Fish diversity and relative abundance at mesohabitat level in Gumara River, Lake Tana Sub-basin, Ethiopia.

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Abstract

Information regarding fish diversity and relative abundance at mesohabitat level plays important roles in monitoring, protecting or managing fish populations and their habitats. Although the presence of different fish species has been reported in Gumara River by various studies, organized information on abundance and diversity of fish species at mesohabitat levels were not available. Such information is very important for the management of the declining fish fauna of Lake Tana. So, this study aimed at investigating the abundance and diversity of fish species at the mesohabitat level. Diversity and relative abundance of fishes have been studied in the Gumara River and its tributaries from November 2018 to April 2019. Physico-chemical parameters of water were measured using the in-situ multi-probe system. Fish sampling was conducted using a technique called point abundance sampling by electrofishing. Fish species identification was done by using reference books and specimens deposited in the laboratory at Bahir Dar fisheries and other aquatic life research center. A total of 3,880 fish specimens were collected from all sampling sites. Among the collected specimens, the most (53.14%) and least (0.26%) dominant were Enteromius humilis and *Labeobarbus* intermedius, respectively. Both of them are cyprinids. In addition to cyprinids, specimens from family Cichlidae (*O. niloticus*) and Clariidae (*C. gariepinus*) were examined and contributed only 0.67 and 0.34%, respectively. There was a significant variation in the abundance of species between habitats and sampling months. Shannon's index (H'=1.21) and evenness value (J'=0.53) in the Gumara River indicate moderate pollution and uniform distribution of individuals. Among the six sampling sites, the highest (H'=1.30) and lowest (H'=0.94) diversity indices were recorded at sites in the upstream near Wanzaye hot spring and below the bridge, respectively. In terms of mesohabitat, the species diversity and evenness were higher in riffle (H'=1.25, J'=0.57) than run (H'=1.15, J'=0.55) and the pool (H'=1.11, J'=0.50). The result revealed that the abundance and diversity of fish in Gumara River varied between sites and mesohabitats and this might be due to attitudinal difference, physico-chemical parameters and impact of different human activities around the river. Therefore, emphasis should be given to the factors which may lead to the collapse of the fish habitats, especially water abstraction for irrigation. Detailed studies on the diversity, abundance, reproductive biology by collecting year-round data should be done to use them as management tools.

Keywords: Diversity, Ethiopia, Lake Tana, Relative abundance, Species composition.

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Introduction

Ethiopia has a sizable amount of running and standing water bodies [1]. The total estimated lake, reservoirs and floodplain area (13,637km^2) and river length about (8,065 km) of the country provide high fish production potential, which is estimated at 94,500 t yr_1 [2]. Currently, about 200 fish species are found in Ethiopia of which 191 of them are valid indigenous (native) species whereas 9 of them are exotic species [3]. They are distributed across the different drainage basins of the country [4]. The highest diversity of fish species has been recorded from Baro-Akobo basin (119 species), followed by Omo-Turkana (79 species), Abay (Blue Nile) (61 species) Tekeze and Awash-Rift Valley system (36 species each) and Shebelle-Genale (33 species) [3]. The highest diversity might be attributed to the presence of diverse and rich habitat in terms of food availability, connection with other ecosystem and a relatively higher degree of exploration done on these water bodies. However, endemicity is highest in Abay basin. The highest endemicity in the Abay basin is attributed to the endemic flock of *Labeobarbus* in Lake Tana [5-7]. Lake Tana is situated in the north-western Ethiopian highlands at an altitude of 1830 m a.s.l and constitutes almost half of the freshwater of the country [7]. Gumara, Ribb, Megech, Gilgel Abbay, Gelda, Arno-Garno and Dirma are the major tributary rivers of Lake Tana [8,9]. Gumara River is among the major tributary rivers in Lake Tana used for irrigation and supports different aquatic organisms. Of these different organisms, fishes are commercially important that can improve the livelihood of the local community. However, information about diversity and relative abundance of fish species in Gumara River are lacking. Therefore, this study aimed at determining the diversity and relative of fish species at the mesohabitat level in Gumara River for proper management of Lake Tana fishery and this work has been addressing the following research questions:

•Are there changes in the physico-chemical parameters between sampling sites?

•What is the fish species composition of the Gumara River? 3) Do different sites and mesohabitats in the Gumara River vary in fish abundance?

•What are the possible reasons that might affect the abundance and diversity of fish?

Materials and Methods

Study area

The study was conducted in Gumara River and its tributaries as well as on the shores of Lake Tana between November 2018 and April 2019 and samples was taken every month. Gumara River (Figure 1) originates from the western side of Gunna Mountain peaks, southeast of Debre Tabor at an altitude of approximately 3,250 m a.s.l [10]. It is one of the largest pe-rennial rivers flowing into Lake Tana and has several tributary rivers such as Duka¬lit, Kizin, Wonzema, Bawaza and Guanta [9]. The river is located to the east of Lake Tana and the geographical location of its watershed is between 11°34' 41.41" N-11º 56' 36" N latitude to 37°29' 30" E-38°10' 58" E longitude [11].

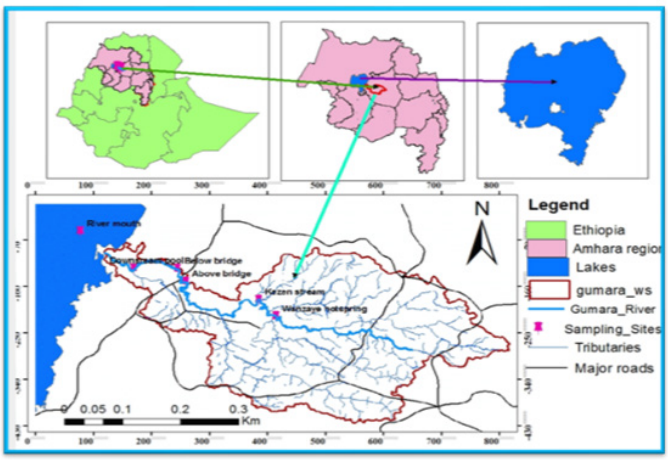

Figure 1. *Map of the study area.*

Climate

According to 20-year climate data (2000-2019) provided by the Central Meteorological Agency, Bahir Dar Branch (2019), the lowest and highest mean temperatures around Gumara River were about 9.8°C (during August) and 32.4 °C (during April), respectively. The lowest and highest rainfalls were also recorded in March (1.4 mm) and August (440.1 mm), respectively (Figure 2).

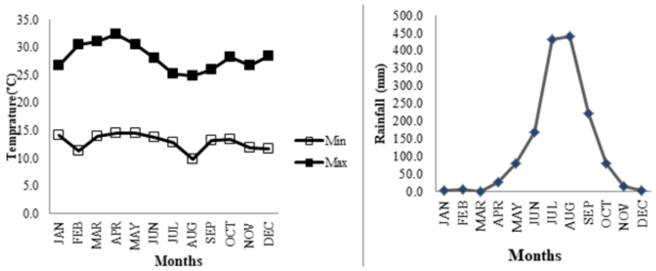

Figure 2. *The monthly minimum (Min) and maximum (Max) temperature and average rainfall.*

Flora and Fauna

Most of the sampling sites for this study were covered by non-woody vegetation (such as grass and many shrubs) and woody trees like a fig tree or "Warka" (*Ficus sycomorus*), Mango (*Mangifera indica L.*), Eucalyptus, Eshe (*Mimusops kummel A*). Among wetland vegetation Typha, Echinochloa spp., Eichhornia crassipes, *Ceratophylum demersum, Nymphaea spp*. and *Cyperus papyrus* were found. The commonly observed bird species in Gumara River include cattle egret (*Bubulcus ibis*), great white pelican (*Pelecanus onocrotalus*), African fish eagle (*Haliacetus vocifer*) and Egyptian goose (*Alopochen aegytiaca*).

Sampling protocol

Based on the proximity of habitat and substrate type, nature and velocity of the flowing river and interference by human beings and other farm animals, the sampling sites were selected starting from upstream around Dukalit stream and its river confluence down to the shore of Lake Tana. Six sampling sites (three above and three below Gumara Bridge, highway to Gondar) were selected by the preliminary assessment/survey, and sampling sites were fixed using GPS (Table 1). The first site was upstream part around Dukalit stream/near to Wanzaye Hot spring; the second site was around the confluence point of Kizen stream; the third was 2km before the bridge; the fourth site about 5km after the bridge; the fifth site was at downstream pool local name is known as Zorfie and the last site pool proximate to river mouth. The selection of the sites was done through consideration of the lotic and lentic characteristics of the river. Simple, stratified and systematic random sampling methods were applied during the period of data collection. Most of the sampling sites exhibited a reduced flow and habitat patches could be easily identified including pool, riffle and run as predominant habitat types. Moreover, shallower stretches of raceway and backwater were also present. There were 20 sampling points (from each site) which were selected randomly based on their suitability to use electrofishing in a Zigzag manner [12]. The distance between points among all sampling sites was 50 m and this helps to reduce disturbance.

Table 1. *GPS coordinates of sampling sites in the Gumara River.*

Sampling site	Code	Coordinate	
Near to Wanzaye Hot spring	G-H	11°47'21.55"N	37°40'28.28"E
Kizen Stream	K-S	11°49'42.51"N	37°38'15.06"E
Above the Bridge	A-G-B	11°50'17.46"N	37°38'12.88"E
Below the Bridge	B-G-B	11°50'27.33"N	37°38'4.32"E
Downstream pool/ Zorfie	D-P-Z	11°53'29.30"N	37°30'33.57"E
Pool proximate to river mouth	P-R-M	11°54'9.54"N	37°28'57.78"E

Physico-chemical parameters and fish sampling

Physico-chemical parameters of water in Gumara River including temperature, dissolved oxygen, conductivity, total dissolved solids and pH were measured in all sampling sites using in-situ YSI 556 multi-probe system. The average turbidity (three times/each point) was determined using the digital turbidmeter, EUTEOH instrument TN-100, serial number 475896. Depth was measured using tape mounted on stick and echo-sounder was used especially in the deepest site of the study area (downstream pool around Zorfie site and pool proximate to river mouth site).

During fish sampling, each sampling point was also electro-fished by moving in a zigzag pattern from one retaining net to the other, usually beginning downstream but sometimes upstream when visibility was high and water velocity and depth were relatively low [13]. Specimens were sampled using Bretschilneder electric fishing device Model EFGI 1300 with a single anode array and pulsed DC (60Hz, voltage 1-470V) and the technique known as point abundance sampling by electrofishing (PASE). At each sampling point, the activated anode of a portable electrofishing apparatus with a dip net was immersed and moved around 1m diameter, horizontal circle for 10 seconds and then they were lifted directly out of the water [12,14]. Several preliminary tests were performed under different conductivity conditions to define the influence range of the anode. To avoid damage by the electric field, sampled fishes were immediately netted and placed into buckets filled with river or lake water until the end of identification or counting. After collecting the necessary data, all specimens except a few for further identification were released back into their habitats. To avoid the chance of recapturing the collected samples were retained in a container until assessing the nearby sampling areas.

Abundance, diversity and equitability

Shannon diversity index (H') for the collected specimens in Gumara River was calculated to indicate diversity at different sampling sites and microhabitats of the river. The Shannon diversity index (H') explains both the variety and the relative abundance of species [15].

H' was calculated as:

$$H' = -\sum_{n=1}^{\infty} Pi*lnPi$$

Where,

H'=the Shannon diversity index

Pi=fraction of entire population made up of the species i

S=number of species encountered

Σ=sum from species 1 to species S

Species equitability or evenness Index (J') that refers to the degree of the relative dominance of each species in the sampling station was calculated according to Pielou (1966). $J' = \frac{H'}{lnS!}$ Where, H' max represent the maximum possible diversity of the site and ln (S) for the natural logarithm of species.

Habitat characterization

Habitat type/ geomorphic unit (e.g. riffle, pool and run) and the water current of each sampling point were measured using Geopacks advanced stream flow meter, model MFP126-S. Substrate type was classified based on their maximum dimensions, using a modified version of the Wentworth scale [16]: bedrock, impermeable and continuous; boulder, >256 mm; cobble, 64-256 mm; gravel, 2-64 mm; sand, 0.0625-2 mm; clay and silt <0.0625 mm and organic matter consist wood chips, leaves and dead branches. Habitat-species relationship was assessed using physico-chemical parameter measurements, substrate types and abundance of fish from each sampling points.

Data analysis

The collected data were organized in Microsoft office, excel 2010. SPSS version 22 software was used to compute descriptive statistics of phyico-chemical parameters. Abundance, equitability and diversity were calculated using Shannon diversity index. Redundancy Analysis (RDA) was used to evaluate fish-habitat relationships.

Results and Discussion

Physico-chemical parameters

Result of measurements of physico-chemical parameters such as dissolved oxygen, temperature, pH, TDS, conductivity, turbidity and water depth in Gumara River were presented Table 2 and its analysis showed significant differences ($p<0.05$) between sampling sites.

Table 2. *Major abiotic parameters in Gumara River with their Mean ± SE (standard error) of the average of means (Where N=75).*

Site								
	Temp (ºC)	DO (mgl-1)	pH	Cond. (µs cm-1)	TDS (ppm)	Turbidity (NTU)	Velocity (m/s	Depth (cm)
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
G-H	21.36 ± 0.21	7.95 ± 0.11	8.69 ± 0.14	179.01 ± 3.76	115.25 ± 5.29	22.11 ± 0.95	0.24 ± 0.06	62.28 ± 6.45
K-S	22.86 ± 0.12	7.84 ± 0.16	8.80 ± 0.14	178.87 ± 3.88	112.20 ± 5.00	20.61 ± 1.46	0.20 ± 0.04	40.73 ± 3.65
A-G-B	20.52 ± 0.29	7.57 ± 0.14	9.10 ± 0.13	203.30 ± 5.47	116.30 ± 7.15	19.23 ± 1.06	0.04 ± 0.03	72.36 ± 4.68
B-G-B	21.24 ± 0.39	7.30 ± 0.28	8.66 ± 0.18	183.52 ± 4.86	120.50 ± 4.93	28.31 ± 2.56	0.14 ± 0.01	58.88 ± 5.17
D-P-Z	20.14 ± 0.27	8.20 ± 0.20	8.20 ± 0.24	198.93 ± 5.63	129.30 ± 6.06	23.21 ± 1.79	0.04 ± 0.02	186.4 ± 24.06
P-R-M	20.91 ± 0.19	7.39 ± 0.17	7.89 ± 0.27	177.30 ± 4.99	109.79 ± 7.71	19.27 ± 1.01	0.05 ± 0.02	109.7 ± 12.30
Average	21.32 ± 0.11	7.71 ± 0.08	8.56 ± 0.08	185.24 ± 2.09	122.22 ± 2.58	22.12 ± 0.67	0.12 ± 0.02	88.41 ± 5.61

Temperature

The average water temperature of the study sites varied between 20.14 ± 0.27 and 22.86 ± 0.12°C with the lowest value recorded in the fifth sampling site (downstream pool around Zorfie) and this might be due to the presence of high water depth and vegetation cover/shading effect. Shading by branches of trees prevents sun rays from direct contact with the water surface. This is in agreement with Johnson, in which vegetation cover/shading effect is the one among different factors that affect water temperature and they are inversely proportional to each other [17]. The highest water temperature was recorded in the Kizen stream and this might be due to shallow depth and wider portions of the surface of the river, which might have caused higher evaporation. According to Farnham et al., shallowness and widening of surface water is a causative agent for the occurrence of high evaporation and is mainly due to the presence of high temperature [18].

Dissolved oxygen

The average concentration of dissolved oxygen in the Gumara River varied between 7.30 ± 0.28 and 8.20 ± 0.20 mg/l with the highest value recorded at the downstream pool site and this might be due to high vegetation cover, high depth and low water temperature. Dissolved oxygen in the Gumara River showed a significant variation ($p<0.05$) among sampling sites. This might be because of the variation of depth, salinity, temperature and vegetation cover between sites. Permlata also mentioned the factors that affect the concentration of DO in water which include temperature, depth, salinity, photosynthesis and availability of nutrients [19]. The survival of fish species is highly dependent on the availability of adequate concentration of DO because low levels of DO can influence growth, survival and movement of different life stages of fishes. Genevieve and James noted a low DO (less than 2mg/l) would indicate poor water quality and thus would have difficulty in sustaining a much sensitive aquatic life. The requirements of DO concentration also varied among species and their life stages. However, DO levels below 3 mg/l are stressful to most aquatic organisms and levels 5 to 6 mg/l are usually required to perform their biological functions [20,21]. Therefore, the mean DO level of Gumara River was 7.71 ± 0.08 mg/l, which is greater than the above-stated values, and it is the required DO level for fish to perform their biological functions.

pH

The highest pH value (9.10 ± 0.13) was recorded from the "above bridge site" while, the lowest value (7.89 ± 0.27) was recorded from the "pool proximate to river mouth" site. There was also a significant difference ($p<0.05$) between sites. The reduced rate of photosynthetic activity, the assimilation of carbon dioxide and bicarbonate and the presence of high conductivity might be the most responsible factors to increase the pH in the water. According to Gupta P, pH is always positively correlated with an electrical conductance [22]. The significant difference in pH is also attributable to the extent of photosynthetic removal of carbon dioxide [23]. The level of pH value at pool proximate to river mouth sites was low and it might be attributed to the presence of high vegetation cover, consequently, which has resulted in a high concentration of dissolved organic carbon. The mean value of pH in this study was 8.56 ± 0.08, which was a bit higher than Lake Tana (6.8-8.3) [24] and Chibirna (8.1 ± 0.13) and Shini Rivers (8.2 ± 0.14) [9]. This might be due to the difference in vegetation cover in Lake Tana and its tributary rivers. However, the mean pH values obtained were almost within the WHO standards (6.8-8.5) that can sustain healthy aquatic life.

Specific conductivity

There was a significant difference in the specific conductance ($p<0.05$) between sampling sites. For instance, the highest (203.30 ± 5.47) and lowest (177.30 ± 4.99) value of specific conductance were recorded at sites above the bridge and the pool proximate to river mouth, respectively. The occurrence of the lowest conductance value at the pool proximate to river mouth site was mainly due to the presence of the lowest value of pH, TDS and temperature, since, they are directly proportional to each other. There is a significant correlation between conductivity with temperature, pH, alkalinity, hardness, chemical oxygen demand (COD), iron and chloride concentration of water. According to the result of this study, Gumara River's mean value of conductivity was (185.24 ± 2.09 μs cm-1) which was higher than the conductivity value of Lake Tana (132.8 μs cm^{-1}) reported by Dejen and much lower than mean conductivity value of Chibirna (313.1 ± 27.19 μs cm^{-1}) and Shini Rivers (239.5 ± 10.2 μs cm^{-1}) [9,25]. This might be due to differences in human activities, vegetation cover, geological factors in the catchment and other environmental difference in the lake and its tributary rivers.

Total dissolved solids (TDS)

Among the sampling sites, the highest (129.30 ± 6.06) and the lowest (109.79 ± 7.71) value of TDS was recorded in a downstream pool around Zorfie and pool proximate to river mouth sites, respectively. It has also the highest significant variation ($P<0.05$) among sampling sites. The occurrence of the lowest TDS value was attributable to the presence of low specific conductance, since they are directly proportional to each other. The highest TDS value in the downstream pool around Zorfie might be inductive that this site might be vulnerable to the introduction of large quantities of waste through runoff. Deas and Orlob noted that the maximum value of TDS can result in polluted waters or waters receiving large quantities of land runoff [26]. The mean average TDS value (122.22 ± 2.58) of the Gumara River was lower than the TDS value of Chibirna (214.30 ± 19.24) and Shini Rivers (162.90 ± 7.07) and this might be due to differences in the vulnerability to runoff [9].

Turbidity

Like other environmental variables, turbidity showed a significant variation ($p<0.05$) among sampling sites. The variation observed might be due to the release of suspended particles resulting from different human activities (e.g. sand mining) in the study area and this is in line with the report of Nkwoji, which mentioned that variation in turbidity was probably due to allochthonous input from river discharges. The highest (28.31 ± 2.56NTU) and lowest (19.23 ± 1.06NTU) value of turbidity were noted from the sites below the bridge and above the bridge, respectively. The high levels of turbidity below the bridge indicate the presence of a large number of micro-organisms or colloidal particles arising from clay and silt during rainfall since the site is much closer to agricultural lands. The other possible reason was also recession agriculture in the river canal following the reduction of river water volume. Whereas, the lower level of turbidity at above the bridge site could be attributed to the low wave action and minimum turbulence, since, the water depth was high. In general, the variation of turbidity within site and time might be due to flood induced from seasonal rain and different activities conducted by the local community around the river.

Velocity

There was a significant variation (P<0.05) in velocity between sampling sites, and this might be due to the shape of channel/ cross-section, the gradient of the slope that the water moves along, volume, depth, width and the roughness of the bottom substrate. For instance, sites near to Wanzay hot spring (0.24 ± 0.06), Kizen (0.20 ± 0.04) and below the bridge (0.14 ± 0.01) tend to show relatively high velocity and this might be due to the presence of steep gradients and narrow channels. In contrast, the lowest velocity was also noted at the remaining sites and this might be attributable to the gentle slope, wide channel, and deep and rough bottom substrate. Under a natural condition riverine fish are subjected to diverse flow velocities and turbulence and they prefer a limited range of water velocity to their advantage, for instance, to minimize energy expenditure for any activities and to maximize energy gain through feeding.

Depth

During the period of the study, the depth of water in all sampling sites was decreasing almost consistently from its maximum in November to its minimum value in April, presumably in associated with the decreasing input from rainfall, in addition to the presence of loss of surface water due to evaporation and water abstraction for different purposes such as irrigation, domestic use etc. Based on the mean average depth, the highest (186.4 ± 24.06 cm) and the lowest (40.73 ± 3.65 cm) was noted in a downstream pool around Zorfie and Kizen sites respectively. The significant difference (p<0.05) in depth among sampling sites might be due to the presence/absence of vegetation cover, topography, volume, surface area and evaporation. Especially, the site downstream pool around Zorfie is significantly (p<0.05) deeper than all of the upstream sites including Wanzaye hot spring, below the bridge, Kizen and river mouth sites. The very shallow water columns of the upstream around Wanzaye hot spring and Kizen stream site are expected during the months of the present study period (largely dry period), as evaporation losses exceed input via rainfall and intensification of water use for irrigation and domestic use (December to April) [27].

Fish species composition in Gumara River

About 3,880 fish specimens belonging to ten fish species representing three families (Cyprinidae, Clariidae and Cichlidae) were collected from all sampling sites (Table 3) from November 2018 to April 2019. Cyprinids were the dominant groups.

Table 3. *Total species composition in Gumara River.*

Genus/species name	Number (N)	Percentage
E. humilis	2062	53.14
L. juvenile (YOY)	945	24.36
Garra spp.	687	17.71
L. beso	29	0.75
L. intermedius	10	0.26
L. brevicephalus	14	0.36
E. pleurogramma	74	1.91
G. dembecha	20	0.52
C. gariepinus	13	0.34
O. niloticus	26	0.67
Total	3,880	100

The presence of different fish species in Gumara River might be associated with species preference due to habitat heterogeneity and water flow of the river. Out of the total catch, four species were from the genus *Labeobarbus* and contributed about 25.73%. Out of this, about 24.36% of the contributions were from YOY (juveniles of the *Labeobarbus* species). The remaining 1.37% was from genus *Labeobarbus* which were identified at a species level such as *L. beso* (0.5%), *L. brevicephalus* (0.36) and *L. intermedius* (0.26) due to the presence of well-developed morphometric characters. In addition to genus *Labeobarbus*, different species from genus Enteromius such as *E. humilis* and *E. pleurogramma* were examined during the study period. *Enteromius humilis* was more dominant than *E. pleurogramma* and other specimens. The total number of specimens of *E. humilis*, was about 2,062 and contributes about 53.14% of the total catch, whereas, *E. pleurogramma* (1.91%) was the least dominant. Garra sp. and *G. dembecha* contribute about 17.71 and 0.52% of the total catch, respectively. *O. niloticus* (Cichilidae) and *C. gariepinus* (Clariidae) specimens were collected and they contribute only 0.67 and 0.34%, respectively from the total catch. Moreover, the species composition of this study was found to be similar to what has previously been done in which the fish species identified were dominated by the cyprinids [8]. Therefore, the dominance of the collected specimens showed, in decreasing order *E. humilis*, *Labeobarbus* juveniles (YOY), *Garra spp*., *E. pleurogramma*, *L. beso*, *O. niloticus*, *G. dembecha, L. brevicephalus, C. gariepinus* and *L. intermedius*. The lowest dominance of *L. intermedius* might be due to the fact that the species is mostly targeted at river mouths and a little distance upstream. It is evident that fishermen catch these fishes during the breeding season from August to October and this study was also done after the breeding season. Anteneh et al. has reported that almost all fishers (both reed boat and motorized boat) mainly operate during the breeding season from August to October and on the spawning ground of each species [28].

Abundance difference between sampling sites

There was a variation of the abundance of fishes between sampling sites (Table 4). This indicated that each species prefers its habitat based on feed availability, predator avoidance, water level, vegetation and other physico-chemical parameters of water in each month and site. Sites might be affected by different human activities (e.g., water abstraction for irrigation); as a result, the abundance and diversity of aquatic organisms are also affected.

Table 4. *The abundance of all collected species from all sampling sites.*

Species	W-H	K-S	A-G-B	B-G-B	D-P-Z	P-R-M	Total
Garra spp	431	162	21	20	15	38	687
E.humilis	571	668	181	201	132	309	2062
L. juvenile	259	258	73	146	84	125	945
E.pleaurogramma	14	10	1	4	23	22	74
L. beso	21	8					29

G. dembecha	17	3					20
L. brevicephalus	8	3		3			14
L. intermedius	9	1					10
O.niloticus	3	2	13	0	4	4	26
G. gariepinus	1	1	2	9			13

Among six sampling sites, sites near Wanzaye hot spring and Kizen were more preferable by three species such as *E. humilis*, *L. juvenile* (YOY) and Garra species. Most of the sampling points at both near Wanzaye hot spring and Kizen sites were shallow in depth, gravel substrate, moderate water velocity with adequate oxygen due to water turbulence and the presence of such circumstance helps to support various species. The presence of gravel substrates is also very important to protect deposited eggs and juveniles from being washed by riffles. According to Shitaw et al. *Labeobarbus* species prefers fast-flowing, clear, highly oxygenated water and gravel-bed streams or rivers [29]. Based on the result of this study, the abundance of *Garra spp*. showed a decreasing trend from the upstream part of the river to the river mouth (Table 4) and this might be attributed to the type of the substrate. *Garra spp*. relatively prefers the gravel and boulder bed of the river. *Enteromius pleurogramma* was the fourth dominant species and relatively found in large numbers in a downstream pool around Zorfie and the river mouth site. Both sites were consisting of different type of wetland vegetation that includes Echinocla grass, water hyacinth, silver snakeroot and other plants. The presence of such plant species also made these sites highly preferable by *E. pleurogramma*. Dejen et al. have reported that *E. pleurogramma* is mainly present in the wetlands around the lake [30].

Major habitat classifications and fish abundance

Based on the water depth, velocity and substrate composition, sampling points of mesohabitat in Gumara River were classified as a pool, riffle and run and contribute 56%, 32% and 12%, respectively. Habitats were different from each other in abundance, diversity and species compositions and this is mainly due to different characteristics of habitat types including substrate type, physico-chemical characteristics of water, vegetation cover, predators etc. Matthews also reported that habitat plays an important role in fish assemblage richness and abundance because it encompassed several physical structures such as rocks, logs, leaves, branches, macrophytes and algae, which are used as a food source, shelter and nesting ground. Different fish species require a specific habitat and habitat loss/alteration can lead to ever-declines of a fish population [31]. For instance, *E. humilis* was the most dominant among all species in all habitat types. *Garra spp*., was the second dominant both in the riffle and run habitat, but not in pool habitat. In pool habitat, YOY of the *Labeobarbus* species was the second dominant. The dominance of YOY in pool habitats showed an increasing trend from the start to the end of the data collection and this might be attributed to habitat shifting. In addition to *E. humilis*, YOY of the *Labeobarbus* spp., and *Garra spp*. there were intermediate dominant species in each habitat type. The least dominant species in the pool, riffle and run mesohabitats were *L. intermedius*, *C. gariepinus* and *O. niloticus*, respectively (Table 5).

Table 5. *Abundance of all collected species between mesohabitat.*

Species	Habitat type		
	Pool	Riffle	Run
B. humilis	1279	536	243
Garra spp.	195	370	128
L. Juvenile	572	312	59
G. dembecha	3	17	0
B. pleurogramma	60	10	5
L. beso	12	9	8
L. brevicephalus	5	8	1
L. intermedius	0	2	8
O. niloticus	23	2	0
C. gariepinus	11	0	2
Total	2,160	1,266	454

Shannon diversity index and evenness

Shannon diversity index and evenness in Gumara River: Based on the the result, Shannon's index value in Gumara River was 1.21 (Table 6) and it shows that the structure of the habitat is moderately balanced. According to Shannon, the index value above 3 indicates that the structure of the habitat is stable and balanced; values below 1 indicate that there are pollution and degradation of habitat structure [32]. A scale of pollution in terms of species diversity (0.0-1.0 heavy pollution, 1.0-2.0 moderate, 2.0-3.0 light, 3.0-4.5 shows slight pollution). Based on this, the Gumara River with species diversity 1.21 is found in a range that falls on the category of moderately polluted. The Shannon diversity index value of the Gumara River was the same with Jigrefa (H'=1.21) and higher than the Rib River mouth (H'=0.63) [33]. Evenness value (J'=0.53), also indicates the uniform distribution of individuals. when the (J') value is getting close to 1; it means that the individuals are distributed evenly. The difference in species distribution between different water bodies is mainly due to different environmental factors. Hossain et al. mentioned water temperature and rainfall as major influential factors for species distribution [34].

Table 6. *Shannon diversity index and evenness value in Gumara River.*

Fish	N	Pi	Lnpi	pi2	pi*ln pi	H'	Evenness (J')
E. humilis	2062	0.531	-0.632	0.28	-0.336	1.21	0.53
L. juvenile (YOY)	945	0.244	-1.412	0.06	-0.344		
Garra spp.	687	0.177	-1.731	0.03	-0.307		
L. beso	29	0.007	-4.896	0	-0.037		
L. intermedius	10	0.003	-5.961	0	-0.015		
L. brevicephalus	14	0.004	-5.625	0	-0.02		
L. pleurogramma	74	0.019	-3.96	0	-0.076		
G. dembecha	20	0.005	-5.268	0	-0.027		
C. gariepinus	13	0.003	-5.699	0	-0.019		
O. niloticus	26	0.007	-5.005	0	-0.034		
Total	3,880			0.37	-1.21		

Shannon diversity index and evenness difference between the sampling sites: The fish diversity, community structure and species assemblages in the sampling sites are interdependent on many biotic and abiotic factors. Some reasons for the difference in species diversity between sampling sites include the difference in water quality parameters, substrate type and availability of food. Among the six sampling sites, the highest diversity was recorded at sites in the upstream near to Wanzaye hot spring (H'=1.30) followed by the downstream pool around Zorfie (H'=1.13) and the lowest diversity was noted at below the bridge (H'=0.94) and pool proximate to river mouth (H'=0.97) sites (Table 7). The remaining sites were intermediate. The occurrence of the highest diversity index in upstream sites might be associated with the suitability of habitat in terms of feed availability, substrate type and physico-chemical characteristics of habitats. Its low evenness value is also indicative that the individuals were not evenly distributed. The lowest Shannon diversity index in sites below the bridge and pool proximate to river mouth indicated that there might be environmental changes (e.g. DO, water temperature and other basic parameters) which led to an increase in the dominance of fewer species. Relatively the lowest value of DO was recorded at the two sites, which might be a cause for stress except for a few tolerant species. Raveendar et al. reported that communities become more dissimilar as the stress increases and accordingly species diversity decreases due to the resulting poor water quality [35]. Singh and Agarwal also noted that decreasing temperature is the main factor for the decrease in diversity and abundance of fish fauna [36]. The low fish diversity at sites below the bridge and river mouth might be due to high altitude as compared to the other sites; hence, there is an inverse relationship between fish diversity and altitude of the river [37]. Sites below the bridge and river mouth have Shannon's index value of less than 1, which indicated that these sites were highly polluted, degraded and unstable. In the case of evenness, higher value (J'=0.70) and (J'=0.62) were recorded at the downstream pool around Zorfie and above the bridge, respectively. This indicates that the species was evenly distributed or it is showing maximum dominance of different species than other sites. The lowest evenness values in sites near to Wanzaye hot spring (J'=0.56) and Kizen (J'=0.46) indicate that relatively species were not evenly distributed while the site was dominated by single species.

Table 7. *Shannon diversity index differences between sampling sites.*

Site code	H'	Evenness (J')
G-H	1.3	0.56
K-S	1.06	0.46
A-G-B	1.11	0.62
B-G-B	0.94	0.59
D-P-Z	1.13	0.7
P-R-M	0.97	0.6

Shannon diversity and evenness difference among mesohabitats: Gumara River is characterized by heterogeneity in habitat type (pool, run and riffle). Each habitat type helps to determine the habitat preference of different fish species at different life stages. In this case, the highest number of individuals (2,160 in 9 species) was recorded in pool habitat type, along with higher abundance than the other habitat types. However, the value of the diversity index and evenness was low. Therefore, the occurrence of such events indicates that the pool habitat is a preferred habitat of most of the similar species, since relatively the lowest evenness value means that the species were less evenly distributed (Table 8). The lowest value of evenness in the case of pool habitat might be associated with habitat homogeneity and depth preference by fewer species. In riffle habitat, the species diversity and evenness were higher (H'=1.25, J'=0.57) than run reach (H'=1.15, J'=0.55) and the pool (H'=1.11, J'=0.50). This also indicated that the species were more evenly distributed in riffle habitat than run and pool. All mesohabitats in Gumara River were highly dominated by *E. humilis* species where n is about 536, 1279, 255 in the pool, riffle and run habitats, respectively. Garra species were also the second dominant species in both pools (n=536) and run (n=128). Whereas, Laeobarbus juvenile (YOY) was the second dominant in riffles (n=572). Since YOY of *Labeobarbus* preferred a riffle habitat during their early stage and riffle habitats in the Gumara River have relatively fast-flowing water, gravel substrate type and shallow water depth. Many studies also summarized that clear, highly oxygenated and gravel-bed streams or rivers are the best habitats of *Labeobarbus* species. In addition to *E. humilis*, *Garra spp* and *Labeobarbus* juveniles, there were also other intermediate dominant species in each habitat type. The least dominant species in the pool, riffle and run mesohabitats were *L. intermedius*, *C. gariepinus* and *O. niloticus*, respectively. All habitats in the Gumara River have Shannon's index value >1 and it indicated that habitats were moderately polluted. The evenness values of each habitat (closest to 1) also indicate the even distribution of different species even though more even distribution was observed in riffle followed by a run and pool.

Table 8. *Diversity and evenness difference among mesohabitats.*

	No. of individuals	Percentage	H'	Evenness (J')
Pool	2160	55.67	1.11	0.5
Riffle	1266	32.63	1.25	0.57
Run	454	11.7	1.15	0.55
Total	3880	100		

Factors that affects fish abundance and diversity

In general, the abundance difference between sampling sites was mainly due to environmental variables and their relationship was shown in the ordination triplot (Figure 3). The first axis (horizontal) of RDA explained 89.3% of the cumulative percentage of the variance. It also showed a negative correlation with conductivity, TDS and water depth. The second axis also explained about 10% of the cumulative percentage of variance in the species-environment relationship and positively correlated with temperature and gravel with sand and silt substrate type (i.e. high embeddedness). Therefore, the first two ordination axes collectively explained 99.3% of the variance in fish abundance and environmental parameters in the Gumara River (Table 9).

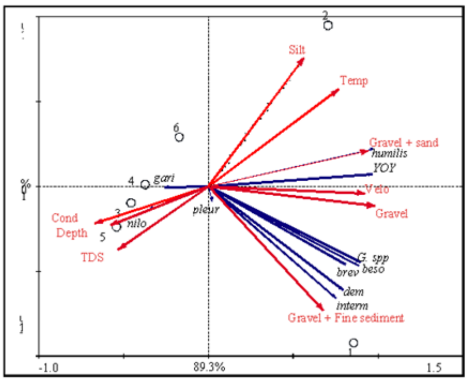

Figure 3. *Ordination diagram of Redundancy Analysis (RDA) of the first two ordination axes summarizing the relationship between physico-chemical variables and fish species(1=Gumara hot spring, 2=Kizin stream,*

3=Above-Gumara Bridge, 4=Below Gumara Bridge,5= Downstream pool, 6=Pool proximate to river mouth; Temp=Temperature, Cond=Conductivity, TDS=Total Dissolved Solid, Velo=Velocity and Depth; humilis= Enteromius humilis, YOY= young-of-the-year, G. spp=Garra species, dem=Garra dembecha, pleu=Enteromius pleurogramma, brev=Labeobarbus brevicephalus, beso=Labeobarbus beso, inter=Labeobarbus intermedius, nilo=Oreochromis niloticus and gari=Clarias gariepinus).

Table 9. *Results of Redundancy Analysis (RDA) of the relationship between environmental variables and fish abundance using the first two Axes.*

Parameter	Axis 1	Axis 2
Eigenvalues	0.893	0.1
% Environmental relationship	89.3	10
Temperature	0.7663	0.5718
Conductivity	-0.6719	-0.2188
TDS	-0.5318	-0.3739
Velocity	0.9205	-0.0402
Depth	-0.5765	-0.2259
Gravel+sand	0.9415	0.2107
Gravel+Fine sediment	0.6778	-0.7313
Gravel	0.9781	-0.1172
Silt	0.558	0.7548

Based on the RDA, most environmental variables and fish species were found in the first axis (Figure 3). Among different environmental factors, temperature, water velocity and substrate types (including silt, gravel with sand, gravel and gravel with fine sediment) were the most determinant factors that affect the abundance of different fish species because such variables had a long arrow/ vector length. The vector length for different environmental variables is also referred as the relative importance of that variable for predicting the fish assemblage and their abundance [38]. The vectors can be extended in either direction to identify the position of a species relative on other species along that gradient [39]. The abundance of *E. humilis*, YOY, *Garra spp*, *L. beso, L. brevicephalus, G. dembecha* and *L. intermedius* were positively correlated with the level of pH, temperature and water velocity at site one and two.

Conclusions and Recommendation

Different fish species were found in the Gumara River and might be attributed to the suitability of the river in terms of habitat (e.g. physico-chemical parameters, substrate type and vegetation cover) and food availability. The most dominant species were *E. humilis* followed by YOY of the *Labeobarbus* spp. and *Garra spp*. The abundance and diversity of fish species between sampling sites and mesohabitats showed a significant variation and this might be due to the difference in physico-chemical parameters of their habitats and altitudinal differences. Based on the Shannon diversity index (H'=1.21), the Gumara River could be grouped under moderately polluted. Activities such as excessive water abstraction, pollution and habitat modification in the river should be reduced because, low volume of water forms barrier between river and lake and as a result, recruitment will be reduced in the lake. Detailed study on the habitat modeling and the habitat suitable index should be done to use them as management tools.

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