobarbus daniellii*. In general, body shape of *Labeobarbus* hybrid is also different from *L. brevicephalus* which has no short head and also has no carp and trout-like body shape structure unlike *L. surkis* and *L. truttiforms*, respectively [4]. The evolutionary diversification of the Lake Tana *Labeobarbus* might be due to resource partitioning [33].

Although Nagelkerke and Sibbing [4] described *L. nedgia* as a single species, we found three different phenotypic characteristics that need further study to confirm the presence of subspecies or not. We found *L. nedgia* specimens which had (1) a well-developed upper lip only, (2) a less developed upper and lower lip, or (3) a well-developed upper and lower lip. However, some of *L. nedgia* which has extra lobes in the upper and lower lip should be described as a single species.

In the study river, we observed that fish migration was influenced by the natural barrier (waterfall). This could be the cause for creating a cutoff population during reproductive season between the upper and lower natural waterfalls. During the spawning migration period, the mature female and male fishes will have a chance to be separated due to the presence of natural barriers while they migrate together due to different capabilities to move over the waterfall. This assumption supported the fact that during the dry season, we found only male *L. nedgia* and female *L. beso* in the pooled site located below the waterfall site where all the hybrid specimens were collected (below the large and small waterfall sites of the Gumaro River). Thus, this indicates there is a probability that different

Table 4: Morphometric characteristics of *L. hybrids*, *L. nedgia* and *L. intermedius*.

Morphometric measurements	Code	*L. hybrid* (24 specimens)					*L. nedgia* (15 specimens)					*L. beso* (12 specimens)				
		Min	Max	Mean	SD.	Range	Min	Max	Mean	SD.	Range	Min	Max	Mean	SD.	Range
Total length	TL	205.0	380.0	257.1	38.0	175.0	250.0	305.0	275.4	16.3	55.0	215.0	290.0	260.7	20.9	75.0
Fork length	FL	195.0	330.0	229.5	32.5	135.0	220.0	275.0	245.4	15.8	55.0	190.0	258.0	230.3	18.4	68.0
Standard length	SL	177.0	310.0	209.6	30.0	133.0	200.0	250.0	224.7	14.1	50.0	170.0	230.0	210.4	17.3	60.0
Total body weight	TW	108.4	414.3	178.0	67.9	305.9	123.0	260.0	183.1	40.9	137.0	115.0	234.8	188.9	38.0	119.8
Body depth	BD	22.0	45.0	30.9	4.1	23.0	25.2	36.6	31.2	3.1	11.4	27.5	34.6	30.8	2.2	7.1
Body width	BW	48.0	85.0	57.3	7.6	37.0	46.0	62.2	55.0	4.2	16.2	53.0	68.1	63.3	4.8	15.1
Head length	HL	30.0	51.0	37.7	5.2	21.0	36.5	51.1	42.9	3.9	14.6	29.1	43.0	36.6	4.0	13.9
Head width	HW	15.0	27.0	18.6	2.5	12.0	14.4	20.9	16.9	1.7	6.5	14.4	22.0	18.5	2.1	7.6
Eye diameter	ED	5.6	9.0	7.1	0.8	3.4	5.9	9.3	7.7	1.1	3.4	5.6	7.7	6.8	0.5	2.1
Preorbital length	Pre-OL	13.0	26.0	17.2	2.9	13.0	15.2	21.2	17.9	1.7	6.0	14.5	19.0	17.1	1.7	4.5
Postorbital length	POL	14.1	25.0	18.3	2.7	10.9	14.7	20.1	17.6	1.7	5.4	12.4	19.0	15.9	1.9	6.6
Snout width	SW	8.4	17.0	11.0	1.7	8.6	8.3	12.6	9.6	1.2	4.3	7.3	12.3	10.5	1.3	5.0
Snout length	SL	10.0	17.0	11.9	1.4	7.0	10.0	17.2	12.9	2.0	7.2	9.5	14.0	11.6	1.6	4.5
Operculum depth	OD	17.2	30.0	22.5	2.9	12.8	12.0	28.6	22.5	3.9	16.6	17.8	26.0	21.9	2.5	8.2
Predorsal fin length	PDFL	52.4	143.0	85.7	16.6	90.6	60.6	125.7	107.1	14.9	65.1	52.3	101.4	88.9	15.2	49.1
Dorsal spine fin length	DFL	30.0	59.0	45.4	5.8	29.0	41.4	56.4	50.4	4.1	15.0	37.2	48.3	41.4	3.3	11.1
Dorsal fin base length	DFBL	24.0	47.0	32.5	5.0	23.0	27.3	35.6	31.2	2.5	8.3	30.4	40.0	35.1	3.5	9.6
Pectoral fin length	PFL	24.0	57.0	39.7	6.3	33.0	39.5	48.2	43.5	2.8	8.7	34.2	46.0	39.9	3.7	11.8
Pectoral-ventral length	PVL	46.0	93.0	57.9	9.1	47.0	50.8	67.7	59.3	4.8	16.9	50.3	68.2	58.9	5.4	17.9
Ventral fin length	VFL	30.2	50.0	36.6	4.7	19.8	32.4	42.1	37.6	2.7	9.7	31.1	42.0	36.2	3.4	10.9
Ventral-annual fin length	VAL	40.0	77.0	55.0	8.6	37.0	47.7	66.0	56.7	5.6	18.3	43.8	60.0	54.2	5.1	16.2
Pre-ventral length	PVL	57.0	153.0	99.4	17.8	96.0	97.6	127.9	111.8	8.2	30.3	37.6	114.0	97.9	19.8	76.4
Anal fin length	AFL	29.0	55.0	39.6	6.0	26.0	32.4	47.5	41.3	3.5	15.1	31.5	49.2	40.4	5.1	17.7
Annal fin base length	AFBL	13.6	25.0	17.1	3.0	11.4	14.2	21.1	17.4	1.8	6.9	13.0	24.0	17.7	3.2	11.0
Pre-anal length	PAL	128.0	235.0	153.3	22.8	107.0	148.4	181.6	163.5	11.1	33.2	127.8	171.0	151.7	12.4	43.2
Caudal peduncle length	CPL	56.0	115.0	76.6	11.9	59.0	67.4	89.1	78.0	6.5	21.7	61.2	88.9	77.8	9.1	27.7
Caudal peduncle depth	CPD	13.0	29.0	20.6	3.6	16.0	20.0	28.8	23.6	2.9	8.8	19.9	29.7	23.7	3.0	9.8
Caudal fin length	CFL	39.0	73.0	49.7	7.8	34.0	46.0	62.0	55.3	4.1	16.0	45.1	60.0	52.2	4.7	14.9
Tail height	TH	52.0	113.6	73.6	13.2	61.6	70.2	99.2	88.5	7.4	29.0	67.0	106.8	89.2	9.4	39.8

Note: Min = minimum and Max = maximum. All measurements in mm, apart from weights in gram.
Abbreviation: SD. = standard deviation.

Table 5: Meristic characteristics of *Labeobarbus nedgia*, *L. beso*, and the putative *Labeobarbus hybrid*.

Meristic characteristics	Code	Putative *Labeobarbus hybrid*				*L. nedgia*				*L. beso*			
		Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
Dorsal fin spines/simple	DFS	1	2	1.08	0.28	1	1	1	0	1	2	1.2	0.4
Dorsal fin rays (branched)	DFR	8	10	9.08	0.43	8	9	8.7	0.5	9	10	9.6	0.5
Anal fin spines (simple)	AFS	1	2	1.08	0.28	1	1	1	0	1	1	1	0
Anal fin ray (branched)	AFR	5	8	6.05	0.66	5	6	5.9	0.3	6	6	6	0
Pectoral fin (total)	PF	11	16	13.54	1.26	12	14	12.9	0.6	12	15	12.8	0.9
Ventral fin (total)	VF	8	10	9.05	0.4	8	9	8.9	0.3	8	9	8.9	0.3
Lateral line scales	LLS	30	36	33.38	1.32	30	35	32.1	1.4	31	34	32.4	1
Predorsal scales	PDS	9	14	11.95	1.08	11	14	12.4	0.9	11	13	11.8	0.6
Scales from dorsal fin to lateral line	SDFLL	5	7	6.22	0.48	6	7	6.2	0.4	6	6	6	0
Scales from ventral fin to lateral line	SFVL	3	6	4.08	0.55	3	4	3.9	0.3	4	6	4.3	0.8
Scales from anal fin to lateral line	SAFL	3	5	4.46	0.77	4	5	4.9	0.3	4	6	5	0.4

Note: Min = minimum and Max = maximum.
Abbreviation: SD. = standard deviation.

species could undergo mating during their reproductive season. A similar assumption was reported: When only females are available, they prefer to mate with conspecific males, resulting in hybrids [34]. Human intervention can also trigger hybridization processes due to overfishing during spawning, which could be the case for *Labeobarbus* species as local fishermen are intensively fishing during spawning migrations. Furthermore, Culicchi [34] reported that eutrophication and turbidity were two potential causes of the hybridization of fish in a freshwater environment.

While the complex haplotype of *L. intermedius* caused the presence of 15 distinct *Labeobarbus* species in Lake Tana [4, 12], morphological and molecular studies of the lake species showed the presence of basic genetic differentiation [8, 11]. The presence of evolutionary differentiation among the Lake Tana *Labeobarbus* species population might be due to the presence of shallow gene divergence and the plasticity of phylogenetic properties [7]. Furthermore, beside phenotypic plasticity, hybridization is one of the potential causes for the complex origins of mouth polymorphism in *Labeobarbus* species, which is reported in the Inkisi River in the Congo River Basin [35]. Thus, detailed studies are required for the whole genome of Lake Tana *Labeobarbus* species, which helps to determine the diversity, evolutionary change, and taxonomic variation of the lake species.

5. Conclusion

The Gumaro River is a hot spot for local fish diversity as it provides habitat for 12 different fish species. It is the main spawning ground for migratory and threatened *Labeobarbus* species. The spatiotemporal distribution of the *Labeobarbus* species was different across the Gumaro River, which is influenced by the presence of natural barriers (waterfall) and the variability of seasons. As evident in the analysis of the morphometric characterization of the unidentified *Labeobarbus* species, our findings suggest that hybridization has occurred between *L. beso* and *L. nedgia*. However, the overall Lake Tana *Labeobarbus* species population needs molecular characterization to determine population genetics and conservation strategies.

Data Availability Statement

The corresponding author can provide the data supporting the study's findings upon reasonable request.

Ethics Statement

The fish specimens used in this study were deceased at the time of gaining from fishermen, which has no specific animal rights or welfare consideration were note noted during the field work.

Disclosure

All authors read and approved of the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

G.T. developed the study design, data collection, data analysis, and manuscript writing. G.T., A.G., and M.M. contributed to securing research grants. All authors contributed to the manuscript writing, data collection, and analysis and approved the final version.

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