



Species diversity, some biological aspects of fishes and water quality of Terie River, Beshilo Basin, Ethiopia

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Abstract

The study was conducted in the Terie River between January and April 2022. The objectives of the study were to assess the fish species composition, determine the length-weight relationship and condition factor and assess the water quality of the river using international water quality guideline for aquatic life. Gillnets with different mesh sizes, 4, 6, 8 and 10 cm were used to collect fish specimens in both dry and wet seasons. Immediately after capture, the total length (TL) and total weight (TW) of each individual were measured in centimeters and grams, respectively, and their relationship was determined using the power function. The physicochemical water quality parameters were analyzed using standard procedures and wagtch portable water quality Kits and Secchi Disk apparatus. A total of 667 fish specimens were collected from the Terie River, 410 and 257 in dry and wet seasons respectively. A total of six fish species, *Oreochromis niloticus*, *Labeobarbus intermedius*, *Labeobarbus nedgia*, *Labeobarbus beso*, *Clarias gariepinus*, and *Ramius loti* were recorded. For length-weight relationship and condition factor analysis, more abundant fish species (*O. niloticus* and *L. intermedius*) which were found in both seasons were selected. The length and weight relationship of *L. intermedius* were $TW = 0.0073TL^{3.04}$ in dry and $TW = 0.0337TL^{2.59}$ in wet season indicated isometric and negative allometric growth respectively. While *O. niloticus* showed negative allometric growth, $TW = 0.096TL^{2.44}$ and $TW = 0.0335 TL^{2.76}$ in dry and wet seasons, respectively. The mean Fulton condition factor (FCF) of *L. intermedius* were 0.85 ± 0.03 and 0.94 ± 0.25 in dry and wet seasons, respectively. The FCF of *O. niloticus* was 1.70 ± 0.13 and 1.73 ± 0.12 in dry and wet seasons respectively. Except for ammonia, the physicochemical water quality parameters were within the permissible limit for aquatic life and are suitable for fishes Terie River. The river has commercially important fish specimens that could be used for food security and livelihood improvement. However, there is very limited fishing activity in the river due to less awareness on the value of fishes. Therefore, sustainable fishery development should be done in the river.

Keywords: Condition factor, Fishery development, Gillnets, Length-weight relationship, Physicochemical water quality parameters

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Introduction

Freshwater rivers have very important ecosystem services, provisional, regulations, supporting, cultural and religious activities (MEA, 2005). Fish is one of the provisional ecosystem services that has both ecological and commercial importance in aquatic ecosystem and for human needs (MEA, 2005).

Ethiopia has many lakes and rivers which are small to large size. Though the actual size of these water bodies were not documented, roughly, the country has about 7,400 km² of lake area and about 7,000 km of river length (Wood & Talling, 1988). Recently new dams like Grand Ethiopian Renaissance Dam and other small and medium sized dams are being constructed for hydroelectric and irrigation activities. In East Africa, Ethiopia is the water-tower and endowed with several water bodies that contain a high diversity of fish (Golubtsov & Darkov, 2008; Golubtsov & Mina, 2003).

Ethiopia has no long history in fish species investigation. The first review, conducted by Shibru (1973) reported 93 fish species. Following this, other researchers, Getahun and Stiasny (1998) reported 65 fish species from Blue Nile Basin, Getahun (2005); Stiasny & Getahun (2007) reported about 193 fish species (153 indigenous, 40 endemic and 10 exotic species) in different freshwater bodies of the country and Golubstov & Darkov (2008) reported 113 fish species from six major drainage basins of Ethiopia including Blue Nile. Since 2006, fish species investigation in rivers of Ethiopia has been conducted by different MSc students mainly by Addis Ababa, Bahir Dar and Wollo Universities. Bahir Dar Fishery and Other Aquatic Life Research Centers has also played significant role in fish species investigation. Although, the fish species investigation is not complete, the diversity of fish species in Ethiopia is estimated to be more than 200 species (Mengesha, 2015; Tesfaye & Wolff, 2014).

Despite the above efforts made on fish species investigation, many of small, medium and large rivers of the country are not fully explored (Getahun, 2017; Mekonen & Hailu, 2021; Mengesha, 2015). Terie River is one of such rivers that have been poorly explored. There was no exhaustive systematic research has been done on the diversity, abundance and biology of fishes in Terie River, one of the major rivers in Blue Nile basin originated from the highlands of Wollo area. Therefore, this study aimed to assess the fish diversity, determine length weight relationship and Fulton condition factor (FCF) of fishes and assess some physicochemical water quality parameters of the

river. The findings are expected to enhance knowledge on fish diversity and biology of fishes in unexplored rivers like Terie River. The findings will be also used as baseline data for further fish biodiversity investigation.

Materials and Methods

Study area

Terie River is one of the major tributaries of Beshilo River. Beshilo River is one of the 16 major tributaries of Abay (Blue Nile River). Terie River joins Beshilo that joins Abay River (Fig. 1). Terie River is located in Delanta District of South Wollo Zone of Amhara Region, Northeastern Ethiopia.

“Terie” River is formed from Dry River (“Derek wenz”) and “Masoria” River. Both of them originate at the higher areas of Woldya. “Derek wenz” begins around Mersa and it is called ‘Workiju’ (the Gold hand). “Masoria” River is relatively big river that originates from the high lands of “Woldya” called “Anbesa Maseria”. When “Masoria” River goes down receiving water along its way, it gets larger and wider and now known as ‘Tirgia’ (meaning large and strong river). Tirgia and “Workiju” Rivers join and form “Terie” River at a distance of about 2 km from the origin of Beshilo River (Mogous, 2007).

Methods

Site selection and sampling

In this study, two sampling sites were selected based on the habitat type (depth and nature of bottom substrate type), accessibility and fish population. Site 1 was shallow in depth and muddy bottom substrate whereas Site 2 was deeper and rocky bottom substrate. The geographic locations of Site 1 and Site 2 in UTM were (X: 549844, Y: 1255489) and (X: 554133, Y: 1249735), respectively. Each sampling site was sampled twice during the dry season (January) and twice during the wet season (April) in 2022. Gillnet of stretched mesh size of 4, 6, 8 and 10 cm were used to sample fish by setting the gillnets. Total length and weight of all specimens of fish were measured. Pictures were taken for each species. After taking all the necessary information individual specimen was preserved with 4% formalin in plastic jar and transported to the Wollo University laboratory for further identification and measurement.

Laboratory studies

In Biology department, Wollo University, specimens of fish were soaked in tap water for one day to wash the formalin and were

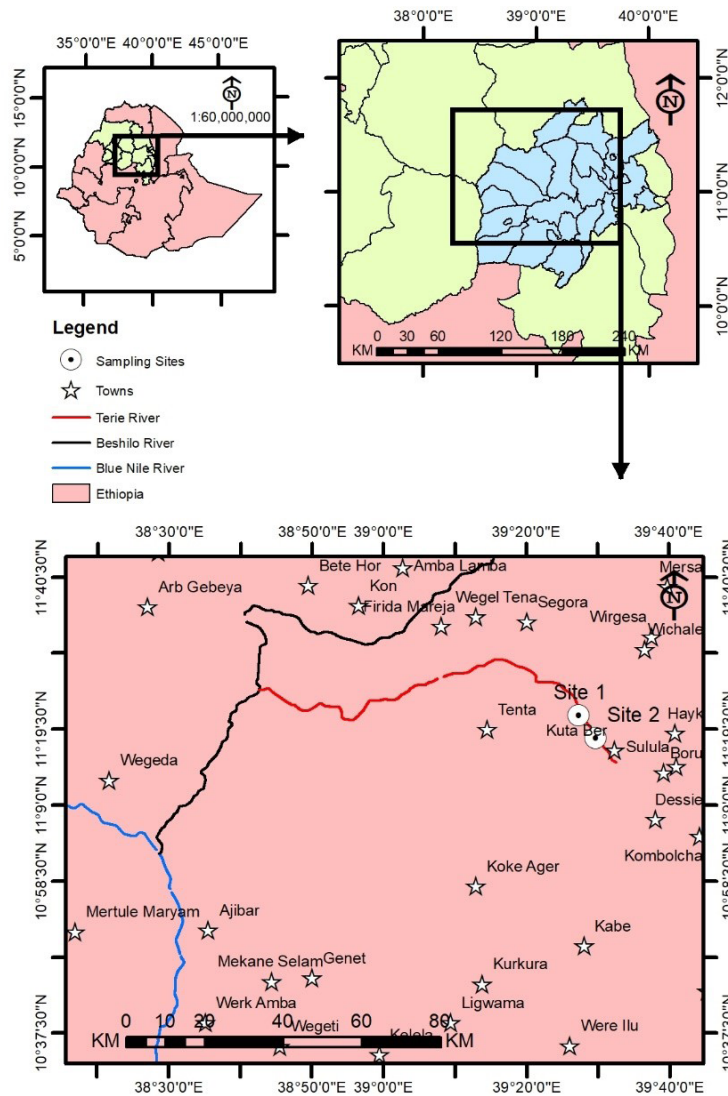


Fig. 1. Map of Terie River and the sampling sites, South Wollo Ethiopia, Northeastern Ethiopia.

identified by identification keys (Getahun, 2017; Golubtsov et al., 1995).

Species diversity

The diversity of fish was determined using the Shannon diversity index (H'). The Shannon index of diversity is a measure of species weighed by the relative abundance (Begon et al., 1990). Shannon index of diversity (H') was calculated using the formula below:

$$H' = \sum Pi \ln pi \tag{1}$$

where pi is the proportion of individuals in the i^{th} species. Shannon index was used to indicate diversity of fishes at different sampling sites or rivers.

Length-weight relationship

The relationship between total length and total weight of most dominant fish (*O. niloticus* and *L. intermedius*) was calculated using power function as in Bagenal & Tesch (1978).

$$TW = aTL^b \tag{2}$$

where TW is the total weight (g), TL is the total length (cm), a is

the intercept of regression line, b is the slope of regression line.

Condition factor (Fulton factor)

The wellbeing of each dominant species was studied by using FCF (Bagnal & Tesch, 1978).

$$FCF = \frac{TW}{TL^3} \times 100 \quad (3)$$

where TW is the total weight in gram and TL is the total length in cm.

Water quality analysis

A total of nine physicochemical water quality parameters (pH, dissolved oxygen (DO), water temperature (WT), Conductivity, TDS, nitrate, phosphate, ammonia and Secchi disk) analysis were done in both dry and wet seasons from the two sampling sites. The pH, DO (mg/L), WT (°C) and conductivity (µS/cm) were measured using Wagatech portable multimeter, nitrate (mg/L), ammonia (mg/L) and phosphate (mg/L) were analyzed with Palintest photometer 7,500 model and the Secchi Disk depth (cm) was measured using Secchi disk apparatus.

Data analysis

Fishery and water quality data

Fish diversity and length-weight ratios were determined using Shannon index and regression, respectively. In addition to this, tables and frequencies were used to summarize the data. Independent *t*-test was used to compare the mean physicochemical water quality parameters difference between seasons and sites. SPSS 20 and Excel 2010 were used to conduct the descriptive and inferential statistics.

Results and Discussion

Fish diversity

A total of six fish species, *Labeobarbus nedgia*, *Labeobarbus beso*, *Ramius loti*, *Labeobarbus intermidus*, *O. niloticus* and *Clarias garipinus* were recorded from Terie River. The first four fish species are members of the family Cyprinidae, the other fish species are member of Cichlidae and Clariidae, respectively (Table 1). In the present study, number of fish species were more in dry season ($H' = 1.36$) than wet season ($H' = 0.49$). The fish species diversity also varied with sampling sites, more fish species in deeper and rocky site (six species) and only one species in muddy and

Table 1. Fish species composition of Terie River (present (+), absent (-))

No	Scientific name	Family	Dry season		Wet season	
			Site 1	Site 2	Site 1	Site 2
1	<i>Labeobarbus nedgia</i>	Cyprinidae	+	-	-	-
2	<i>Labeobarbus beso</i>	Cyprinidae	+	-	-	-
3	<i>Ramius loti</i>	Cyprinidae	+	-	-	-
4	<i>Labeobarbus intermidus</i>	Cyprinidae	+	-	+	-
5	<i>Oreochromis niloticus</i>	Cichlidae	+	+	+	+
6	<i>Clarias garipinus</i>	Clariidae	+	+	+	+

shallow site. Therefore, the fish species diversity was different between sites and seasons. The higher fish species in dry season could be due to less challenge from water velocity (less), availability of pools for feeding and reproduction and better water quality for their biology though the clarity of the water in dry season also has some challenges such as exposure to predation and fishing mortality (Gebremendhin & Mingist, 2014; Getahun et al., 2020; Tewabe, 2008). The lower fish diversity in wet season could be due to high rainfall, wood logs, leaves and roots which were brought by flooding could have decreased the efficiency of gill-nets and some less tolerant fish species could be washed away by the flood. This result is in consistent with previous study conducted in some rivers of Ethiopia, Upper Millie (Tessema et al., 2012; Yizezew, 2023), Lower Millie (Hussein, 2023) and Aveya River (Gebremendhin & Mingist, 2014).

The fish species diversity of Terie River was lower than those reported from some other freshwater rivers of Ethiopia. For instance, 57 fish species from Baro and other tributary rivers in Gambella Region (Tesfaye & Wolff, 2014), 27 species from Guang, Shinfu and Aymen Rivers in Blue Nile Basin (Tewabe, 2008), 23 fish species from the Beles and Gilgel Beles Rivers (Getahun et al., 2020), 13 species from Gilgel Abay and Andassa Rivers (Aynalem et al., 2018) and 17 species in the head of the Blue Nile River (Oumer et al., 2011). However, the fish diversity of Terie River was higher than Upper Millie River (four species; Yizezew, 2023) but equivalent with Lower Millie River (six species; Hussein, 2023). The lower fish diversity in the present study might be due to difference in intensity of fishing and efficiency of fishing gears (Limbu et al., 2018; Parvez et al., 2017).

The diversity of fish species was more in deeper and rocky site than in shallow and muddy site. The higher fish species in deeper and rocky site could be due to more suitable refuge site, access to hide under rocks and going deep to escape from

predation and fishing mortality than the shallow and muddy site. The fish species diversity was also varied between sampling sites, more in Site 1 than site 2. The difference in fish diversity between sites could be attributed to habitat selectivity, change in catchment area, canopy closure, substrate type, distance from source, depth and width of rivers (André & Teugels, 1998; Getahun et al., 2020).

Fish species abundance

The abundance of fish species varied between seasons; fish were more abundant in dry season than wet season. In dry season, *O. niloticus* was the most dominant (175) and *R. loti* was the least abundant (1) (Fig. 2). In wet season, *L. intermidus* was more dominant (206) than *O. niloticus* (50).

Fish abundance may vary seasonally due to different factors. For instance, variation in available nutrients and habitats, temperature, water level, turbidity, fishing effort, fish behavior, size and life history stages of fishes, sampling seasons and altitude could have impact on fish abundance in rivers (Graaf, 2003; Karengé & Kolding, 1995; Mengesha, 2015; Zinabu et al., 2002).

Length weight relationship of dominant fish species

The regression coefficient value (b) in fishes may be nearly 3, indicating the fishes retain the same shape and their specific gravity remains unchanged during their life time (Joung et al., 2008). If the weight increased according to the fish length, it is said to be isometric growth (Raje, 2006). But, the b value in fishes may be greater or less than 3 showing allometric growth

condition (De Graaf et al., 2005). The length and weight relationship of *L. intermedius* were $TW = 0.0073 TL^{3.04}$ in dry and $TW = 0.0337TL^{2.59}$ in we season indicating isometric and negative allometric growth, respectively (Fig. 3). While *O. niloticus* showed negative allometric growth, $TW = 0.096TL^{2.44}$ and $TW = 0.0335 TL^{2.76}$ in dry and wet seasons, respectively (Fig. 4). In the present study, the b value of *L. intermedius* was greater than the same species (2.5) in Geba and Sor Rivers in White Nile Basin (Simagegnew et al., 2017) and comparable (2.96) with the species in Angereb and Sanja Rivers, Tekeze Basin (Tesfaye, 2006). In the present study the b value of *O. niloticus* was lower compared to the value (3.1) reported for Koka Reservoir (Berhan et al., 2019). But it was higher than the value (0.47) reported from Wudil River in Nigeria (Getso et al., 2017).

Fulton condition factor (FCF)

The mean FCF of *L. intermidus* were 0.84 ± 0.03 and 0.94 ± 0.25 in dry and wet seasons, respectively (Table 2). In the present study, the FCF of *L. intermidus* was comparable (1) with the same species in Beles and Gilgelbeles Rivers, Nile basin (Tesfaye, 2006). But it was lower (1.21) in Geba and Sor Rivers, White Nile System (Simagegnew et al., 2017) and (1.23) in Borkena River, Awash Basin (Tessema et al., 2012).

The mean FCF of *O. niloticus* was 1.70 ± 0.13 and 1.73 ± 0.12 in dry and wet seasons, respectively (Table 2). The FCF of both *O. niloticus* and *L. barbus* were higher in wet season than dry season. The FCF of *O. niloticus* in Terie River was higher (1.66) reported from Koka Reservoir in Ethiopia (Berhan et al., 2019). The FCF value of the present study was comparable with

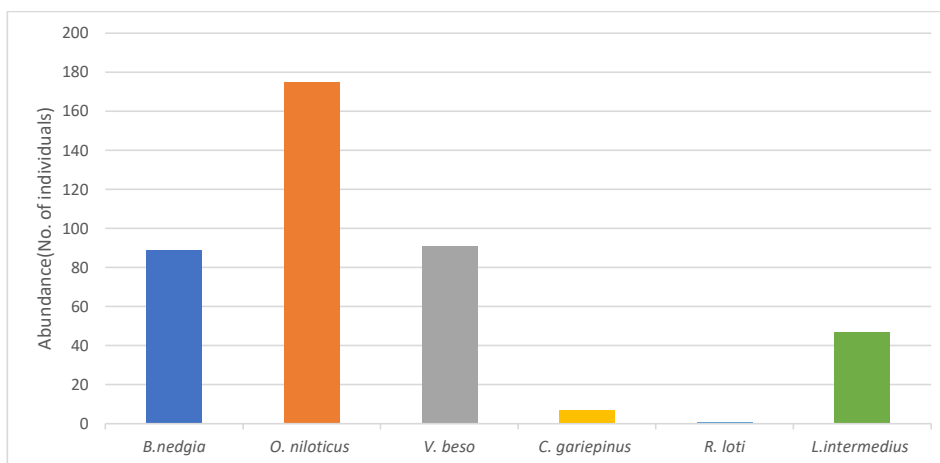


Fig. 2. Fish species recorded in dry season from Terie River, 2022.

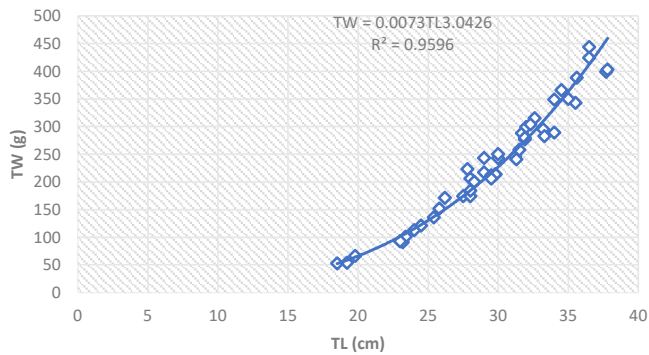


Fig. 3. Length-weight relationship of *Labeobarbus intermedius* in dry season in Terie River. TL, total length; TW, total weight.

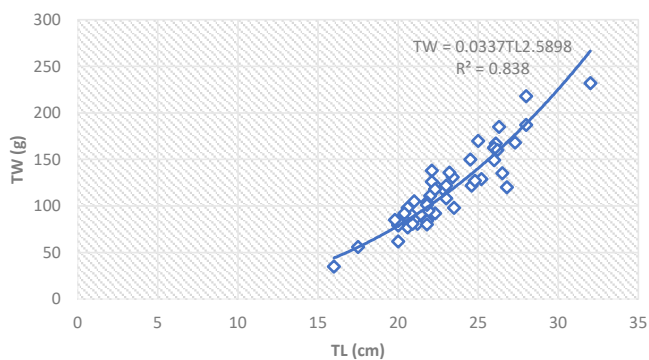


Fig. 4. Length-weight relationship of *Labeobarbus intermedius* in wet season in Terie River. TL, total length; TW, total weight.

Table 2. Mean Fulton condition factor (FCF) of the dominant fish species in Terie River

Season	Species	Mean	SE
Dry	<i>Labeobarbus intermedius</i>	0.844	.026
	<i>Oreochromis niloticus</i>	1.708	.013
Wet	<i>Labeobarbus intermedius</i>	0.943	.025
	<i>Oreochromis niloticus</i>	1.730	.012

the value (1.73) reported from Tekeze Reservoir in Ethiopia. However, it was lower than the value (1.80) reported for Wudil River in Nigeria (Getso et al., 2017).

The more FCF in both fish species in wet season could be attributed to the availability of more food and important nutrients washed and accumulated in the sampling site. The Chi-

square analysis showed that there was no significant difference in FCF between season (Chi-square = 899, $df = 420$ and $p > 0.05$). The condition factor is a good indicator of fish well-being's. It shows the well-being of fishes in their natural habitat or in aquaculture and it is represented by the coefficient of body condition. It is an indicator of different biological and ecological factors in relation to fish feeding habits (Nehemia et al., 2012). Better body condition is correlated with high values of condition factors. Similarly, poor body condition is obtained when the values of the condition factor are less (Gupta & Tripathi, 2017).

Physicochemical water quality

The independent *t*-test analysis of physicochemical water quality parameters showed that there was significant difference in DO, Secchi disk depth, water temperature, NH_3 and conductivity between seasons (Table 2). However, only conductivity and TDS were statistically significant between sampling sites (Table 3).

Water quality parameters especially temperature, DO and pH are the key factors to regulate the fish biodiversity and populations in freshwater bodies (Sarkar & Saha, 2021). Water transparency and electrical conductivity have also very important role in species diversity. Different fish species prefer different habitats due to the difference in their ecological requirements (Huang et al., 2019). Knowledge on the spatial fish assemblages in relation to their water quality is critical for fish assemblage management and conservation (Zona et al., 2022). Hydromorphology and DO were more important for fish diversity. Substrate and riparian habitat quality (refuge habitat and as pollutant) could also determine the fish diversity and population (Comte et al., 2010; Posthuma & de Zwart, 2005; Yuan & Norton, 2003).

The mean concentration of DO in the present study was (5.13 mg/L) in dry and (3.90 mg/L) in wet season. The lower DO in wet season could be attributed to more nutrient and silt load. In wet season the DO was slightly lower than the recommended limit for fishes (> 4 mg/L) (Shrestha & Basnet, 2018; UNEP, 2018). Low levels of DO are often linked to fish kill incidents. On the other hand, optimum levels can result to good growth, thus result to high production yield (Table 4).

The mean pH of Terie River was 8.79 in both dry and wet season indicating it was in alkaline range and was in suitable water quality standard range (6.5–9.0) for aquatic life (UNEP, 2018; Woynarovich et al., 2020). The pH of an aquatic ecosystem is important because it is closely linked to biological pro-

Table 3. Mean water quality parameters of Terie River in dry and wet seasons

Parameter	Season	Mean	SE	t-test	df	p-value
DO (mg/L)	Dry	5.13	0.21	5.117	14	0.000***
	Wet	3.91	0.12			
pH	Dry	8.79	0.06	0.033	14	0.974
	Wet	8.79	0.09			
Tem (°C)	Dry	28.08	0.20	2.810	14	0.014*
	Wet	27.16	0.25			
Trans (cm)	Dry	11.75	0.59	7.333	14	0.000***
	Wet	7.00	0.27			
Cond (µS/cm)	Dry	301.88	6.20	3.620	14	0.003**
	Wet	345.00	10.18			
PO ₄ (mg/L)	Dry	0.9212	0.15	1.302	14	0.214
	Wet	1.1250	0.05			
NO ₃ (mg/L)	Dry	3.2575	0.28	0.838	14	0.416
	Wet	3.5262	0.16			
NH ₃ (mg/L)	Dry	1.8038	0.19	2.654	14	0.019*
	Wet	2.4288	0.13			
TDS (mg/L)	Dry	171.62	1.57	0.506	14	0.621
	Wet	170.00	2.80			

*, significant; **, highly significant; ***, very highly significant.

ductivity.

The concentration of NH₃ in Terie River was around 2.2 mg/L which was higher than the recommended limit (< 0.015 mg/L) (UNEP, 2018). The higher NH₃ in this study could be due to the more nutrient and sediment load generated from the nearby geology and agricultural activities. High concentrations of ammonia could be the cause of higher pH and ammonia concentration in the blood of the fish which can damage the gills, the red blood cells, affect osmoregulation, reduce the oxygen-carrying capacity of blood and increase the oxygen demand of tissues (Lawson, 1995). In the present study, except NH₃ the mean physicochemical water quality parameters of Terie River were within the surface water quality permissible limit for aquatic life as shown in Table 5.

Conclusion

From Terie River, five commercially important fish species, *O. niloticus*, *L.intermedius*, *C. gariepinus*, *L. nedia* and *L. beso* and one ecological important fish species, *R. loti*, were identified.

Table 4. Mean water quality parameters difference with sampling sites

Parameters	Sites	Mean	SE	t-test	df	Sig. (2-tailed)
DO (mg/L)	Deep	4.61	0.335	0.471	14	0.645
	Shallow	4.42	0.214			
pH	Deep	8.79	0.082	-0.165	14	0.871
	Shallow	8.80	0.078			
Tem (°C)	Deep	27.30	0.256	-1.742	14	0.103
	Shallow	27.95	0.271			
Trans (cm)	Deep	10.25	1.07	1.300	14	0.215
	Shallow	8.50	0.824			
Cond (µS/cm)	Deep	341.88	10.77	2.767	14	0.015*
	Shallow	305.00	7.85			
PO ₄ (mg/L)	Deep	0.823	0.125	-3.141	14	0.007
	Shallow	1.22	0.0236			
NO ₃ (mg/L)	Deep	2.95	0.221	0.074	14	
	Shallow	3.83	0.074			
NH ₃ (mg/L)	Deep	1.76	0.182	0.122	14	
	Shallow	2.47	0.122			
TDS (mg/L)	Deep	166.50	1.79	-3.784	14	0.002**
	Shallow	175.12	1.41			

*, significant; **, highly significant.

Table 5. Physicochemical water quality parameters of Terie River compared with international standard (UNEP, 2018) and other literature Woynarovich et al. (2020)

Parameter	Present study	UNEP (2018)	Woynarovich et al. (2020)
DO (mg/L)	4.5	> 3 mg/L	> 4
pH	8.8	6.5–9.0	8.3–9.0
Tem (°C)	27.6	ND	23–33
Trans (cm)	9.4	ND	30–50
Cond (µS/cm)	323.4	1,000	1,000–2,700
PO ₄ (mg/L)	1.0	ND	0.6–1.8
NO ₃ (mg/L)	3.4	ND	< 40
NH ₃ (mg/L)	2.2	0.015	ND
TDS (mg/L)	170.8	ND	< 500

ND, not detected.

The number of fish species diversity and abundance could be increased if we could be able to increase the sampling sites and sampling period. Except ammonia, all the physicochemical water quality parameters of Terie River were within the aquatic life permissible standard. The most preferred commercially important fish species, *O. niloticus* in the region and in the country as a

whole is very abundant in the river. However, the communities in the vicinity have no interest to use the fish for food. This study is the first report which can be used as baseline. However, intensive study, more sampling sites and extended sampling period should be conducted to get full picture about the fish species diversity and biology of fishes of Terie River. Awareness creation should be also conducted about the importance of fishes for fish nutrition and livelihoods.

Competing interests

No potential conflict of interest relevant to this article was reported.

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Availability of data and materials

Upon reasonable request, the datasets of this study can be made available from the corresponding author.

Ethics approval and consent to participate

This study authors approved that the care and handling of the experimental animals used in this study met all ethical requirements.

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References

- André KT, Teugels GG. Diversity patterns of fish assemblages in the lower Ntem River basin (Cameroon), with notes on potential effects of deforestation. *Arch Hydrobiol.* 1998;141:421-46.
- Aynalem Y, Mingist M, Getu A. Diversity, relative abundance, species composition and some biological aspects of fishes in Gilgel Abay and Andassa rivers, Blue Nile Basin, Ethiopia. *Fish Aquac J.* 2018;9:1-13.
- Bagenal TB, Tesch FW. Age and growth. In: Bagenal T, editor. *Methods for assessment of fish production in fresh waters.* Oxford: Blackwell Science Publications; 1978. p. 101-36.
- Begon M, Harper JL, Townsend CR. *Ecology: individuals, populations and communities.* 2nd ed. Boston, MA: Blackwell Scientific Publication; 1990. p. 945.
- Berhan A, Birhanu B, Misikire T, Abraham A. Length-weight relationships and condition factor of Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) (Cichlidae) in Koka reservoir, Ethiopia. *Int J Fish Aquat Res.* 2019;4:47-51.
- Comte L, Lek S, De Deckere E, de Zwart D, Gevrey M. Assessment of stream biological responses under multiple-stress conditions. *Environ Sci Pollut Res.* 2010;17:1469-78.
- De Graaf M, Nentwich ED, Osse JWM, Sibbing FA. Lacustrine spawning: is this a new reproductive strategy among 'large' African cyprinid fishes? *J Fish Biol.* 2005;66:1214-36.
- Gebremendhin S, Mingist M. Length-weight relationship, gonado somatic index and fulton condition factor of the dominant fishes at Aveya River, Blue Nile Basin, Ethiopia. *J Fish Aquat Sci.* 2014;9:1-13.
- Getahun A. An overview of the diversity and conservation status of Ethiopian freshwater fish fauna. In: *Proceeding of the Pan Africa fish and fisheries society; 2003; Cotonou, Benin.*
- Getahun A. *The freshwater fishes of Ethiopia: diversity, and utilization.* Addis Ababa: View Graphics and Printing PLC; 2017. p. 349.
- Getahun A, Bereie Z, Dejen E. Diversity of fishes in Beles and Gilgel Beles rivers, Abay basin, Ethiopia. *Int J Aquac Fish Sci.* 2020;6:68-73.
- Getahun A, Stiassny MLJ. The freshwater biodiversity crisis: the case of Ethiopian fish fauna. *Sinet Eth J Sci.* 1998;21:207-30.
- Getso BU, Abdullahi JM, Yola IA. Length-weight relationship and condition factor of *Clarias gariepinus* and *Oreochromis niloticus* of Wudil river, Kano, Nigeria. *Agro Sci.* 2017;16:1-4.
- Golubtsov AS, Darkov AA. A review of fish diversity in the main drainage systems of Ethiopia based on the data obtained by 2008. In: *Ecological and Faunistic Studies in Ethiopia, "Proceedings of Jubilee Meeting Joint Ethio-Russian Biological Expedition: 20 years of scientific cooperation"*, Moscow: KMK Scientific Press; 2008. p. 69-102.
- Golubtsov AS, Darkov AA, Dgebuadze YY, Mina MV. An artificial key to fish species of the Gambela region (the White Nile basin in the limits of Ethiopia). In: *Joint Ethio-Russian Biological Expedition; 1995; Addis Ababa, Ethiopia.*
- Golubtsov AS, Mina MV. Fish species diversity in the main

- drainage systems of Ethiopia: current state of knowledge and research perspectives. *Ethiop J Nat Resour.* 2003;5:281-318.
- Graaf M. Lake Tana's *Piscivorous barbuis* (Cyprinidae, Ethiopia) ecology - evolution - and exploitation [Ph.D. dissertation]. Wageningen: Wageningen University; 2003.
- Gupta D, Tripathi M. Length-weight relationships and condition factors of five cyprinidae species (subfamily-Barbinae) from three diverse rivers of Uttar Pradesh, India. *Int J Fish Aquac Study.* 2017;5:594-8.
- Huang J, Huang L, Wu Z, Mo Y, Zou Q, Wu N, et al. Correlation of fish assemblages with habitat and environmental variables in a headwater stream section of Lijiang river, China. *Sustainability.* 2019;11:1135.
- Hussein Y. Diversity, relative abundance and biology of fish in Mille river around Chifra, Ethiopia [M.S. thesis]. Dessie: Wollo University; 2023.
- Joung SJ, Chen CT, Lee HH, Liu KM. Age, growth, and reproduction of silky shark, *Carcharhinus falciformis*, in north-eastern Taiwan waters. *Fish Res.* 2008;90:78-85.
- Karenge L, Kolding J. Inshore fish population and species changes in Lake Kariba, Zimbabwe. In: Pitcher TJ, Hart PJB, editors. *The impact of species changes in African lakes.* Dordrecht: Springer; 1995. p. 245-75.
- Lawson TB. *Fundamentals of aquacultural engineering.* New York, NY: Chapman and Hall; 1995.
- Limbu JH, Shrestha OH, Prasad A. Ichthyofaunal diversity of Bakraha river of Morang district, Nepal. *Int J Fish Aquat Stud.* 2018;6:267-71.
- Mekonen S, Hailu, A. Ichthyofauna of Gibe Sheleko National Park and some morphometric relationships of fish of the tributary rivers, Southern Ethiopia. *J Fish.* 2021;9: 91206.
- Mengesha AT. Fish species diversity in major river basins of Ethiopia: a review. *World J Fish Mar Sci.* 2015;7:365-74.
- Millennium Ecosystem Assessment [MEA]. *Ecosystems and human well-being: synthesis.* Washington, DC: Island Press; 2005. p. 137.
- Mogous B. Diversity, relative abundance and biology of fishes in some rivers, and cestode parasites of African catfish (*C. gariepinus*) in some lakes of Ethiopia [M.S. thesis]. Addis Ababa: Addis Ababa University; 2007.
- Nehemia A, Maganira JD, Rumisha C. Length-weight relationship and condition factor of tilapia species grown in marine and fresh water ponds. *Agric Biol J N Am.* 2012;3:117-24.
- Oumer M, Mingist M, Dejen E. Diversity and relative abundance of fishes in the head of Blue Nile river, Ethiopia. *Ethiop J Biol Sci.* 2011;10:207-12.
- Parvez MT, Chaki N, Mohsin ABM, Galib SM. Risking lives for living: a study on underwater fishing in the Padma river, Bangladesh. *J Fish.* 2017;5:525-30.
- Posthuma L, de Zwart D. Predicted effects of toxicant mixtures are confirmed by changes in fish species assemblages in Ohio, USA, rivers. *Environ Toxicol Chem.* 2006;25:1094-105.
- Raje SG. Some aspects of biology of catfishes *Tachysurus caelatus* (Valenciennes) and *Osteogeneiosus militaris* (Linnaeus) from Mumbai. *Indian J Fish.* 2006;53:330-43.
- Sarkar C, Saha NC. Seasonal variation of water quality parameters and their impact on fish biodiversity indices of Hasadanga Beel: a case study. *Curr World Environ.* 2021;16:7-17.
- Shibru T. *Fresh water fishes of Ethiopia.* Addis Ababa: Haile Selassie I University; 1973. p. 107.
- Shrestha AK, Basnet N. The correlation and regression analysis of physicochemical parameters of river water for the evaluation of percentage contribution to electrical conductivity. *J Chem.* 2018;2018:8369613.
- Simagegne M, Getahun A, Wakjira M. Population aspects of fishes in Geba and Sor rivers, White Nile system in Ethiopia, East Africa. *Int J Biodivers.* 2017;2017:1252604.
- Stiassny MLJ, Getahun A. An overview of labeonin relationships and the phylogenetic placement of the Afro-Asian genus *Garra* Hamilton, 1922 (Teleostei: Cyprinidae), with the description of five new species of *Garra* from Ethiopia, and a key to all African species. *Zool J Linn Soc.* 2007;150:41-83.
- Tesfaye G. Diversity, relative abundance and biology of fishes in Angereb and Sanja rivers, Tekeze basin, Ethiopia [M.S. thesis]. Addis Ababa: Addis Ababa University; 2006.
- Tesfaye G, Wolff M. The state of inland fisheries in Ethiopia: a synopsis with updated estimates of potential yield. *Ecology Hydrobiol.* 2014;14:200-19.
- Tessema A, Mingist M, Dejen E. Diversity, relative abundance and biology of fishes in Borkena and Mille Rivers, Awash Basin, Ethiopia. *J Fish Int.* 2012;7:70-6.
- Tewabe D. Diversity, relative abundance and biology of fishes in Gendwuha, Guang, Shinfa and Ayima rivers, North Gondar, Ethiopia [M.S. thesis]. Addis Ababa: Addis Ababa University; 2008.
- UNEP. *A framework for freshwater ecosystem management.*

- Volume 4: scientific background. Nairobi: United Nations Environment Programme; 2018.
- Wood RB, Talling JF. Chemical and algal relationship in a salinity series of Ethiopian inland waters. *Hydrobiologia*. 1988;158:29-67.
- Yizezew E. Fish-habitat relationship: the case of *Labeobarbus beso* in Mille river, Ethiopia [M.S. thesis]. Bahir Dar: Bahi Dar University; 2023.
- Yuan LL, Norton SB. Comparing responses of macroinvertebrate metrics to increasing stress. *J N Am Benthol Soc*. 2003;22:308-32.
- Zinabu GM, Chapman LJ, Chapman CA. Conductivity as a predictor of a total cations and salinity in Ethiopian lakes and rivers: revisiting earlier models. *Limnologica*. 2002;32:21-26.
- Zona Z, Ali Z, Ahmad R, Zainab I. Fish diversity and water quality in different zones of upper river Indus Basin, Pakistan. *Pak J Zool*. 2022;54:2791-9.