Habitat Use and Characterization of Young-of-the-Year (YOY) *Labeobarbus* spp. in Gumara River, Lake Tana Sub-basin, Ethiopia

By

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Here I declare that this thesis entitled "*Habitat use and characterization of Young-of-the-Year of the Labeobarbus species in Gumara River, Lake Tana Sub-basin, Ethiopia*", submitted in partial fulfillment of the requirements for the award of the Degree of Master of Science in Biology (Aquatic Ecosystems and Environmental Management) to the Graduate Program of the Addis Ababa University, College of Natural and Computational Sciences, Department of Zoological Sciences is my original work and has not been submitted earlier for the award of any degree or diploma. Works of literature that used to support my thesis have been also acknowledged in the text and list of references.

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THESIS APPROVAL SHEET

This thesis entitled "*Habitat use and characterization of Young-of-the-Year of the Labeobarbus species in Gumara River, Lake Tana, Sub-basin, Ethiopia*", by Felegush Erarto Trfie has been evaluated by the board of examiners and was accepted in partial fulfillment of the requirements of the Degree of Masters of Science in Biology (Aquatic Ecosystems and Environmental Management).

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ADC	Austrian Development Cooperation
AEEM	Aquatic Ecosystem and Environmental Management
A-G-B	Above Gumara Bridge
ANOVA	Analysis of Variance
B-G-B	Below Gumara Bridge
COD	Chemical Oxygen Demand
CPUE	Catch per Unit Effort
D-P-Z	Downstream Pool Zorfie
FAO	Food and Agriculture Organization
FO	Frequency of Occurrence
G-H	Gumara Hot spring
IUC	Institutional University Collaboration
JERBE	Joint Ethio-Russian Biological Expedition
K-S	Kizen Stream
MRCEP	Mekong River Commission Environment Program
NMA	National Meteorological Agency
PAST	Paleontological Statistics Software Package for Education and data Analysis
P-R-M	Pool Proximate to River Mouth
RDA	Redundancy Analysis
SPSS	Statistical Software for Social Sciences
TDS	Total Dissolved Solid
YOY	Young-of-the-Year

ABSTRACT

Information regarding habitat requirements of different fish species at early life stages plays important roles for monitoring, protecting or managing fish populations and their habitats. Although spawning migration of Labeobarbus species to Gumara River has been reported by various studies, organized information on abundance, distribution, habitat use and preference of young-of-the-year were not available. Such information is very important for the management of the declining endemic Labeobarbus species of Lake Tana. So, the aim of this study was to investigate abundance, habitat use and characterization of young-of-the-year of the Labeobarbus species. Habitat use and characterization of young-of-the-year of the migratory riverine spawning Labeobarbus species of Lake Tana were studied in Gumara River and its tributaries from November 2018 to April 2019. Physico-chemical parameters were measured using probes and there were significant variation ($p<0.05$) among sampling sites. Fish sampling was conducted using point abundance sampling by electrofishing across banks and mid-channel to cover all habitat types. A total of 3,880 fish specimens were collected from all sampling sites. Out of the total catch, about 24.36% of the contributions were from young-of-the-year of the Labeobarbus species. The abundance of fishes varied between sampling months and sites and this might be attributed to the differences in physico-chemical parameters, substrate type, altitude, depth and velocity of the water. The Shannon's index (H'=1.21) and evenness value (J'=0.53) in 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 index were recorded at sites in the upstream near to 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 showed that the species prefer at a mesohabitat scale riffles and later pools in Gumara River and this is mainly due to the drying of riffle habitats during the dry season and hence forced to shift to pool habitats. At a microhabitat scale also juveniles prefer sites with moderate water depth, low to medium water velocity; gravel substrate type and vegetation cover. Pool habitat served as the only option until the next rainfall comes. Therefore, emphasis should be given to the factors which may lead to the collapse of the pool habitats, especially water abstraction through pumping for small scale irrigation. The detailed study on the habitat modeling and the habitat suitability index should be done for proper management of the Lake Tana fishery.

Keywords: Abundance; Electrofishing; Habitat preferences; Lake Tana; Young-of-the-Year

1. INTRODUCTION

1.1. Background of the study

Ethiopia is the country that has a sizable amount of running and standing water bodies with a high diversity of aquatic fauna (Brook Lemma, 1987). 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} (Gahaw Tesfaye and Wolff, 2014). 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 (Abebe Getahun, 2017). They are distributed across the different drainage basins of the country (Tadlo Awoke, 2017). 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) (Abebe Getahun, 2017). 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 the highest in Abay basin (Abebe Getahun, 2007). The highest endemicity in Abay basin (25 species) is attributed to the endemic flock of *Labeobarbus* in Lake Tana (Nagelkereke, 1997; de Graaf *et al*., 2000; Golubstov and Mina, 2003; Tadlo Awoke, 2015).

About seven large and perennial tributary rivers contribute more than 95% of the total annual inflow into Lake Tana and the remaining inflow is provided by small seasonal rivers (Shkil *et al*., 2017). Gumara, Ribb, Megech, Gilgel Abbay, Gelda, Arno-Garno and Dirma are the major perennial tributary rivers of Lake Tana (Abebe Getahun and Eshete Dejen, 2012). Gilgel Abay and Megech Rivers are flowing into the south-western and northern part of the lake, respectively. Gumara and Ribb Rivers are also flowing into the eastern part of the lake. The Blue Nile River is the only surface outflow from the lake. Lake Tana is characterized as turbid, well mixed and has no major thermocline (Eshete Dejen *et al*., 2004), meso-oligotrophic (i.e. oligotrophic based on primary production and mesotrophic on the basis of chemistry) (Tesfaye Wudneh, 1998).

There are 28 fish species in the lake, out of which 21 of them are endemic to the country (Abebe Getahun and Eshete Dejen, 2012), and, the largest of the endemic species are cyprinids (Nagelkerke, 1997). Its high endemicity is probably because of the fact that the incipient lake offered new habitats for adaptive radiation (de Graaf *et al*., 2008). The fish fauna of Lake Tana is includes the genera *Oreochromis*, *Clarias*, ‘large’ barbs (*Labeobarbus*), ‘small’ barbs (*Enteromius*), *Garra* and *Afronemacheilus* (Abebe Getahun, 2017). Majority of *Labeobarbus* species in Lake Tana were migrating to different tributary rivers; and rivers differ in their size, discharge, nutrient level, flora, fauna and physico-chemical parameters. Besides, serving as an input, especially during the rainy season, tributary rivers of Lake Tana also provide nursery habitat for juveniles of migratory *Labeobarbus* species. Gumara River is among the major tributary rivers in Lake Tana where *Labeobarbus* spp. spawning migration has been studied. The river and its tributary streams are also important nursery habitats for the larvae and 0+juveniles of the migratory riverine spawning *Labeobarbus* species. However, the river is faced with different human activities including overexploitation and water abstraction for irrigation uses. Moreover, information about habitat use and characterization of young-of-the-year (YOY) of the *Labeobarbus* spp. at microhabitat level in Gumara River are lacking. Therefore, this study was designed to determine habitat preference and habitat shifting of young-of-the-year across different microhabitats within the river, tributary streams and the pool proximate to river mouth by using a technique known as Point Abundance Sampling by Electrofishing (PASE). Additionally, this work is also expected to deliver useful recommendations for the management of the fish and freshwater to minimize any risk which may lead to the collapse of fish stock and habitat loss.

1.2. Statement of the problem

Gumara River is one of the tributary rivers of Lake Tana that provide habitat for different aquatic organisms, water for irrigation and household uses. Among aquatic organisms that are found in Gumara River, migratory *Labeobarbus* species are commonly known. According to Palstra *et al*. (2004), six species during the rainy season and *L. intermedius* throughout the year migrate to Gumara. Tributaries of the river such as Dukalit, Kizen and Wenzema also serves as the spawning ground for migratory riverine *Labeobarbus* species (Dgebuaze *et al*., 1999; Palstra *et al*., 2004). According to Wassie Anteneh (2013), Gumara River and its tributary streams are also reported as the best nursery habitats for the larvae and 0+ juveniles (YOY) of the migratory *Labeobarbus* species. Even though, habitat use of *Labeobarbus* juveniles (YOY) at mesohabitat level is reported by Wassie Anteneh (2013), the detailed investigation related to abundance, distribution, habitat use and preference of juveniles at microhabitat level are lacking. Information regarding the habitat preference of the juveniles (YOY) is very crucial to conserve these unique fish fauna. Therefore, it was found necessary to carry out a detailed investigation of habitat use and preference of the juveniles of the *Labeobarbus* species in Gumara River to recommend a good management option to prevent ever-increasing declines of the endemic *Labeobarbus* species. Thus, this study aimed to generate baseline information on abundance, habitat use and characterization of young-of-the-year (YOY) of the *Labeobarbus* spp. at microhabitat level in Gumara River.

1.3. Research questions

- Are there changes in the physico-chemical parameters of water between sites?
- Does the abundance and diversity of fishes vary in different habitats of Gumara River?
- Which riverine habitats are frequently used by the young-of-the-year (YOY)?
- How is habitat preference associated with the specific size of YOY?
- Do YOY show habitat shifting?

1.4. Objectives

1.4.1. General objective

The general objective of this study was to collect and establish baseline scientific information on habitat use and characterization of young-of-the-year (YOY) of the *Labeobarbus* spp. in Gumara River for proper management of the fishery of Lake Tana

1.4.2. Specific objectives

The specific objectives of the study were to:

- assess changes in physico-chemical parameters of water among sampling sites
- determine the abundance and diversity of fish in different habitats
- identify riverine habitat(s) commonly used by YOY
- assess the relationship between habitat preference and the specific size of YOY
- determine the presence/absence of habitat shifting

1.5. The hypothesis of the problem

This study hypothesized that there is significant variation in physico-chemical parameters and abundance of young-of-the-year of the *Labeobarbus* species and habitat-shifting among sampling sites in Gumara River.

1.6. Significance of the study

Basic information mainly on physico-chemical parameters of water, commonly used riverine habitat and causes for habitat shifting of young-of-the year (YOY) of the *Labeobarbus* species in Gumara River was generated from the study. These also suggested appropriate fishery management measures that should be implemented in the study area to conserve endemic *Labeobarbus* species and their habitats. Moreover, the study will motivate research and academic institutes to undertake further investigations on Lake Tana fishery and biodiversity.

1.7. Limitations of the study

The limitation of the present study is the fact that the identification of YOY of the *Labeobarbus* species at the species level is difficult due to the absence of well-developed morphometric characteristics and identification keys. To solve such limitation, specimens were cultured in glass aquarium/laboratory at Bahir Dar University, School of Fisheries and Wildlife. Unfortunately, due to the absence of formulated feed (feed which promotes the growth of fish), the size of fish was not well developed for identification. As a result, identification at species level was not done. Moreover, the volume of the river was very low in March and April and some sampling points have also dried and continuity of the river was blocked. As a result, comparison of fishing effort and other parameters of a given sampling point throughout the sampling period was difficult.

2. Literature Review

2.1. *Labeobarbus* species in Lake Tana

The family Cyprinidae is the most widespread group and has the highest diversity (>2000 species) among all freshwater fish families (de Graaf *et al*., 2008). The same is true in Lake Tana, Cyprinidae is the largest family of fish and is represented by three genera: *Enteromius*, *Garra* and *Labeobarbus* (Abebe Getahun, 2017). Recently, the taxonomic revision was done related to the small barbs (Yang *et al.*, 2015), "*Varicorhinus*" (Beshera *et al*., 2016) and "Tilapia" (Dunz and Schliewen, 2013). Accordingly, the small barbs, which were formerly known as "*Barbus*" are represented as "*Enteromius*", the "*Varicorhinus*" species are recognized under "*Labeobarbus*" and haplotilapiine cichlid fish formerly referred to as "Tilapia" is presented as "*Coptodon*". Each genus of the family Cyprinidae in Lake Tana is represented by one or more species. For instance, the "small" *Barbus* of Lake Tana was represented by *Enteromius pleurogramma* (Boulenger, 1902), *Enteromius humilis* (Boulenger, 1902) and *Enteromius trispilopleura* (Leveque and Daget, 1984) and *Enteromius tanapelagius* (de Graaf *et al*., 2000). After a few years, species grouped in "small" *Barbus* were again grouped into three species based on a study conducted by Eshete Dejen (2003) include *E. humilis*, *E. pleurogramma* and *E. tanapelagius* and hypothesizing that *E. humilis* and *E. trispilopleura* are not separate species. *Garra* is represented by four species: *G. dembecha*, *G. regressus*, *G. tana* and *Garra* sp. (Akewake Geremew, 2007).

In Lake Tana, the *Labeobarbus* species have previously been classified under genus *Barbus*, however, large hexaploid African barbs are renamed as *Labeobarbus* (Berrebi, 1995; Snoeks, 2004). The genus name *Labeobarbus* better reflects their phylogenetic distance from other members of the overly lumped genus *Barbus* (Nagelkerke and Sibbing, 2000). Based on this, the most abundant genus *Labeobarbus* in Lake Tana consists of 15 species (*L. acutirostris, L. brevicephalus, L. crassibarbis, L. dainellii, L. gorgorensis, L. gorguari, L. intermedius, L. longissimus, L. macrophtalmus, L. megastoma, L. nedgia, L. platydorsus, L. surkis, L. truttiformis* and *L. tsanensis*) (de Graaf *et al*., 2008).

Labeobarbus species differ in their morphometric structure (Nagelkerke and Sibbing, 2000); their resource partitioning (de Graaf, 2003); their reproductive strategies (Palstra, *et al*., 2004); their ecology and sites of reproduction (Shkil *et al*., 2017). Most of them migrate to rivers for spawning and head down to the lake after spawning (Shkil *et al*., 2017). The feeding ecology and distributional patterns of *Labeobarbus* species are also well-diversified (Sibbing and Nagelkerke, 2001; de Graaf, 2003). According to Sibbing and Nagelkerke (2001) five trophic groups based on species gut content analysis and morphological prediction were distinguished and it includes: zooplanktivorous-insectivore (*L. brevicephalus*), molluskivorous (*L. gorgorensis*), macrophytivore (*L. surkis*), four species that feed on benthic invertebrates (mainly insect larvae) (*L. crassibarbis*, *L. intermedius, L. nedgia* and *L. tsanensis*) and the remaining piscivores (*L. acutirostris, L. dainellii, L. gorguari, L. longissimus, L. macrophtalmus, L. megastoma* and *L. truttiformis*). Most of Lake Tana *Labeobarbus* species are piscivore species (de Graaf *et al*., 2000; Abebe Getahun and Eshete Dejen, 2012). The reason for their commonness in Lake Tana is due to the absence of other common African piscivorous fishes (like perciform fishes) as competitors and allows the *Labeobarbus* of Lake Tana to use their potential for trophic diversification to they occupied (de Graaf *et al*., 2000).

Cyprinids are adapted to live in lakes or lacustrine environments; however, most of these species still migrate upstream to spawn in tributary rivers, which indicate that they are not still fully adapted to the lake environment (de Graaf *et al*., 2005; Abebe Getahun *et al*., 2008). According to de Graaf *et al*. (2004b) about six species of *Labeobarbus* migrate greater than 30 km upstream into Gumara River for spawning during the rainy season (July to October). Wassie Anteneh (2013) also mentioned based on the summary of different studies conducted in Gumara River, the remaining species were missing from upstream spawning tributaries of the river. Almost all lacustrine cyprinids are thought to migrate to upstream rivers for spawning (Skelton, 1991). These missing *Labeobarbus* species in Lake Tana probably developed a new strategy of spawning in the lake or adjacent floodplain wetlands (de Graaf *et al*., 2005).

Spawning migration of *Labeobarbus* species of Lake Tana can be partitioned into three stages (Palstra *et al*., 2004): (1) migration from the foraging area in the lake to the river mouth (pre-spawning aggregation), (2) ascending upstream the river's main channel and (3) entering a tributary for spawning. Sexual differences in aggregation profile and the exact period the aggregating fishes spend at the river mouths before swimming upstream is not clearly known. From gonado-somatic indices and abundance data, however, they probably spend days or weeks aggregating at the river mouths (de Graaf *et al*., 2005). This pre-spawning aggregation at the river mouths might improve the synchronization of individual gonad cycles of the widely dispersed Lake Tana *Labeobarbus* rather than swimming directly to the river main channels without pre-spawning aggregation (Nagelkerke and Sibbing, 1996).

Spawning migration of *Labeobarbus* into the main channels of the rivers occurs mostly after the peak of the heavy rain season when flow rate and average water level decrease (Wassie Anteneh *et al*., 2008). Most of the lake-dwelling cyprinids spawn in rivers, by undertaking a single annual breeding migration up rivers. This spawning strategy makes the large African cyprinids vulnerable for modern fisheries since the fishermen target spawning aggregations at river mouths by selectively blocking them, preventing mature individuals from reaching the upstream spawning areas (Skelton *et al*., 1991; Eshete Dejen *et al*., 2017). As de Graaf *et al.* (2004a) mentioned the reason for the decline of the *Labeobarbus* stock in Lake Tana is thought to be recruitment overfishing by the commercial gillnet fishery that targets the riverine spawners and the poisoning of the spawning stock in rivers using the crushed seeds of Birbira (Abebe Amha, 2004). According to de Graaf *et al*. (2004a), the catch per unit effort of *Labeobarbus* species from the commercial gillnet fishery drastically declined from 63 kg/trip in 1991 to 28 kg/trip in 2001. The same authors reported about 75% decline (in biomass) and 80% (in number) of the *Labeobarbus* spp. (*L. acutrostris, L. brevicephalus, L. intermedius, L. macrophthalmus, L platydorsus* and *L. tsanensis*) from the southern Gulf of Lake Tana. de Graaf *et al*. (2005) and de Graaf *et al*. (2006) also noted more than 50% of the annual catch is obtained at the river mouths during August and September. The strong decline in the proportion of juvenile fish of the riverine spawning *Labeobarbus* is the most likely part of the result of this practice (de Graaf *et al*., 2006).

The upstream spawning migration of some lacustrine *Labeobarbus* species was reported from different studies conducted in tributary rivers of Lake Tana such as Gelda, Gelgel Abay and Gumara (Palstra *et al*., 2004; de Graaf *et al.*, 2005) and Dirma, Megech and Ribb Rivers (Wassie Anteneh, 2005; Abebe Getahun *et al.*, 2008). Based on these studies, *L. acutirostris, L. brevicephalus, L. intermedius, L. macrophtalmus, L. megastoma, L. platydorsus, L. truttiformis* and *L. tsanensis* were reported as riverine spawners; whereas, the remaining *L. crassibarbis, L. dainellii, L. gorgorensis, L. gorguari, L. longissimus* and *L. surkis* have been assumed either migrating and spawning in other tributaries or associated wetlands or they might be lacustrine spawners (Palstra *et al*., 2004; de Graaf *et al*., 2005; Abebe Getahun *et al.*, 2008). A study conducted in Arno-Garno River by Shewit Gebremedhin *et al*. (2012) and Shini and Chibirna Rivers by Gizachew Teshome *et al*. (2015) also reported *L. nedgia* as riverine spawner. Dgebuaze *et al*. (1999) and Palstra *et al*. (2004) reported that in Gumara River, riverine spawning *Labeobarbus* enter into small tributaries such as Dukalit, Kizen and Wenzema in the evening, spawn overnight and return to the main channel in the morning. Most of the time, the rain starts around Lake Tana in the late afternoon and causes a fast rise in the small tributaries and the water level falls in the following morning. This late afternoon rain may trigger nocturnal spawning (Palstra *et al*., 2004).

2.2. Point abundance sampling by Electrofishing

Electrofishing is the term commonly applied to a process that establishes an electric field in the water to capture fish (Portt *et al*., 2006). It is the most widely used method for assessing fish assemblages in both temperate and tropical streams throughout the world (Tomanova *et al*., 2013). It has the main advantage of permitting fish to be captured with a low risk of injury (Vanderkooi *et al*., 2001), least biased, least destructive and most cost-effective (Persat and Copp, 1990). In contrast, it can also be harmful and cause spine injuries and hemorrhages that might lead to decreased growth rates in some fish species are very frequent and may not be detected externally (Snyder, 2003). The efficiency of electrofishing is highly dependent on different environmental factors, including conductivity of water: electrofishing is sensitive to low water conductivity (Penczak *et al*., 1997). It is inefficient and undervalues lower than 60µScm^{-1} (Beaumont, 2002) and efficiency generally peaks at intermediate water conductivities and increase with fish size (Dolan and Miranda, 2003). Water depth and width are also another possible factors that might cause electrofishing to be recognized as catch efficiency are higher in small streams than the large ones mainly due to its inefficiency in water depths >1m and applicable in rivers <10 m wide (Murphy and Willis, 1996). Likewise, fish characteristics can also affect electrofishing efficiency at small-sized fish are less sensitive than large ones (Cowx and Lamarque, 1990) and species can have different sensitivities due to their behavior, morphology and physiology (Reyjol *et al*., 2005).

2.3. Habitat use and characterization

Habitats can be defined as infinite patches that help to understand the function of the ecosystem within a known ecosystem (Beier, 2013). Studies on species-habitat relationships are used for developing management tools such as habitat suitability indices (Lamouroux *et al*., 1999) and manage flow regimes to conserve native fish populations (Bernardo *et al*., 2003). Factors that should be considered to compare one habitat to the other include abiotic factors such as light, temperature, substrate type, etc. and biotic factors, such as prey-predation and competition (Lucas *et al*., 2001). The distribution of population among different habitats is highly affected by the strength and magnitude of biotic interaction (Morris, 1988). That is why habitat availability, characteristics and suitability are considered as key factors to determine the physiology, development, local abundance and structure of species assemblages (Leahy, 2016).

Habitat which is very important for fish and serves as a source of food, breeding ground and helps to growth can be considered as essential fish habitat. Rosenberg *et al.* (2000) defined essential fish habitat as those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity. Some of the most important components of essential fish habitat include substrate type, water quality and quantity, depth, velocity, food, cover, habitat connectivity and other environmental gradients (Rosenberg *et al.*, 2000). Identification and explanation regarding how environmental gradients affect the distribution of organism is a central task of ecology. This task has been rendered more difficult due to the fact that most ecosystems exhibit substantial spatial and temporal heterogeneity (i.e., patchiness) along these gradients (Thompson *et al*., 2001). Habitat availability can also influence the movement of fishes by providing a mechanism for enhancing fitness by seeking optimal habitats (Kahler *et al*., 2001).

Optimal or suitable habitats are those considered to improve an individual's fitness by increasing food availability and decreasing predation risk and metabolic costs (Furry *et al*., 2013). The suitability of potential habitat types or areas can vary with time, as factors influencing fitness (i.e. predation, food and physico-chemical conditions) are dynamic (Bowler and Benton, 2005). For instance, rivers provide diverse habitats; however, their habitat is being destroyed by industrial development projects, construction of dams, water pollution and river maintenance (Kingsford, 2000). Flood protection such as levees cause many rivers to lose inundated floodplains and this loss reduces natural processes and weighted usable area for fish (Copp, 1989). The fishes that need floodplain habitat and periodic inundation are seriously impacted by flow regulation and floodplain reduction (Poff and Zimmerman, 2010). As a result, many fish species became extinct due to environmental change and instability of the river ecosystems (Xenopoulos *et al*., 2005).

Human activity is the most commonly cited cause of declines in the fish population through changing of river ecosystems (Garner, 2010). Habitat loss and degradation, flow modification, introduced species, over-exploitation and pollution are considered the most important impact factors acting on species extinction and threats to biodiversity (Dudgeon *et al*., 2006). Concerning freshwater ecosystems, hydrologic alterations and biological invasions represent two of the greatest threats to freshwater biota (Johnson *et al*., 2008). Although the relationship between these impact sources is not well understood, hydropower impoundments are associated with both of them (Agostinho *et al*., 2010). Habitats are altered via modification of bottom type and above-bottom structure, channelization, dam building, watershed perturbation and competition for water (Al-Kahem *et al.,* 2008). Inflowing waters, rocks, vegetation and logs provide shelter from the current and a site of attachment for eggs, algae and associated fauna. Human activities such as ridging for navigation and to obtain construction materials, removal of logs and debris to aid navigation and watershed disruption that leads to increased erosion and silt deposition (Garner, 2010). The increment of erosion and silt deposition are also important factors which alter physico-chemical parameters/water quality of any ecosystems. Water quality can be changed due to the direct and indirect watershed or channel modifications. Direct watershed/channel modification such as from violent storms or dam construction (Han *et al*., 2007). Indirect modifications include the replacement of native forests with agricultural crops or by urban or industrial land uses in which functional interactions between a watercourse and adjacent lands have been altered (Dale and Beyeler, 2001). The direct discharge of effluents from urban and industrial sources is also a well-documented as a modifier of water quality (Leelahakriengkrai and Peerapornpisal, 2010). Studies on habitat selection of stream fishes are usually based on species conservation (Moran-Lopez *et al.,* 2005). Many of these studies focused on local microhabitat variables, such as substrate, depth, velocity and vegetation, from the template to which stream fishes depend on feeding, breeding and refuge. One of the most frequently used methods that used to determine fish densities, to examine population structure and to study habitat preference of the fishes is the Point Abundance Sampling by Electrofishing (PASE) (Fladung *et al*., 2003). In fish, size-dependent habitat use has been well described in many species and it can occur within one year class, because of intra-cohort size differences (Huss *et al.,* 2008). Large and older individuals, mostly utilized deep-water habitats; whereas, smaller and younger fish are found in shallower habitats (Garcia-Berthou, 2001). Larger individuals also utilize the upper part of the water column more frequently than smaller individuals (Gustafsson *et al*., 2010).

In a stream environment, Harvey and Stewart (1991) found that larger individuals vacate shallow habitats to avoid visual terrestrial predators, whereas smaller individuals utilize shallow habitats to decrease predation by piscivorous fishes. In freshwater lakes, size-dependent habitat use may also be caused by distinct habitat preferences, this decrease predation risk or to find a trade-off between predation risk and profitable feeding (Bystrom *et al*., 2004). In addition to anti-predator strategies, a change in mouth structure as the fish grows can lead to size-dependent habitat use because mouth structures can delimit the fish so that distinct sizes prefer distinct food sources and different habitats (Garcia-Berthou, 2001). In fish, many YOY use low-velocity, shallow habitats close to the shoreline and bottom substrate (Girard *et al*., 2004).

In general, determination of habitat quality, especially for YOY fishes, is difficult because linkages between fishes and their habitat are complex and dynamic (Able, 1999), yet an understanding is critical toward defining nursery habitats (Beck *et al*., 2001). The condition associated with high growth and survival rates, high abundance, low mortality and weight loss is referred to as optimal conditions (Wanat, 2002). Variation or degradation, in an environmental condition drives ultimate effect on individual growth, survival and recruitment to stocks. Fish mortality is highest at the early life stages as they are highly susceptible to environmental changes (fragmentation of spawning and nursery habitats) and predation (Anderson, 1988). YOY fish may be the least tolerant of all life stages to environmental stresses and more susceptible to predation (Wanat, 2002). To reduce mortality, the size-related shift in habitat use has been observed in many freshwater fishes (Toham and Teugels, 1997). The requirements of the specific habitat decrease with an increase in the age of the fish (Schiemer *et al*., 1991). Any habitat that makes a greater-than-average contribution to the recruitment of adults can be considered as nursery habitat; thus, some portions of juvenile habitats, but not all, are nurseries (Beck *et al*., 2001). Life history adaptations to the nursery habitats increase recruitment success by increasing the survival of vulnerable life stages (such as eggs, larvae and juveniles) (Seegrist and Gard, 1972). Shallow areas or shores of lakes, wetlands, inlets, bays, streams, riparian zones, pools, floodplains and backwaters of rivers are generally some of the most common sites where potential nursery habitats are located (Please *et al*., 2006).

2.4. Specific habitat requirements of Young-of-the-Year (YOY)

The survival of fish in their first year of life known as young-of-the-year or 0+ years plays an essential role in the life history of a particular population as it determines recruitment (Rulifson and Manooch, 1990). Classification of riverine fish habitats based on their requirements is a very important aspect for species conservation (Huet, 1959). Milner *et al*. (1985) mentioned three areas of fisheries management that habitat assessment can be applied: classification of sites for the conservation of high-value sites, assessment of impacts and enhancement. All of these tasks require that detailed information concerning the habitat preferences of the target species is compiled and can be interpreted in terms of the behaviors of the fish (Garner, 2010). Under a natural condition, rivers differ from other aquatic environments in two key characteristics: they have unidirectional water flow and are subject to high variability both in space and time. For an organism to survive in a riverine system, it must be well adapted and able to utilize areas which increase its fitness (Hynes, 1970). Use of the most suitable habitats results in maximizing success, in terms of survival of fish age with 0+, reproductive potential and growth performance (Conover, 1992). Different habitats might be required at specific periods during the life history of a fish species, owing to variation in physiology and behavior of the organism (Copp, 1990). For example, the habitat requirements of brown trout are described on a life stage basis: adult, embryo, fry and juvenile (Raleigh, 1986). Optimal temperature requirements for good growth and survival of brown trout are 12 to 19 °C, with a temperature tolerance range of 0 to 27 °C (Tebo, 1975). Similarly, the requirement of DO varied with species, age, prior acclimation temperature, water velocity, the concentration of substances in the water and activity level (e.g. swimming speed and growth rates for salmonids declined with decreasing DO) (Doudoroff and Shumway, 1970). In general, the YOY (i.e. fish, aged 0+ years), have received considerable attention over the last two decades, owing to a recognition of their important contribution to the success of the species as a whole (Mann, 1995).

2.5. Microhabitat preference of YOY

According to Hatfield and Adam (2007), three scales of fish habitats are identified: macrohabitat (reach scale), mesohabitat (hydraulic unit scale) and microhabitat (site-specific scale). Johnstone and Slaney (1996) also define the term macrohabitats as "large homogeneous sections of fish habitat equivalent to stream reaches and characterized by uniform discharge, gradient, morphology and streambed" and Mesohabitats as medium-sized stream features defined by stream hydraulic characteristics that include pools, glides, runs, riffles, cascades, etc. Microhabitats are point-specific physical habitat conditions and these conditions are typically quantified using measures of depth, velocity, substrate, cover, etc. (Lewis *et al*., 2004). Carnie *et al*. (2016) also noted the term microhabitat as the quality of fish habitat at the scale of single fish with a meter resolution. Habitat and microhabitat use influence individual physiology (Huey, 1991) and population dynamics (Pulliam and Danielson, 1991). Different studies reported that various factors affect habitat preference of young-of- the-year (0+) fish species in microhabitat. For instance, Magoulic (2004) mentioned that substrate, water depth and velocity of water flow are the most common factors influencing the use of stream habitat by species. Besides, vegetation cover (Eros *et al*., 2003) and water level (Vlach *et al*., 2005) are predictors of fish composition in streams. Schiemer *et al*. (2001) also added vegetation cover and shallow sloping embankments serve as buffer zones for 0+ fish against wash-out effects at sudden flood events. To define fish microhabitat the most commonly used technique is known as Point Abundance Sampling by Electrofishing (PASE), though the method is known to be size-selective and induces fish escapement behavior (Nelva *et al*., 1979).

2.6. Major causes of YOY habitat shifting

Habitat shifting refers to “changes in habitat used at a reduced scale from their first feeding habitat to occupy at the end of the juvenile stage”; mainly cyprinids at younger stage encountered a succession of habitat shifts at temporal and spatial scales (Gaudin, 2000). This shift could be associated with both abiotic and biotic factors, including physiological and morphological attributes of the fish in the environment. Among abiotic factors, temperature, discharges, water current and turbidity are considered as the main cause that can initiate the larvae and juvenile fishes to change their habitat, particularly in river systems (Bult *et al*., 1999; Gillette *et al*., 2006; Kucera-Hirzinger *et al*., 2009). For instance, increased temperature leads to a decrease in dissolved oxygen, which stimulated larvae to drift or actively swim from streams into lakes (Lucas, *et al*., 2001). Competitors (intraspecific and interspecific) as prey and predator are the main biotic factors, which induces habitat shifting. To avoid predation pressure also, many fish species at different life stages prefer movement to refuge areas (Magurran *et al*., 1996). Regardless of these factors, the fishes which cannot fit for the habitat used have to shift into a suitable place to get their needs (Gaudin, 2000). Due to their structural protection from the main current, lateral habitats provide a low water velocity, causing the sedimentation of fine particles used by YOY of most cyprinids, such habitat named as a “dead zone” by Gaudin (2000). Habitat preferences of juveniles/young-of-the-year are limited and usually inhabit the shallower habitats closer to stream or lakeshores. At subsequent growth, change in size and morphology, larvae and juvenile fish move to open water for searching food and adapt slow stream or river flow and low turbidity (Copp, 1990). Some fish species may also prefer offshore habitats. For instance, Wassie Anteneh (2013) mentioned juveniles of some piscivorous *Labeobarbus* spp. of Lake Tana show positive relationship with depth. This tendency to offshore habitat is linked with association to evading competition or predation by the predatory fishes (de Graaf *et al*., 2004a).

3. MATERIALS AND METHODS

3.1. Study area

The study on habitat use and characterization of young-of-the-year of *Labeobarbus* species was conducted in Gumara River and its tributaries as well as on the shores of Lake Tana every month between November 2018 and April 2019 except February 2018. Gumara River (Figure 1) originates from the western side of Gunna Mountain peaks, southeast of Debre Tabor at an altitude of 3,250 m a.s.l (Mengstie Abate *et al*., 2015). It is one of the largest perennial rivers flowing into Lake Tana and has a number of tributary rivers such as Dukalit, Kizen, Wonzema, Bawaza and Guanta (Gizachew Teshome *et al*., 2015). The tributaries contribute water and enrich the ecology of the Gumara River. 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 (Andargachew Melke and Fantahun Abegaz, 2017). It has a total drainage area of 127,186 ha up to the gauging station (near Woreta) and the total mainstream length from its origin (near mountain Gunna) is approximately 132.5 km before the river joins Lake Tana (Gashaw Chakilu and Mamaru Moges, 2017).

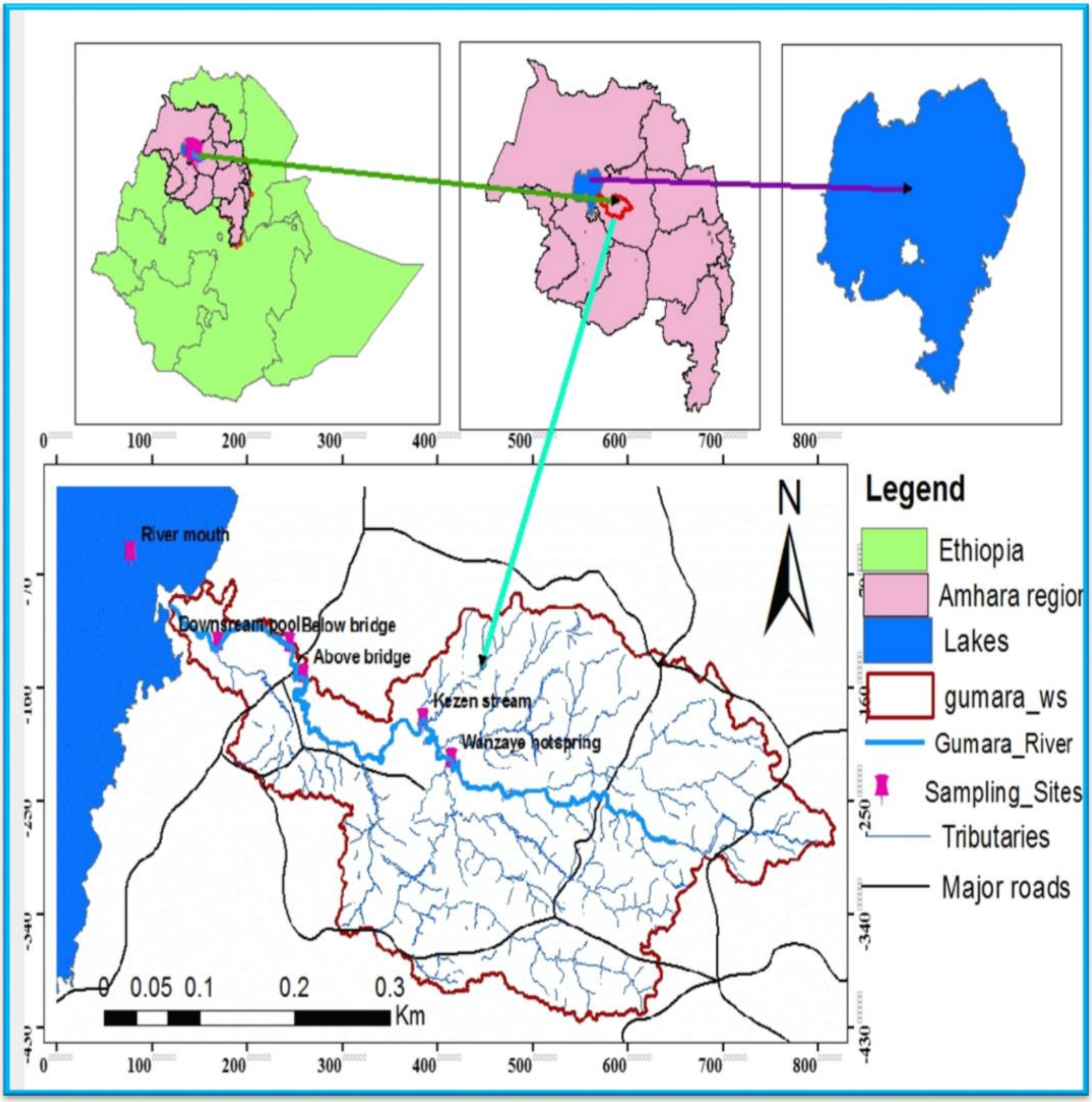


Figure 1: Map of the study area showing sampling sites

3.2. Climate

Based on 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 (Figure 2). The lowest and highest amounts of rainfalls were also recorded in March (1.4 mm) and August (440.1 mm), respectively (Figure 3).

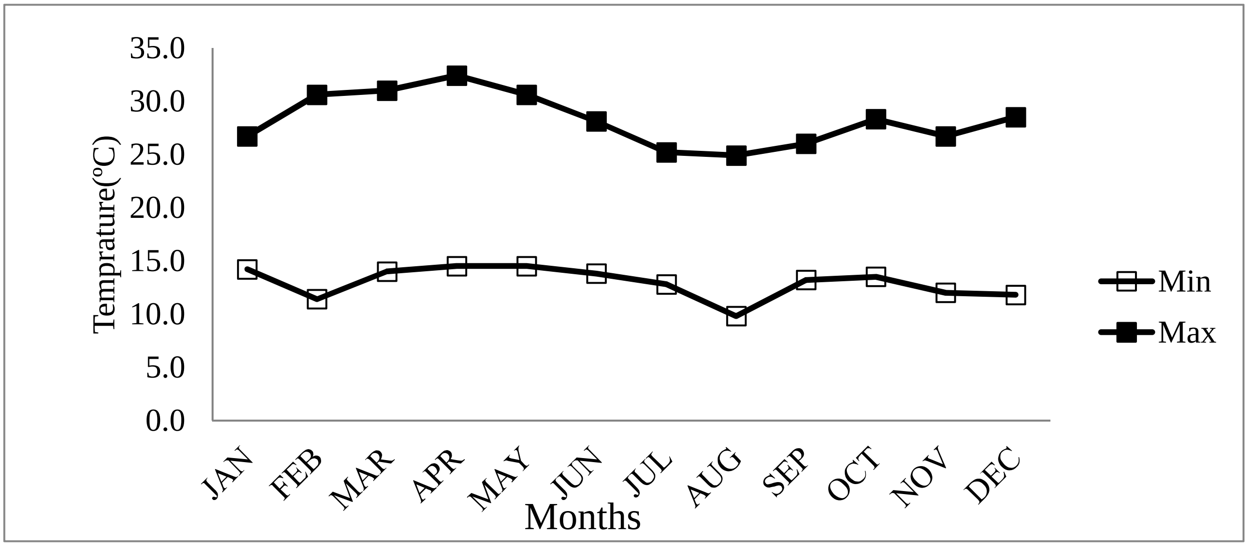


Figure 2: The monthly minimum (Min) and maximum (Max) temperature around Gumara River from 2000-2019 (National Meteorological Agency, Bahir Dar Branch, 2019)

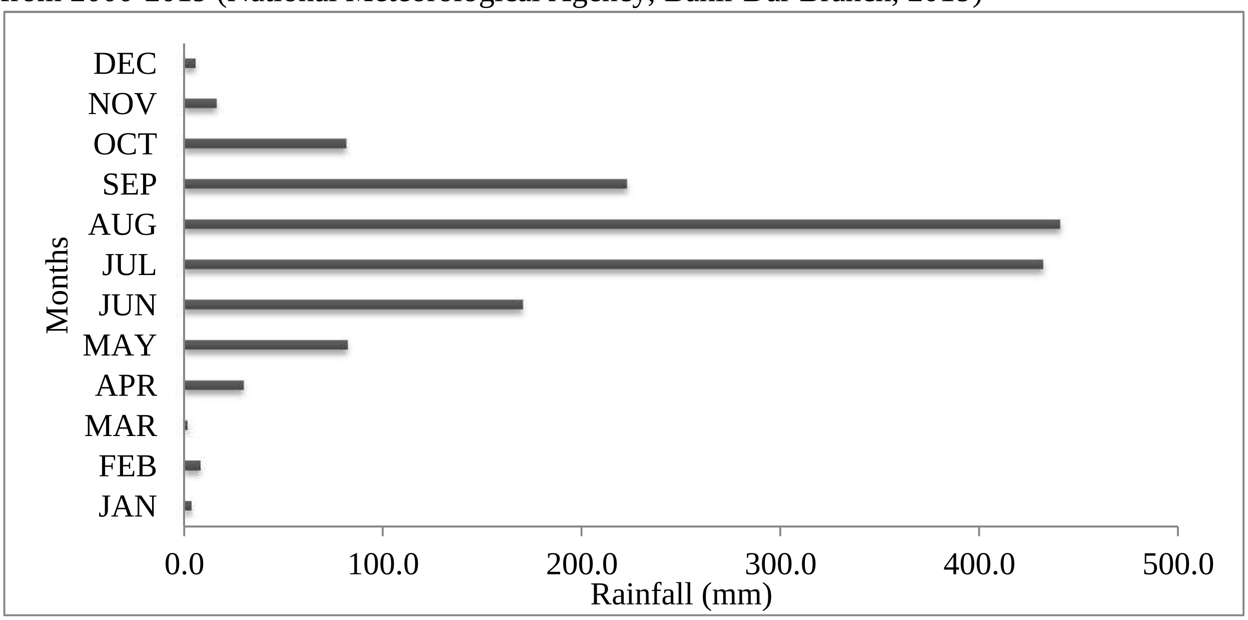


Figure 3: Monthly total rainfall distribution around Gumara River from 2000-2019 (National Meteorological Agency, Bahir Dar Branch, 2019)

3.3. Sampling sites

Based on the accessibility 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 (Appendix 1), 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 is 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 the downstream pool at a place is known as Zorfie and the last site a pool proximate to the river mouth. Simple random sampling method was used for sampling. Stratified random sampling also used to classify heterogeneous habitat to the homogeneous. The selection of the sites was done through consideration of lotic and lentic characteristics of the river. The simple random sampling method was applied for sampling. To classify a heterogeneous habitat into homogeneous, stratified random sampling method was used. Most of the sampling sites exhibited a reduced flow and habitat patches, which could be easily identified as pool, riffle and run as predominant habitat types. Moreover, shallower stretches of raceway and backwater were also present, but only pool, riffle and run were sampled since they were frequently present. There were 20 sampling points (from each site) which were selected randomly based on their suitability to use electrofishing in a Zigzag manner (Gozlan *et al*., 1999). 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

3.4. Flora and fauna

During the rainy season, the river mouth of Gumara River was covered with dense vegetation such as grass and many shrubs. Nagelkerke and Sibbing (1996) and Wassie Anteneh (2005) mentioned *Cyperus papyrus* as a common plant species at Gumara and Gelda River mouths. The upper part of the Gumara River was covered with many shrubs, a few big trees and some *Eucalyptus*. 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.)*, Shinshina, etc. Among woody trees: Fig tree or “Warka”, Mango, Eshe and Shinshina were dominant in the site close to the hot spring. In the case of Kizen stream, the area is relatively free of woody trees; instead, it is dominated by grass and many shrubs. Substrate type of nearby the hot spring, Kizen stream and below the bridge sites were a mixture of cobble, boulder, gravel and silt. Whereas, the remaining sites have a very muddy bottom substrate, since, thus sampling site are much closed to farmlands. Sites above and below Gumara Bridge were covered with a plant species locally known as “Shinshena” and “Zemed Begidie”. Downstream pool around Zorfie and pool proximate to river mouth sites were covered with sparse “Shinshina” and “Zemed Begdie” plant species. Instead, relatively dense coverage of grass and water hyacinth (especially at the end of sampling time) was observed. The most frequently observed vegetation types in the site around the pool proximate to river mouth include *Typha*, *Echinochloa spp*., *Eichhornia crassipes*, *Ceratophylum demersum*, *Nymphaea* spp. and *Cyperus papyrus*. Key developed by Getachew Desalegn *et al*. (2012) was used to identify plant species. 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*).

3.5. 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 (Appendix 2). 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 a stick and echo-sounder was used especially in the deepest site of the study area (downstream pool around Zorfie site and pool proximate to the 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 (Tongnunui and Beamish, 2016). YOY 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 (Gozlan *et al*., 1999; Allard, 2014). 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. Methods of size class classification of specimens using their total length and a key to differentiate YOY of *Labeobarbus* spp., from other cyprinids were adopted from Wassie Anteneh (2013). Identification of YOY of *Labeobarbus* at the species level is difficult due to their small size and absence of well-developed organs for identification. After collecting the necessary data, all specimens except 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.

3.6. Abundance, diversity and equitability

Abundance difference of the dominant fish groups between sampling months, sites and mesohabitats were determined using their corresponding number of catches. Shannon diversity index (H') for the collected specimens in Gumara River was calculated to indicate diversity at different sampling sites and mesohabitats of the river. The Shannon diversity index (H') explains both the variety and the relative abundance of species (Naesje *et al*., 2004). H' was calculated as:

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

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.

3.7. 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. Microhabitat characterization was done using the information provided from point-specific physico-chemical parameter measurements (Lewis *et al*., 2004) and the abundance of fish species. It was analyzed using Paleontological Statistics software package (PAST) software. Substrate type was classified based on their maximum dimensions, using a modified version of the Wentworth scale (Jones, 2011): 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. Substrate embeddedness was also expressed as low (< 25%), medium (25-50%) and high (> 50%) based on the presences of gravel, pebble, cobble and boulder surfaces surrounded by fine sediment (Kaufmann *et al*., 1999). Habitat-species relationship or preference was assessed using physico-chemical measurements, substrate types and abundance of juveniles in each size class from each sampling point. Habitat shifting was also determined by electrofishing sampling points in every month and recording dried (especially riffle) sampling points (i.e. considering when riffles points dried; juveniles were forced to shift into pools). Necessary pictures showing specimens and habitat types were taken. Representative specimens were preserved in 10% formalin in plastic jars (Wassie Anteneh, 2013; Tongnunui and Beamish, 2016) and transported to the laboratory at Bahir Dar University for further identification.

3.8. Gut content analysis

The result from the gut content analysis was also used to determine habitat preference and shifting of YOY. It was done after the morphometric measurements; specimens were dissected and gut samples were taken and immediately preserved in 10% formalin within a small vial. In the laboratory, the preserved gut samples in small vials were reversed into the petri dish and diluted with water to identify food items using a dissecting microscope (Leica, MS5, magnification-40x). Frequency of occurrence of the gut contents was examined and the individual food organisms were sorted and identified using phytoplankton and zooplankton key (Sanet *et al*., 2006; MRCEP, 2015). The number of guts in which each item occurs is recorded and expressed as a percentage of the total number of guts examined.

%Frequency of occurrence was calculated using this equation, $O_i = \frac{\mathrm{Ji}}{p} * 100$

Where J_i is the number of fish containing certain prey and P is the number of fish with food in their gut.

3.9. 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. Redundancy Analysis (RDA) using CANOCO version 4.5 was used to evaluate fish-habitat relationships. PAST (Paleontological Statistics software package), version 3.22 was used to determine the abundance and preference of juveniles at the microhabitat level.

4. RESULTS AND DISCUSSIONS

4.1. Physico-chemical parameters

Physico-chemical parameters such as dissolved oxygen, temperature, pH, TDS, conductivity, turbidity and water depth in Gumara River were measured (Table 2) and the analysis showed significant differences ($P<0.05$) between sampling sites (Appendix 3).

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

Sites	Temperature (ºC)	DO (mgl^{-1})	pH	Conductivity ($\mu s\ cm^{-1}$)	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

4.1.1. 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 (2004), in which vegetation cover/ shading effect is the one among different factors that affect water temperature and they are inversely proportional to each other. Water temperature is also inversely related to dissolved oxygen. This is also in agreement with Genevieve and James (2008), in which the amount of any gas, including oxygen is inversely proportional to the water temperature. 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*. (2015), 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. Mean surface water temperatures in the river showed a significant variation (P<0.05) among sampling sites and exhibited a trend of decreasing levels from the upstream around Dukalit to the shore of Lake Tana. This also indicates the effect of macrophytes on heat transfer from the near-surface region to deeper parts of the water column through vertical mixing (Wetzel, 2001). However, the mean surface water temperatures of all sampling sites were within the range of variation reported for most tropical water bodies (20-30 ºC) (Talling and Lemoalle, 1998).

4.1.2. 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 (2009) also mentioned the factors that affect the concentration of DO in water, which include temperature, depth, salinity, photosynthesis and availability of nutrients. 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 (2008) 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 (Campbell and Wildberger, 1992). Therefore, the mean DO level of Gumara River was 7.71±0.08 mg/l, which was greater than the above-stated values, and it was the required DO level for fish to perform their biological functions.

4.1.3. 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. According to Guptaa *et al*. (2009), pH is always positively correlated with an electrical conductance. The significant difference in pH is also attributable to the extent of photosynthetic removal of carbon dioxide (Reynolds, 2006). 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. In agreement with Wetzel (2001) high concentrations of dissolved organic carbon can emanate from macrophytes. 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) (Eshete Dejen *et al*., 2004) and Chibirna (8.1±0.13) and Shini Rivers (8.2±0.14) (Gizachew Teshome *et al*., 2015). 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.

4.1.4. Electric 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 the river mouth, respectively. The occurrence of the lowest conductance value at the pool proximate to the 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. According to Navneet *et al*. (2010), 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 Eshete Dejen *et al*. (2004) 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}) (Gizachew Teshome *et al*., 2015). 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.

4.1.5. Total dissolved solids (TDS)

Among the sampling sites, the highest (129.30±6.06) and the lowest (109.79±7.71) value of TDS were recorded at downstream pool around Zorfie and the pool proximate to river mouth sites, respectively. It also showed a significant variation ($P<0.05$) between 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 high TDS value in the downstream pool around Zorfie might be inductive that this site might be vulnerable to the introduction of large quantities of nutrients through runoff. Deas and Orlob (1999) noted that the maximum value of TDS can result in polluted waters or waters receiving large quantities of land runoff. 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) (Gizachew Teshome *et al*., 2015) and this might be due to differences in the vulnerability to runoff.

4.1.6. 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 agree with the report of Nkwoji (2010), which mentioned that variation in turbidity 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 (Appendix 4).

4.1.7. 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, 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.

4.1.8. 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. It also associated with the decreasing inflow 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) (Ayalew Wondie *et al*., 2007).

4.2. 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 excluding February. However, cyprinids were the dominant groups.

Table 3: Composition and abundance of fish species caught in Gumara River

Genus/species name	Number (N)	Percentage	Family
E. humilis	2062	53.14	
L. juvenile (YOY)	945	24.36	
Garra spp.	687	17.71	
L. beso	29	0.75	Cyprinidae
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	Clariidae
O. niloticus	26	0.67	Cichlidae
Total	3,880	100.00	

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 (Appendix 5). 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, L. brevicephalus* and *L. intermedius*) due to the presence of well-developed morphometric characters. About 945 young-of-the-year (YOY) *Labeobarbus* specimens were collected. These, specimens were very small in size (i.e., total length less than 7 cm except few) and they were very difficult for identification at a species level due to the absence of well-developed morphometric structures; instead, they were simply differentiated from other cyprinids using key (Appendix 6). Among the identified *Labeobarbus* species, *L. beso* (0.5%) was more dominant than *L. brevicephalus* (0.36%) followed by *L. intermedius* (0.26%). In addition to genus *Labeobarbus*, different species from genus *Enteromius* such as *E. humilis* and *E. pleurogramma* were examined during the study period. *E. 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* spp. and *G. dembecha* were among the species of *Garra* examined and contribute about 17.71 and 0.52% of the total catch, respectively. In addition to cyprinids, specimens from family Cichlidae and Clarriidae were collected. For instance, *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 reported (de Graaf, 2003) in which the fish species identified were dominated by the cyprinids. 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 abundance 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. Wassie Anteneh *et al*. (2008) 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.

4.3. Abundance of fish across sampling months

The abundance of dominant fish varied between sampling months (Figure 4) and this might be associated with the variation in physico-chemical parameters of water and food availability of the different sites. This is in agreement with Zeleke Berie (2007) who stated that water level and turbidity affect the abundance and diversity of fish. The water temperature is also another factor that affects the abundance, diversity and biological process (including physiological, biochemical and life-history) of fish. In April, the abundance of almost all dominant specimens declined due to its high water temperature, low water level and DO since it is the dry season.

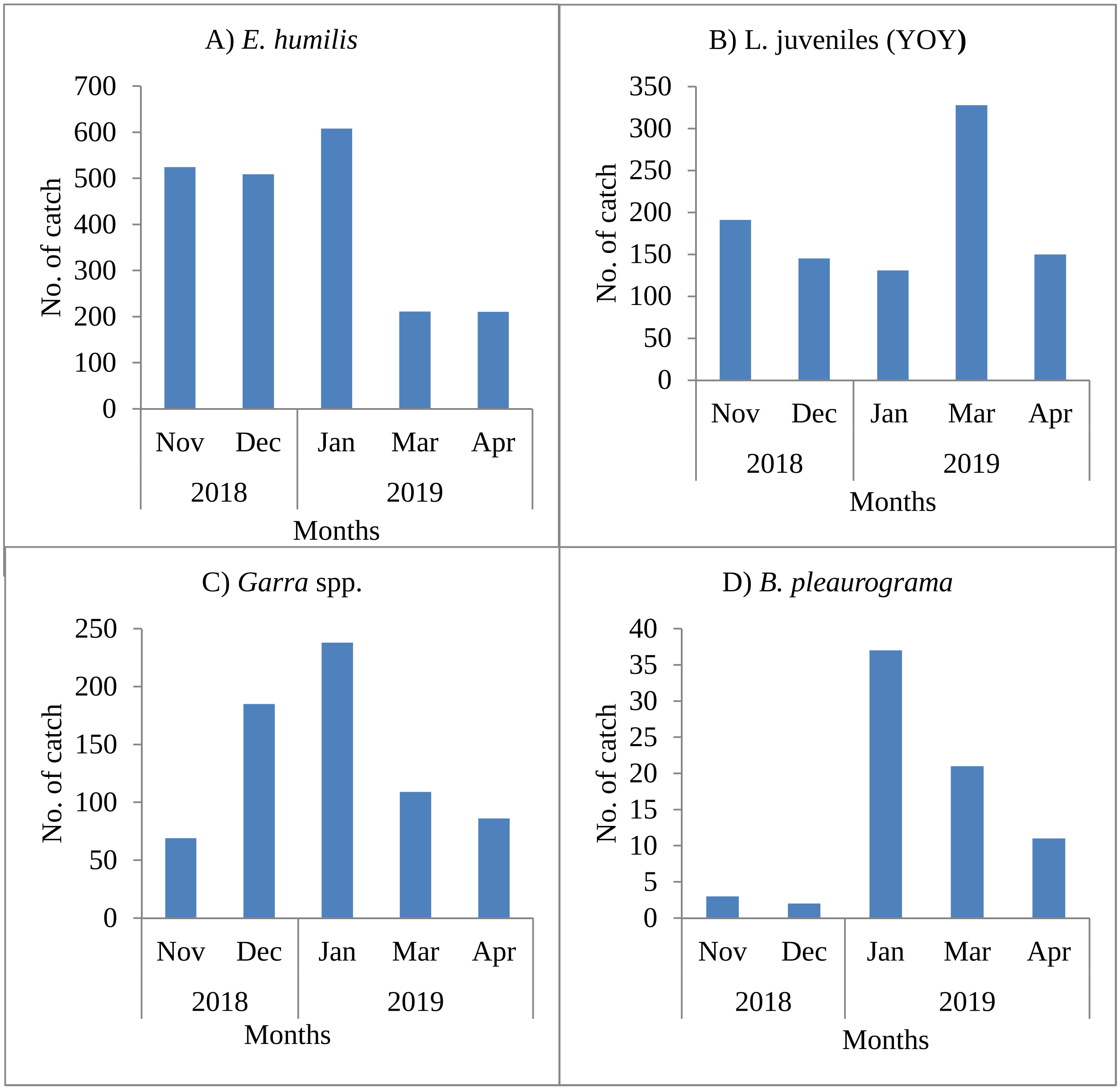


Figure 4: Variation in abundance of the dominant species in Gumara River between sampling months

4.4. Abundance difference between sampling sites

There was a variation of the abundance of fishes not only between months, but also between sampling sites (Table 4). This indicated that each species prefers its habitat based on foodavailability, 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
C. 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 (Harvey and Stewart, 1991; Girard *et al*., 2004). The presence of gravel substrates is also very important to protect deposited eggs and juveniles from being washed by riffles. According to Takele Shitaw *et al.* (2018) *Labeobarbus* species prefers fast-flowing, clear, highly oxygenated water and gravel-bed streams or rivers. 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*. Eshete Dejen *et al*. (2006) have reported that *E. pleurogramma* is mainly present in the wetlands around the lake. In general, the abundance difference between sampling sites was mainly due to environmental variables and their relationship was shown in the ordination triplot (Figure 5). 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 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 5).

Table 5: 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

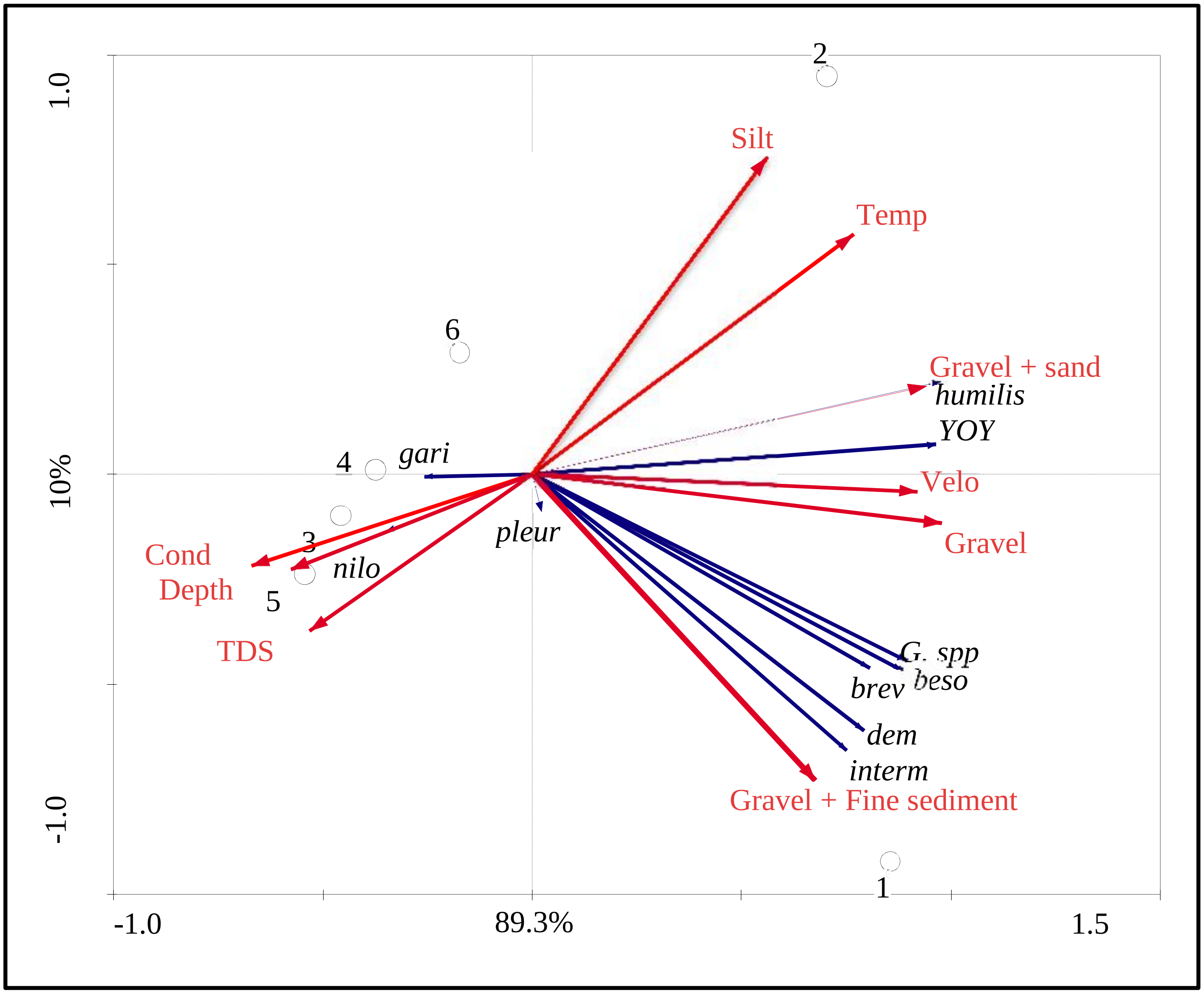


Figure 5: Ordination diagram of Redundancy Analysis (RDA) of the first two ordination axes summarizing the relationship between physico-chemical variables and fish species(1=Gumara hot spring, 2=Kizin stream, 3=Above-Gumara Bridge, 4=Below Gumara Bridge,5= Downstream pool, 6=Pool proximate to river mouth; 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*).

Based on the RDA, most environmental variables and fish species were found in the first axis (Figure 5). 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. In agreement with Sebastian-Gonzalez and Green (2014), the vector length of a variable represents the relative importance of that variable for predicting the fish assemblage composition. The vectors can be extended in either direction to identify the position of a species relative on other species along that gradient (Ter Braak, 1986). The abundance of *E. humilis*, YOY, *Garra* spp, *L. beso*, *L. brevicephalus*, *G. dembecha* and *L. intermedius* were positively correlated with the level of temperature and water velocity at site one and two.

4.5. Abundance difference between mesohabitats

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 (Figure 6). 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 (1998) 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. 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 (Figure 7).

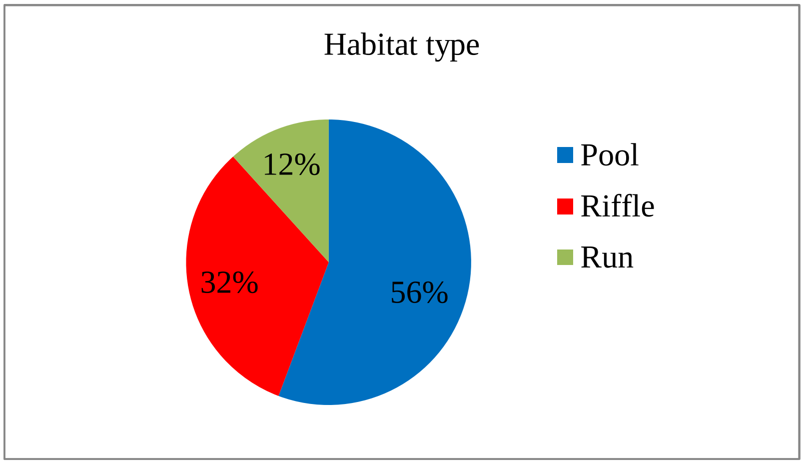


Figure 6: Major habitat types sampled in Gumara River

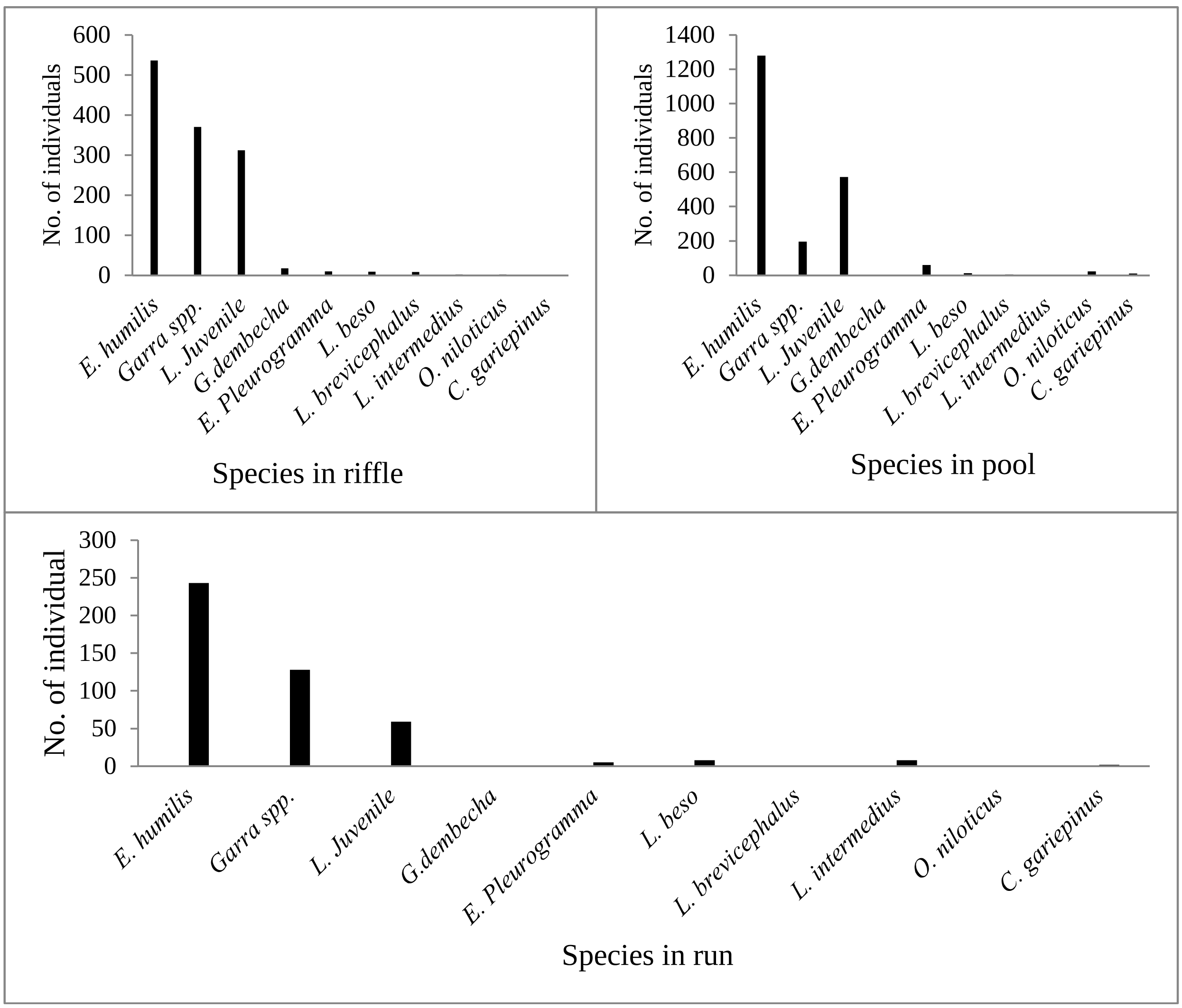


Figure 7: Abundance of sampled fish in different mesohabitats

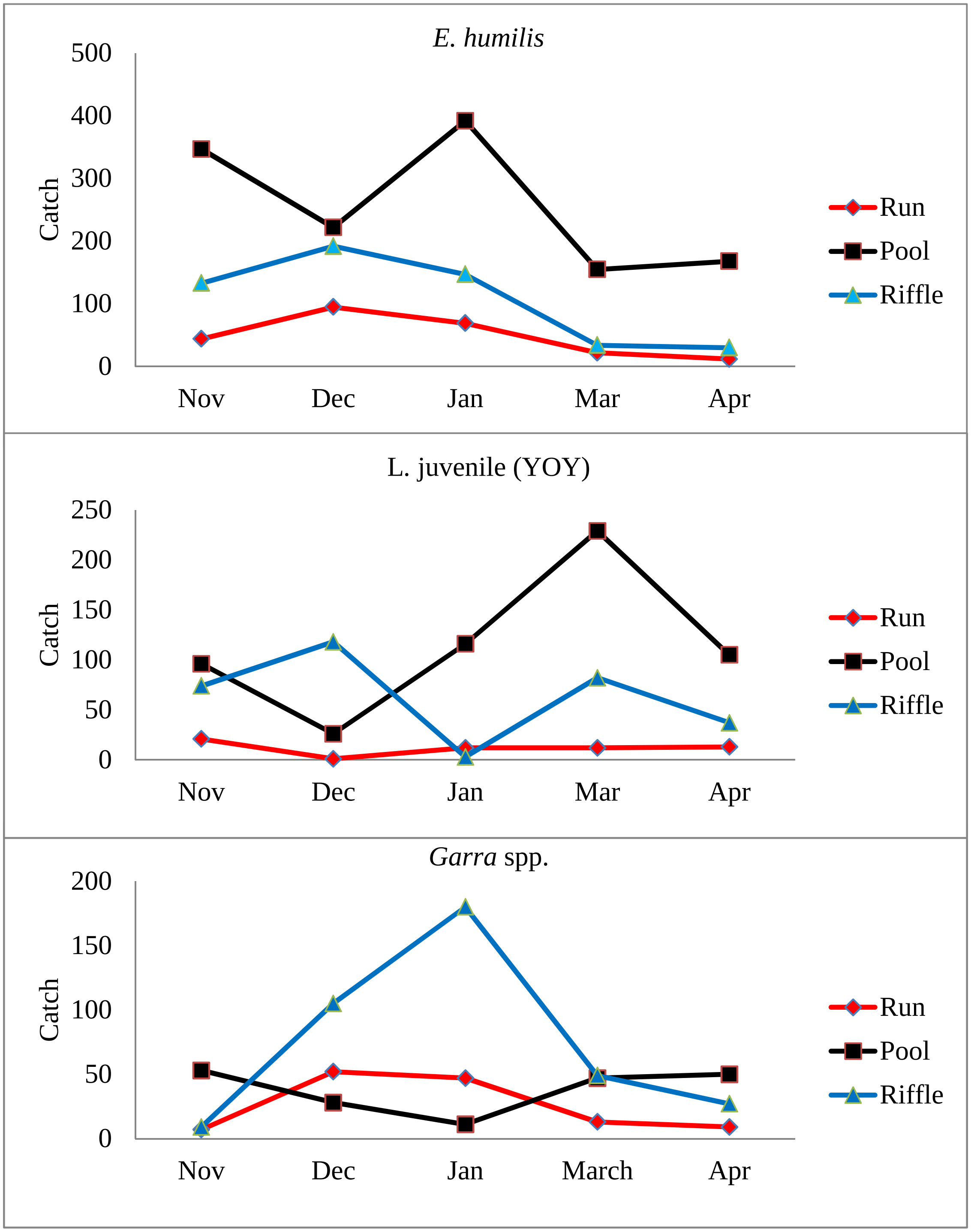


Figure 8: The abundance variation of dominant fish group between months and mesohabitats

There was abundance variation of dominant species in different mesohabitat throughout the sampling months (Figure 8). *Enteromius humilis* was dominant in pool habitat; however, the highest abundance was found in January but declined in March and April. Relatively the highest abundance was founded in December in both riffle and run habitat, but started to decline in January when the water level was low and some sampling points started to dry. Initially, the abundance of young-of-the-year of the *Labeobarbus* species was relatively high in both riffle and pool. In December juveniles (YOY) started to decline from pool, whereas, riffle habitat was highly preferred since the water level was maintained. In January riffle habitats dried and as a result, juveniles migrated to the pool and high abundance was found in pool habitat. In April the abundance of YOY of *Labeobarbus* species declined in all habitats. The abundance of *Garra* species in pool habitats was higher in November and replaced by riffle in December and January (a bit high) and again started to decline in March and April. Abundance in different habitats indicated that altered and high altitude habitats support fewer fish species. In general, all dominant species again declined, especially in April. This indicated that the Gumara River faced disturbance, pollution and excessive water abstraction for irrigation during the dry season and these all affect the abundance of fish.

4.6. Shannon diversity index and evenness

4.6.1. Shannon diversity index and evenness in Gumara River

Based on the result, Shannon's index value in Gumara River was 1.21 (Table 6) and it showed that the structure of the habitat was moderately balanced. According to Shannon (1949), 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. Staubet *et al*. (1970), also mentioned 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 River Jigrefa (H' = 1.21) and higher than the Rib River mouth (H' = 0.63) (Yeshizerf Shumye, 2016). Evenness value (J'=0.53) also indicates the uniform distribution of individuals. Sheldon (1969) stated that 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*. (2012) mentioned water temperature and rainfall as major influential factors for species distribution.

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	0.00	-0.037		
L. intermedius	10	0.003	-5.961	0.00	-0.015		
L. brevicephalus	14	0.004	-5.625	0.00	-0.020		
L. pleurogramma	74	0.019	-3.960	0.00	-0.076		
G. dembecha	20	0.005	-5.268	0.00	-0.027		
C. gariepinus	13	0.003	-5.699	0.00	-0.019		
O. niloticus	26	0.007	-5.005	0.00	-0.034		
Total	3,880			0.37	-1.21		

4.6.2. 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 ($P<0.05$) 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 low diversity was found 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 high 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 low 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 low 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*. (2018) reported that communities become more dissimilar as the stress increases and accordingly species diversity decreases due to the resulting poor water quality. Singh and Agarwal (2013) also noted that decreasing temperature is the main factor for the decrease in diversity and abundance of fish fauna. Sites below the bridge and river mouth have Shannon’s index value of less than 1, which indicated that these sites might be polluted since, relatively high human interference were observed. 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 were evenly distributed or it shows 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	1.30	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	0.70
P-R-M	0.97	0.60

4.6.3. Shannon diversity and evenness difference among mesohabitats

Gumara River is characterized by heterogeneity in habitat type (pool, run and riffle). Each habitat type helped to serves as habitat for different life stages. In this case, the highest number of individuals (2,160 in 9 species) was recorded in pool habitat type. However, the value of the diversity index and evenness was low. Therefore, this indicates that the pool habitat was a preferred habitat of most of the similar species since relatively low evenness value. It also indicates 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, the gravel substrate type and shallow water depth. 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

Mesohabitats	No. of individuals	Percentage	H'	J'
Pool	2160	55.67	1.11	0.50
Riffle	1266	32.63	1.25	0.57
Run	454	11.7	1.15	0.55
Total	3880	100.00		

4.7. Size classification of *Labeobarbus* juvenile (YOY)

Juveniles of the *Labeobarbus* species were grouped into four size classes such as size class ≤3 cm, 3.1-5 cm, 5.1-7 cm and >7 cm. Most of them were found in a size class ranging from 3.1-5 cm (Figure 9) and it contributed about 55.8%. Whereas, the remaining 6.1%, 33.9% and 4.2% of them were found in the size class of ≤3 cm, 5.1-7 cm and >7 cm, respectively. However, juveniles of size class,10 cm and above were not found and identification to a species level was difficult. Mina *et al*. (1996) mentioned that the identification of juveniles of *Labeobarbus* species before they reach 10 cm fork length was difficult.

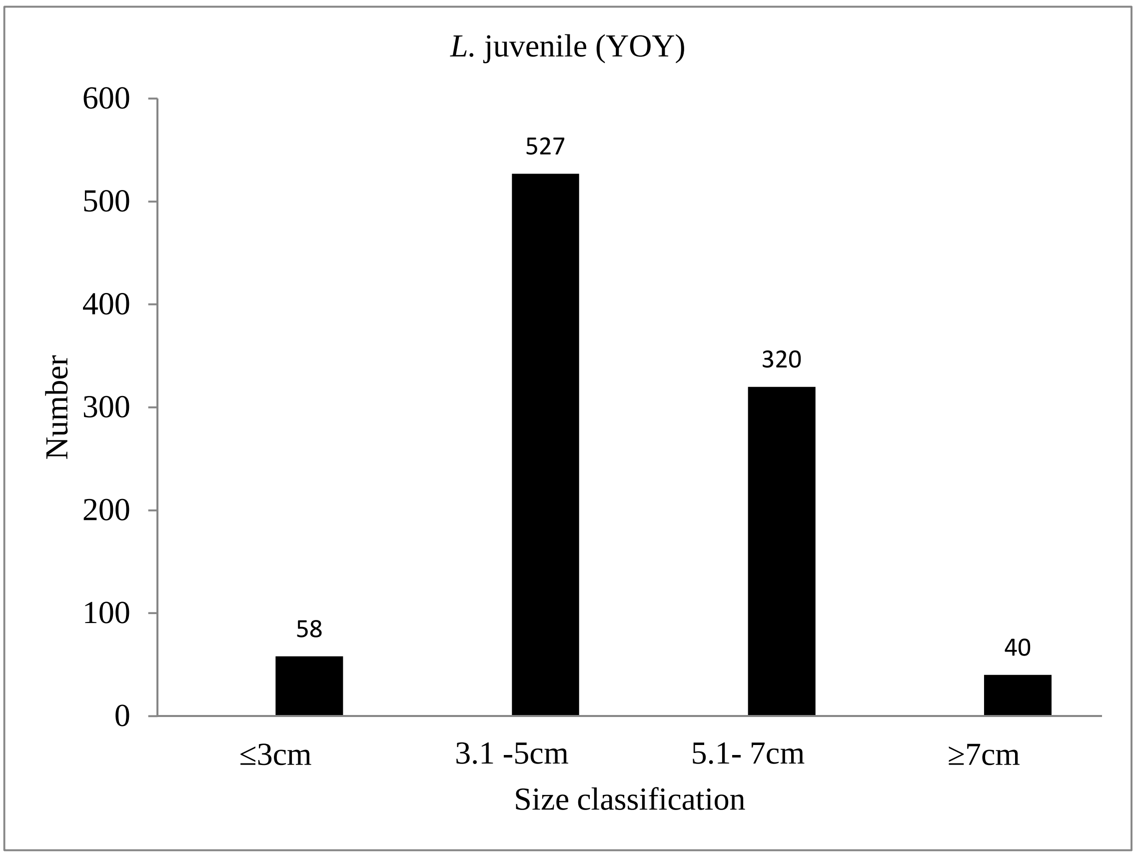


Figure 9: Size classifications of all collected YOY

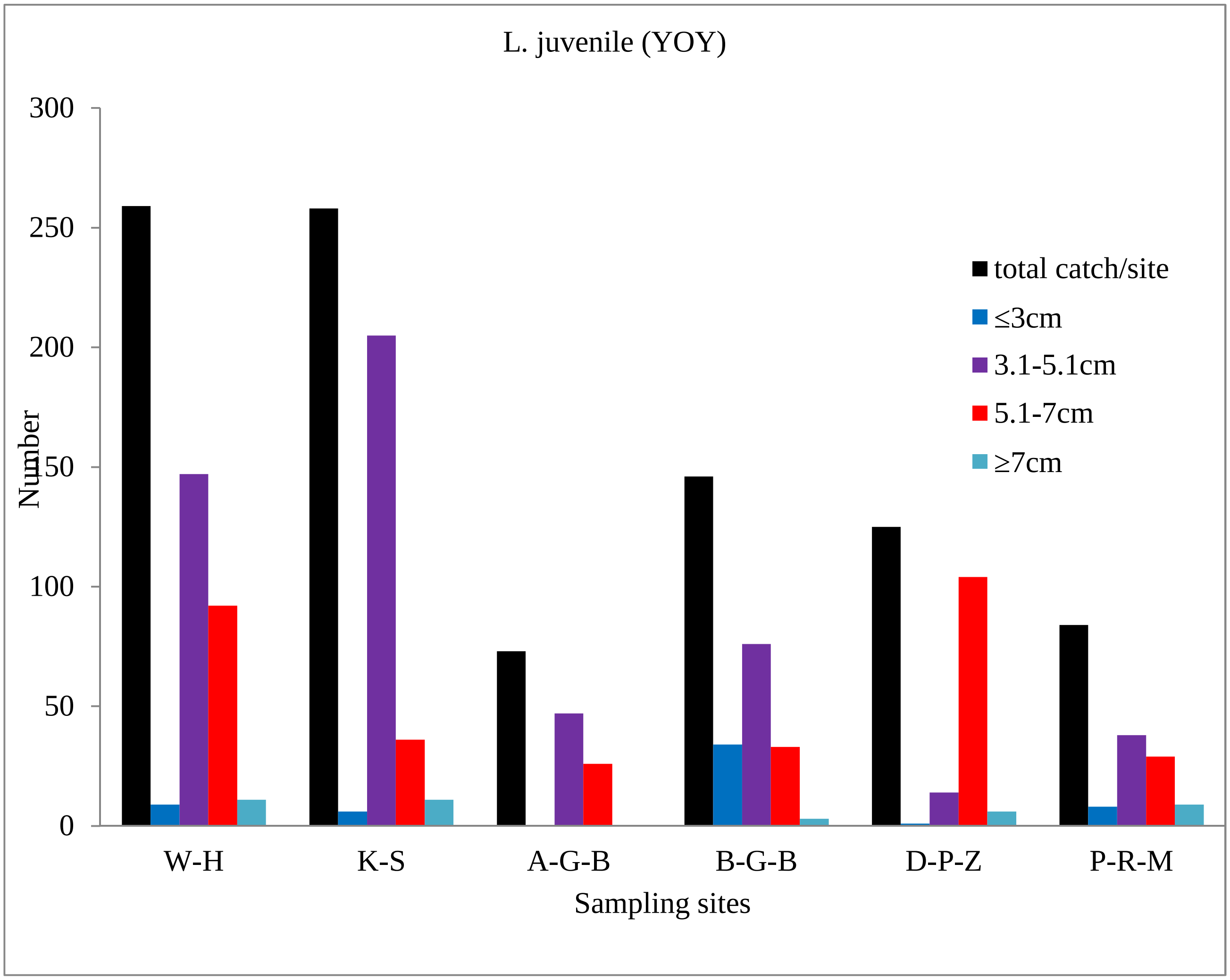


Figure 10: Size classes of YOY between sampling sites

There was variation in the size class of YOY between sampling sites (Figure 10). Relatively high number of small-sized YOY (i.e. ≤3 cm sized class) was recorded in the site below the bridge followed by Wanzaye hot spring and Kizen. These sites were characterized by shallow depth and gravel substrate types. Utilization of shallow habitats by smaller individuals is high and it is mainly to avoiding visual predators e.g. piscivore fishes (Harvey and Stewart, 1991). Wassie Anteneh (2013) also mentioned that the small-sized YOY remain in the upstream until they reach a free swimming juvenile stage.

YOY found in size class of 3.1-5 cm was dominant in the Kizen followed by Wanzaye hot spring and below the bridge, while the lowest was found in a downstream pool around Zorfie. YOY that were included in 5.1-7 cm size class were more dominant in a downstream pool around Zorfie site followed by near to Wanzaye hot spring and Kizen. During the end of the data collection, most of the large-sized (≥7 cm) specimens were found in the downstream pool and pool proximate to the river mouth sites. This is also mainly due to their returning time from their early-stage nursery site to the lake. This is also in agreement with Coop (1990) who reported that the shift in habitat of the juvenile fish to find adequate food, adapt slow water flow and clear water is results from their subsequent growth and change in size. Additionally, most of the riffles and run habitats were dry (during the dry season especially in the last two months) and as a result, juveniles shift their habitat to the downstream pool. Habitat shifting by juveniles/YOY from upstream sites to the downstream pool might be attributed to avoid visual terrestrial predators, high water temperature, turbidity and human disturbance (e.g. water abstraction). Lucas *et al*. (2001) mentioned that low dissolved oxygen resulted due to the presence of high water temperature, which motivated larvae to drift or actively swim from streams into lakes. However, the barrier between the Gumara River and Lake Tana made juveniles in the downstream pool unable to migrate to the lake. Barriers resulted from different human activities (e.g. water abstraction, sand mining and dam building) that might lead to habitat modification and floodplain disconnections. Such circumstances have also played a role by reducing recruitment. Wassie Anteneh (2013) reported in Gumara downstream pool, the movements of juveniles were impeded due to disconnection (in April/May) of the pools, because of water pumping for irrigation. Aarts *et al*. (2004) also stated that habitat types or connection between habitat loss due to hydrologic modification and floodplain disconnection is primary causes that reduce recruitment.

4.8. Young-of-the-year of *Labeobarbus* species and microhabitat relationship

The relationship between the YOY and environmental variables was shown in the ordination triplot (Figure 11). The first axis of RDA explained 79.7% of the cumulative percentage of the variance of YOY and their habitat relationships. It also showed a negative correlation with conductivity, TDS and water depth, while positively correlated with temperature, velocity and all substrate types. The second axis also explained about 18.1% of variance and except temperature all parameters were positively correlated. The first two ordination axes collectively explained 97.8% of the variance in YOY fish abundance and environmental parameters in the Gumara River (Table 9)

Table 9: Results of Redundancy Analysis (RDA) of the relationship between environmental variables and YOY using the first two Axes

Parameters	Axis 1	Axis 2
Eigenvalues	0.797	0.181
% Environmental relationship	79.7	18.1
Temperature	0.9405	-0.2278
DO	0.136	0.8817
Conductivity	-0.5912	0.1062
TDS	-0.5	0.5722
Velocity	0.8415	0.1751
Depth	-0.7491	0.5112
Gravel +sand	0.9565	0.2252
Clay with dead plant matter	0.3832	0.5753
Gravel + fine sediment	0.3832	0.5753
Gravel	0.8774	0.3912
Muddy	0.7223	0.0135
Silt	0.7847	-0.1613

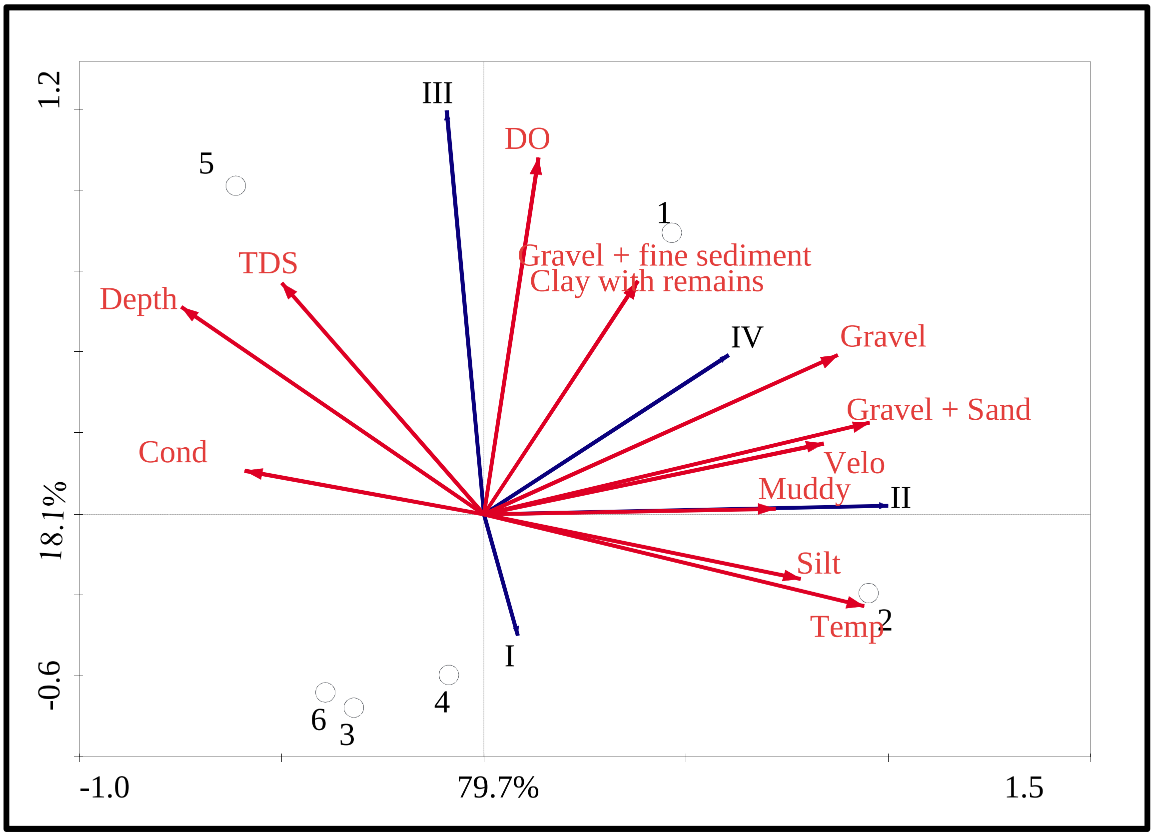


Figure 11: Ordination diagram of Redundancy Analysis (RDA) of the first two ordination axes summarizing the relationship between physico-chemical variables and abundance of YOY(1= Gumara hot spring, 2=Kizin stream, 3=Above-Gumara Bridge, 4=Below Gumara Bridge, 5=Downstream pool around zorfie, 6=Pool proximate to river mouth; Temp=Temperature, Cond=Conductivity, TDS=Total Dissolved Solid, Velo=Velocity and Depth; I= size class ≤3 cm, II= size class 3.1-5 cm, III=size class 5.1-7 cm and IV= size class ≥7 cm)

Based on the RDA, most environmental variables were found in the first axis (Figure 11) and they were positively correlated with almost all classes of YOY. Substrate preference of YOY was done by recording substrate, type of each electrofished sampling points and their correlation with species among sampling sites was also generated from the analysis (Figure 11). Besides this, silt, gravel with sand (medium embeddedness), gravel with fine sediment, muddy, gravel and silt substrate type were positively correlated with the abundance of all size classes of YOY. This also indicates the suitability of the river which is used as the best spawning area for *Labeobarbus* species since it has fast-flowing, gravel bed (especially upstream sites and below the bridge) clear and highly oxygenated water. Different fish species mainly, cyprinids (e.g. *Labeobarbus*) lack parental care for their offspring because they are non-guarders. Due to this, they require fast-flowing, clear and highly oxygenated water with gravel-bed streams or rivers. A similar study conducted by Tomasson *et al*. (1984) showed that a fast-flowing, gravel-bed and highly oxygenated water bodies are required by non-parental care fish species due to their critical importance in the development of eggs and larvae. Baras (1997) and Abebe Getahun *et al*. (2008) also added that cyprinids (e.g. *Labeobarbus*) require a fast-flowing, clear and highly oxygenated water with gravel-bed as spawning ground and development of larvae in streams and rivers.

Many migratory *Labeobarbus* fish species deposit their eggs in the gravel beds to protect their eggs from being washed. Lowe-McConnell (1975) also noted that the deposition of eggs in the gravel or pebble beds protects them from being washed away by riffle; clear water will not cover them with a film of sediment obstructing the diffusion of oxygen. Although their significance was a bit low, sand and clay substrate type/ clay with remains of the dead plants were also preferred by YOY. Such preference was also observed during the dry season (March and April) when riffles dried; juveniles migrate to the downstream pool site in this study. Since these sites were very close to agricultural areas clay soils were released to the river through runoff. Initially, juveniles were dominant in riffle and gravel substrate type in upstream sites and after a month the riffle habitats dried-up (related to water abstraction for irrigation during dry season) and as a result there occurred habitat shift to pools. Many pool sampling points in this site were also covered with clay soil and remains of dead plant matter/clay and silt substrate type.

The occurrence of habitat/substrate shifting, in this case, might be associated with the only options/ not choice by juveniles. Because when the gravel dominated riffle and run habitats dried, juveniles were forced to shift their habitat into the pool. Living in a pool for a long time also might cause stress for juveniles because of inadequate dissolved oxygen due to lack of turbulence and decomposition of organic matters. Therefore, maintaining the depth of pool habitat is crucial to maintain juveniles until the rainy season, to regulate water temperature and enhancing dissolved oxygen since the water temperature is inversely related to depth and dissolved oxygen. This could also be achieved by avoiding water abstraction for irrigation and other uses from pool habitat during the dry season. Almost all size class of YOY were positively correlated with axis one in both site one and two. Whereas, all size classes were negatively correlated with water depth, TDS and conductivity. This might be due to their small size, since small individuals utilize shallow habitats to avoid predation. Garcia-Berthou (2001) and Gustafsson *et al*. (2010) have also reported that large and older individuals mostly utilize deep-water habitats; unlike smaller and younger fish. The other possible reasons for different size classes of YOY between sampling sites could be related with PASE technique since, conductivity, water depth, turbidity, substrate type, size and behavior of fish affect the efficiency of the device.

Based on the frequency of occurrence of YOY at a specific environmental parameter value and PAST analysis of the environmental variables (Figures 12 and 13), young-of-the-year of the *Labeobarbus* species preferred low water depth and low to medium velocity. According to Girard *et al*. (2004) many YOY fish species use low-velocity; shallow habitats close to the shoreline and bottom substrate. Water velocity influenced the variation in swimming behavior concerning size and sex, hence, with increasing body length, fish swam further and more frequently between boulder regions (Hockley *et al*., 2014). Fish assemblage is affected by flow variability since high water flow destroys fish habitat and also wash the eggs and the larvae of fish. In contrast, during the dry season, the low water velocity caused fishes to shift their habitat into pools. In the study area, relatively large-sized juveniles were shifting to the downstream pool and the site is characterized by low water velocity and high water depth. The occurrence of shifting to the pool habitat might have caused stress on fish and make them vulnerable to predators and hence, only very tolerant species (e.g. Cyprinidae and Clariidae) survive in seasonal and swiftly flowing rivers (Genanaw Tesfaye, 2006). The mean water temperature value of Gumara River was 21.32 ± 0.11 which was <32.5 ºC, the limit for aquatic life (Hauer and Hill, 2007). Juveniles of *Labeobarbus* species prefer water temperature ranges from 20-25 ºC, within which maximal growth rate, efficient food conversion and the best condition of fish. Fish also require oxygen for respiration, but the requirement varied based on species and their life stages. DO ranges from 5.5-9 mg/l were more preferred by young-of-the-year of the *Labeobarbus* species.

Svobodova *et al*. (1993) reported cyprinids as less demanding; they can thrive in water containing 6-8 mg /l and show signs of suffocation only, when the oxygen concentration falls to 1.5–2.0 mg/l. Specific conductivity is among the environmental variables that affect the abundance of fish and value < 200 µS/cm are preferred by juveniles. The number of juveniles was high in pH ranges between 6 and 10 and at low turbidity.

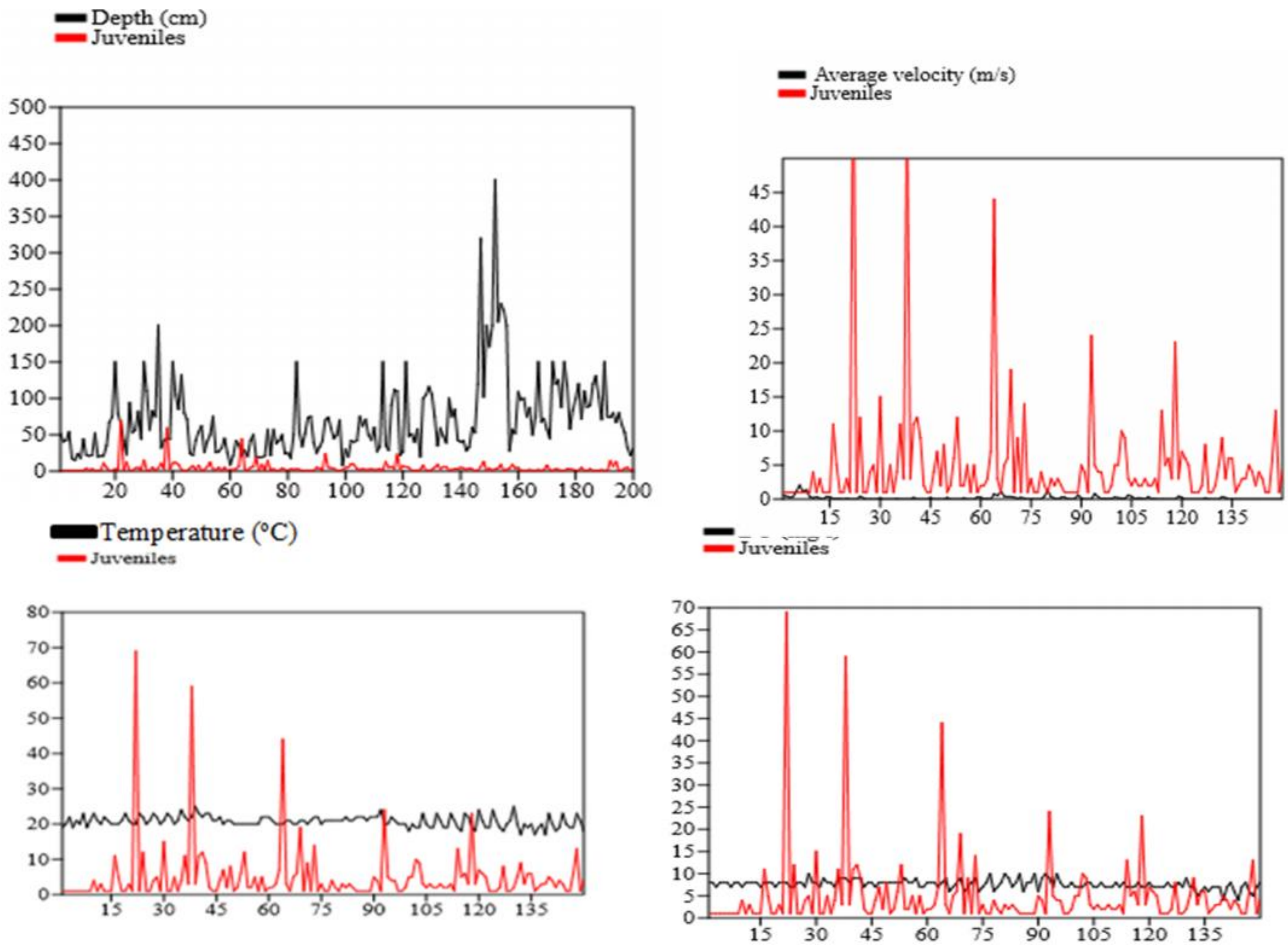


Figure 12: Microhabitat and abundance of juveniles (where x-axis is juveniles and y-axis is environmental variables

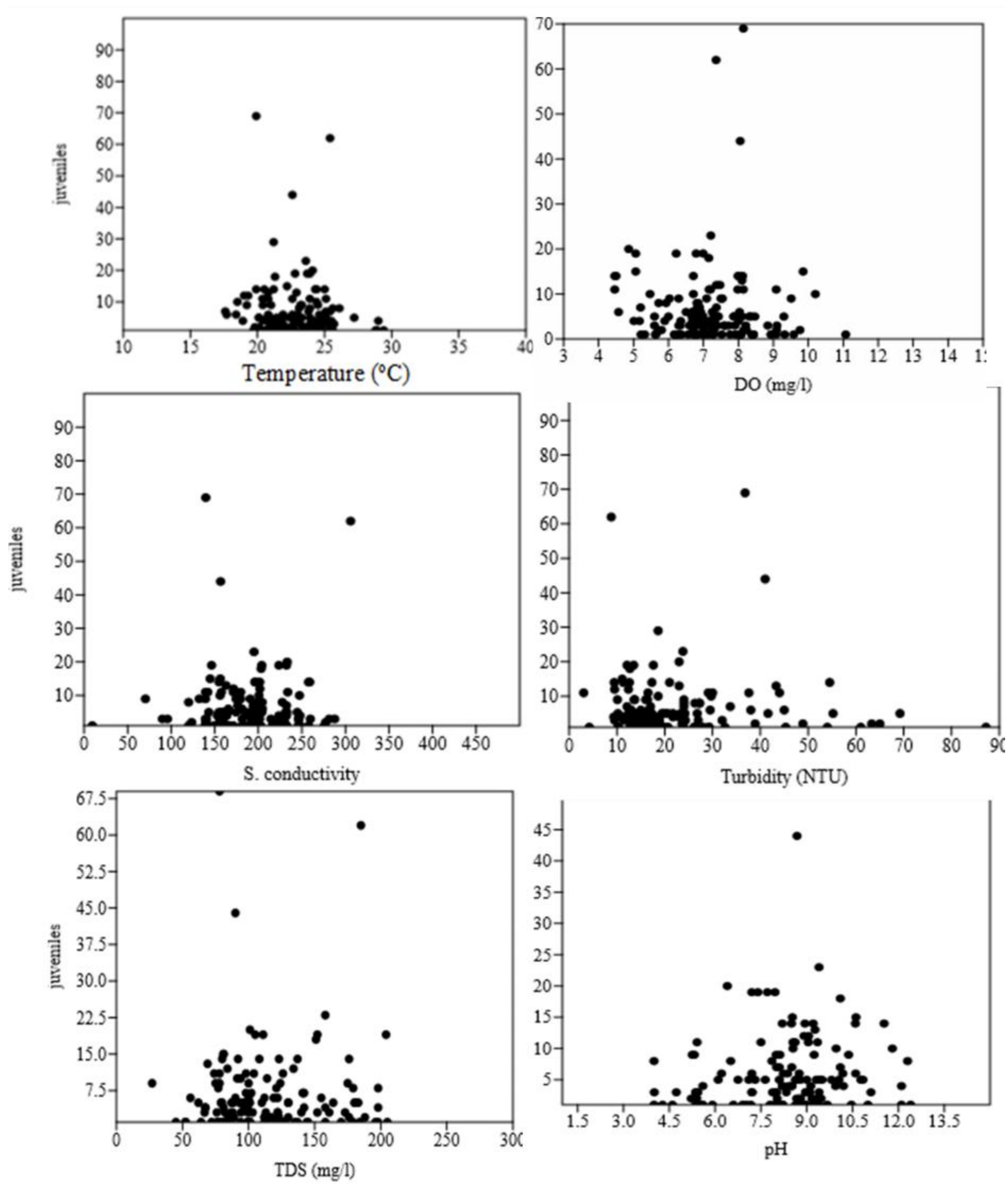


Figure 13: A range of microhabitat variables preferred by juveniles where x-axis is environmental parameters and y-axis is the number of juveniles

4.9. Gut content analysis and frequency of occurrence of food items of *Labeobarbus* juveniles YOY in relation to habitat shifting

In this study, the gut contents of a total of 120 *Labeobarbus* juveniles (20 for each site) were analyzed. Out of this almost half (48) of them had an empty gut. The total lengths for the selected specimens were in the range of 7-9 cm, since it was very difficult for dissecting and prey identification below this range. Percentage frequency of occurrence of the food items for YOY of the *Labeobarbus* spp. in Gumara River showed different phytoplankton and zooplankton were consumed by juveniles (Table 10). The food items include *Aulacoseira* (96.8%), *Navicula* (67.7) and *Nitzschia* (59.7%) from Bacillariophyceae (diatoms). Plant matters and detritus were also consumed (100%), since they were juveniles and might not consume large-sized food items. Different zooplankton groups include Cyclopoids (29%), Cladoceran (Daphina, 33.9%) and Rotifers (100%). Among zooplankton, rotifers were most frequently observed in juveniles at all sampling sites (Appendix 7). Sibbing *et al.* (1986) reported a large portion of rotifers in the diet of small fish, which decreased in the diet of large fish. Their low proportion in gut samples of large fish could also be explained by rapid degradation in the fish gut (Sutela and Huusko, 1997). In cyprinids, the most significant change in the diet of juveniles and adults was the shift from phytoplankton and rotifers to crustaceans and chironomid larvae (Mark *et al.*, 1987, 1989). Detritus and plant matters were consumed by specimens that were sampled from the downstream pool. This site is dominated with clay and silt substrate with the remains of plant matters. It is possible that the plant matter was consumed by juveniles due to its availability. The other possible reason might be associated with the presence of habitat shifting that leads most juveniles in the downstream pool able to feed plant matters and detritus since, their size was a bit larger than juveniles which are found in upstream sites. Davey *et al*. (2005) added larger individuals inhabiting coarser substrate than smaller individuals. Whereas, the food item identified from specimens collected from the riffle and other shallow pool habitats were phytoplankton and zooplankton. This might be attributed to the presence of a gravel substrate type which is unable to consume by juveniles due to its large size and absence of plant matter.

In general, feeding habits of fish species varied due to their geographical niche, species preference, availability, habitat shifting and their life stages. Information regarding the feeding habits of any fish species is also very important to predict their habitat preference. Allan and Castillo (2007) noted studies related to the food and feeding habits of a species used for evaluating the ecological role and positioning of the species in the food web of the ecosystem.

Table 10: Major food items recorded in gut content of juveniles

Food items Group/genus	YOY *Labeobarbus* spp. (n=62) % occurrence	Number of gut
Bacillariophyceae (diatom)		
Aulacoseria	96.8 [a]	60
Navicula	67.7[c]	42
Nitzschia	59.7[c]	37
Zooplankton		
Cyclopoids	29.0[r]	18
Cladoceran (Daphina)	33.9[r]	21
Rotifers	100 [a]	62
Detritus	100[a]	62
Plant debris	100[a]	62

[a] Abundant = food item present in more than 30 and repeatedly observed, [c]Common= food item=30, [r]Rare=food item present in <30

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The significant variation of physico-chemical parameters between sampling sites was observed and this might be due to anthropogenic activities such as agriculture, water abstraction, pollution etc. However, all measured physico-chemical parameters were within the permissible limit of different guidelines for aquatic life.

The abundance and diversity of fish species between sampling month, sites and habitats was varied and this might be due to the difference in physico-chemical parameters, substrate type and food availability. About 3,880 fish specimens were collected during the study period from all sampling sites, and the most dominant species were *E. humilis* followed by YOY of the *Labeobarbus* spp. and *Garra* spp. Based on the Shannon diversity index (H' = 1.21), the Gumara River could be grouped under moderately polluted.

Except small sized individuals, pool habitats were commonly used by YOY. Because, they showed habitat shifting due to the drying of the riffle habitats in upstream sites and pools serve as the last option to serve as a refuge habitat for juveniles during the dry season when riffle habitats dried-up.

5.2. Recommendations

- Awareness creation on the migratory *Labeobarbus* species should be conducted to promote the conservation of these species and their habitats.
- Activities including blocking of the river using stationary nets, dragging the net in the pool habitats and water extractions for irrigation in the dry season are major challenges for migratory *Labeobarbus* species in the Gumara River, so emphasis should be given to these factors as they affect the breeding and nursery grounds of the species.
- Excessive water abstractions should be reduced/prevented because low volume of water forms barrier between the river and the lake and as a result, recruitment will be reduced in the lake.
- Prior attention should be given to the pool habitats of Gumara River because they are very important in serving as habitats for juveniles until the upcoming rainfall.
- Detailed study on the habitat modeling and the habitat suitability index should be done to use them as management tools.

6. REFERENCES

Aarts, B., Van Den Brink, F. and Nienhuis, P. (2004). Habitat loss as the main cause of the slow recovery of fish faunas of regulated large rivers in Europe: the transversal floodplain gradient. *River Research and Applications*. **20**:3-23.

Abebe Amheha (2004). The effect of Birbira, *Milletia ferruginea* (hochst.) baker on some *Barbus* spp. (Cyprinidae, Teleostei) in Gumara River (Lake Tana), Ethiopia M.Sc. Thesis, Addis Ababa University, School of Graduate Studies. P. 57.

Abebe Getahun (2007). An overview of the diversity and conservation status of the Ethiopian freshwater fish fauna. *J. Afrotrop. Zool. Spec* Pp. 87-96.

Abebe Getahun (2017). *Freshwater Fishes of Ethiopia: Diversity and Utilization*, View Graphics and Printing PLC, Addis Ababa. Pp. 1-349.

Abebe Getahun and Eshete Dejen (2012). *Fishes of Lake Tana: a guide book*. Addis Ababa University Press. Pp. 1-140.

Abebe Getahun, Eshete Dejen and Wassie Anteneh (2008). Fishery studies of Ribb River, Lake Tana basin, Ethiopia. *A report submitted to World Bank.* **2**:116.

Able, K. (1999). Measures of juvenile fish habitat quality: Examples from. *Fish habitat: Essential fish habitat and rehabilitation*. **22**:134-147.

Agostinho, A., Pelicice, F., Gomes, L. and Julio Jr, H. (2010). Reservoir fish stocking: when one plus one may be less than two. *Nat. Conserv.* **8**:103-111.

Akewake Geremew (2007). Taxonomic Revision, Relative Abundance, and Aspects of the Biology of some Species of the Genus *Garra*, Hamilton 1922 (Pisces: *Cyprinidae*) in Lake Tana, Ethiopia Unpublished MSc Thesis, Addis Ababa University, Addis Ababa Ethiopia.

Al-Kaheem, H., Al-Ghanim, K., Ahamad, Z., Temraz, T., Al-Akel, A., Al-Misned, F. and Annazri, H. (2008). A threatened fish species (*Aphaniusdispar*) in Saudi Arabia, A Case Study. *Pak. J. Biol. Sci*. 1-8.

Allan, J. and Castillo M. (2007). *Stream Ecology: structure and function of running waters,* 2nd edition, Springer. P. 372.

Allard, L. (2014). Electrofishing efficiency in low conductivity neo-tropical streams: towards a non-destructive fish sampling method. *Fish. Manage. Ecol.* **21**:234-243.

Andargachew Melke and Fantahun Abegaz (2017). Impact of climate change on hydrological responses of Gumara catchment, in the Lake Tana Basin Upper Blue Nile Basin of Ethiopia. *Int. J. Water Resour. Environ. Eng.* **9**:8-21.

Anderson, J. (1988). A review of size dependent survival during pre-recruit stages of fishes in relation to recruitment. *J. Northwest Atl. Fish. Sci.* **8**: 55-66.

Ayalew Wondie, Seyoum Mengistou, Vijverberg, J. and Eshete Dejen (2007). Seasonal variation in primary production of a large high altitude tropical lake (Lake Tana, Ethiopia): effects of nutrient availability and water transparency. *Aquat. Ecol.* **41**: 195-207.

Baras, E. (1997). Environmental determinants of residence area selection and long term utilization in a shoaling teleost, the common barbel (*Barbus barbus* L.). *Aquat. Living Resour.* **10**:195-206.

Beaumont, W. (2002). *Guidelines for Electric Fishing Best Practice*. Bristol: Environment Agency, Pp.197.

Beck, M, Heck, K., Able, K., Childers, D., Eggleston, D., Gillanders, B. and Orth, R. (2001). The identification, conservation and management of estuarine and marine nurseries for fish and invertebrates: a better understanding of the habitats that serve as nurseries for marine species and the factors that create site-specific variability in nursery quality will improve conservation and management of these areas. *Biosci.* **51**:633-641.

Beier, U. (2013). Habitat selection and indirect interactions in fish communities mechanisms Licentiate Thesis, Swedish University of Agricultural Sciences, Department of Aquatic Resources. P.57.

Bernardo, J., Ilhe M., Matono P. and Costa A. (2003). Interannual variation of fish assemblage structure in a Mediterranean river: implications of stream flow on the dominance of native or exotic species. *River Research and Applications.* **19**: 521–532.

Berrebi, P. (1995). Speciation of the genus *Barbus* in the north Mediterranean basin: recent advances from biochemical genetics. *Biol. Conserv.* **72**: 237-249.

Beshera, K., Harris, P. and Mayden, R. (2016). Novel evolutionary lineages in *Labeobarbus* (Cypriniformes; Cyprinidae) based on phylogenetic analyses of mtDNA sequences. *Zootaxa*. **4093**:363-381.

Boulenger, G. (1902). Diagnoses of new Cichlid fishes discovered by Mr. JES Moore in Lake Nyassa. *J. Nat. Hist.* **10**: 69-71.

Bowler, D. and Benton T. (2005). Causes and consequences of animal dispersal strategies: relating individual behavior to spatial dynamics. *Biol. Rev.* **80**:205-225.

Brook Lemma (1987). The present status and potential for future development of inland fisheries in Ethiopia. In: *proceeding of management of water and Natural resource to increase food production in Africa*. IAR, Pp. 99-108.

Bult, T., Riley, S., Haedrich, R., Gibson, R. and Heggenes, J. (1999). Density dependent habitat selection by juvenile Atlantic salmon (*Salmo salar*) in experimental riverine habitats. *Can. J. Fish. Aquat. Sci.* **56**:1298-1306.

Byström, P., Andersson, J., Persson, L. and De-Roos, A. (2004). Size-dependent resource limitation and foraging-predation risk trade-offs: growth and habitat use in young arctic char. *Oikos*, **104**: 109-121.

Campbell, G., and Wildberger, S. (1992). *The Monitor's Handbook*. LaMotte Company, Chestertown, MD. P. 71.

Carnie, R., Tonina, D., McKean, J. and Isaak, D. (2016). Habitat connectivity as a metric for aquatic microhabitat quality: application to Chinook salmon spawning habitat. *Ecohydrology*. **9**: 982-994.

Conover, D. (1992). Seasonality and the scheduling of life history at different latitudes. *J. Fish. Biol.* **41**:161-178.

Copp, G. (1989). The habitat diversity and fish reproductive function of floodplain ecosystems. *Environ. Biol. Fishes*. **26***:*1-27.

Copp, G. (1990). Shifts in the microhabitat of larval and juvenile roach, *Rutilus rutilus* (L.), in a floodplain channel. *J. Fish Biol.* **36**:683-692.

Cowx, I. and Lamarque P. (1990). *Fishing with Electricity: Applications in Freshwater. Fisheries Management*. Oxford: Fishing News Books, Pp.248.

Dale, V. and Beyeler, S. (2001). Challenges in the development and use of ecological indicators. *Ecol. Indic*.**1**:3-10.

Davey, A. Hawkins, S., Turner, G. and Doncaster, C. (2005). Size-dependent microhabitat use and intraspecific competition in Cottus gobio. *J. Fish Biol*. **67**:428-443.

de Graaf, M. (2003). Lake Tana's piscivorous *Barbus* (Cyprinidae, Ethiopia) Ecology. Evolution Exploitation. PhD thesis, Wageningen Agricultural University, The Netherlands.

de Graaf, M., Eshete Dejen, Osse, J. and Sibbing, F. (2008). Adaptive radiation of Lake Tana's (Ethiopia) *Labeobarbus* species flock (Pisces, Cyprinidae). *Mar. Freshwat. Res*. **59**: 391-407.

de Graaf, M., Eshete Dejen, Sibbing, F. and Osse, J. (2000). *Barbus tanapelagius*, a new species from Lake Tana (Ethiopia): its morphology and ecology. *Environ. Biol. Fish*. **59**: 1-9.

de Graaf, M., Machiels, M., Tesfaye Wudneh and Sibbing, F. (2004a). Declining stocks of Lake Tana's endemic Barbus species flock (Pisces, Cyprinidae): natural variation or human impact?. *Biol. Conserve.* **116**: 277-287.

de Graaf, M., Nentwich, E., Osse, J. and Sibbing, F. (2005). Lacustrine spawning: is this a new reproductive strategy among 'large' African cyprinid fishes. *J. Fish Biol.* **66**:1214-1236.

de Graaf, M., Palstra, A. and Sibbing, F. (2004b). Riverine spawning and reproductive segregation in a lacustrine cyprinid species flock, facilitated by homing? *Anim. Biol.* **54**:393-415.

de Graaf, M., Van Zwieten, P., Machiels, M., Lemma Abera, Tesfaye Wudneh Eshete Dejen and Sibbing, F. A. (2006). Vulnerability to a small-scale commercial fishery of Lake Tana's (Ethiopia) endemic *Labeobarbus* compared with African catfish and Nile tilapia: An example of recruitment-overfishing? *Fish. Res.* **82**: 304-18.

Deas, M., and Orlob, G. (1999). Assessment of alternatives for flow and water quality control in the Klamath River below Iron Gate Dam. University of California Davis center for environmental and water resources engineering. P. 379.

Dgebuadze, Y., Mina, M., Alekseyev, S. and Golubtsov, A.(1999). Observations on reproduction of the Lake Tana barbs. *J. Fish. Biol*. **54**:417-423.

Dolan, C. and Miranda, L. (2003). Immobilization thresholds of electrofishing relative to fish size. *Trans. Am. Fish. Soc.***132**: 969-976.

Doudoroff, P., and Shumway D. (1970). Dissolved oxygen requirements of freshwater fishes. Tech. Pap.86. P.291.

Dudgeon, D., Arthington, A., Gessner, M., Kawabata, Z., Knowler, D. J, Leveque, C. and and Sullivan, C. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biol. Rev.* **82**:163-182.

Dunz, A., and Schliewen, U. (2013). Molecular phylogeny and revised classification of the haplotilapiine cichlid fishes formerly referred to as “Tilapia”. *Mol. Phylogenet. Evol.* **68**: 64-80.

Eros, T., Botta-Dukat and Grossman, G., (2003). Assemblage structure and habitat use of fishes in a Central European submontane stream: a patch-based approach. *Ecol. Freshwat. Fish.* **12**:141-150.

Eshete Dejen (2003). Ecology and potential for fishery of the small barbs (Cyprinidae, Teleostei) of Lake Tana, Ethiopia. PhD Dissertation, Agricultural University, Wageningen, the Netherlands, Pp.180.

Eshete Dejen, Vijverberg, J., Nagelkerke, L. and Sibbing, F. (2004). Temporal and spatial distribution of micro-crustacean zooplankton in relation to turbidity and other environmental factors in a large tropical lake. Lake Tana, Ethiopia. *Hydrobiologia* **513**:39-49.

Eshete Dejen, Vijverberg, J. and Sibbing, F. (2006). Spatial and temporal variation of cestode infection and its effects on two small barbs (*Barbus humilis* and *B. tanapelagius*) in Lake Tana, Ethiopia. *Hydrobiologia*. **556**:109-117.

Eshete Dejen, Wassie Anteneh and Vijverberg, J. (2017). The decline of The Lake Tana (Ethiopia) fisheries: causes and possible solutions. *Land Degrad. Dev.* **28**:1842-1851.

Farnham C., Nakao M, Nishioka, M., Nabeshima, M. and Mizuno, T. (2015). Effect of water temperature on evaporation of mist sprayed from a nozzle. *Journal of Heat Island Institute International*. **10**:35-40.

Fladung E., Scholten M. and Thiel R. (2003). Modeling the habitat preferences of pre adult and adult fishes on the shoreline of the large, lowland Elbe River. *J. Appl. Ichthyol*. **19**:303-314.

Furey, N., Dance, M. and Rooker, J. (2013). Fine-scale movements and habitat use of juvenile southern flounder Paralichthys lethostigma in an estuarine seascape. *J. Fish Biol.* **82**:1469-1483.

García-Berthou, E. (2001). Size-and depth-dependent variation in habitat and diet of the common carp (*Cyprinus carpio*). *Aquat. Sci.* **63**:466-476.

Garner, P. (2010). Habitat use by 0+ cyprinid fish in the River Great Ouse, East Anglia. In *Freshwater Forum.* 8-1.

Gashaw Chakilu and Mamaru Moges (2017). Assessing the Land Use/Cover Dynamics and its Impact on the Low Flow of Gumara Watershed, Upper Blue Nile Basin, Ethiopia, *Hydrol Curr. Res*. **8**:1-6.

Gashaw Tesfaye and Wolff, M. (2014). The state of inland fisheries in Ethiopia: a synopsis with updated estimates of potential yield. *Ecohydrol. Hydrobiol.* **14**:200-219.

Gaudin, P. (2000). Habitat shifts in juvenile riverine fishes. *Arch. Hydrobio. suppl.*135: 393-408.

Getachew Desalegn, Melaku Abegaz, Demel Teketay and Alemu Gezahgne (2012). *Commercial Timer Species in Ethiopia: Characteristics and Uses, A Handbook for Forest Industries, Construction and Energy Sectors, Foresters and Other Stakeholders.* Addis Ababa University Press, Addis Ababa Pp. 1-342.

Genanaw Tesfaye (2006). Diversity, relative abundance and biology of fishes in Angereb and Sanja Rivers, Tekeze basin, Ethiopia. MSc. Thesis. Addis Ababa University. Pp. 90.

Geneviève, M. and James, P. (2008). Water quality for ecosystem and human health. In: *International Institute of Polish Academy of Sciences, European Regional Centre for Eco hydrology under the auspices of UNESCO and University of Lodz*. Pp. 1-154.

Gillette, D., Tiemann, J., Edds, D. and Wildhaber, M. (2006). Habitat use by a Midwestern USA riverine fish assemblage: effects of season, water temperature and river discharge. *J. Fish Biol.* **68**:1494-1512.

Girard, I., Grant, J. and Steingrímsson, S. (2004). Foraging, growth, and loss rate of young-of-the-year Atlantic salmon (*Salmo salar*) in relation to habitat use in Catamaran Brook, New Brunswick. *Can. J. Fish. Aquat. Sci*. **61**:2339-2349.

Gizachew Teshome, Abebe Getahun, Minwyelet Mingist and Wassie Anteneh (2015). Spawning migration of *Labeobarbus* species to some tributary rivers of Lake Tana, Ethiopia. *Ethiop. J. Sci. Technol*. **8**:37-50.

Golubtsov, A., and Mina, M. (2003). Fish species diversity in the main drainage systems of Ethiopia: current state of knowledge and research perspectives. *Ethiop. J. Natu. Reso.* **5**: 281-318.

Gozlan, R. Mastrorillo, S., and Lek, S. (1999). Predicting the structure and diversity of Young-of-the-Year fish assemblages in large rivers. *Freshwat. Biol*.**41**:809-820.

Gupta, P., Vishwakarma, M. and Rawtani, P. (2009). Assessment of water quality parameters of Kerwa Dam for drinking suitability. *Int. J. Theor. Appl. Sci.*1: 53.

Gustafsson, P., Bergman, E. and Greenberg, L. (2010). Functional response and size-dependent foraging on aquatic and terrestrial prey by brown trout (*Salmo trutta L*.). *Ecol. Freshwat. Fish.* **19**:170-177.

Han, M., Fukushima, M., Kameyama, S., Fukushima, T. and Matsusita, B. (2007). How do dams affect freshwater fish distributions in Japan? Statistical analysis of native and non-native species with various life histories. *Ecol. Res*. **23**:735-743.

Harvey, B. and Stewart, A. (1991). Fish size and habitat depth relationships in headwater streams. *Oecologia*. **87**:336-342.

Hatfield T. and Adam L. (2007). Guidelines for the collection and analysis of fish and fish habitat data for the purpose of assessing impacts from small hydropower projects in British Columbia.Pp. 1-32.

Hauer, F. and Hill, W. (2007). Temperature, light, and oxygen. In: *Methods in stream ecology.* Academic Press. 103-117.

Hockley. F. Wilson C., Brew A. and Cable, J. (2014). Fish responses to flow velocity and turbulence in relation to size, sex and parasite load. *J. R. Soc. Interface*. **11**: 20130814.

Hossain, M., Das, N., Sarker, S. and Rahaman, M. (2012). Fish diversity and habitat relationship with environmental variables at Meghna river estuary, Bangladesh. *Egypt. J. Aquat.* **38**: 213-226.

Huet, M. (1959). Profiles and biology of western European streams as related to fish management. *Trans. Am. Fish. Soc*. **88**:155-163.

Huey, R. (1991). Physiological consequences of habitat selection. *The American Naturalist*, **137**:91-115.

Huss, M., Bystrom, P. and Persson, L. (2008). Resource heterogeneity, diet shifts and intra-cohort competition: effects on size divergence in YOY fish. *Oecologia.* **158**:249-257.

Hynes, H. (1970). *The ecology of running waters*. Liverpool: Liverpool University Press. P. 555.

Johnson, P., Olden, J. and Vander Z. (2008). Dam invaders: impoundments facilitate biological invasions into freshwaters. *Front. Ecol. Enviro.* **6**:357-363.

Johnson, S. (2004). Factors influencing stream temperatures in small streams: substrate effects and a shading experiment. *Can. J. Fish. Aquat. Sci.* **61**:913-923.

Johnston, N. and Slaney P. (1996). *Fish Habitat Assessment Procedures*. Watershed Restoration

Technical Circular No. 8. B.C. Ministry of Environment, Lands and Parks and Ministry of Forests, Victoria, BC. P.51.

Jones, N. (2011). Electrofishing rivers : Near shore community sampling methodologies for O ntario's flowing waters. Aquatic Research and Development Section Ontario Ministry of Natural Resources. *Aquat. Res. Ser.* 2011-06.

Kahler, T., Roni, P. and Quinn, T. (2001). Summer movement and growth of juvenile anadromous salmonids in small western Washington streams. *Can. J. Fish. Aquat. Sci.* **58***:*1947-1956.

Kaufmann, P. Levine, E., Robison, C. Seeliger and Peck D. (1999). Quantifying physical habitat in wadeable streams. EPA Report Corvallis, Oregon.620-99/003.

Kingsford, R. (2000). Ecological impacts of dams, water diversions and river management on floodplain wetlands in Australia. *Aust. Ecol*. **25**:109-127.

Kucera-Hirzinger, V., Schludermann, E., Zornig, H., Weissenbacher, A., Schabuss, M. and Schiemer, F. (2009). Potential effects of navigation-induced wave wash on the early life history stages of riverine fish. *Aquat. Sci.* **71**: 94-102.

Lamouroux, N., Olivier, J. Persat, H., Pouilly, M., Souchon, Y., and Statzner, B. (1999). Predicting community characteristics from habitat conditions: fluvial fish and hydraulics. *Freshwat. Biol*. **42**:275-299.

Leahy, M. (2016). Habitat determinants of Chaetodon butterflyfish and fishery-targeted coral reef fish assemblages in the central Philippines, PhD Dissertation, James Cook University, Australia, Pp.1-184.

Leelahakriengkrai, P. and Peerapornpisal, Y. (2010). Diversity of Benthic diatoms and water quality of the Ping river, Northern Thailand. *Environ. Asia*, **3**: 82-94.

Leveque, C. and Daget, J. (1984). Cyprinidae. In: Daget, J. Gosse and Thys, A. (Eds.). Check-List of the Freshwater Fishes of Africa. **1**:217-342.

Lewis, A., Hatfield, T., Chilibeck, B. and Roberts, C. (2004). Assessment Methods for Aquatic Habitat and In stream Flow Characteristics in Support of Applications to Dam, Divert Or Extract Water from Streams in British Columbia: Final Version. Ministry of Water, Land and Air Protection. P.55.

Lowe-McConnell, R. (1975). Fish communities in tropical freshwaters. In *Fish communities in tropical freshwaters*. Longman. New York P. 337.

Lucas, M. Baras, E., and Thom, T. (2001). *Migration of Freshwater Fishe*s. Oxford: Blackwell Science. P. 1-433

Magoulick, D. (2004). Effects of predation risk on habitat selection by water column fish, benthic fish and crayfish in stream pools. *Hydrobiologia*. **527**:209-221.

Magurran, A. Irving, P. and Henderson, P. (1996). Is there a fish alarm pheromone? A wild study and critique. *Proceedings of the Royal Society of London. Series B: Biol. Sci.* **263**: 1551-1556.

Mann, R. (1995). Natural factors influencing recruitment success in coarse fish populations. In: Harper D. and Ferguson A. (Eds). *The Ecological Basis for River Management*. 339-348.

Mark, W., Hofer, R. and Wieser, W. (1987). Diet spectra and resource partitioning in the larvae and juveniles of three species and six cohorts of cyprinids from a subalpine lake. *Oecologia*.**71**:388-396.

Mark, W., Wieser, W. and Hohenauer, C. (1989). Interactions between developmental processes, growth, and food selection in the larvae and juveniles of *Rutilus rutilus* (L.) (Cyprinidae). *Oecologia*, **78**:330-337.

Matthews, W. (1998). Morphology, habitat use, and life history. In: *Patterns in freshwater fish ecology.* Springer, Boston, MA. 380-454.

Mekong River Commission Environmental Program (2015). Identification, Handbook of Freshwater Zooplankton of Mekong River and its tributaries. MRC Technical paper No. 45, Pp. 1-209.

Mengistie Abate, Nyssen, J., Steenhuis, T. S., Mamaru Moges and Enyew Adgo (2015). Morphological changes of Gumara River channel over 50 years, upper Blue Nile basin, Ethiopia. *J. hydrol*. **525**:152–164.

Milner, N., Hemsworth, R. and Jones, B. (1985). Habitat evaluation as a fisheries management tool. *J. Fish Biol*. **27**:85-108.

Mina, M. Mironovsky, A. and Dgebuadze, Y. (1996). Lake Tana large barbs: phenetics, growth and diversification. *J. Fish Biol.* **48**: 383-404.

Moran-Lopez, R., Perez-Bote, J. Silva, E. and Corbacho A. (2005). Summer habitat relationships of barbels in south-west Spain. *J. Fish Biol*. **67**:66-82.

Morris, D. (1988). Habitat-dependent population regulation and community structure. *Evol. Ecol.* **2**:253-269.

Murphy, B. and Willis, D. (1996). Fisheries Techniques, 2nd edn. Bethesda, MD: *Am. Fish. Soc*. P. 732.

Naesje, T., Hay, C., Nickanor, N., Koekemoer, J., Strand, R., and Thorstad, E. (2004). Fish populations, gill net catches and gill net selectivity in the Kwando River, Namibia. Norwegian Institute for Nature Research Tungasletta 2, NO-7485 Trondheim, Norway. P. 65.

Nagelkerke, L. (1997). The barbs of Lake Tana, Ethiopia: morphological diversity and its implications for taxonomy, trophic resource partitioning and fisheries. Agricultural University, Wageningen Institute of Animal Sciences (WIAS), Experimental Zoology Group, Marijkeweg 40, 6709 PG Wageningen, The Netherlands 1-298

Nagelkerke, L. and Sibbing, F. (1996). Reproductive segregation among the *Barbus intermedius complex* of Lake Tana, Ethiopia. An example of intralacustrine speciation? *J. Fish. Biol.* **49**:1244-1266.

Nagelkerke, L., and Sibbing, F. (2000). The large barbs (*Barbus* spp., Cyprinidae, Teleostei) of Lake Tana (Ethiopia), with a description of a new species, *Barbus osseensis*. *Neth. J. Zool*. **50**: 179-214.

Nagelkerke, L., Sibbing, F, vanden B., Lammens, E. and Osse, J. (1994). The barbs (*Barbus* spp.) of Lake Tana: a forgotten species flock? *Environ. Biol. Fish*. **39**:1-22.

Navneet K. and Sinha D. (2010). An Approach to River Water Quality Management through Correlation Study among Various Water Quality Parameters. *Int. J. Environ. Sci.***1**: 253-259.

Nelva, A., Persat H. and Chessel D. (1979). New method for investigating fish populations in large streams by multiple point abundance sampling. *C. R. Acad. Sci. Paris,* **289**:1295-1298.

Nkwoji J., Yakubu A, Ajani G., Balogun K., Renner K. and Igbo J. (2010). Seasonal variations in water chemistry and benthic macro invertebrates of a South Western Lagoon, Lagos, Nigeria. *J. Am. Sci*. **6**:85-92.

Palstra, A., de Graaf, M. and Sibbing, F. (2004). Riverine spawning and reproductive segregation in lacustrine cyprinid species flock, facilitated by homing. *Anim. Biol.* **54**: 393-415.

Penczak T., Agostinho A., Głowacki Ł. and Gomes L. (1997). The effect of artificial increases in water conductivity on the efficiency of electric fishing in tropical streams. *Hydrobiologia*. **350**: 189-202.

Persat, H., and Copp H. (1990). Electrofishing and point abundance sampling for the ichthyology of large rivers. Blackwell Scientific Publications, Oxford, UK. Pp. 203-215.

Pielou, E. (1966). The measurement of diversity in different types of biological collections. *J. Theor. Biol.***13**:131-144.

Please A., Davis J., Edwards, M., and Turner T. (2006). Habitat and resource use by larval and juvenile fishes in an arid-land river (Rio Grande, New Mexico). *Freshwat. Biol.* **51**: 475-486.

Poff, N. and Zimmerman, J. (2010). Ecological responses to altered flow regimes: a literature review to inform the science and management of environmental flows. *Freshwat. Biol*. **55**:194-205.

Portt, C., Coker, G., Ming, D. and Randall, R. (2006). A review of fish sampling methods commonly used in Canadian freshwater habitats. *Can. Tech. Rep. Fish. Aquat. Sci*. 2604:51.

Premlata, V. (2009). Multivariate analysis of drinking water quality parameters of Lake Pichhola in Udaipur, India. In: *Biological Forum*. Satya Prakashan.**1**: 86-91.

Pulliam, H. and Danielson, B. (1991). Sources, sinks, and habitat selection: A landscape perspective on population dynamics. *The American Naturalist*, **137**: 50-66.

Raleigh, R., Zuckerman, L. and Nelson, P. (1986). Habitat suitability index models and in stream flow suitability curves: brown trout. U.S. Department of the Interior, Fish and Wildlife Service, National Ecology Center, *Biol. report*: **82**:57-65.

Raveendar, B., Sharma, A., Gurjar, U. and Gugulothu, R. (2018). Assessment of the present status of fish diversity in relation to physicochemical characteristics of Nanaksagar reservoir of Uttrakhand, *Entomol*. **6**:477-484.

Reyjol Y., Loot G. and Lek S. (2005). Estimating sampling bias when using electrofishing to catch stone loach. *J. Fish Biol*. **66**: 589-591.

Reynolds, C. (2006). *The ecology of phytoplankton*. Cambridge University Press. Pp. 409

Rosenberg, A., Bigford, S. Leathery, R., and Bickers K. (2000). Ecosystem approaches fishery management through the essential fish habitat. *Bull. Mar. Sci*. **66**:535-542

Rulifson, R, and Manooch, C. (1990). Recruitment of juvenile striped bass in the Roanoke River, North Carolina, as related to reservoir discharge. *N. Am. J. Fish. Manage.* **10**: 397-407.

Sanet, J. Vuuren J. and Carin V. (2006). A guide for the identification of microscopic algae in South African freshwaters. North-west University and Department of Water Affairs and Forestery. P. 11-212.

Schiemer, F. Keckeis, H., Winkler, G. and Flore, L. (2001). Large rivers: the relevance of ecotonal structure and hydrological properties for the fish fauna. *Arch.Hydrobiol.Suppl.* 487-508.

Schiemer, F., Spindler, T., Winters berger, H., Schneider, A. and Chovanec, A. (1991). Fish fry associations: important indicators for the ecological status of large rivers. *Limnol*. **24**:2497-2500.

Sebastian-Gonzalez, E., and Green, A. (2014). Habitat use by water birds in relation to pond size, water depth, and isolation: lessons from a restoration in southern Spain. *Restor. Ecol.* **22**: 311-318.

Seegrist, D. and Gard, R. (1972). Effects of floods on trout in Sagehen Creek, California. *Trans. Am. Fish. Soc.* **101**: 478-482.

Shannon, C. and Weaver W. (1949). The Mathematical Theory of Communication. Urbana 243 III. University of Illinois Press.

Sheldon, A. (1969). Equitability indices: dependence on the species count. *Ecol.* **50**: 466-467.

Shewit Gebremedhin, Minwyelet Mingist, Abebe Getahun and Wassie Anteneh (2012). Spawning migration of *Labeobarbus* spp. (Pisces: Cyprinidae) of Lake Tana to Arno-Garno river, Lake Tana sub-basin, Ethiopia. *SNET: Ethiop. J. Sci*. **35**: 95-106.

Shkil, F., Kirill, F. Dzerzhinskii, Belay Abdissa, Vasily B. Borisov, Wondie Zelalem, Daria V. Kapitanova, Mesfin Tsegaw and Sergei V. Smirnov (2017). Notes on the breeding of large Lake Tana Barbs (*Labeobarbus* spp.) in nature and laboratory, *Ethiop. J. Biol. Sci.***16**:149-170.

Sibbing, F. Osse, J. and Terlouw, A. (1986). Food handling in carp (*Cyprinus carpio*, L.): its movement patterns, mechanisms and limitations. *J. Zool*. **210**:161-203.

Sibbing, F. and Nagelkerke, L. (2001). Resource partitioning by Lake Tana barbs predicted from fish morphometric and prey characteristics. *Rev. Fish Biol. Fish.***10**: 393-437.

Singh, G. and Agarwal, N. (2013). Fish diversity of Laster stream, a major tributary of river Mandakini in Central Himalaya (India) with regard to altitude and habitat specificity of fishes. *J. Appl. Nat. Sci.* **5**:369-374.

Skelton, P., Tweddle, D. and Jackson, P. (1991). Cyprinids of Africa. In: Winfield, I. and Nelson, J. (Eds). *Cyprinid Fishes, Systematics, Biology and Exploitation*, London: Chapman and Hall. Pp. 211-233.

Snoeks, J. (2004). The non-cichlid fishes of the Lake Malawi system. In: Snoeks J (Ed). *The Cichlid diversity of the Lake Malawi: identification, distribution and taxonomy*, Cichlid pres, EI paso, Texas, Pp. 20-26.

Snyder, D. (2003). Invited overview: Conclusions from a review of electrofishing and its harmful effects on fish. *Rev. Fish Biol. Fish.***13**:445-453.

Staub, R. and Hass, I. (1970). The effect of industrial effluents of Memphis and Shelby country on primary plankton production. *Biosci.* **20**: 905-912.

Sutela, T. and Huusko A. (1997). Food consumption of vendace Coregonus albula larvae in Lake Lentua, Finland. *J. Fish Biol.* **5**: 939-951.

Svobodová, Z., Lloyd, R., Machova, J. and Vykusova, B. (1993). Water quality and fish health. EIFAC Technical Paper. No. 54. Rome, FAO. P.59.

Tadlo Awoke (2015). Fish species diversity in major river basins of Ethiopia: A review. *World J. Fish Mar. Sci.* **7**: 365-374.

Tadlo Awoke (2017). Review on the natural conditions and anthropogenic threats of Wetlands in Ethiopian. Life Sciences Group. *Glob. J. Ecol.* **2**:6-14.

Takele Shitaw, Shewit Gebremedhin and Wassie Anteneh (2018). Spatio-temporal distribution of *Labeobarbus* species in Lake Tana. *Int.J. Fish. Aquat. Stud.* **6**: 562-570.

Talling, J. F. and Lemoalle, J. (1998). *Ecological dynamics of tropical Inland waters*. Cambridge University press. P. 441.

Tebo J. (1975). Review of selected parameters of trout stream quality. In: *Symposium on Trout Habitat Research and Management Proceedings*, US Forestry Service, Southwest, Forestry Experiment Station, Asheville, NC. Pp. 20-32.

Ter Braak, C. (1986). Canonical Correspondence Analysis: a new eigenvector technique for multivariate direct gradient analysis. *Ecol.* **67**:1167-1179.

Tesfaye Wudneh (1998). Biology and management of fish stocks in Bahir Dar Gulf, Lake Tana, Ethiopia. PhD. Dissertation, Wageningen Agricultural University, Wageningen, The Netherlands.

Thompson, A., Petty, J. and Grossman, G. (2001). Multi-scale effects of resource patchiness on foraging behaviour and habitat use by longnose dace, Rhinichthys cataractae. *Freshwat. Biol.* **46**:145-160.

Toham, A. and Teugels, G. (1997). Patterns of microhabitat use among fourteen abundant fishes of the lower Ntem River Basin (Cameroon). *Aquat. Living Resour*. **10**: 289-298.

Tomanova S., Tedesco P., Roset N., Berrebi, T. and Belliard J. (2013). Systematic point sampling of fish communities in medium-and large-sized rivers: sampling procedure and effort. *Fish. Manage. Ecol.* **20**:533-543.

Tómasson, T., Cambray, J. and Jackson, P. (1984). Reproductive biology of four large riverine fishes (Cyprinidae) in a man-made lake, Orange River, South Africa. *Hydrobiol.* **112**:179-195.

Tongnunui, S., Beamish, F. and Kongchaiya, C. (2016). Fish species, relative abundances and environmental associations in small rivers of the Mae Klong River basin in Thailand. *Agric. Nat. Res.* **50**: 408-415.

Vanderkooi S., Maule A. and Schreck C. (2001). The effects of electroshock on immune function and disease progression in juvenile spring chinook salmon. *Trans. Am. Fish. Soc.* **130**:397-408.

Vlach, P., Dusek, J., Svatora, M., and Moravec, P. (2005). Fish assemblage structure, habitat and microhabitat preference of five fish species in a small stream. *Folia Zool*. **54**:421-431.

Wanat, J. (2002). Using Habitat Suitability Models to Identify Essential Fish Habitat for the Winter Flounder, *Pseudopleuronectes americanus*, in Great Bay Estuary, NH, PhD *Dissertation*, University of New Hampshire.

Wassie Anteneh (2005). The spawning migration and reproductive biology of *Labeobarbus* (Cyprinidae: Teleostei) of Lake Tana to Dirma and Megech Rivers Ethiopia. *SINET*: *Ethiop. J. Sci*. **31**:21-28.

Wassie Anteneh (2013). Ecology of spawning migration and juvenile habitat use by *Labeobarbus* Spp. (Cyprinidae, Teleostei) of Lake Tana, Ethiopia. PhD Dissertation, Addis Ababa University, Addis Ababa.

Wassie Anteneh, Abebe Getahun and Eshete Dejen (2008). The lacustrine species of *Labeobarbus* of Lake Tana (Ethiopia) spawning at Megech and Dirma Tributary Rivers. *SINET: Ethiop. J. Sci.* **31**:21-28.

Wetzel, R.(2001) *Limnology: lake and river ecosystems*. Elsevier Academy Press, St Louis, USA.

Xenopoulos, M., Lodge, D., Alcamo, J., Marker, M., Schulze, K., and Van, D. (2005). Scenarios of freshwater fish extinctions from climate change and water withdrawal. *Global change biol.* **11**:1557-1564.

Yang, L., Sado, M. Hirt, E. Pasco-Viel, M. Arunachalam, J. Wang, J. Freyhof, K. Saitoh, A. Simons, M. Miya, S. and Mayden R. (2015). Phylogeny and polyploidy: resolving the classification of cyprinine fishes (Teleostei: Cypriniformes). *Mol. Phylogen. Evol*. **85**:97-116.

Yeshizerf Shumye (2016). Species composition, relative abundance and socio-economic value of fishes in Ribb and Gumara River, eastern Lake Tana, MSc. Thesis. Addis Ababa University, Ethiopia.

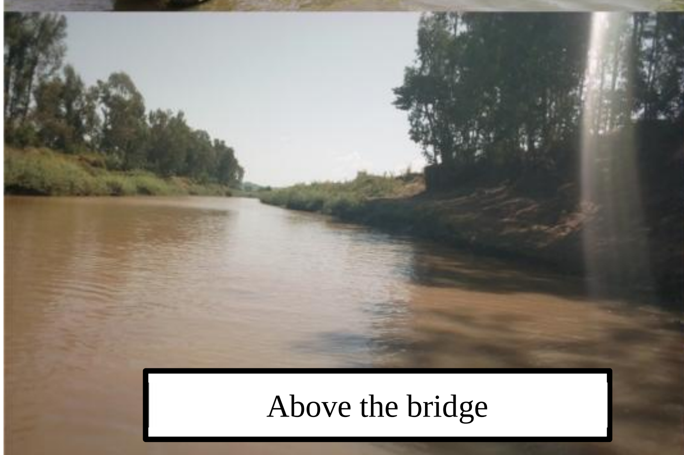
Zeleke Berie (2007). Diversity, relative abundance and biology of fishes in Beles and Gelgel Beles Rivers, Abay basin Ethiopia. MSc. Thesis, Addis Ababa University, Ethiopia.

7. **APPENDICES**

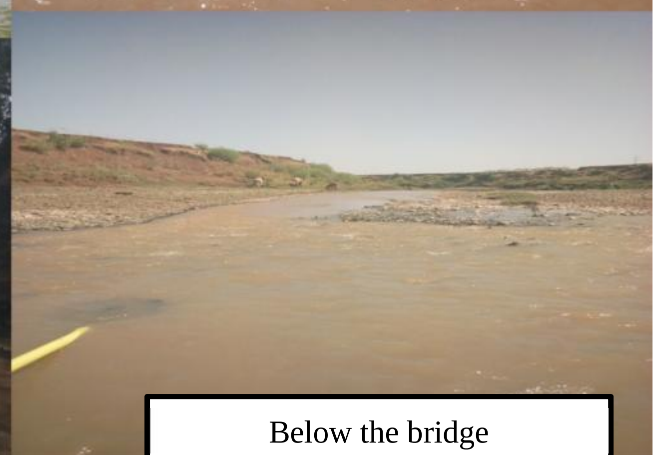
Appendix 1: Sampling sites

Near Wanzaye hot spring

Kizen stream



Above the bridge

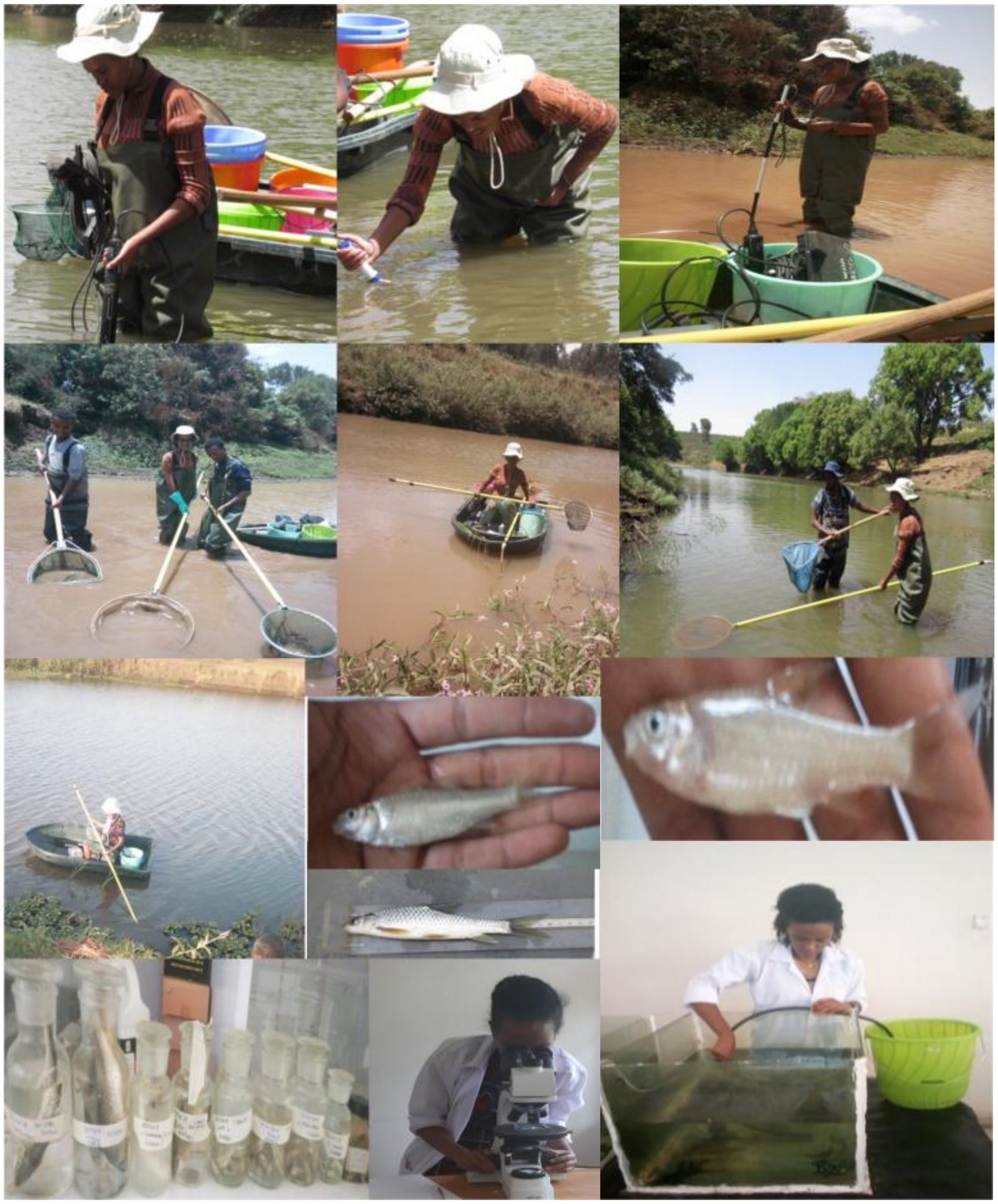


Below the bridge

Downstream pool

Pool proximate to river mouth

Appendix 2: Activities during field and laboratory work



Appendix 3: Major physico-chemical parameters and their level of significance

ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
Temp (ºC)	Between Groups	5947.765	74	80.375	30.644	.000
	Within Groups	10173.984	3879	2.623		
	Total	16121.748	3953			
DO (mg/l)	Between Groups	206279.693	74	2787.563	4.507	.000
	Within Groups	2399589.290	3880	618.451		
	Total	2605868.983	3954			
pH	Between Groups	2982.451	74	40.303	29.055	.000
	Within Groups	5384.898	3882	1.387		
	Total	8367.348	3956			
S.cond (µs cm^{-1})	Between Groups	3717274.307	74	50233.437	58.749	.000
	Within Groups	3319285.393	3882	855.045		
	Total	7036559.700	3956			
TDS (ppm)	Between Groups	2255135.649	74	30474.806	29.441	.000
	Within Groups	3998708.688	3863	1035.130		
	Total	6253844.337	3937			
Turb (NTU)	Between Groups	309839.224	74	4187.017	27.251	.000
	Within Groups	593995.820	3866	153.646		
	Total	903835.044	3940			
Velocity (m/s)	Between Groups	168.443	74	2.276	97.581	.000
	Within Groups	90.275	3870	.023		
	Total	258.718	3944			
Depth (cm)	Between Groups	24433143.195	74	330177.611	155.518	.000
	Within Groups	8239686.843	3881	2123.083		
	Total	32672830.038	3955			

Appendix 4: Major human disturbance observed in Gumara River

Appendix 5: Some collected species during the data collection

Appendix 6: Preliminary qualitative descriptions used in the field to distinguish 0+ juveniles of the cyprinid genera (or species) of the Lake Tana Watershed (adopted from Wassie Anteneh, 2013)

Genus/Species	**Qualitative description based on general body appearance**
Labeobarbus species	Silver-brown colour without any spots, lateral bands and blotches, relatively strong (rigid) first dorsal spine, parallel scale striation, cylindrical body
L. beso	Brown-gray colour, irregular vertical blotches on the lateral part of the body, deep bodied, strong (rigid) first dorsal spine, radial scale striation
'E.' humilis	Mostly 1 up to 3 dark spots or lateral band, silvery-white colour, weak first dorsal spine, small eye, lower jaw straight, radial scale striation
E.' pleurogramma	Pale-brown body colour, visible (even with naked eye) serrated first dorsal spine, lateral band, serrated first dorsal spine, straight lower jaw, radial scale striation
E.' tanapelagius	Big eye (eye diameter ≥ snout length), light body colour, no lateral spot and band, weak first dorsal spine, obliquely upward curved lower jaw, radial scale striation
Garra spp.	Dark body, chisel-like mouth, body elongated and tapering posterior, big head, weak first dorsal spine, radial scale striation

Appendix 7: Gut content analysis of juveniles of *Labeobarbus* spp.