# FISH BIOLOGY AND FISHERIES OF THE FLOODPLAIN RIVERS IN THE ALITASH NATIONAL PARK, NORTHWESTERN ETHIOPIA

**BY**

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This is to certify that the thesis prepared by **Alamrew Eyayu** entitled "**Fish biology and fisheries of the floodplain rivers in the Alitash National Park, northwestern Ethiopia"**, and submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Biology (Fisheries and Aquatic Sciences Stream) complies with the regulations of the university and meets the accepted standards regarding originality and quality.

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## Abstract

Ethiopia is a landlocked country endowed with over 13637 $km^2$ of standing water surface area and 8065 km river length arranged into 12 drainage basins and harbor unevenly diversified fish species of which about 20% are endemic. However, there is lack of a trust worthy quantitative ichthyofaunal accounts of these basins. Among the notable ones in the country, the Blue Nile and Tekeze-Atbara Basins span the northwestern parts of the country and are fed by many floodplain tributaries originating from the Ethiopian highlands. Except that of the Lake Tana sub-basin, the middle and lower reaches of the floodplains of the two basins generally lack an inclusive study on ichthyofaunal diversity, ecology, biology and fisheries. This study was thus undertaken to fill these gaps in some floodplain rivers in the Alitash National Park (ALNP) for management options. Fishes were sampled using gillnets (mono- and multi-filament) of different mesh sizes, cast nets, electro-fishing, traps and mosquito nets from six sampling sites of the three "temporary" rivers (Gelegu, Ayima and Shinfa Rivers) for two dry and two wet months (April 2015 to November 2016). Physico-chemical parameters were analyzed to examine habitat preferences of fishes. A static bioassay toxicity test was done to test the piscicidal efficacy of *Balanites aegyptiaca* on a pond experiment. A focus group discussion and structured interview were also employed to assess the fishing activities and socio-economic returns of the small scale fisheries in the ALNP area. Different statistical tools and methods were used to compute both biological and environmental data. From the total of 2719 specimens, 43 fish species with some new records of the two basins, included into 25 genera, 15 families and 6 orders were identified. A total of 11 species are new records of the present study. The Cyprinidae which constituted 10 species was the dominant family followed by Mormyridae, Alestidae and Mochokidae represented by 6, 5 and 4 species, respectively. Gelegu River was species rich and abundant. Based on frequency of individual occurrence (%FOi) in all assemblages, only 5 species fell in the category of "euconstant occurrence" or their FOi was $\geq$75%, while many species were laid in the "constants range of occurrence" (FOi=50.1-75%). About 77.5% of the total importance of relative index (IRI) was contributed by 12 species. In Ayima, Gelegu and Shinfa Rivers 16, 12 and 17 species had a significant contribution in relative abundance and accounted for 84.7, 85.9 and 95.3% of the total IRI, respectively. Among the group of physico-chemical and environmental variables; EC, site depth, secchi depth and river channel diameter were the key environmental factors determining fish community structure. Similarity percentage (SIMPER) produced an overall average Bray-Curtis dissimilarity of 60.8% between the fish communities of the three rivers and about 51.2% of this global average dissimilarity is accounted by 17 dominant fish species. As a result of fish species abundance and environmental variables association, the redundancy analysis (RDA) showed that eigenvalues of the first axis ($\lambda$CC1 = 69.0%) and second axis ($\lambda$CC2 = 24.0%), where CCA2 and CCA4 axes accounted for 79.7% and 96.5%, respectively of the species environmental relation. The final model accounted for 77.2% of the total variance in fish composition and all canonical axes were significant (Monte Carlo test 499, p = 0.002). Length-weight relationship, condition factor (CF) and feeding habits of five selected commercially important fish species with a total sample of 449 from the Ayima and Gelegu Rivers have been identified and examined. All species had a growth pattern of negative allometry to isometric and positive allometry, while only *Labeobarbus bynni* had a CF value greater than 1.0. All fish species consumed a large variety of prey, however only fish, macrophytes and detritus were the most important contributors to the dietary variation in predator fishes. Although, all fish species were a generalist feeder, some fishes also seemed to be specialist feeders for a particular prey category. A significant dietary overlap was calculated for three combinations and much higher in the combination made between *Heterotis niloticus* and *L. bynni* ($\alpha$=0.91) from the Gelegu River. Ontogenetic and seasonal dietary variations were encountered on relative basis for a particular prey, not a complete shift from one prey to another. The fishing communities of the ALNP are using different piscicides for fishing; however *B. aegyptiaca* is a widely used and effective poisonous plant. A 96 h static toxicity bioassay in ponds was carried out to examine fish responses and to determine the median lethal concentration ($LC_{50}$) of *B. aegyptiaca* stem bark aqueous extract on adults of *Brycinus nurse*, *L. bynni* and *Labeobarbus intermedius*. Experimental fish were exposed to piscicide extracts of 0.0 (control), 15.0, 17.5, 20.0, 22.5, and 25.0 $mgL^{-1}$. Fish exposed to these extracts except the control showed symptoms of toxicity. These responses were specific to species and level of concentration. The 96 h $LC_{50}$ value for the different test fishes were 18.832, 20.720 and 20.724 $mgL^{-1}$ for *L. bynni*, *L. intermedius* and *B. nurse*, respectively. Based on the present investigation, applying *B. aegyptiaca* extract causes lethal toxic effects on different fishes even at low concentrations and hence, indiscriminate use of the plant for fishing should be discouraged and regulated to protect fish biodiversity lose in the ALNP area. The riverine fisheries of the ALNP is small-scale only dominated by individual fishers who owned mono-filament and hook fishing that provided livelihood, income and employment to full-time, part-time and occasional fishers. The Amhara National Regional State should take a prime responsibility related to infrastructure organization, controlling and enforcing of poison fishing and handling the ethnic based conflict arising due to resource utilization for sustainable use and development of the fisheries in the ALNP.

**Key words/phrases**: Alitash National Park, Blue Nile Basin, diversity, Ethiopia, feeding habit, floodplain rivers, identification key, $LC_{50}$, Length-weight relationship, piscicide, poison fishing, socioeconomics, Tekeze-Atbara Basin.

## Dedication

This thesis is dedicated to my father Ato Eyayu Zeleke, who passed away in 2000 who, attaining no formal education, led me to go to school in areas where my peers couldn't get the chance. Let his soul rest in peace in heaven. I always miss you DAD!

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Alamrew Eyayu

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## List of Abbreviations

| | |
|---|---|
| ALNP | Alitash National Park |
| ANRS | Amhara National Regional State |
| BGNRS | Benishangul Gumuz National Regional State |
| BNB | Blue Nile Basin |
| CF | Fish Condition Factor |
| EPA | Environmental Protection Authority |
| FAL | Fishes of Alitash |
| GII | Geometric Index of Importance |
| h | hour(s) |
| IFP | Index of Food Preponderance |
| IRI | Index of Relative Importance |
| JERBE | Joint Ethio-Russian Biological Expedition |
| $LC_{50}$ | Lethal concentration causing 50% mortality |
| LWR | Length-Weight Relationship |
| $mgL^{-1}$ | Milligram per Liter |
| OECD | Organization for Economic Cooperation Development |
| RDA | Redundancy Analysis |
| RMPQ | Relative Measure of Prey Quantity |
| SL | Standard Length |
| SSF | Small scale fisheries |
| TAB | Tekeze-Atbara Basin |
| TL | Total Length |
| TW | Total Weight |
| ZNHM | Zoological Natural History Museum (AAU) |

# CHAPTER ONE

## 1. General introduction

### 1.1. Freshwater fishes of Ethiopia

Although, Ethiopia is a landlocked country, there are about 13637 $km^2$ lakes area and 8065 km of rivers (Gashaw Tesfaye and Wolf, 2014). These huge freshwater bodies are arranged into 6-12 drainage basins and harbor a high diversity of fishes of which about 20% are endemic (Golubtsov and Darkov, 2008; Redeat Habteselassie, 2012; Abebe Getahun, 2017). Ichthyofaunal distribution within the main drainage systems of the country are uneven (Abebe Getahun, 2007; 2017; Golubtsov and Darkov, 2008; Vijverberg *et al.*, 2012). The uneven ichthyofaunal patterns of distribution among the basins are mainly because of the amount and nature of tributaries and the very scenery of their geological formation (e.g., some connected with West African river systems) (Abebe Getahun, 2007).

Studies indicated that the highest fish species diversity has been reported from the Baro-Akobo Basin, followed by the Omo-Turkana, Blue Nile or Abay and the Tekeze-Atbara Basins (Table 1). Diverse floodplain habitats in the Baro-Akobo and Blue Nile Basins support high fish species diversity (Abebe Getahun, 2007). In Ethiopia, generally fish species diversity increases with decreasing altitude. This is particularly evident because of the steep altitude gradients and occurrence of rich lowland fauna in most basins (Golubtsov and Mina, 2003). All ichthyofaunal studies done on Ethiopian water bodies revealed that compared to fluvial ecosystems, the lacustrine fish fauna is very impoverished in the number of species and families (Golubtsov and Mina, 2003; Abebe

Getahun, 2007; Golubtsov and Darkov, 2008). This statement can be further expounded by considering the Lake Tana and the associated floodplain rivers in the same basin.

**Table 1**. Freshwater fish diversity in the major drainage basins of Ethiopia**;** numbers in parenthesis are endemic species.

| Drainage system | Families | Genera | Species | |
|---|---|---|---|---|
| | | | Golubtsov and Darkov (2008) | Abebe Getahun 2017 |
| Abay (Blue Nile) | 15 | 37 | 77(25) | 62 |
| Tekeze-Atbara | 10 | 22 | 34(4?) | 35 |
| Baro-Akobo | 26 | 60 | 113(5) | 119 |
| Omo-Turkana | 20 | 42 | 79(6-8) | 79 |
| Awash River and Rift Valley Lakes | 11 | 18 | 28-31(10) | 36 |
| Shebelle and Genale | 12 | 21 | 33(5) | 33 |

The freshwater fish fauna of Ethiopia constitutes a mixture of Nilo-Sudanic, East African and endemic forms (Roberts, 1975; Abebe Getahun and Stiassny, 1998). Except for the Lake Tana sub-basin in the Blue Nile, the highest number of fish individuals collected in many of the Ethiopian drainage basins revealed Nilo-Sudanic affinities (Golubtsov and Mina, 2003; Genanaw Tesfaye, 2006; Dereje Tewabe, 2008; Tesfaye Melak and Abebe Getahun, 2012; Mulugeta Wakjira, 2016). The Nilo-Sudanic affinities which are related to West African species are the dominant in terms of diversity and distributed in many basins and highly dominate the Nile Basin fishes, whilst absent from northern and central Ethiopian Rift Valley Lakes (ERVLs) (Abebe Getahun, 2007). The East African highland forms are those related to eastern and southern Africa and parts of the Arabian Peninsula, which includes the genera *Clarias*, *Garra*, and *Oreochromis*. The East African affinities are distributed in the northern and central ERVLs, Awash Basin, highland Lakes (Tana and Hayq) and the associated tributaries of the Blue Nile Basin (BNB) (Abebe Getahun, 2007).

The endemic forms are notably represented by the *Labeobarbus* “species flock” of Lake Tana. This lake within the BNB alone is home to 28 fish species of which about 75% are endemic (Abebe Getahun, 2007; Golubtsov and Darkov, 2008). The endemic “species flock” identified from this lake elevated the number of endemicity of the country (Nagelkerke and Sibbing, 2000; Stiassny and Abebe Getahun, 2007; Abebe Getahun and Eshete Dejen, 2012). However, the Baro-Akobo and Omo-Turkana Basins, which are rich in ichthyofaunal diversity, contribute insignificant proportions to the country’s endemic fauna (Table 1). These two basins are believed to connect with the Nile and West and central African river systems and largely composed of Nilo-Sudanic affinities (Abebe Getahun, 2007).

The only known representative in Africa of the Euro-Asiatic Balitoridae, *Afronemacheilus abyssinicus* Boulenger, 1902, is also among the distinguished endemic forms in Lake Tana (Witte *et al*., 2009) and the Baro-Akobo Basin (Abebe Getahun, 2007). Some species of the genus *Garra* adapted to water habitats of the central and northern highlands of the country are also included in the accounts of Ethiopian endemic ichthyofauna (Abebe Getahun, 2000).

Unfortunately, the current full account and true extent of the Ethiopian fish faunal diversity is incomplete. This is because the taxonomy of fishes of fluvial habitats is poorly explored and even taxonomically uncertain (Abebe Getahun and Stiassny, 1998; Abebe Getahun, 2007; Redeat Habteselassie *et al*., 2009). Therefore, results reported with few taxonomical interventions are likely underestimated, new species are continually being discovered and some requiring more scrutiny (e.g., Nagelkerke, 1997; Nagelkerke and Sibbing, 2000; Abebe Getahun and Lazera, 2001; Redeat Habteselassie *et al*., 2009). Because of problems related to taxonomical resolution, therefore, the ichthyofaunal accounts of Ethiopia had been narrated differently. For example, according to the reports of Abebe Getahun (2007) and Golubtsov and Darkov (2008), the Ethiopian fish fauna consists of 153 and 180 species, respectively. However, the recent national assessments lifted this number to over 200 species (Redeat Habteselassie, 2012; Abebe Getahun, 2017).

Unlike the lacustrine habitats, only few literatures are found about the riverine fishes of Ethiopia (e.g., Genanaw Tesfaye, 2006; Dereje Tewabe, 2008; Tesfaye Melak and Abebe Getahun, 2012). The focuses of such studies were basically on either larger or accessible rivers but small and marginalized rivers remain virtually unexplored. However, these water bodies are still supporting the livelihoods of economically marginalized riparian communities through fisheries and sometimes potentially able to contribute to the national GDP. Nevertheless, a management strategy for such water bodies having dearth information on their fishes and fisheries seems obscure.

Generally, basins of the ERVLs, Baro-Akobo and Blue Nile are relatively studied. The former basin is well explored about fish biology and liminological aspects of the different lakes (e.g., Getachew Teferra, 1987; 1989; Elisabeth Kebede *et al*., 1994; Demeke Admassu and Elias Dadebo, 1997; Gashaw Tesfaye and Zenebe Tadesse, 2008). The second basin, received little attention but some information on its fish diversity are available (e.g., Golubtsov *et al.*, 1995; Hussien Abegaz *et al*., 2010; Tesfaye Melak and Abebe Getahun, 2012).

The ichthyofaunal exploration of the BNB is highly localized. As part of the Nilotic lakes, Lake Tana is receiving much attention in the basin due to the presence of the unique "species flock" of the *Labeobarbus* complex having unique evolution and adaptations (e.g., Mina *et al*., 1998; Nagelkerke and Sibbing, 2000; Eshetie Dejen *et al*., 2003). Fishes of the tributary rivers of the Lake Tana and the Abay River are relatively well explored (e.g., Abebe Ameha *et al*., 2006; Abebe Getahun *et al*., 2008; Wassie Anteneh *et al*., 2008). However, the diversity and biology of fishes of other lower tributary rivers of the Blue Nile and the Tekeze-Atbara Basins of the northwestern Ethiopian lowlands (e.g., Ayima, Gelegu, Alitash, Adebuluk, Shinfa, etc) remain uninvestigated. As far as known only a single study was undertaken by Dereje Tewabe (2008) about the fishes of Ayima, Shinfa and some other rivers in the middle reaches of the Tekeze-Atbara Basin (TAB).

Many of the Ethiopian rivers are strongly influenced by the natural rain. In addition extreme human activities such as channeling rivers for irrigation coupled with deforestation of riparian vegetation and other anthropogenic activities contribute to the intermittent flow of rivers in the highlands. Following these anthropogenic activities with population growth, poor agricultural practices and industrialization in Ethiopia are expected to contribute to a huge freshwater biota loss (Abebe Getahun and Stiassny, 1998; Zinabu Gebremariam, 2002). This calls on an urgent necessity to document the ichthyofaunal diversity in Ethiopia facing danger of loss even before they are known to science. The present study is, therefore, designed to deal with the unexplored fish and fisheries of Ayima, Gelegu and Shinfa Rivers in the lower reaches of the BNB and TAB within the territory of Ethiopia.

### 1.2. Ichthyofaunal (taxonomic) exploration in Ethiopia: a history

In the first half of the 19$^{th}$ century, European naturalists started fish specimen collection and descriptions from Africa. During the century, scientific exploration was largely following the route of colonialism. For this reason, Ethiopian waters received less attention, while other countries in the continent were explored in depth. The first written information about fishes of Ethiopia (the *Clarias* catfish from Lake Hayq) appeared in a story printed by the Portuguese Embassy to Ethiopia by Father Francesco Alvares in 1520 (Beckingham and Huntingford, eds., 1961). However, the first scientific description of fishes from Ethiopia was made by Eduard Rüppell (1829, 1836). This German traveler, merchant and explorer described several cyprinid and cyprinodontid species from the coastal regions of the Red Sea (now part of Eritrea) and Lake Tana (Redeat Habteselassie, 2012). Some groups of the Lake Tana barbs, which draw so much attention today, were first described by him (Golubtsov and Mina, 2003) with one visit while he made two rounds of expeditions in northeast Africa. Rüppell described large barbs of Lake Tana under the genera *Barbus* and *Labeobarbus* and others in the genera *Garra* and *Varicorhinus*. Some of these genera are revised today (e.g., the *Barbus* into *Enteromius* and the *Varicorhinus* into *Labeobarbus*).

Among the group of species described by Rüppell in the Lake Tana region include; *Garra dembeensis* (Rüppell, 1836), *Labeobarbus gorguari* (Rüppell, 1836), *L. intermedius* (Rüppell, 1836), *L. nedgia* (Rüppell, 1836), *L. surkis* (Rüppell, 1836) and *L. beso* (Rüppell, 1836) as appeared in literatures (Abebe Getahun and Eshete Dejen, 2012; Redeat Habteselassie, 2012; Abebe Getahun, 2017). Later in this century, fishes were collected from northern and central Ethiopia by the British and Italian naturalists (e.g., Jesse, Blanford, and Antinori) and identified by Blanford (1870), Vinciguerra (1883) and Boulenger (1901, 1909).

Few foreigners long thrived to collect and named fishes of Ethiopia until the end of the $19^{th}$ century. However, exhaustive ichthyofaunal exploration in Ethiopia has been undertaken since the early $20^{th}$ century. Edward Degen (1852-1922), a Swiss national affiliated to the British, was engaged in the collection of fishes by this century (Mulugeta Wakjira, 2016). The fish specimens collected by Degen from the Lake Tana sub-basin, Awash, Wabishebelle and southern ERVLs (Abaya, Chamo and Chew Bahir) were identified into 34 species, and 21 were new descriptions as presented in Boulenger's book. Other explorers in the century made many scientific expeditions in Ethiopia and collections were rendered to the British Natural History Museum (NHMB) and identified by Boulenger (1901; 1902) who had made no scientific expedition in Africa (Paugy, 2010 a & b ). The collections obtained from Africa made Boulenger famous and led him to prepare his book the "*Catalogue of Freshwater Fishes of Africa*" (Boulenger, 1909; 1911; 1915; 1916) by which he described and identified the freshwater ichthyofaunal diversity of the continental Africa.

Between the First and Second World Wars, substantial progress was made in the studies of the Ethiopian ichthyofauna. However, after the Second World War, ichthyofaunal studies in Ethiopia became fragmented. Then Ethiopian scholar, Shibru Tedla (1973) made a review on fishes of Ethiopia, essentially from the catalogues of Boulenger. Consequently, Shibru Tedla (1973) accounted 94 species to be found in all freshwater systems of Ethiopia. Although, there was a limitation in Shibru's review, it was the first essential work by Ethiopian author and the first complete assessment of the Ethiopian ichthyofauna (Golubtsov and Mina, 2003). Shibru Tedla listed only 8 species for the whole White Nile Basin, while about over 100 species have been reported after two decades by Golubtsov *et al*. (1995). In the whole span of the BNB, Shibru accounted only 30 fish species, whereas more than double of this figure is known today (Golubtsov and Darkov, 2008). Taxonomic resolution and sampling efforts might attribute for these differences without neglecting the role of speciation (Mina *et al*., 1998). But, many species names considered as valid by Shibru Tedla are currently recognized as synonyms following more amendments and taxonomic revisions made on fish phylogeny.

Then, the freshwater biology group of the Joint Ethio-Russian Biological Expedition (JERBE), took over and has been active in the country since 1980s (e.g., Golubtsov *et al*., 1995; Mina *et al*., 1998; Golubtsov and Mina, 2003; Golubtsov and Darkov, 2008; Redeat Habteselassie, 2012). Later on, a team of experts from the Wageningen Agricultural University (Netherlands) was attracted by the only extant "species flocks" of the world from Lake Tana and initiated a localized project restricted to this region. The team conducted research activities on the presumptive "species flock" of large *Labeobarbus* complexes pertaining to their ecology, biology, taxonomy and evolution.

These studies highlighted the problem of possible intralacustrine origin of the Lake Tana cyprinids and the need for proper management (Nagelkerke *et al*., 1994; Nagelkerke and Sibbing, 2000; Eshete Dejen *et al*., 2003). The contribution of the team played a significant role in the study of taxonomy, nomenclature, evolution, biology and ecology of the 'flocks'.

Besides biological, ecological and behavioral studies, the staff of Wageningen University made an extensive revision on the Lake Tana 'flocks' and described eight new *Labeobarbus* species. These included *Labeobarbus brevicephalus* (Nagelkerke & Sibbing, 1997), *L. crassibarbis* (Nagelkerke & Sibbing, 1997), *L. longissimus* (Nagelkerke & Sibbing, 1997), *L. megastoma* (Nagelkerke & Sibbing, 1997), *L. ossensis* (Nagelkerke & Sibbing,1997), *L. platydorsus* (Nagelkerke & Sibbing, 1997), *L. truttiformes* (Nagelkerke & Sibbing,1997) and *L. tsanensis* (Nagelkerke & Sibbing, 1997). At the same time, Ethiopian researchers alone and jointly have participated in the study of the Ethiopian ichthyofaunal diversity, taxonomy, biology and conservation (Abebe Getahun and Stiassny, 1998; Abebe Getahun, 2000; 2007; 2017; Abebe Getahun and Lazera, 2001; Stiassny and Abebe Getahun, 2007; Abebe Getahun and Eshete Dejen, 2012; Abebe Getahun, 2017).

River systems in the TAB have not been studied at all due to security related problems. The knowledge of ichthyofaunal diversity in the TAB is more scarce than in the BNB if we consider Lake Tana as part of the later. Following the review work made by Shibru Tedla (1973), the only field oriented expedition to TAB was made by JERBE in 1996. JERBE groups extend their survey to 1999/2003/2005 and they reported 34 fish species referable to 22 genera in the basin (Golubtsov and Darkov, 2008). Some fragmented reports are also available on fishes of the trunk tributaries of this basin (e.g., Muhammed Oumer and Belay Abdissa, 2001; Genanaw Tesfaye, 2006; Dereje Tewabe, 2008). Except for very few species, fishes identified from the TAB are similar to that of the BNB, where the later basin harbors more diversified fish fauna than the former.

### 1.3. Alitash National Park and the associated drainage basins

#### 1.3.1. Alitash National Park

There are many national parks and community protected areas in Ethiopia of which four national parks are found in the Amhara National Regional State (ANRS). In this Region, North Gondar Zone alone possesses two national parks and one is recorded by the UNESCO as a world heritage site because it is inhabited by the endemic mammals; Walia ibex (*Capra walie*) and Gelada baboon (*Theropithecus gelada*). The other national park found in the West-Gondar Zone (new administrative setup) is the Alitash National Park (ALNP), also referred to as 'Alatish' National park in some literature. ALNP is the most important terrestrial protected area located between $11^0$47'5.4"—$12^0$31'3.6"N longitude and $35^0$15'48"—$35^0$48'5.5"E latitude in the northwestern Ethiopia bordered with the Dinder National Park (DNP) of Sudan (Figure 1). The ALNP was established as a park by the ANRS with recognition by the Federal Council of Ministers (Regulation No. 541/2007) in 2006 on an area of 2,666 $km^2$. ALNP covers about 35% of the total land (c.f. 7707 $km^2$) of the Quara Woreda and is almost $1/4^{th}$ of the adjacent 10,000 $km^2$ DNP designated already in 1935 following the London Convention on the Conservation of the African Flora and Fauna (Khalid *et al*., 2016). Both parks share about 75 km of a common border exhibiting familiar ecosystems under Sudan-Guinea Savanna Biome.

According to Mesfin Woldemariam (1972), the geological formation process which divides the whole of Ethiopia into four physiognomic regions placed Alitash under the "associated lowlands of the northwestern region". The park is situated in the flat endless plain (500-900 m.a.s.l) in the lower reaches of the BNB. The territory of the park falls within a flat to undulating plain (97%) with a general slope inclination from South to North, interrupted by valleys, streams, scattered hills and seasonal wetlands (Abraham Marye *et al*., 2008).

Alitash is little known for its biological diversity. The zoological resources of Alitash and surrounding areas are considerable. Larger mammals (e.g., threatened African elephant, lion and leopard, smaller mammals and bats) (Tadesse Habtamu and Afework Bekele, 2008; Kruskop *et al*., 2016), 143 birds (Girma Mengesha and Afework Bekele, 2008), 27 fish species (Dereje Tewabe, 2008), different reptile species including African rock python (*Python sebae*), Monitor lizard (*Varanus spp*.), Egyptian cobra (*Naja haje*), Black mamba (*Dendroaspis polylepis*), Blending tree snake (*Dendrelaphis punctulatus*) and Nile crocodile (*Crocodylus niloticus*) use the ALNP area as their home. Amphibians, porcupines, scorpions and other animals are common in this region. The park is also home to a diversified botanicals: *Combretum molle* (locally named "Chariya"), *Acacia spp*., *Balanites aegyptiaca* (locally called "Lallob or Kudekuda"), *Intada africana*, and common grass species like *Hyperrhenia spp*., *Sorghum spp*., *Pennisitum spp*., *Diospyros mespliformis* (locally named "Serkin") and *Tamarindus indica* (locally called "Kumer") are among the major plant species found in and around the park.

The park is not only known for its biological diversity, but also for its socio-cultural and economic importance. Besides ecological studies, the Alitash area attracted scientists for paleoanthropological exploration and the Metema-Shinfa-Excavation site extending to lower river courses of Shinfa, Gelegu and Ayima for archaeological survey is an example for the huge potential of the area as a tourist destination. This is because the ethnic groups living in this area had varied socio-cultural profile. The populations living around the Alitash are characterized by the residents composed of: Amhara (83.5%), Agew (10%), Gumuz (6%) and Qimant (0.5%) ethnic groups with different culture and dialects but over 95% of the populations settled along the Alitash area use and understand Amharic language (Abraham Marye *et al*., 2008).

The human population is relatively small in the Quara Woreda. However, there is a high tendency to prepare the area for human settlement, agriculture and grazing land (Genanew Agitew, 2011). The total population in the woreda is about 137284 of which 41% of the population lives near to the park. The figure is growing every year for the last decade due to regular flow of migrants into this area. Migrants come to the area mainly in search of fertile land for crop production and it is a labor intensive area because of the large production potential of cash crops like Sesame and Cotton. It is also a candidate woreda for government sponsored human resettlement area identified by the regional and federal government. For example, from the current total population of the area, more than half of the populations are migrants for settlement reasons (Genanew Agitew, 2011).

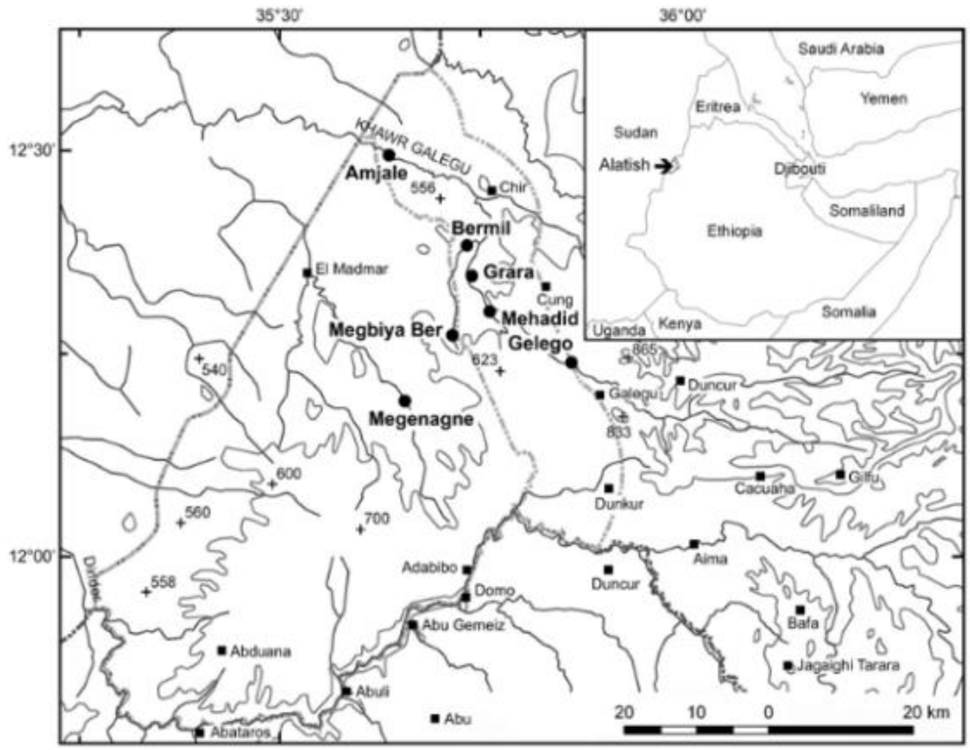


**Figure 1**. Map of Alitash National Park with surrounding villages (source: Kruskop *et al*., 2016).

The community livelihoods' surrounding the Alitash is mainly depending on agriculture (crop and animal production) and some other related activities. Agricultural production is where 87% of the income comes from and livestock resources including fishing consisted of 64% as livelihood sources (Abraham Marye *et al*., 2008). Livelihoods of the indigenous Gumuz people are largely based on hunting and fishing (Abbute Wolde-Selassie, 2004; Abraham Marye *et al*., 2008). However, the two ethnic groups fish but the Gumuz are involved to an extent much greater than the Amhara. For the fishing communities, fishing is more important in the dry season as traditional fishing techniques are effective when rivers form small water pools locally named "Bahir" (Abbute Wolde-Selassie, 2004; Kappelman *et al*., 2014; Alamrew Eyayu and Abebe Getahun, 2019).

Due to lack of recommended gears, fishers in the ALNP are forced to use traditional and destructive fishing methods and they are practicing seasonal fishing (Alamrew Eyayu and Abebe Getahun, 2019). These traditional and destructive fishing practices include the bow and arrow or spears (Plate 1 c), mosquito nets (Plate 1 d), basket traps (locally named "Guramba") (Plate 1 a & b), locally available piscicidal plants such as fruits and barks of 'Desert date' *B. aegyptiaca* (Plate 3), crushed seeds of 'Birbira' *Millettia ferruginea* and barks of *C. molle*, and seldom synthetic piscicides are also used (pers. obs.).

Protecting the ALNP is an urgent task as ecological threats of the park are emerging from two directions: first the natural process (e.g., drought) which could adversely interfere in the normal functioning of the natural ecosystem and interactions with biodiversities. The second and most serious threat is from the human side that destroys natural habitat and the biota. For example, poaching and encroachment, poison fishing, seasonal grazing inside the park and along river courses, human wildlife conflict for resources and habitat competition and water abstraction by channeling rivers for irrigation are among the problems prevalent in the area. Therefore, in combating such problems there is a need to study the biological resources in the park and forwarding some management options for sustainable utilization.


**Plate 1**. Traditional fishing methods in the ALNP: a & b, trap nets (Guramba) fishing at the Gelegu River; c, spear fishing at Ayima River and d, kids dragging mosquito nets for juvenile fishing at Ayima River.

### 1.3.2. Drainage basins in and around the Alitash National Park

#### 1.3.2.1. The Blue Nile Basin

The BNB accounts for about 20% of the total land in Ethiopia, 50% of its total average annual runoff, and 25% of its population. The basin is within parts of each of the regional states of Amhara, Oromiya and Benishangul-Gumuz. In all successive flow ranges of the regional states, the BNB receives many tributaries in its upper course in the Ethiopian highlands and one further: River Ayima with Gelegu and Alitash as its cardinal tributaries in its lower reaches and drain towards Sudan. Ayima River that joins the Blue Nile in Sudan has headwaters in the Ethiopian plateau.

Ayima drains the southeast to South and southwestern part of the park, while Alitash begins from southeast escarpments and flows to west passing through the park center. Gelegu River drains from the northern to central part of the ALNP. These rivers dry up during the hot dry season from December to April; however, some water pools may remain along the rocky bed of the river courses and hold water up to the next rainy season (Pers. obs.).

**Ayima River**: River Ayima begins west of Lake Tana, at a place called “Serako” and flows into Sudan before joining the Blue Nile South of Wad-Medhani in Sudan. The river is a border line between two administrative regional states; ANRS and Benishangul-Gumuz National Regional State (BGNRS). Ayima is the main river with diverse fish fauna that guarantee food security for a considerable number of fishing communities that settled along the river courses. Small to medium sized furrow irrigation schemes extract water from this river for over nine months in a year. As it is bordered by the two regional states, there is sporadic conflict on utilization of the river’s resources, and this disagreement exposed the river for illegal fishers and hence demands conservation measures (Mr. Medhani Ali, pers. comm.).

Ayima is the largest tributary of the BNB in its lower course. The river named Dinder after crossing the Ethio-Sudan border has a catchment area of around 16,000$km^2$ and has average annual discharge of about 3$bm^3$ (Ali, 2014). The river has a wide channel width (around 225 m during flooding) crossing the way to Abaydar village (Plate 2 d). Dominantly sandy and rarely muddy to rocky bottoms are observed along most reaches of the river. The river fit the classic description of a ‘temporary river’ (Larned *et al*., 2010; Steward *et al*., 2012). During the wet season, the entire river network is connected following the natural route, but small stagnant water pools are formed during the extended dry season. This seasonal variation in river flow regime attributes to the difference in ichthyofaunal diversity and distribution in the Ethiopian Ayima and the Sudanian Dinder River since it limits movement of fishes upstream and downstream during the wet and dry months, respectively.

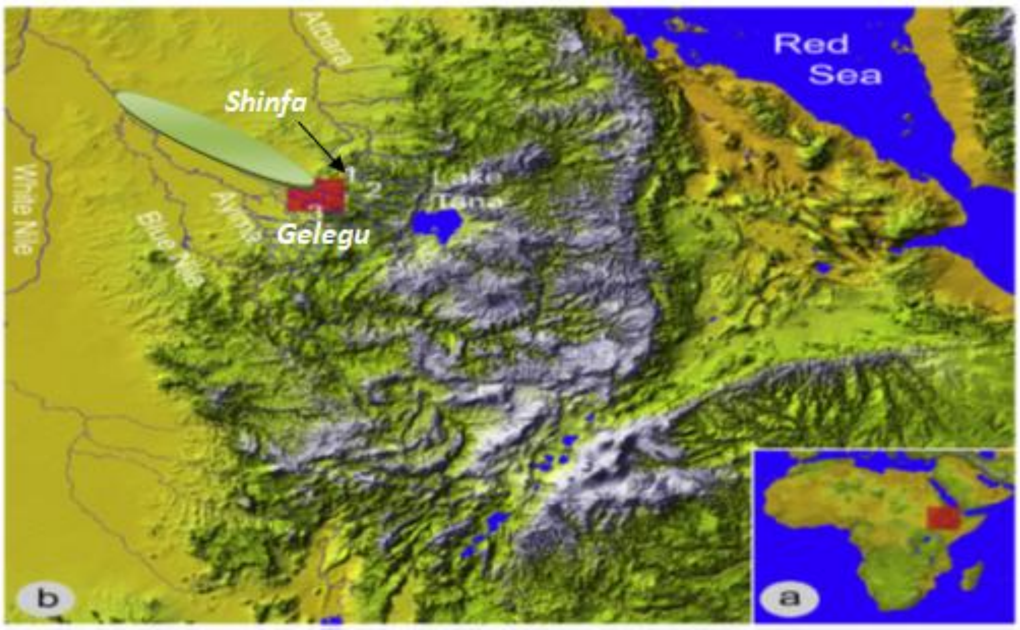


**Figure 2**. Topographic map of (a) Africa with the Horn of Africa (inset- highlighted in red) showing (b) the lower courses of the major tributaries of the BNB that originate in the northwestern highlands of Ethiopia. The Atbara is shown in the far northwest where Shinfa River (#1 in the map) is a major tributary of the lower reach in TAB (modified after Kappelman *et al*., 2014).

**Alitash River**: This is among relatively the largest river along the ALNP from which the name of the park was derived. It is a cardinal tributary of Ayima with immense affluent streams and has a comparable size with that of Gelegu River. Alitash River has a relatively wider channel as compared to Gelegu and its river bed consisting of thick fine sand, whereas largely rocky in Gelegu River. The neither sandy nor rocky course of the

Alitash River has an important aspect for people to dig water for drinking in only up to 1-2 m deep during the extended dry season. As it is part of the ALNP, this river is also subjected to a wide range of human interference. A onetime survey of the present study revealed that the fish diversity in this river was low as compared with the other rivers in the ALNP.

**Gelegu River**: There are many rivers in Ethiopia with varied sizes and remarkable geomorphology. However, apart from the big rivers and major tributaries, there is hardly to find any perennial flow in areas of the northwestern lowlands of Ethiopia. The Gelegu River (Figure 2 No. 3) is relatively smaller located between the Shinfa and Ayima Rivers that has largely eroded gorge with a very narrow channel as seen in plate 2 a. The river is seasonal and flows directly into the ALNP.

The extreme hydraulics of this river during high water flows are attested to by the numerous river potholes that mark the edges of pools. Numerous fish with high species diversity are trapped in such small waterholes when flooding cease and the waterholes evaporate and are reduced in size and depth (Plate 2 b). The channel (with small water volume during the dry month) is appropriate for fishing (plate 2 c).

**Plate 2**. The Gelegu River (see Figure 2, item no. 3 for details) (a) eroded narrow channel of the river; (b) numerous fish with high species diversity in a small waterhole during the dry season; (c) site of intensive fishing activity at Gelegu and sun drying and wind ventilation for preservation; (d) a wide water channel of Ayima River.

#### 1.3.2.2. The Tekeze-Atbara Basin

The Tekeze is perhaps the true upper course of the Atbara, as the former follows the longer course before the confluence of the two rivers in the Ethiopian highlands (Abebe Getahun, 2007). The upper Atbara sub-basin, known as the Tekeze in Ethiopia, has a seasonal rainfall (950 mm, annually) which is even shorter than the Blue Nile and is largely concentrated in July and August (Conway, 2000).

Unlike the BNB, along the courses of the Tekeze-Atbara Basin (TAB), there is no natural lake in Ethiopia, and fishery activities rely entirely upon lotic systems. Data on fish and fisheries of the Tekeze–Atbara system are much limited (Golubtsov and Mina, 2003) and few studies were conducted on the ichthyofauna by Muhammed Oumer and Belay Abdissa (2001), Genanaw Tesfaye (2006) and Dereje Tewabe (2008). According to those authors Rivers Angereb, Guang, Sanja, Shinfa and Gendawuha host some Nilo-Sudanic, endemic and East African highland fish forms. The diversity and fishery potential of these rivers in the basin is considerable. For example, River Sanja has noticeable fishery potential with considerable fish species (Genanaw Tesfaye, 2006).

According to the report of Muhammed Oumer and Belay Abdissa (2001), the majority (42%) of the catch from Sanja comprised *Labeo* species while the majority (78%) of the catch from Zarima River (another tributary of the TAB) is constituted by *Labeobarbus beso*. The collection made by Genanaw Tesfaye (2006) from Angereb and Sanja Rivers showed that the largest contribution is due to *Labeo forskalii* (46.3%), whereas the contribution of commercially important fish species like *C. gariepinus* and *O. niloticus* was small.

**1.4. Climate**

The climate of the Alitash and surrounding area is semi-arid and characterized by two extremes: moist cloudy wet (May-October) and extreme hot dry (December-April). The wettest and extreme dry months of the year are August and April, respectively. The annual temperature can reach 21-47 $^0$C with a mean average air temperature of about 35-41 $^0$C (Kruskop *et al*., 2016). According to the nearby meteorological station based in

Gendawuha (town of West Gondar Zone), the average annual rainfall of the area goes up to 800 mm. Based on Ethiopian agroecoological classification, therefore, areas of the Alitash region fall within hot-to-warm sub-moist agroecological zone.

### 1.5. Statement of the problem and research questions

Before initiating any fisheries development and management programme, it is desirable to have an idea of the fish species taxonomy, their proportion, biological aspects and their socio-economical role for the fishing community. Therefore, an inventory to assess all aspects of fish and fisheries is essential for effective management, sustainability and development of the artisanal fisheries.

Past ichthyofaunal explorations in Ethiopia were more localized and studies pertaining to ichthyofaunal diversity of small and inaccessible rivers are limited (Abebe Getahun, 2007). For example, no comprehensive studies were undertaken in the floodplain rivers of the ALNP. However, besides Dereje Tewabe's (2008) study, the fresh water biology group (JERBE) did a onetime sampling from the Ayima River at Omedlla area **(**$11^{0}$48' N, $35^{o}$18' E and Alt. c. 535 m**)** (Golubtsov and Darkov, 2008) and they largely collected Sudanian ichthyofauna than their Ethiopian counterparts. These authors raised the issue of security for biasness in the areas while they made exhaustive sampling throughout the country lasting three decades (Golubtsov, email exchange). Thus, the extent of fish distribution in the lower reach tributaries of BNB and TAB within the limits of Ethiopia is not accurately described. The present study was, therefore, designed to document the ichthyofaunal diversity, biology of some selected fishes and fisheries of the Ayima, Gelegu and Shinfa Rivers with the following research questions:

1. What is the ichthyofaunal diversity of the lower reach tributaries of the BNB and TAB along the ALNP?

2. To what extent do community structures of the fish fauna of the rivers of the two basins differ? Is there any significant difference on distribution of fishes in the rivers based on the indexes of relative importance (IRI) and other indices? Do water physico-chemical and river morphometric variables contribute to fish distribution differences and which environmental variable is more important to explain the fish community structure as a potential environmental determinant?
3. What are the different biological aspects (feeding, length-weight relationship and condition factor) of the commercially important fish species in the rivers? How is the body condition of different fishes in the rivers compared? How are LWRs correlated with their diet preferences? What are the prey composition of predator fishes and what feeding strategies can be followed by fishes of floodplain habitats? Do diets of selected fish species vary within the different size classes and season?
4. What are the different piscicides used by local fishermen? Which concentrations of the aqueous stem bark extracts of the 'Desert date' *B. aegyptiaca* could stupefy fishes in a pond experiment?
5. What is the level of socio-economic contributions of the fishery activities in the area? What roles do fisheries play in the livelihoods of fishing communities? What are the major constraints related to the fisheries management of the riverine small scale fisheries? What is the fishers' perception about proper resource utilization and management?

### 1.6. Dissertation structure and outline

The dissertation consists of six chapters. The first chapter is an introductory part of the dissertation, which gives an outline on the background of the study, an overview of the study area (ALNP, BNB and TAB): topography and location, water resources, biodiversity and climate, and the associated floodplain rivers of the ALNP and brief review on the basin wise distribution and ichthyofaunal exploration of Ethiopian freshwater fishes. It also includes the problem statement and the research questions.

The second chapter deals with the ichthyofaunal diversity of the Ayima, Gelegu and Shinfa Rivers. Fish species distribution, relative abundance, community structure and habitat associations in relation to water physico-chemical and habitat variables were discussed in the third chapter. The fourth chapter dealt more about biological aspects (LWRs, fish condition factor and feeding ecology) of some selected commercially important and major fish stocks of the studied rivers. Assessment and documentation of piscicidal plants and the piscicidal efficacy test of water extract stem bark of *B. aegyptiaca* on some adult fish species based on a pond experiment was presented in the fifth chapter.

The last chapter (chapter six) is exclusively more about the socio-economic overview of the fish and fisheries of the Ayima and Gelegu Rivers and the respective small-scale fisheries management implications. It presents the fishery profiles, fishers' categories and identified and documented the primary strategic adaptations involved in the fishing communities of the ALNP area.

# CHAPTER TWO

## 2. Ichthyofaunal diversity in the three lower reach floodplain rivers of the Blue Nile and Tekeze-Atbara Basins along the Alitash National Park

### 2.1. Introduction

Freshwater biodiversity is declining at an alarming rate, far greater than that which has been noted for even the most affected terrestrial ecosystems (Erȍs, 2007). Abebe Getahun and Stiassny (1998) noted that there is a reduction in fish species diversity from northern and central highlands of Ethiopia to the ERVLs, with a magnitude of 40-85% due to human interferences. Therefore, there is a need to document fish diversity in all parts of Ethiopia because the judicious use and rational management of biodiversity depends on taxa identification.

Understanding the full picture of biodiversity of an area is a central tenet in ecological studies. Thus, ecologists have long ventured to distinguish between different components of biodiversity (e.g., Whittaker, 1972; Legendre and Legendre, 2012). Complete biodiversity comprises components measured at various scales (Legendre and Legendre, 2012). Commonly local diversity (α), differentiation (β diversity) and regional diversity (γ) can be recognized. Alpha (α) measures species richness at a single locality or community and tells how finely species are partitioning ecological resources, whereas beta (β) diversity can reflect the level of habitat selection or species composition among sites within a geographical area (Legendre and De Cằceres, 2013). β diversity, the spatial turnover or change in the identities of species, is a measure of the difference in species composition along regional assemblages (Whittaker, 1972). Among the different measures of β diversity, the Whittaker beta diversity (βw) is widely used in ecology (Koleff and Gaston, 2001). A high βw index indicates a low level of similarity and vice versa. Understanding patterns in β diversity may be important for human-dominated landscapes, where habitat modification can lead to both homogenization and differentiation of communities (Erὂs, 2007). This is unquestionably the case in the Ethiopian lotic habitats where practically all major river basins are affected by various forms of human activities (Abebe Getahun and Stiassny, 1998).

Knowledge on diversity, community structure, distribution and biology of the Ethiopian ichthyofauna has been poorly known; a large number of small, medium and even large rivers have not been exhaustively explored including the rivers explored in the present study (Abebe Getahun and Stiassny, 1998; Abebe Getahun, 2007). It is an urgent task, therefore, to investigate large-scale spatial patterns of ichthyofaunal diversity of Ethiopian rivers, which can be used for implementing more effective conservation schemes, or can support existing conservation strategies. Thus, studies pertaining to fish diversity in less explored water systems will add information on local and global diversity components to riverine fish diversity in the ALNP.

Ayima and Gelegu Rivers in the BNB and Shinfa River in the TAB virtually harbor many fish species and considerably provide animal protein for the local communities. However, studies pertaining to fish species diversity of such rivers are limited. The scanty and patchy information on fishes of these rivers are due to the recurring insecurity or flaring war along borders and inaccessibility for sampling. Thus, the extents of fish diversity on these rivers were not documented and not precisely known to science. Therefore, lack of fishery data that hamper management strategies on these rivers initiate the need to conduct this study and intends to achieve these objectives:

- To determine the ichthyofaunal diversity in the rivers,
- To determine both the local and global species diversity measures, and
- To prepare a checklist and identification keys for easy naming of fishes of the basins.

## 2.2. Materials and methods

### 2.2.1. Sampling sites

Two complementary data sets of ichthyofauna and environmental variables on seasonal basis were collected from six sampling sites (two from each river) (Figure 3). These sampling sites were assigned during the reconnaissance period (November 2014) based on relative accessibility for sampling and habitat types. The distance between the sampling sites of a river ranges from ca.3 to 67 kms. The longest distance is between the sampling sites (A1 and A2) from Ayima while the shortest is at Gelegu (G1 and G2). The reasonable large disparate distant in the sampled rivers is attributed to its accessibility and sampling safety.

The sampling sites in each river have different habitat characterization and substrate type (Table 3). In Ayima (Abay Dar, A1-is pool to riffle with a muddy and rarely sandy bottom and Farshaho (A2)-is rocky with sandy bottom and largely riffle). This river has very wide channel that ranges from 25-225 m during dry and wet months, respectively.

River Gelegu has largely rocky eroded gorges with a very narrow channel of 3-17 m. Hence, the sampling sites at this river were rocky bottom at St. George (G1) and muddy and sandy to rocky bottom at Shimelgir (G2) and the channel is relatively wider in G2. G1 is riffle to pool with about a 2m "Water Fall" on the upper side that impedes fishes to move upstream, whereas G2 is precisely pool. In Shinfa, Duldula Bahir (S2) is rather riffle with muddy bottom and Ziqesh Bahir (S1) is pool with rocky substratum. The channel length of the river was 12-68 m around the sampling sites.

**Table 2**. Summary of sampling sites with a GPS position A1 and A2 (Ayima), G1 and G2 (Gelegu) and S1 and S2 (Shinfa); Alt.=Altitude.

| | | Site (m) | depth | Secchi depth (cm) | | Channel diameter (m) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Site | Alt. (m) | Dry | Wet | Dry | Wet | Dry | Wet | GPS readings | |
| | | | | | | | | N | E |
| A1 | 633 | 3.7 | 5.0 | 135 | 78 | 28.3 | 45 | 12° 0' 47.2" | 35°56'39.2" |
| A2 | 689 | 2.9 | 4.3 | 63 | 43 | 25.9 | 38.5 | 12° 1' 18.5" | 35°7'14.3" |
| G1 | 636 | 2.3 | 4.6 | 85.3 | 39.2 | 2.8 | 6.2 | 12° 13' 31.4" | 35°52'53.9" |
| G2 | 627 | 3.2 | 3.5 | 68.6 | 47.6 | 3.1 | 7.0 | 12° 13' 42.6" | 35°52'39.8" |
| S1 | 587 | 6.1 | 7.6 | 41.3 | 18 | 3.8 | 12.5 | 12° 33' 48.4" | 36°7'34.1" |
| S2 | 589 | 2.0 | 4.7 | 34 | 23.5 | 5.0 | 16.5 | 12° 34' 55.5" | 36°9'1.0" |

Morphometric variables of the sampling sites such as site depth (m) measured using *PLASTIMO ECHOTEST* II-73420, channel length (m) measured using a rope and Secchi Depth (cm) gauged by a standard 20 cm diameter Secchi disk were taken on a seasonal basis during each sampling occasion (Table 2). Points using Global Positioning System (GPS) were taken to locate sampling stations on a map (Figure 3).

Based on observation, sampling sites of each river was characterized for the level of human interference, habitat type, bottom substrate and vegetation cover (Table 3). The grazing intensity referred to mean the area is endowed with a huge number of herds of cattle and largely used by the local communities as a site of intensive grazing during the extended dry season. Since the number and scale of irrigation sites in the sampling sites of each river are different, and the level of water extraction for the different scale of irrigation schemes is rated as “small” when water from the river site is rarely used and in little quantity, and “very large” when huge amounts of water is frequently used by farmers. The other human induced pressure currently operated in the different sections of the rivers was using the river side as a waste discharging field. The rate of this anthropogenic activity has a high score in sites near to settlement areas and nearby farmlands. In the lower reach river sections and along the major courses of the Shinfa River, where management options are not effective, many fishers use different types of piscicides.

**Table 3**. Habitat characterization and human induced activities score in the sampling sites: field observation.

| Variables | Sampling stations | | | | | |
|---|---|---|---|---|---|---|
| | A1 | A2 | G1 | G2 | S1 | S2 |
| Habitat type | Pool to riffle | Riffle | Pool | Pool to riffle | Pool | Riffle to pool |
| Bottom substrate | Muddy and cobles (rarely) | Rocky and sandy (rarely) | Rocky | Muddy and sandy to rocky | Rocky | Sandy and cobles |
| Aquatic vegetation | Reed species | Attached algae | Reeds | Reeds | No | No |
| Bank vegetation | Perennials | Perennials | Reeds, land plants | Echinochloa spp. | Perennials | Perennials |
| Grazing intensity | Mild | High | Mild | Mild | High | High |
| Waste disposal | Very low | Mild | Very high | Mild | Very high | Mild |
| Water abstraction for irrigation | Very large | Small | Small | Small | Small | Very large |
| Poison fishing (2-km radius) | Very high | High | Mild | High | Very high | Very high |

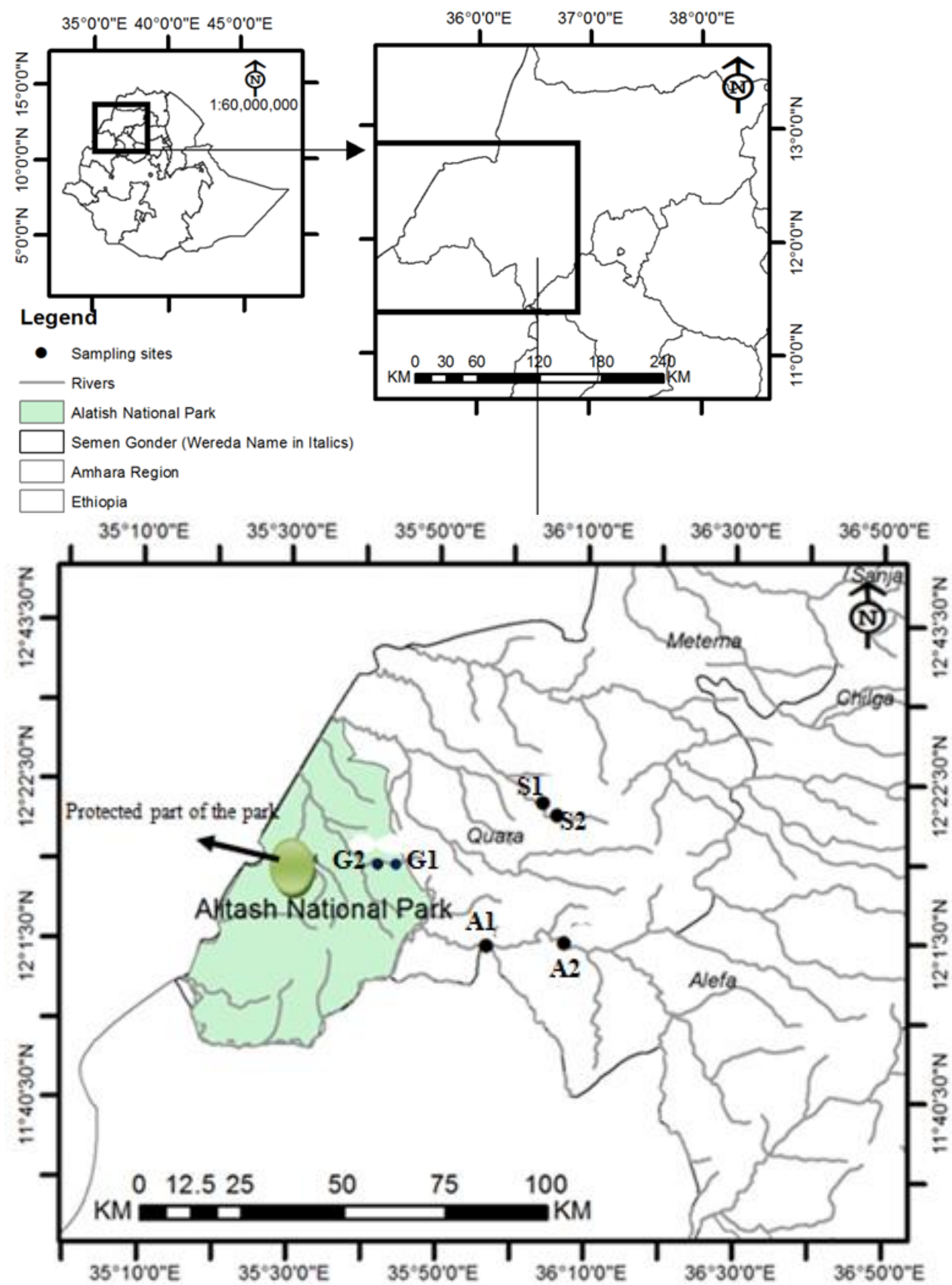


**Figure 3**. Sampling sites for collection of fish and water samples from Ayima (A1 and A2), Gelegu (G1 and G2) and Shinfa (S1 and S2) Rivers, northwestern Ethiopia.

### 2.2.2. Fish sampling and specimen identifications

Fish samples were collected from April 2015 to November 2016 for two dry and two wet sampling times. Exceptional sampling was made in April, 2018 at Shinfa because of the 2015/16 El Niño impact on this river and security problems. Monofilament and multifilament gillnets were used for fishing. Gillnets had stretched mesh sizes of 4-14 cm with a panel length of 25-75 m and width of 1.5-2 m per mesh size. Hooks, long and hand lines (size 6-14), cast nets, old mosquito nets and electro fishing were also used for fish sampling. Observations of fishermen collection at fishing sites were also used as a supplementary data for this study. Voucher specimens were soaked in 10% formaldehyde and transported to AAU fisheries laboratory for further scrutiny and verifications.

In the laboratory, samples were carefully washed using tap water and transferred to 70% ethanol and identification was made using morphometric and meristic parameters by referring to identification keys developed for Ethiopian and African freshwater fishes (Boulenger, 1909; 1911; 1915; 1916; Sandon, 1950; Shibru Tedla, 1973; Bailey, 1994; Golubtsov *et al*., 1995; Skelton, 2001; Abebe Getahun and Eshete Dejen, 2012; Redeat Habteselassie, 2012; Abebe Getahun, 2017). Local and/or vernacular names mostly given based on special body structure or color of fishes have played a crucial role in this study for preliminary identification at the field. Although some local names overlapped, almost 95% of the species identified in this study hold local name(s) in two languages (Amharic and Gumuz).

Nelson (2006) was followed for higher fish taxa nomenclature. Families were arranged in a phylogenetic order (Skelton, 2001) and species nomenclature followed FishBase and

***CLOFFA***, Check-List of the Freshwater Fishes of Africa compiled by Daget *et al*. (1984, 1986 and 1991). CLOFFA provides a list of freshwater fish species of Africa with full synonyms, and subsequent revisions which include new taxonomic changes, except for the family group Arapaimidae (formerly Osteoglossidae), which is according to Laan *et al.* (2014). Alestidae (formerly African Characidae) is according to Paugy (1984) and Laan *et al.* (2014), the Schilbeidae is arranged based on Skelton (2001), and Trewavas (1933) was followed for *Oreochromis*. A newly modified name of the genus *Coptodon* (formerly *Tilapia*) is considered. The common name(s) used for all species throughout this work is based on the information from FishBase; with additions and modifications for recent name changes (Skelton, 2001). Valid scientific names (*italicised*) and recent common name for each species, along with citations to literature used in identification and the examined voucher specimens and brief diagnostic characters used for identifying the species, are also provided under **Appendix 1**. The list also includes the number of families (F), genera (G), species (Sp.), and other characterizing features (e.g., SL in cm) of the examined and museum deposited specimens. Number of each taxon under **Appendix 1** is only referable to the present collection.

After proper identification was made, representative voucher specimens of each fish species were tagged with important information (e.g., type localities/coordinates, date of collection, name of collector, etc) and deposited at the Zoological Natural History Museum (ZNHM), Addis Ababa University (AAU), Addis Ababa, Ethiopia (see **Appendix 1**; **Appendix 2- Figures 1-43**). The designation used for museum deposited specimens was **ZNHM − FAL − XXX:**−Zoological Natural History Museum (AAU)−Fishes of Alitash−followed by identity numerals in three digits.

## 2.3. Data analysis

Nonparametric measures of different indices including Shannon diversity index (H') (Shannon and Weaver, 1963) and equitability (J′) indices (Maurer and McGill, 2011) were used to evaluate the extent of fish species diversity as a measure of species richness in the rivers:

$$\mathbf{H}' = -\sum_{\mathbf{i=1}}^{\mathbf{s}} \mathbf{pi} * (\mathbf{ln\ pi}) \qquad \mathbf{J}' = \frac{\mathbf{H}'}{\mathbf{Ln\ S}}$$

Where; Pi = is the relative cover of the $i^{th}$ species;   S = species richness; ni = abundance of the $i^{th}$ species in an area; and N= total number of species

The rank order abundance (Whittaker) plot, often useful to evaluate equitability in species abundance among rivers, generated as natural logarithm of relative abundance values (Y-axis) versus the species abundance rank (X-axis). Differences in the parameters of α diversity measures between the rivers were evaluated using a randomization (permutation) test (Solow, 1993). Whittaker‘s beta diversity index (βw), which is thought to be strong index of diversity (Koleff and Gaston, 2001), was used to evaluate the rate of fish species differentiation between the rivers (Whittaker, 1972): $\boldsymbol{\beta}\mathbf{w} = \frac{\mathbf{S}}{\acute{\alpha}} - \mathbf{1}$

Where; S = total number of species of the habitat and ά = average species richness per habitat

An individual based rarefaction analysis was performed to standardize diversity comparison between the rivers (Magurran, 2004; Gotelli and Colwell, 2011). All statistical analyses were carried out in PAST version 3.20 (Hammer *et al.*, 2001).

## 2.4. Results

### 2.4.1. Fish species diversity

Altogether 2719 specimens identified into 43 fish species and ascribed into 6 orders, 15 families and 25 genera were collected during the entire sampling program of the present survey (Table 4). Fishes of the order Siluriformes with 6 families, 7 genera and 13 species was the most diverse group, which accounted 30.2% of the total species richness and 36.4% of the individuals collected (Tables 4 and 7). The Cypriniformes were only represented by a single family and 3 genera that include 10 species and accounted for over 23 and 32% of the species richness and abundance, respectively (Tables 4 and 7). Characiformes with 3 families, 5 genera and 9 species accounted for about 21% of the total species richness, but only for 14% of the total individuals captured, was the third important order in species richness (Tables 4 and 7). The two other orders (Osteoglossiformes and Perciformes) comprised two families each; the former was represented by 7 species while the later has 3 species. Order Polypteriformes was represented by a single family and one species.

The highest number of species and specimens were collected from Gelegu River (38 species and 1124 specimens) followed by Ayima (35 species and 1006 individuals) and the smallest number both in species and specimens were from Shinfa (25 and 589, respectively). Three species (8.6%); *Distichodus brevipinnis*, *Raiamas senegalensis* and *Lates niloticus* with the catch of 267 individuals were sampled from the Ayima River only. Eight species (21.1%) were unique to the Gelegu River and accounted 196 individuals (7.2%) from the total catch (Figure 4). 21 species (48.8%) are common to all rivers considered in this study and contributed 1970 individuals (72.5%) of the total abundance.

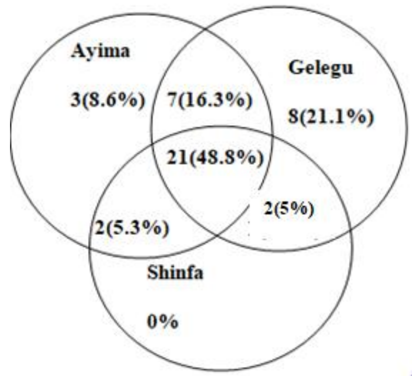


**Figure 4**. Fish species percentage distribution in a river, shared between two rivers and common species collected from all the studied rivers of the ALNP.

**Table 4**. Fish species recorded in the ALNP (based on the present collection); place of collection where, A= Ayima; G= Gelegu; S= Shinfa; * new records reported by this study after Dereje Tewabe (2008).

| | | | | Local name (s) in: | |
|---|---|---|---|---|---|
| **Order** | **Families** | **Species** | **Common name (s)** | **Amharic** | **Gumuz** |
| Polypteriformes | Polypteridae | *Polypterus bichir* (G) | Nile bichir | Ebabosh | Yedildil |
| Osteoglossiformes | Arapaimidae | *Heterotis niloticus* (AG) | African arowana | Dulesie | Paloluha |
| | Mormyridae | *Hyperopisus bebe** (GS) | Ngai | Ayit-Assa | Tsibilla |
| | | *Marcusenius cyprinoides** (AGS) | Thick-lipped fish | Gurtosh | “ |
| | | *Mormyrus caschive* (AS) | Elephant snout fish | Ayitosh | “ |
| | | *Mormyrus kannume* (AGS) | Bottle-nose | “ | “ |
| | | *Mormyrops anguilloides** (G) | Cornish jack | Ayit-Assa | |
| | | *Petrocephalus keatingii** (G) | Ngai | “ | “ |
| Characiformes | Alestidae | *Alestes baremoze* (AGS) | Pebbly fish | Beresho | Lipka/ Chilentie |
| | | *Brycinus nurse* (AGS) | Nurse Tetra | Nech-Assa | |
| | | *Brycinus macrolepidotus** (AG) | Big scale tetra | Shimello | |
| | | *Hydrocynus vittatus* (AG) | Tiger-fish | Tirso | Enza |

| Order | Families | Species | Common name (s) | Local name (s) in: Amharic | Gumuz |
|---|---|---|---|---|---|
| | | *Hydrocynus forskahlii* (AG) | >> | " | " |
| | Citharinidae | *Citharinus latus* (AG) | Moonfish | Sefedo | Yambda |
| | Distichodontidae | *Distichodus brevipinnis** (A) | Grass eater | Gosh-Millas | |
| | | *Distichodus engycephalus** (G) | Grass eater | " | |
| | | *Distichodus rostratus** (AG) | Grass eater | " | |
| Cypriniformes | Cyprinidae | *Labeobarbus bynni* (AGS) | Nile barb | Guanja | Tsiwiya |
| | | *Labeobarbus crassibarbis* (AGS) | | Tsimo | |
| | | *Labeobarbus intermedius* (AGS) | African big barb | Kuba | " |
| | | *Labeobarbus degeni* (AGS) | | Guanja | " |
| | | *Labeobarbus nedgia* (AGS) | | Guanja | " |
| | | *Labeo cylindricus* (AGS) | Redeye Labeo | Tikur Kuba | " |
| | | *Labeo forskalii* (AGS) | | " | " |
| | | *Labeo horie* (AGS) | | Kuba | " |
| | | *Labeo niloticus* (AGS) | Nile carp | " | Mangata |

| Order | Families | Species | Common name (s) | Local name (s) in: Amharic | Gumuz |
|---|---|---|---|---|---|
| | | *Raiamas senegalensis** (A) | Silver fish | Worka-Workit | |
| Siluriformes | Auchenoglanididae | *Auchenoglanis occidentalis* (AGS) | Black spotted catfish | Lemlem kuri | Jejumma |
| | Clariidae | *Clarias gariepinus* (AGS) | African catfish | Bermuts | Bilbutsie |
| | | *Heterobranchus longifilis* (AGS) | Vundu | Sorz | Bedena |
| | Bagridae | *Bagrus bajad* (AS) | Forskal's catfish | Ambazza | Besessie |
| | | *Bagrus docmak* (AGS) | Bagrid catfish | " | " |
| | Malapteruridae | *Malapterurus electricus** (G) | Electric catfish | Assa Adenziz | Bamdandi |
| | | *Malapterurus minjiriya** (AG) | Electric catfish | " | Bamdandi |
| | Mochokidae | *Synodontis clarias** (AG) | Mandi/Squeaker | Kurri | Baquqo |
| | | *Synodontis schall* (AGS) | Shield-head fish | " | " |
| | | *Synodontis serratus* (AGS) | Squeaker | " | " |
| | | *Synodontis sorex** (G) | Squeaker | Tengallo Kurri | " |
| | Schilbeidae | *Schilbe mystus* * (G) | African butter catfish | Liben | |

| Order | Families | Species | Common name (s) | Local name (s) in: | |
|---|---|---|---|---|---|
| | | | | Amharic | Gumuz |
| | | *Schilbe uranoscopus* (GS) | Silver catfish | Liben | |
| Perciformes | Cichlidae | *Oreochromis niloticus* (AGS) | Nile tilapia | Koroso | |
| | | *Coptodon zillii* (AGS) | Red belly tilapia | Koroso | |
| | Latidae | *Lates niloticus* (A) | Nile perch | Ayilla | Burwa |

### 2.4.2. Diversity indices

The values of local diversity indices of fishes and the *p* value for rivers of the ALNP are summarized in table 5. The species richness, Shannon diversity and eveness index between the rivers fish composition was statistically significant ($p<0.05$) (Table 5). The number of individuals only vary between Gelegu and Shinfa Rivers ($p=0.0408$). Figure 5 summarizes the relationship between the number of individuals and different local diversity indices among the sampling sites.

**Table 5**. Summary of variation in species abundance (n), species richness (S), Shannon index (H') and index of equitability (J') for the Ayima River (AR), Gelegu River (GR) and Shinfa River (SR).

| Parameter | AR | GR | SR | F | P |
|---|---|---|---|---|---|
| n | 1006 | 1124 | 589 | 1.642 | 0.080 |
| S | 35 | 38 | 25 | 67.444 | 0.000* |
| H' | 2.86 | 3.02 | 2.95 | 15.413 | 0.000* |
| J' | 0.81 | 0.83 | 0.92 | 66.618 | 0.000* |

* For significant values, $p<0.05$.

The Whittaker beta diversity index ($\beta w=0.33$) for the rivers showed the existence of turnover in species composition between these floodplain habitats.

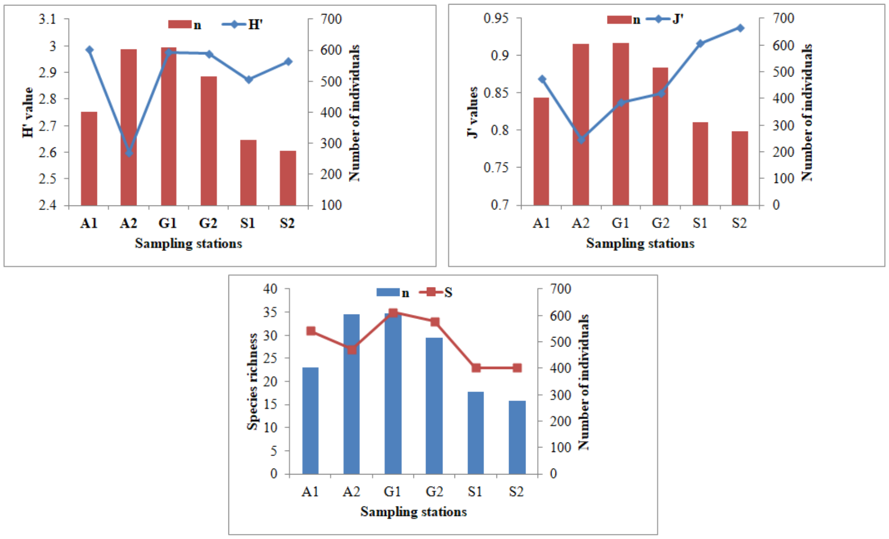


**Figure 5**. Site based status of some diversity indices in relation to number of individuals of fishes in the ALNP.

The likely species richness of Shinfa River (i.e., the smallest sample) rarefied from the Ayima and Gelegu Rivers (i.e., the largest sample) and the expected rarified species richness of the Shinfa River at a sample size of 534.356±22.91 at 95 % confidence interval (CI) is shown in Figure 6.

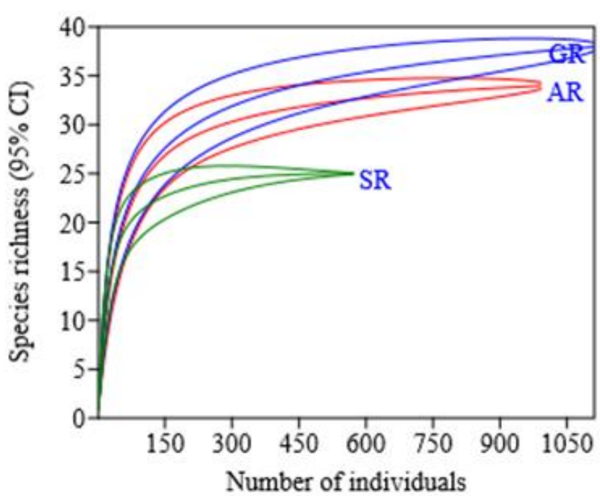


**Figure 6**. River wise individual based rarefaction analysis for Shinfa (n = 589) and over the Gelegu (n = 1124) for their species abundances.

The rank order abundance plot in figure 7 showed that fish communities of the Gelegu and Shinfa Rivers are more even than in the Ayima River.

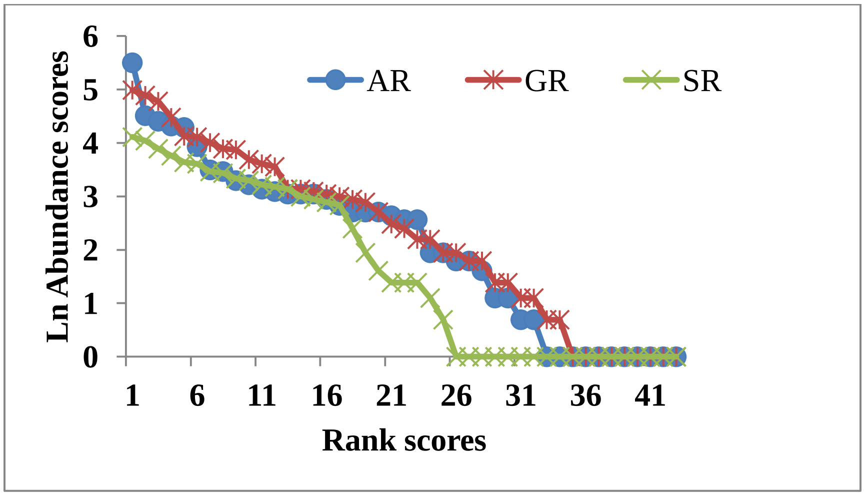


**Figure 7**. Whittaker plot for fish communities of the lower reaches of the BNB and TAB within the ALNP.

### 2.5. Discussion

The analysis of fish species diversity showed that Gelegu River followed by Ayima were more speciose than Shinfa. Although only few rivers were assessed in the present study, this showed that the BNB is richer in species than the TAB. Thus, the difference in species richness between the rivers may be due to greater number of affluent streams and rivers, whilst Shinfa River in the TAB is only fed by two cardinal floodplain rivers in the limits of Ethiopia where this study was conducted.

Similar fishing efforts and techniques were used throughout the sampling periods at all sampling sites and thus the difference in species diversity could not be attributed to the difference in sampling effort (Magurran, 2004; Gotelli and Colwell, 2011). However, it is very important to underpin that sampling data document only the verified presence of species in an assemblage and sampling usually covers smaller sections of rivers or lakes. Therefore, the absence of a particular species in a sample may represent either an exact absence (the species is not present in that habitat or assemblage) or a false absence (the species is present, but was not detected in the sample). This is associated with the fact that biotic diversity at all levels of organization is often high, and biodiversity sampling is usually labor intensive and biases are usually considerable (Gotelli and Anne, 2013). Therefore, to refer this work in a very particular case, it is indispensable to consider meticulously other studies pertaining to fish diversity of the two basins and the country checklists in general. For that reason analysis of combined data of the present and past studies would become more informative for understanding of the basins' ichthyofauna. Based on such analysis 77 valid native fish species can be recognized from the two basins (Golubtsov and Darkov, 2008). Simplified bracketed identification key for easy naming of fishes is provided in **Appendix 3** for the whole valid species of the two basins.

The family Cyprinidae by large constituted the largest number of species in both basins (3 genera and 10 spp.). With the cyprinids of Lake Tana, species of the family Cyprinidae constituted 50% of the entire BNB ichthyofauna (Abebe Getahun, 2007; Golubtsov and Darkov, 2008). Based on the present collection 23.3% and 36% of the BNB and TAB, respectively in Ethiopia are dominated by species of this family. In accordance with the present finding, Golubtsov and Darkov (2008) found that the Cyprinidae family is the only group of fish which is more diverse in the Blue Nile drainage system than in the White Nile. This may be due to the fact that seasonally inundated floodplain rivers are adapted by the resilient cyprinids (Abebe Getahun, 2007). Previous studies on several rivers and lakes in the BNB and TAB showed that fish communities were dominated by species of Cyprinidae (e.g., Genanaw Tesfaye, 2006; Dereje Tewabe, 2008; Zeleke Berie, 2007; Golubtsov and Darkov, 2008). Out of the tropical region, species of the Cyprinidae family also dominates the river basin of Yangtze in China (Fu *et al*., 2003).

The family Alestidae and Mochokidae were represented by 5 and 4 species each, respectively (Table 4). Both families are among the primary freshwater fishes of Africa represented by many species elsewhere in the continent (Lèvèque *et al*., 2008). In the BNB within the limits of Ethiopia, the Mormyridae and Mochokidae families have more representatives in the rivers than lakes (Abebe Getahun, 2007). The families Cyprinidae, Clariidae, Cichlidae, Mormyridae, Auchenoglanididae, and Bagridae have almost equal number of representative species in all rivers assessed in the present survey. It was reported that the aforementioned families and the Alestidae (with five representative species) together accounted for more than half the number of fish species in the main Nile (Greenwood, 1976).

Families Arapaimidae, Auchenoglanididae, Citharinidae, Latidae and Polypteridae were poorly represented by the number of species in the present study: African bonytongue (*Heterotis niloticus*), Black spotted catfish (*Auchenoglanis occidentalis*), Moonfish (*Citharinus latus*), Nile perch (*Lates niloticus*) and Nile bichir (*Polypterus bichir*), respectively. These peripheral freshwater fish families are also relatively poorly represented in African inland waters (Lèvèque *et al*., 2008). Similarly, the abovementioned families were represented by only a single species each in the present collection and the numbers of specimens collected for these representatives were too small except for species of the first two families.

Ichthyofaunal diversity of the ALNP is much higher than the DNP of Sudan. In the two parks a single cardinal river (Ayima in Ethiopia and Dinder in Sudan) is the only water source with many floodplain stream tributaries. This river in the Ethiopian territory is home to 35 fish species (present study), while 31 species were identified from Dinder River (the same river in the Sudan) (Khalid *et al*., 2016). The difference in the number of species may be associated with the seasonal nature of the river that impedes fish movements while disconnected for a long period of the year after flooding.

By considering the current numerical values reported by Abebe Getahun (2017) for the whole BNB (62 species), fish species identified in the present collection in the ALNP represent 69.35% of the basin fishes. In the TAB 35 species were reported by Abebe Getahun (2017) and Shinfa alone constituted about 71.43% of the basin fishes (present study). The presence of many species in the rivers of the two basins is attributed to their location at lower altitude favoring higher fish diversity (Golubtsov and Mina, 2003).

By referring to the only literature by Dereje Tewabe (2008) and unpublished report by Abebe Getahun (2012), there are 15 and 4 species of unreported records (represented by * in Table 4) for the Ayima and Shinfa Rivers, respectively. The genera *Marcusenius* and *Hyperopisus* were identified in the TAB for the first time from Shinfa River by this study. The discovery of these two Mormyrid genera represented by a single species each from Shinfa River may be due to using varied sampling techniques and exhaustive surveying. It was difficult to make a comparison on identified species collected from the Gelegu River since there is no available data on fish diversity and hence only basin wise comparison was made. *Polypterus bichir*, *Hyperopisus bebe*, *Marcusenius cyprinoides*, *Petrocephalus keatingii*, *Mormyrops anguilloides*, *Distichodus rostratus*, *Synodontis* *clarias*, *S. sorex*, *Malapterurus electricus* and *M. minjiriya* are new records for the BNB (the specific occurrences of each species is cataloged in **Appendix 1**; Table 4). The occurrences of the aforementioned species in the BNB were not known before. For example, *M. cyprinoides* was only reported in the White Nile and Omo-Turkana systems, and in the southern portion of the ERVLs (Golubtsov and Darkov, 2008). *P. keatingii* in the Mormyridae family was reported from the White Nile by JERBE, but the present collection from Gelegu River realized this species in the BNB. Although, it is from the group of the lowland Nilotic fish fauna (Lèvèque *et al*., 2008), *P. bichir* was collected from the Gelegu River in the BNB for the first time. *Distichodus engycephalus*, *D. rostratus*, *Citharinus latus* and *Schilbe mystus* are also other new records reported for the first time by the present study from the BNB.

The Shannon diversity index was higher for the Gelegu River (H'=3.02) than Shinfa (H'=2.95) and Ayima (H'=2.86) Rivers, and the difference was statistically significant ($p<0.05$). The difference among the number of individuals was not statistically significant in the rivers ($p>0.05$). However, there was significant difference between individual numbers of G1 and to that of S1 ($p=0.042$) and S2 ($p=0.039$) or between Gelegu and Shinfa rivers ($p=0.0408$). Both the Shannon evenness index (Table 5; Figure 5) and the rank order abundance (Whitaker) plot (Figure 7) showed that species abundance distribution was more even for the Gelegu River. This might be due to rocky gorges for sheltering the fish species from predators, the smaller channel length and hence ease for fish collection the Gelegu River. River Ayima with wider channel and inundated by several tributaries had a high number of fish species. This result agrees with the study of

Dereje Tewabe (2008) who reported high fish species diversity from Ayima than Guang and Gendawuha Rivers, the last two rivers belonging to the TAB.

Sampling station G1 from the Gelegu River contained the most diversified fish fauna, with 35 species and Shannon's diversity index of 2.98 and with 0.84 index of equitability. Numerically, *C. gariepinus* dominates the catch of this sampling site followed by *S. schall*, *S. mystus*, *S. serratus* and *H. niloticus* (Figure 9). Other species collected from G1 were relatively with small numerical abundance. G2 ranked second in fish species diversity, with 33 species and H′ value of 2.97 and an equitability index of 0.85 (Figure 5). The most dominant fish species at this site in descending order were *S. schall, S. mystus, L. forskalii, C. gariepinus, S. serratus* and *H. niloticus* with numerical contributions of 78, 56, 45, 44, 38 and 24, respectively. High fish species diversity in both sampling sites of the Gelegu River may be attributed to the low human intervention at both sites. Fish community structure and the potential environmental determinants for the variation in species composition and relative abundance between the sampling stations are presented in chapter 3.

### 2.6. Conclusion

The ALNP is drained by many small to large sized floodplain rivers and streams belonging to the Blue Nile and Tekeze-Atbara Basins. These seasonally inundated water bodies harbor a large number of freshwater fishes in the Ethiopian territory. According to the present survey, ichthyofaunal diversity of the ALNP area was much diversified than other such habitat types in Ethiopia. Generally, based on the present investigation, these conclusions are made:

- The rivers assessed in the BNB and TAB harbor native fishes of largely Nilo-Sudanic affinities than endemic species as compared to other rivers in the basins, for instance the Beles and Gilgel Beles Rivers in the BNB and Angereb and Sanja Rivers in the TAB.
- In Ethiopia, the BNB is one of the richest in its fish diversity only next to the Baro-Akobo and Omo-Turkana Basins. The rivers assessed in the present study were more speciose than in any river in the basin and in the country too. But, the TAB is relatively poor in fish species diversity as compared to some other basins in the country, but Shinfa River harbors many species diversity than any other river in the basin.
- The area where the present study was undertaken requires an appropriate conservation measure as the ALNP is facing many ecological crises.
- The annotated checklists believed to resolve taxonomic problems of fish fauna for the entire basins are provided and expected to be useful for upcoming investigators, policy makers and can show research gaps.

# CHAPTER THREE

## 3. Fish species abundance and relative importance in relation to water physico-chemical parameters in Ayima, Gelegu and Shinfa Rivers of the Blue Nile and Tekeze-Atbara Basins

### 3.1. Introduction

Unlike the lacustrine, fish species distribution in lotic habitats that are differing in hydrological connectivity is dynamic in temporal and spatial spectrum. Besides seasonal or annual environmental differences, short term changes, such as day or night cycle and behavioral activities (e.g., search of prey among others) can affect the spatial and temporal distribution and abundance of fishes (Axenrot and Hansson, 2004). Determining which factors are responsible for structuring fish communities in the natural ecosystem is a primary focus in aquatic ecology (Solomon Tesfay, 2016).

Studies on freshwater fish have shown that biological, chemical and physical factors cause differences within and among communities (Erȍs, 2007; Hossain *et al*., 2012) and all operate on a range of both local and large spatial scales (Tonn, 1990). On a local scale, biological factors (Wang *et al.,* 2003), physical factors (e.g., habitat diversity) (Hossain *et al*., 2012), water chemistry and water temperature (Araoye, 2009) and flood regime and channel morphology in floodplain rivers (Moses, 1987) interact to influence fish species community distribution and relative abundance. Species richness in floodplain habitats is highly determined by physical factors (Hossain *et al*., 2012; Tongnunui *et al*., 2016) while biological ones being more important under stable environmental conditions (Axenrot and Hansson, 2004). On larger spatial scales, physical factors such as river size

(Welcomme, 1990), climate and speciation or dispersal (Hughes *et al*., 1987) can regulate fish community structure and distribution.

Floodplain fish and fisheries are characterized by diverse species assemblages, fishing gear and threats (Welcomme, 1985). Tropical floodplain fisheries are a key livelihood of the socio-economically marginalized riparian communities, particularly in Africa, Asia and South America (Mosepele, 2014). Floodplain rivers of the lower reaches of the BNB and TAB are the only water resources that support all life requested activities in northwestern Ethiopia (e.g., domestic use, fisheries, irrigation, etc). Fisheries of these floodplain rivers are also the mainstay of livelihoods for fishing communities of the ALNP. Despite the role of these rivers for food security through fisheries, they are under pressure from various development activities including hydropower plant construction and water abstraction for irrigation along the whole courses. The areas of Alitash and the whole course of the two basins in the Ethiopian plateau are also a corridor of herds of cattle and the river side provides dry season grazing. Illegal fishers using piscicides for fishing are massive in the area (pers. obs.). Urbanization following the shorelines of these habitats largely contributed to the modification of the natural hydrological cycle besides habitat loss and hence could affect fish communities.

Due to the above and other anthropogenic activities, these floodplain rivers are facing habitat alteration and modifications for agriculture that affect fisheries and hence associated livelihoods. Thus, understanding what factors are involved in the structuring of riverine fish community abundance and distribution is an important step towards managing and conserving the remaining floodplain ecosystem (Welcomme, 1979).

Local habitat patterns created in the moving littoral areas of floodplain rivers are disposed to disturbance triggered by seasonal variation patterns between drying and inundation. This disturbance can affect biological, chemical and physical factors in temporary rivers, which collectively act on individual or species level and can determine fish distribution and relative abundance. However, regardless of the possible environmental alterations due to human activities and their impending effects, there is no published ecological study available on fish community structure in the BNB and TAB along the ALNP. Of course, some reports and limited studies are available on the species occurrences (e.g., Genanaw Tesfaye, 2006; Dereje Tewabe, 2008; Golubtsov and Darkov, 2008; Abebe Getahun, 2012). These studies focused only on fish diversity and lack information on ecological factors that determine fish distribution and abundance. Therefore, this study tried to address the effects of different environmental factors on distribution and abundance of fish. It was also intended to describe fish assemblages and community structure of the ALNP in relation to water physico-chemical parameters.

Specific objectives are:

- To compare the relative abundance contribution of each species in the assemblage
- To determine the differences in relative abundance of fishes between the rivers
- To describe the association between water physico-chemical parameters and fish species distribution

## 3.2. Materials and methods

### 3.2.1. Fish sampling

As stated in **section 2.2.2** samples for the study of relative abundance and community structure of fishes were obtained from the same sites of the Ayima, Gelegu and Shinfa Rivers. Sampling methods, sampling time and season, measurement and enumeration techniques of fish specimens were the same as used in chapter 2.

### 3.2.2. Water physico-chemical parameters

Sampling stations in each river were selected purposively based on human disturbances like water abstraction for intensive irrigation, waste disposal, oil spill from motor pumps, sand mining, and cattle grazing. In addition, accessibility was considered during site selection.

Water samples for physico-chemical parameter analysis were taken twice a year along with fish catches. Some physico-chemical parameters were measured *in situ* at all sampling sites during the time of fish sampling. Conductivity ($\mu Scm^{-1}$), dissolved oxygen (DO) ($mgL^{-1}$), water temperature ($T^0$) ($^0C$) and pH were measured using a Multimeter probe (Model HQ 40d) in the field. Water transparency was measured with Secchi disc (20 cm in diameter). The concentrations of phosphates, nitrates, nitrites, silica, ammonium ions, and total phosphorus were determined in the laboratory using spectrophotometer based on standard methods (APHA, 1998). In addition river morphometric variables were measured from each site including depth and channel diameter.

### 3.3. Data analysis

Descriptive statistics was used to determine the average values of each physico-chemical parameter and to evaluate the percentage contribution in weight and number of each fish species. Multivariate analysis of variance (MANOVA) was used to test for significant spatial differences of the water physico-chemical parameters between the different sampling sites of the studied rivers. After running MANOVA, significant spatial differences on the parameters were observed, and then one way analysis of variance (ANOVA) was used to test the specific physico-chemical parameters that attributed to significant variation between study sites between the sampling sites in the rivers.

To reduce the deliberate biases associated with using component parameters (number, weight, and frequency of occurrence) and to ascertain the exact ecological importance of individual fish in an assemblage, a compound index such as index of relative importance (IRI) was recognized for the analysis:

The IRI combines simultaneously individuals number (N), weight (Wt) and frequency of occurrence (FO), to evaluate ecological importance of fish species. This index was originally used for fish diet analysis and then later modified for the assessments of ecological importance of a species in an assemblage (Pinkas *et al*., 1971). This index can be computed for each species as $IRI_i$ = (%Ni + %Wti)*%Fi; and run to evaluate overall %IRI as:

$$\%\mathbf{IRIi} = \frac{(\%\mathbf{Wti} + \%\mathbf{Ni}) * \%\mathbf{Fi}}{\boldsymbol{\Sigma}(\%\mathbf{Wj} + \%\mathbf{Nj}) * \%\mathbf{Fj}}\mathbf{X100}$$

Where; % Wti = percentage weight of each fish of total catch,

% Ni = number of each species of total catch,

% Fi = percentage of frequency of occurrence of each species in total settings,

% Wj = percentage weight of total species of total catch,

% Nj = number of total species of total catch,

% Fj= percentage frequency of occurrence of total species in total settings,

S = total number of species.

To maintain a resemblance matrix measured as Cophenetic correlation index, the unweighted pair group algorithm method of arithmetic mean averaging (UPGMA) and the Bray-Curtis similarity index were used for clustering in a dendrogram. For clustering the mean fish number at each sampling site was employed to explore the pattern of fish community structure. A similarity percentage (SIMPER), based on the Bray-Curtis dissimilarity measure, was used to find out specific fish species that contributed to dissimilarity between the three river fish composition (Clarke, 1993; Zuur *et al*., 2007). All statistical analysis was performed in PAST version 3.20 (Hammer *et al*., 2001), SPSS version 24.0 and Microsoft Office Excel 2007.

Fish community structure in relation to environmental variables was assessed using ordination techniques. Detrended correspondence analysis (DCA) was performed to determine if species response followed linear or unimodal model (Legendre and Legendre, 1998; Lepš and Smilauer, 2003). Therefore, based on this analysis a linear ordination was used because the gradient length along axis-1 in DCA was less than 3.0 turnover units. A redundancy analysis (RDA) triplot of species, sites and environmental variable data was used to determine community structure that could be explained by the specific measured environmental variables. Then, the extent of variability in fish assemblages explained by each environmental variable was explored further with RDA, a constrained ordination technique, using forward selection for appropriate environmental variable (Lepš and Šmilauer, 2003).

Fish species whose variability was related to a particular environmental variable were defined in RDA using percentage variance in species composition produced by that environmental parameter. Only environmental variables explaining significant variance ($p < 0.05$) were retained in the model and tested for significance. The relationships between species and the selected environmental variables were examined in RDA ordination plots based on species scores. All ordination procedures were performed in CANOCO for Windows Version 4.5 (ter Braak and Šmilauer, 1997–2002).

## 3.4. Results

### 3.4.1. Water physico-chemical parameters

All parameters, but the level of pH, conductivity and water temperature, differed significantly between the sampling sites (ANOVA, $p< 0.05$; Table 6). The mean values of conductivity ranged from 260.06±193.0 to 305.87±251.4 $\mu Scm^{-1}$ and did not show significant variation among the sampling sites ($p = 0.479$). The pH range of the water was slightly alkaline (8.08-8.39) and was higher in the A1 of Ayima River and smaller in Shinfa at S1 but there was no significant difference among sites ($p = 0.320$; Table 6). The mean values of temperature ranged from 27.32±2.90 to 29.68±2.0 $^0C$ and there was no significant difference among the sampling stations ($p=0.108$; $F=1.897$; Table 6). The mean level of DO in all sites was 7.26±0.6-8.95±0.7 mg $L^{-1}$ and significantly different among sites (P=0.002; F=18.444).

**Table 6**. Summary of descriptive statistical results of water physico-chemical and morphometric variables of study sites (DO-dissolved oxygen; $T^0$-temperature; $NO_2^-$-nitrite; $NO_3^-$-nitrate; $NH_4^+$-ammonium ion; $SiO_2$-silicate; $PO_4^{-2}$ –phosphate; TP- total phosphorus; Cond.-conductivity; SD=Secchi depth; SZ-site depth; CD-channel diameter).

| **Parameter** | **A1** | | **A2** | | **G1** | | **G2** | | **S1** | | **S2** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Range | Mean+SD | Range | Mean+SD | Range | Mean+SD | Range | Mean+SD | Range | Mean+SD | Range | Mean+SD | F | P |
| DO ($mgL^{-1}$) | 7.27-8.42 | 7.72±0.4 | 5.90-7.84 | 7.26±0.6 | 7.86-10.3 | 8.95±0.7 | 8.26-8.64 | 8.51±0.1 | 8.01-8.97 | 8.23±0.4 | 8.01-8.14 | 8.09±0.6 | 18.444 | 0.002* |
| pH | 8.16-8.57 | 8.36±0.1 | 8.12-8.7 | 8.39±0.2 | 8.11-8.46 | 8.25±0.2 | 7.9-8.45 | 8.22±0.2 | 7.72-8.9 | 8.22±0.3 | 7.8-8.34 | 8.08±0.21 | 1.20 | 0.320 |
| $T^0$($^0$C) | 25.7-30.8 | 27.81±2.3 | 26.2-32 | 28.28±2.2 | 24.6-31 | 27.43±2.9 | 24.4-31.2 | 27.32±2.9 | 27.3-32.5 | 29.10±1.9 | 27.4-32.8 | 29.68±2.0 | 1.897 | 0.108 |
| $NO2^-$ ($mgL^{-1}$) | 0.118-0.12 | 0.019±0.00 | 0.165-0.167 | 0.023±0.00 | 0.086-0.088 | 0.017±0.00 | 0.085 | 0.017±0.00 | 0.154-0.166 | 0.023±0.00 | 0.113 | 0.019±0.00 | 187.70 | 0.000* |
| $NO3^-$ ($mgL^{-1}$) | 0.032-0.035 | 0.173±0.00 | 0.035-0.038 | 0.177±0.00 | 0.023-0.026 | 0.161±0.00 | 0.017-0.020 | 0.153±0.00 | 0.049-0.056 | 0.198±0.01 | 0.076-0.078 | 0.229±0.00 | 17503.725 | 0.000* |

| **Parameter** | **A1** | | **A2** | | **G1** | | **G2** | | **S1** | | **S2** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Range | Mean+SD | Range | Mean+SD | Range | Mean+SD | Range | Mean+SD | Range | Mean+SD | Range | Mean+SD | F | P |
| $NH_4^+$($mgL^{-1}$) | 0.018-0.022 | 0.029±0.00 | 0.019-0.020 | 0.029±0.00 | 0.020 | 0.030±0.00 | 0.019-0.021 | 0.030±0.00 | 0.042-0.045 | 0.043±0.00 | 0.024-0.025 | 0.033±0.00 | 75.148 | 0.000* |
| $SiO_2$($mgL^{-1}$) | 0.670-0.668 | 0.404±0.00 | 0.641-0.646 | 0.395±0.00 | 0.781-0.786 | 0.443±0.00 | 0.661-0.665 | 0.402±0.00 | 0.7-0.703 | 0.415±0.00 | 0.603-0.609 | 0.382±0.00 | 3738.021 | 0.000* |
| $PO_4^{-2}$ ($\mu gL^{-1}$) | 0.040-0.042 | 0.003±0.00 | 0.032 | 0.003±0.00 | 0.021-0.024 | 0.002±0.00 | 0.019-0.020 | 0.002±0.00 | 0.044-0.045 | 0.003±0.00 | 0.023-0.028 | 0.002±0.00 | 29.00 | 0.000* |
| TP ($\mu gL^{-1}$) | 0.089-0.096 | 0.004±0.00 | 0.061-0.062 | 0.003±0.00 | 0.042-0.047 | 0.003±0.00 | 0.038-0.040 | 0.003±0.00 | 0.235-0.238 | 0.007±0.00 | 0.214-0.219 | 0.006±0.00 | 188.02 | 0.012* |
| Cond. ($\mu Scm^{-1}$) | 94.8-530 | 281.58±214.6 | 107.6-685 | 284.21±296.9 | 73.8-493 | 278.09±213.4 | 73.7-447 | 260.06±193.0 | 64.6-555 | 305.87±251.4 | 63.6-486 | 269.88±215.2 | 0.912 | 0.479 |
| SD (cm) | 55.5-135 | 95.25±56.2 | 48-63 | 55.50±10.6 | 31.7-85.3 | 58.50±37.9 | 28-68.6 | 48.30±28.7 | 17-41.3 | 29.15±17.2 | 12.5-35 | 23.75±15.9 | 11.56 | 0.000* |

| Parameter | A1 | | A2 | | G1 | | G2 | | S1 | | S2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Range | Mean+SD | Range | Mean+SD | Range | Mean+SD | Range | Mean+SD | Range | Mean+SD | Range | Mean+SD | F | P |
| SZ (m) | 3.7-4.3 | 4.00±0.4 | 4.2-5.8 | 5.00±1.3 | 1.8-5 | 3.40±2.3 | 1.9-3.6 | 2.75±1.2 | 6.1-6.5 | 6.30±0.3 | 2.9-3.7 | 3.30±0.6 | 58.48 | 0.025* |
| CD (m) | 14.3-45 | 29.65±21.7 | 14.5-38.5 | 26.50±16.9 | 2.8-6.8 | 4.80±2.8 | 4.1-7 | 5.55±2.1 | 3.8-12.5 | 8.15±6.2 | 5-16.5 | 10.75±8.1 | 14.89 | 0.000* |

*Statistically significant values at p<0.05.

### 3.4.2. Fish assemblages

A total of 2719 fish specimens belonging to 43 species were sampled and the number of species across families and specimens across species were different. Based on frequency of individual occurrence (FOi) only five fish species (*Synodontis schall*=95.8%, *S. serratus*=83.3%, *Oreochromis niloticus*=83.3%, *Labeobarbus bynni*=79.2% and *Labeo forskalii*=75%) fell in the category of euconstant species occurrence range or their FOi was $\geq$75%. Many species lay in the constants range of occurrence (FOi=50.1-75%), while very few species were regarded as accidental taxa whose FOi was less than 15% (Table 7). The five most abundant species *S. schall* (n=283), *Raiamas senegalensis* (n=245), *S. serratus* (n=159) followed by *Coptodon zillii* (n=155) and *Clarias gariepinus* (n=152) accounted for approximately 36.6% of the overall numerical catch and about 40% of the total relative importance (IRI) (Table 7). Smaller individual counts were obtained for *Mormyrops anguilloides* and *Malapterurus electricus* (n=1, each), *M. minjiriya* and *Petrocephalus keatingii* (n=2, each), *Distichodus rostratus* (n=5), *D. brevipinnis*, *Hyperopisus bebe* (n=7, each) and *Mormyrus caschive* (n=9). Highest number of individuals (n=609) was counted for St3 throughout the whole sampling period, whereas lowest number of individuals (n=277) was collected at St6. Seasonal (dry and wet) variation in the number of individuals were significant in St2, St3 and St5 ($p<0.05$).

Based on numerical values (%N), about 79% of the overall itemized individuals were contributed by 16 species. These included *S. schall* (10.41%), *Raiamas senegalensis* (9.01%), *S. serratus* (5.85%), *C. zillii* (5.70), *C. gariepinus* (5.59%), *O. niloticus* (5.22%), *Brycinus nurse* (4.82%), *L. bynni* (4.82%), *L. forskalii* (4.82%), *Schilbe mystus* (4.38%), *Labeo niloticus* (3.94%), *Alestes baremoze* (3.46%), *Auchenoglanis occidentalis* (3.35%), *Labeobarbus crassibarbis* (2.65%), *Heterotis niloticus* (2.46%) and *Labeobarbus intermedius* (2.35%). The other 6 species (*Schilbe uranoscopus*, *Labeo cylindricus*, *L. horie*, *Hydrocynus forskahlii*, *Bagrus docmak* and *Mormyrus kannume*) collectively accounted 11.51% of the numerical composition of the present collection (Table 7). The remaining 21 species were regarded as relatively rare in the present catch and contributed only 9.64% of the total collection (Table 7).

Analysis of the index of relative importance (%IRI) showed that 12 species had 77.51% of the overall collection. These included *S. schall*, *C. gariepinus*, *S. serratus*, *L. bynni*, *L. forskalii*, *B. docmak*, *O. niloticus*, *Labeo niloticus*, *A. occidentalis*, *H. niloticus*, *C. zillii*, and *B. nurse* which contributed 12.77, 12.32, 8.42, 6.93, 6.15, 5.48, 4.71, 4.60, 4.49, 4.16, 4.03 and 3.45%, respectively. 5 species (*P. keatingii*, *H. bebe*, *M. cyprinoides*, *M. minjiriya* and *M. electricus*) with a small numerical contribution together accounted 0.20% of the total IRI (Table 7). The other remaining 26 species contributed an IRI of 22.29% altogether.

**Table 7**. Percentage by number (%N), weight (%W) and relative importance index (%IRI) of fishes collected from Ayima, Gelegu and Shinfa Rivers of the ALNP.

| Fish species | Component indices (%) | | | Compound index (%) |
|---|---|---|---|---|
| | N | W | FO | IRI |
| *Polypterus bichir* | 0.67 | 1.69 | 20.83 | 0.43 |
| *Heterotis niloticus* | 2.46 | 8.12 | 45.83 | 4.16 |
| *Hyperopisus bebe* | 0.26 | 0.18 | 16.67 | 0.06 |
| *Marcusenius cyprinoides* | 0.44 | 0.06 | 16.67 | 0.05 |
| *Mormyrus caschive* | 0.33 | 0.10 | 29.17 | 0.14 |
| *Mormyrus kannume* | 1.29 | 1.48 | 20.83 | 0.32 |
| *Mormyrops anguilloides* | 0.05 | 1.82 | 50.00 | 1.33 |
| *Petrocephalus keatingii* | 0.07 | 0.17 | 4.17 | 0.01 |
| *Alestes baremoze* | 3.46 | 1.44 | 66.67 | 2.86 |
| *Brycinus nurse* | 4.82 | 1.22 | 66.67 | 3.45 |
| *Brycinus macrolepidotus* | 0.69 | 0.57 | 29.17 | 0.32 |
| *Hydrocynus vittatus* | 0.96 | 2.03 | 41.67 | 1.07 |
| *Hydrocynus forskahlii* | 1.95 | 3.29 | 25.00 | 1.12 |
| *Citharinus latus* | 0.77 | 1.64 | 20.83 | 0.43 |
| *Distichodus brevipinnis* | 0.26 | 2.10 | 12.50 | 0.25 |
| *Distichodus engycephalus* | 0.85 | 1.88 | 20.83 | 0.49 |
| *Distichodus rostratus* | 0.18 | 0.67 | 16.67 | 0.12 |
| *Labeobarbus bynni* | 4.82 | 5.39 | 79.17 | 6.93 |
| *Labeobarbus intermedius* | 2.35 | 3.55 | 45.83 | 2.32 |
| *Labeobarbus degeni* | 0.48 | 0.52 | 29.17 | 0.25 |
| *Labeobarbus nedgia* | 0.48 | 0.46 | 25.00 | 0.20 |
| *Labeobarbus crassibarbis* | 2.65 | 1.57 | 70.83 | 2.56 |
| *Labeo cylindricus* | 2.02 | 0.65 | 37.50 | 0.86 |

| Fish species | Component indices (%) | | | Compound index (%) |
| --- | --- | --- | --- | --- |
| | N | W | FO | IRI |
| *Labeo forskalii* | 4.82 | 4.75 | 75.00 | 6.15 |
| *Labeo horie* | 2.02 | 1.23 | 50.00 | 1.39 |
| *Labeo niloticus* | 3.94 | 4.12 | 66.67 | 4.60 |
| *Raiamas senegalensis* | 9.01 | 0.36 | 25.00 | 2.01 |
| *Auchenoglanis occidentalis* | 3.35 | 4.50 | 66.67 | 4.49 |
| *Clarias gariepinus* | 5.59 | 14.74 | 70.83 | 12.32 |
| *Heterobranchus longifilis* | 0.85 | 3.19 | 37.5 | 1.21 |
| *Bagrus bajad* | 0.52 | 1.45 | 29.17 | 0.49 |
| *Bagrus docmak* | 1.91 | 7.12 | 70.83 | 5.48 |
| *Synodontis clarias* | 0.81 | 0.48 | 12.50 | 0.14 |
| *Synodontis schall* | 10.41 | 5.14 | 95.83 | 12.77 |
| *Synodontis serratus* | 5.85 | 5.95 | 83.33 | 8.42 |
| *Synodontis sorex* | 0.33 | 0.30 | 20.83 | 0.13 |
| *Malapterurus electricus* | 0.05 | 0.09 | 4.17 | 0.01 |
| *Malapterurus minjiriya* | 0.07 | 0.08 | 8.33 | 0.01 |
| *Schilbe mystus* | 4.38 | 0.51 | 12.50 | 0.52 |
| *Schilbe uranoscopus* | 2.32 | 0.52 | 45.83 | 1.11 |
| *Oreochromis niloticus* | 5.22 | 1.37 | 83.33 | 4.71 |
| *Coptodon zillii* | 5.70 | 2.36 | 58.33 | 4.03 |
| *Lates niloticus* | 0.55 | 1.17 | 20.83 | 0.31 |

#### 3.4.2.1. Ayima River

In Ayima River, 16 (45.71%) of the recorded fish species had the highest individual relative importance (2.05-14.69, %IRIi) comprising altogether 84.7% of the total IRI, and were relatively frequently occurring species in both sampling sites and occasions (37.5-100, %FOi) (Table 8; Figure 8). These included *R. senegalensis*, *L. bynni*, *S. schall*, *O. niloticus*, *B. docmak*, *C. gariepinus*, *C. zillii*, *B. nurse*, *H. vittatus*, *A. occidentalis*, *S. serratus*, *H. longifilis*, *Lates niloticus*, *L. intermedius*, *H. forskahlii* and *H. niloticus* in descending order of their relative importance. The first 5 species (14.29%) listed above made up over 51% of the total IRI.

**Table 8**. Percentage contribution of component and compound indices of fishes of the Ayima River.

| **Fish species** | **Component indices (%)** | | | **Compound index (%)** |
|---|---|---|---|---|
| | **N** | **W** | **FO** | **IRI** |
| *H. niloticus* | 0.59 | 4.73 | 50 | 2.05 |
| *H. bebe* | 0.09 | 0.07 | 12.5 | 0.02 |
| *M. cyprinoides* | 0.59 | 0.08 | 25 | 0.13 |
| *M. caschive* | 0.69 | 3.80 | 37.5 | 1.29 |
| *M. kannume* | 1.29 | 2.56 | 62.5 | 1.86 |
| *P. keatingii* | 0.49 | 0.09 | 37.5 | 0.17 |
| *A. baremoze* | 2.09 | 1.17 | 62.5 | 1.57 |
| *B. macrolepidotus* | 1.29 | 1.12 | 62.5 | 1.16 |
| *B. nurse* | 5.08 | 1.06 | 75 | 3.54 |
| *H. forskahlii* | 3.29 | 4.49 | 37.5 | 2.25 |
| *H. vittatus* | 1.89 | 3.59 | 75 | 3.17 |
| *C. latus* | 0.29 | 0.30 | 25 | 0.12 |
| *D. brevipinnis* | 0.69 | 6.01 | 37.5 | 1.94 |
| *D. rostratus* | 0.19 | 1.03 | 12.5 | 0.12 |
| *L. bynni* | 9.07 | 9.85 | 100 | 14.56 |

| Fish species | Component indices (%) | | | Compound index (%) |
|---|---|---|---|---|
| | N | W | FO | IRI |
| *L. crassibarbis* | 2.09 | 0.89 | 62.5 | 1.44 |
| *L. degeni* | 0.49 | 0.64 | 37.5 | 0.33 |
| *L. intermedius* | 2.29 | 5.58 | 37.5 | 2.27 |
| *L. nedgia* | 0.19 | 0.12 | 25 | 0.06 |
| *L. cylindricus* | 2.69 | 0.86 | 37.5 | 1.02 |
| *L. forskalii* | 3.19 | 0.78 | 50 | 1.53 |
| *L. horie* | 2.49 | 2.38 | 37.5 | 1.41 |
| *Labeo niloticus* | 2.09 | 3.26 | 37.5 | 1.55 |
| *R. senegalensis* | 24.43 | 1.02 | 75 | 14.69 |
| *A. occidentalis* | 1.49 | 3.79 | 75 | 3.05 |
| *C. gariepinus* | 1.39 | 7.27 | 75 | 5.00 |
| *H. longifilis* | 0.68 | 4.52 | 62.5 | 2.51 |
| *B. bajad* | 0.29 | 0.79 | 12.5 | 0.10 |
| *B. docmak* | 1.69 | 11.12 | 62.5 | 6.16 |
| *S. schall* | 7.48 | 5.19 | 87.5 | 8.54 |
| *S. serratus* | 2.19 | 2.95 | 75 | 2.97 |
| *M. minjiriya* | 0.09 | 0.05 | 12.5 | 0.01 |
| *O. niloticus* | 7.28 | 1.96 | 100 | 7.11 |
| *C. zillii* | 8.18 | 3.53 | 50 | 4.50 |
| *Lates niloticus* | 1.49 | 3.35 | 62.5 | 2.33 |

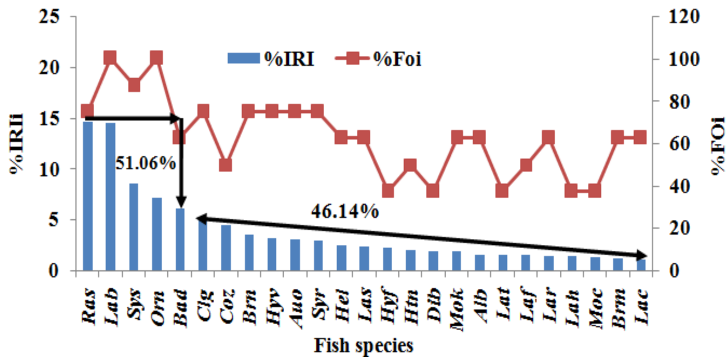


**Figure 8**. Illustrations showing indices of relative importance (%IRIi) versus frequency of occurrence (%FOi) for major contributing fish species with %IRIi>1.0 of the Ayima River.

**Species acronyms**: Ras (*R. senegalensis*), Lab (*L. bynni*), Sys (*S. schall*), Orn (*O. niloticus*), Bad (*B. docmak*), Clg (*C. gariepinus*), Coz (*C. zillii*), Brn (*B. nurse*), Hyv (*H. vittatus*), Auo (*A. occidentalis*), Syr (*S. serratus*), Hel (*H. longifilis*), Las (*Lates niloticus*), Hyf (*H. forskahlii*), Htn (*H. niloticus*), Dib (*D. brevipinnis*), Mok (*M. kannume*), Alb (*A. baremoze*), Lat (*Labeo niloticus*), Laf (*L. forskalii*), Lar (*L. crassibarbis*), Lah (*L. horie*), Moc (*M. caschive*), Brm (*B. macrolepidotus*) and Lac (*L. cylindricus*).

### 3.4.2.2. Gelegu River

In the Gelegu River, 12 species (31.58%) contributed the largest relative importance (2.14-23.76, %IRIi) and comprised of altogether 85.87% of the total IRI, and occurred in most sampling sites and occasions (62.5-100%) (Table 9; Figure 9). Species with the highest contribution in relative importance included *C. gariepinus* (100%, FOi), *S. schall* (100%, FOi), *H. niloticus* (87.5%, FOi), *L. forskalii* (100%, FOi), *S. serratus* (87.5%, FOi), *Labeo niloticus* (87.5%, FOi), *A. occidentalis* (62.5%, FOi), *S. mystus* (37.5%, FOi), *D. engycephalus* (62.5%, FOi), *S. uranoscopus* (75%, FOi), *L. crassibarbis* (87.5%, FOi) and *P. bichir* (62.5%, FOi) in descending order of their relative importance.

Five (13.16%) species (*C. gariepinus*, *S. schall*, *H. niloticus*, *L. forskalii*, and *S. serratus*) made up 64.24% of the overall IRI (Table 9; Figure 9).

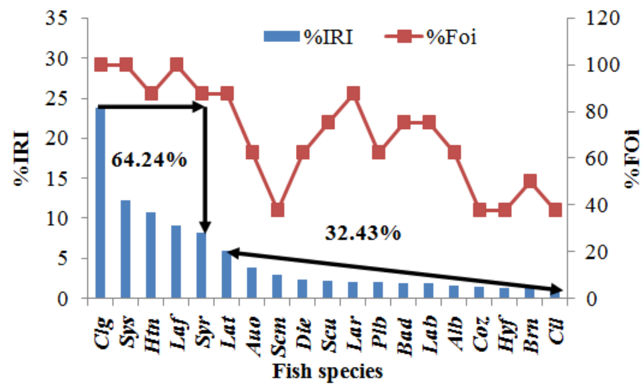


**Figure 9**. The percentage of IRIi vs. %Foi for fish species with significant contribution in the fish assemblages of the Gelegu River (Species acronyms are similar as used in figure 8 except for: Scm (S. *mystus*), Die (*D. engycephalus*), Scu (*S. uranoscopus*), Plb (*P. bichir*), Hyf (*H. forskahlii*) and Cil (*C. latus*)).

**Table 9**. Percentage by number, weight and IRI values of fishes of the Gelegu River.

| Fish species | Component indices (%) | | | Compound index (%) |
|---|---|---|---|---|
| | N | W | FO | IRI |
| *P. bichir* | 1.69 | 3.42 | 62.5 | 2.14 |
| *H. niloticus* | 5.43 | 13.04 | 87.5 | 10.63 |
| *H. bebe* | 0.09 | 0.06 | 12.5 | 0.01 |
| *M. cyprinoides* | 0.27 | 0.08 | 37.5 | 0.09 |
| *M. kannume* | 0.36 | 0.39 | 12.5 | 0.06 |
| *M. anguilloides* | 0.09 | 0.35 | 12.5 | 0.04 |
| *P. keatingii* | 0.18 | 0.05 | 12.5 | 0.02 |
| *A. baremoze* | 3.11 | 0.85 | 62.5 | 1.61 |
| *B. macrolepidotus* | 0.53 | 0.36 | 25 | 0.15 |
| *B. nurse* | 3.29 | 0.61 | 50 | 1.21 |

| Fish species | Component indices (%) | | | Compound index (%) |
|---|---|---|---|---|
| | N | W | FO | IRI |
| *H. forskahlii* | 1.78 | 3.49 | 37.5 | 1.32 |
| *H. vittatus* | 0.62 | 1.56 | 50 | 0.73 |
| *C. latus* | 1.60 | 3.09 | 37.5 | 1.18 |
| *D. engycephalus* | 2.05 | 3.79 | 62.5 | 2.44 |
| *D. rostratus* | 0.27 | 0.62 | 37.5 | 0.22 |
| *L. bynni* | 1.87 | 1.85 | 75 | 1.87 |
| *L. crassibarbis* | 2.05 | 1.63 | 87.5 | 2.16 |
| *L. degeni* | 0.36 | 0.25 | 25 | 0.10 |
| *L. intermedius* | 0.80 | 0.67 | 25 | 0.25 |
| *L. nedgia* | 0.62 | 0.63 | 37.5 | 0.31 |
| *L. cylindricus* | 0.98 | 0.33 | 37.5 | 0.33 |
| *L. forskalii* | 5.52 | 8.08 | 100 | 9.11 |
| *L. horie* | 0.53 | 0.37 | 37.5 | 0.23 |
| *Labeo niloticus* | 4.89 | 5.24 | 87.5 | 5.94 |
| *A. occidentalis* | 4.36 | 4.84 | 62.5 | 3.85 |
| *C. gariepinus* | 11.83 | 23.63 | 100 | 23.76 |
| *H. longifilis* | 0.18 | 0.76 | 25 | 0.16 |
| *B. docmak* | 1.33 | 2.62 | 75 | 1.79 |
| *S. clarias* | 1.96 | 0.97 | 37.5 | 0.73 |
| *S. schall* | 13.08 | 5.25 | 87.5 | 12.29 |
| *S. serratus* | 7.83 | 6.23 | 87.5 | 8.25 |
| *S. sorex* | 0.80 | 0.61 | 62.5 | 0.46 |
| *M. electricus* | 0.09 | 0.18 | 12.5 | 0.02 |
| *M. minjiriya* | 0.09 | 0.13 | 12.5 | 0.02 |
| *S. mystus* | 10.59 | 1.02 | 37.5 | 2.92 |

| Fish species | Component indices (%) | | | Compound index (%) |
|---|---|---|---|---|
| | N | W | FO | IRI |
| *S. uranoscopus* | 3.56 | 0.77 | 75 | 2.18 |
| *O. niloticus* | 1.07 | 0.61 | 62.5 | 0.43 |
| *C. zillii* | 4.27 | 1.58 | 37.5 | 1.47 |

### 3.4.2.3. Shinfa River

From the total of 25 identified species in the river, 17 (68%) species had the highest relative importance and accounted to 95.29% of the total IRI (Table 10; Figure 10).

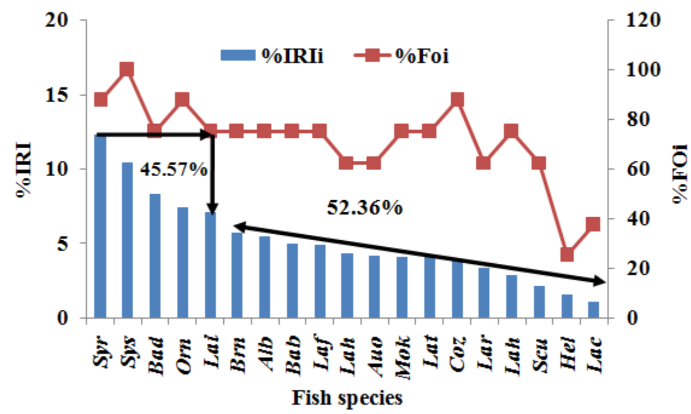


**Figure 10.** The percentage in IRIi vs. %Foi of fish species with significant contribution in the assemblages of the Shinfa River. **Species acronyms**: Bab; *B. bajad* and the rest are as used in Figures 8 & 9.

The species with highest %IRIi from this river included *S. serratus* (87.5%, FOi), *S. schall* (100%, FOi), *B. docmak* (75%, FOi), *O. niloticus* (87.5%, FOi), *L. intermedius* (75%, FOi), *B. nurse* (75%, FOi), *A. baremoze* (75%, FOi), *B. bajad* (75%, FOi), *L. forskalii* (75%, FOi), *L. bynni* (62.5%, FOi), *A. occidentalis* (62.5%, FOi), *M. kannume* (75%, FOi), *Labeo niloticus* (75%, FOi), *C. zillii* (87.5%, FOi), *L. crassibarbis* (62.5%, FOi), *L. horie* (75%, FOi) and *S. uranoscopus* (62.5%, FOi) in descending order of their relative importance (Table 10; Figure 10). Five (20%) species (*S. serratus*, *S. schall*, *B. docmak*, *O. niloticus* and *L. intermedius*) accounted to 45.57% of the total IRI from Shinfa River (Figure 10).

The Cyprinidae, Mormyridae, Auchenoglanididae and Schilbeidae were represented by 9, 4, 1 and 1 species, respectively in the Shinfa River, while the other identified families comprised 2 species each.

**Table 10**. Percentage Number and weight and %IRI values of fishes of the Shinfa River.

| Fish species | Component indices (%) | | | Compound index (%) |
|---|---|---|---|---|
| | N | W | FO | IRI |
| *H. bebe* | 0.85 | 0.78 | 25 | 0.28 |
| *M. cyprinoides* | 0.51 | 0.23 | 25 | 0.13 |
| *M. caschive* | 0.34 | 1.01 | 25 | 0.24 |
| *M. kannume* | 3.06 | 4.72 | 75 | 4.07 |
| *A. baremoze* | 6.45 | 3.94 | 75 | 5.43 |
| *B. nurse* | 7.30 | 3.56 | 75 | 5.68 |
| *L. bynni* | 3.23 | 6.68 | 62.5 | 4.31 |
| *L. crassibarbis* | 4.75 | 2.92 | 62.5 | 3.34 |
| *L. degeni* | 0.68 | 1.111 | 25 | 0.31 |
| *L. intermedius* | 5.43 | 8.19 | 75 | 7.12 |
| *L. nedgia* | 0.68 | 0.67 | 12.5 | 0.12 |
| *L. cylindricus* | 2.89 | 1.18 | 37.5 | 1.06 |
| *L. forskalii* | 6.28 | 2.99 | 75 | 4.85 |
| *L. horie* | 4.08 | 1.38 | 75 | 2.85 |
| *Labeo niloticus* | 5.26 | 2.47 | 75 | 4.04 |
| *A. occidentalis* | 4.58 | 5.03 | 62.5 | 4.19 |

| Fish species | Component indices (%) | | | Compound index (%) |
|---|---|---|---|---|
| | N | W | FO | IRI |
| *C. gariepinus* | 0.68 | 3.09 | 37.5 | 0.98 |
| *H. longifilis* | 1.19 | 7.94 | 25 | 1.59 |
| *B. bajad* | 1.87 | 7.59 | 75 | 4.94 |
| *B. docmak* | 3.39 | 12.52 | 75 | 8.32 |
| *S. schall* | 10.36 | 4.64 | 100 | 10.45 |
| *S. serattus* | 8.32 | 11.81 | 87.5 | 12.27 |
| *S. uranoscopus* | 3.91 | 0.87 | 62.5 | 2.08 |
| *O. niloticus* | 9.68 | 2.47 | 87.5 | 7.41 |
| *C. zillii* | 4.24 | 2.21 | 87.5 | 3.93 |

### 3.4.3. Fish community structure

Figure 11 depicts the dendrogram illustration of species abundance based on the average paired group algorithm method (UPGMA) as a function of Bray-Curtis similarity index to expound the similarity matrix. Agglomerative hierarchical cluster analysis (AHCA) of 43 fish species identified two distinct spatial clusters representing Shinfa and Ayima sampling sites on one hand and the Gelegu sites on the other. SIMPER produced an overall average Bray-Curtis dissimilarity of 60.83% between the three rivers' fish communities. About 17 (39.5%) fish species accounted for 51.17% dissimilarity between the three rivers' fish communities. These included *C. gariepinus, S. mystus, R. senegalensis, D. rostratus, L. bynni, H. niloticus, S. schall, A. occidentalis, L. forskalii, D. engycephalus, Labeo niloticus, S. uranoscopus, O. niloticus, A. baremoze, B. nurse, L. cylindricus* and *L. horie*. The vast remaining 26 (60.5%) fish species contributed to 48.83% dissimilarity between the rivers.

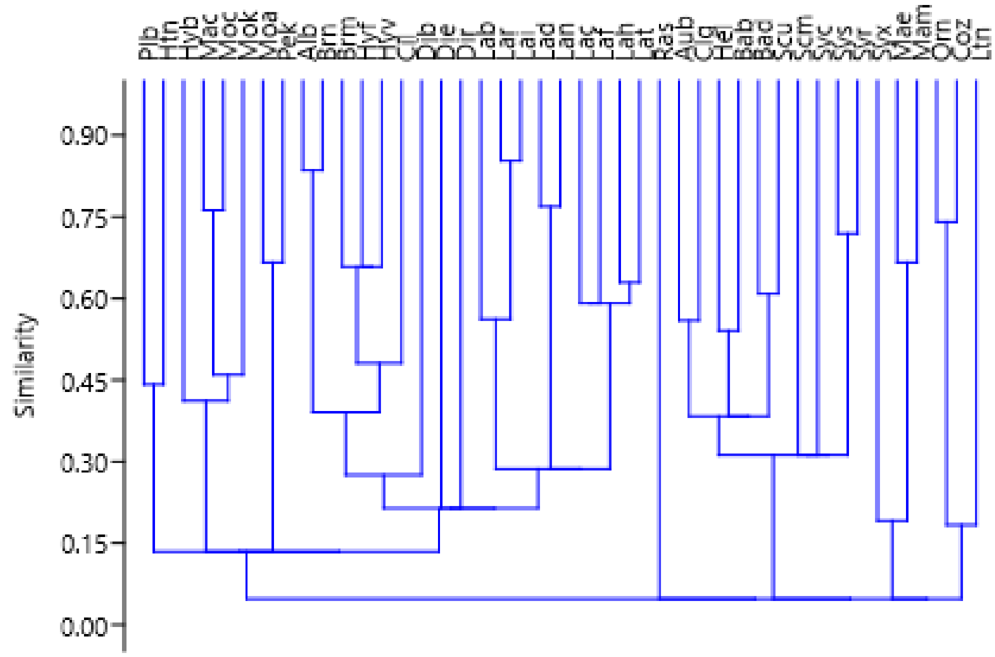


**Figure 11**. Unweighted paired group method with arithmetic means dendrogram of fish species of the three rivers (6 sites) from the ALNP. The clustering was based on spatial fish assemblage as a function of Bray-Curtis similarity of fish community abundance data showing resemblance of fish assemblage structure among the sampling sites (at Coph. corr.=0.8292).

**Species acronyms**: *Plb- Polypterus bichir; Htn- Heterotis niloticus; Hyb- Hyperopisus bebe; Mac- Marcusenius cyprinoides; Moc- Mormyrus caschive; Mok - Mormyrus kannume; Moa- Mormyrops anguilloides; Pek- Petrocephalus keatingii; Alb- Alestes baremoze; Brn- Brycinus nurse; Brm- Brycinus macrolepidotus; Hyf- Hydrocynus forskahlii; Hyv- Hydrocynus vittatus; Cil- Citharinus latus; Dib- Distichodus brevipinnis; Die- Distichodus engycephalus; Dir- Distichodus rostratus; Lab- Labeobarbus bynni; Lar- Labeobarbus crassibarbis; Lai- Labeobarbus intermedius; Lad- Labeobarbus degeni; Lan- Labeobarbus nedgia; Lat- Labeo niloticus; Lac- Labeo cylindricus; Laf- Labeo forskalii; Lah- Labeo horie; Ras- Raiamas senegalensis; Auo- Auchenoglanis occidentalis; Clg- Clarias gariepinus; Bab- Bagrus bajad; Bad- Bagrus docmak; Syc- Synodontis clarias; Sys- Synodontis schall; Syr- Synodontis serratus; Syx- Synodontis sorex; Mae- Malapterurus electricus; Mam- Malapterurus minjiriya; Scm- Schilbe mystus; Scu- Schilbe uranoscopus; Orn- Oreochromis niloticus; Coz- Coptodon zillii; Las- Lates niloticus.*

Between Ayima and Gelegu Rivers the overall average dissimilarity was calculated and found to be 60.01%, of which 62.19% of the dissimilarity was contributed by eight species (*R. senegalensis, S. mystus, C. gariepinus, S. schall, L. bynni, S. serattus, O. niloticus* and *H. niloticus*). Between Ayima and Shinfa Rivers, the overall average dissimilarity percentage was 48.09 and 51.24% of this dissimilarity was contributed by only four species (*R. senegalensis, L. bynni, C. zillii* and *H. forskahlii*). But, SIMPER produced 49.97% average dissimilarity between fish communities of the Gelegu and Shinfa Rivers and 51.22% of this dissimilarity was contributed by five fish species (*C. gariepinus, S. mystus, S. schall, H. niloticus* and *O. niloticus*).

**Table 11**. Summary of Detrended Correspondence Analysis (DCA) for fish community structure.

| **Axes** | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| Eigenvalues | 0.397 | 0.025 | 0.002 | 0.000 |
| Length of gradient | 1.958 | 0.592 | 0.553 | 0.000 |

Gradient lengths of all axes were shorter than 3 SD turnover units (Table 11), in DCA suggesting linear species response model and RDA should be used for ordination. Only dissolved oxygen (DO), total phosphorus (TP) and channel diameter (CD) over other environmental variables largely affected the ordination and species community structure in Redundancy analysis (RDA) based on the assessment of variance inflation factor (VIF<20). These environmental variables were retained as significant contributors to the RDA model while the vast remaining was redundant or did not increase the significance.

**Table 12**. Results of the RDA for the species-environmental data including eigenvalues, correlations and percentage of variance explained by the four canonical axes (CCA1, CCA2, CCA3 and CCA4); T. In. = total inertia; sp-env't = species-environment.

| Axes | | 1 | 2 | 3 | 4 | T. In. |
|---|---|---|---|---|---|---|
| Eigenvalues | | 0.690 | 0.240 | 0.038 | 0.022 | 1.000 |
| Species-environment correlations | | 0.989 | 0.978 | 0.993 | 0.000 | |
| Cumulative % variance of: | species data | 54.7 | 77.2 | 88.9 | 96.0 | |
| | sp-env't relation | 56.1 | 79.7 | 91.7 | 96.5 | |
| Sum of all eigenvalues | | | | | | 1.000 |
| Sum of all canonical eigenvalues | | | | | | 0.709 |

Figure 12 shows an RDA triplot of 43 fish species, 6 sampling sites and 14 environmental variables. Table 12 summarized output of the RDA analysis. The first two axes (Axis-1 & 2) represented 79.7% of the total variability in species composition with the four environmental variables accounting for 70.9% of the total variability in the structure of fish community. The results of the RDA showed that eigenvalues of the first axis (λCC1 = 69%) and second axis (λCC2 = 24%). CCA2 and CCA4 axes accounted for 79.7% and 96.5%, respectively of the cumulative variation in the environmental data (Table 12). The final model accounted for 77.2% of the total variance in fish composition and all canonical axes were significant (Monte Carlo test, $p = 0.002$).

The ordination space of factors Axis1 (CCA1) and Axis2 (CCA2) were characterized by many of the environmental variables and fish species composition or relative abundance. The first factor load (CCA1) was correlated negatively with most of the nutrients, temperature ($T^0$), EC, channel diameter and site depth. EC, pH and site depth were positively correlated, whereas DO was negatively correlated with CCA2 (Figure 12). Many species collected from St3 and laid in the negative wing of CCA 2 is characterized by DO.

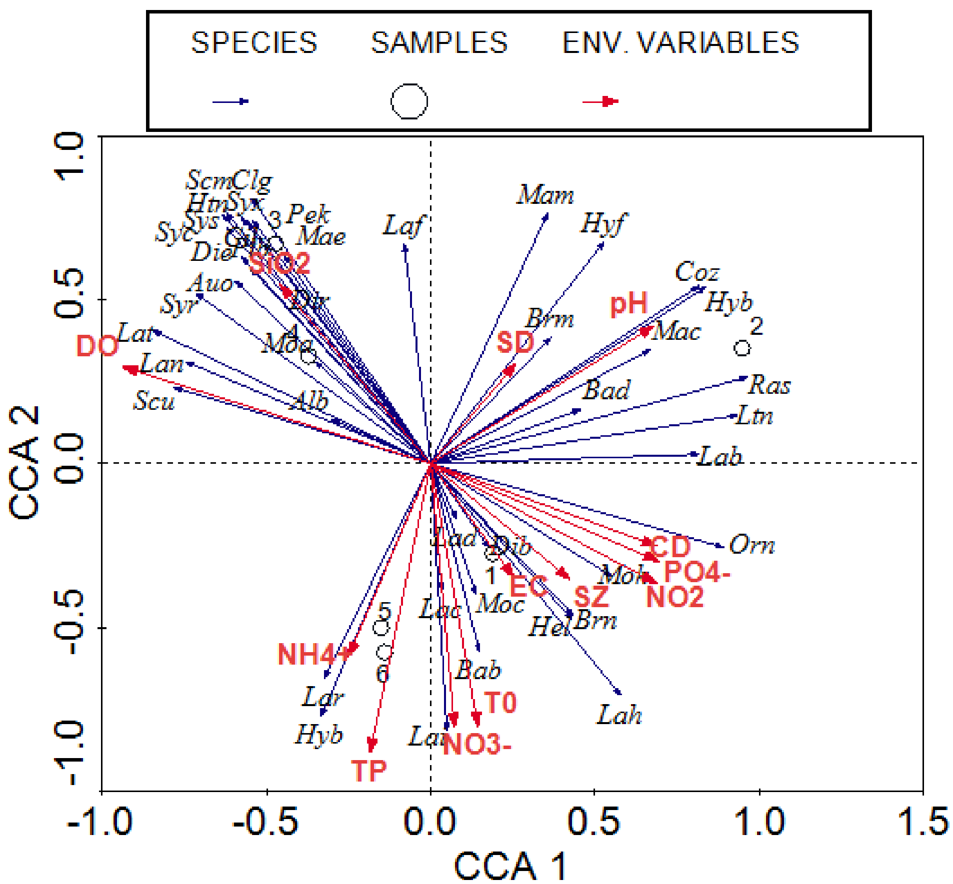


**Figure 12**. The species-environment-site RDA triplot of fish community for the Rivers Ayima (1-Ay1 & 2-Ay2), Gelegu (3-Ge1 & 4-Ge2) and Shinfa (5-S1 & 6-S2). The length of the arrow is proportional to the importance of that variable in the assemblage ordination. For fish species abbreviations see Figure 11.

**Table 13**. Summary of Monte Carlo permutation test (p=499) for the strength of variability in fish assemblages explained by each environmental variables in the constrained ordination listed after the automatic forward selection. The *p* values and F-statistics were obtained by Monte Carlo test (499 permutations).

| Environmental Variable | % variance | F-value | *p*-value | VIF |
|---|---|---|---|---|
| DO* | 38 | 4.701 | **0.002** | 14.26 |
| $NH_4^+$ | 12 | 0.801 | 0.558 | 0.00 |
| $SiO_2$ | 19.1 | 1.486 | 0.258 | 0.00 |
| $PO_4^{-2}$ | 4.2 | 0.440 | 0.774 | 0.00 |
| TP* | 16.1 | 2.962 | **0.012** | 0.000 |
| EC | 8 | 0.785 | 0.546 | 0.000 |
| SD | 12.5 | 0.859 | 0.374 | 0.000 |
| SZ* | 18.3 | 1.397 | **0.025** | 0.000 |
| CD* | 30.9 | 3.119 | **0.002** | 0.000 |

*environmental variable with significant effect on fish community structure, $p < 0.05$.

**3.5. Discussion**

The present study showed that variations in fish abundance and community structure were related to some environmental variables. Major environmental gradients related to the structuring of fish communities involved site depth, channel diameter, total phosphorus, and DO, whereas EC, Secchi depth, silicate, and ammonium ion played a minor role for fish community structuring in the floodplain rivers. Amount of DO was higher in both sampling sites of the Gelegu River (Table 6). This might be due to the constantly flowing nature of the river, while other sampling sites in Ayima and Shinfa are somehow stagnant during the dry month and unable to bind atmospheric oxygen. The higher EC value was recorded for St5 at Shinfa River as this site is largely used by the nearby residents as a waste discharging field. Shinfa River originates from the very highlands of Ethiopia and inundated by a large volume of floods during rainy months and carried soluble ions from surrounding farm lands that increase the water conductivity and attributed for the higher EC values of this site.

The pH values of the present study showed similarity in all sites of the examined rivers. Very similar pH values of different sites for Ayima and Shinfa was reported by Dereje Tewabe *et al*. (2010). High pH value at St2 might be due to port and extreme human interference in the river. Human activities as a trigger for high pH value in rivers are reported by Hossain *et al*. (2012) for sections of Meghna River in Bangladesh.

The greater seasonal variation between dry and wet months is attributed to the higher temperature range in the sampling sites of Shinfa River. The lower altitudinal range and higher atmospheric temperature also attribute to high water temperature in floodplain rivers (Hossain *et al*., 2012). Different and similar temperature ranges were obtained for Shinfa and Ayima Rivers, respectively by Dereje Tewabe *et al*. (2010) from different sections of both rivers. This difference in temperature ranges of the Shinfa River in the present and previous studies may be due to the increasing human impact operating on many segments of the river. The other possible reason for such difference might be associated with the frequent prone on physical and chemical characteristics of floodplain habitats due to global warming. However, water temperature variation showed less impact on species distribution as value of this parameter was more or less similar in all sampling stations ($P=0.108$), while significant difference was found for transparency and DO concentration.

Water transparency taken as a function of rainfall pattern was maximum during the dry month (April) and smaller in the wet month (October). The highest rainfall is July and August, whilst there is no rain from December to April and this may be the cause for the significant difference in water transparency. During rainy months of the year, large quantities of soluble organic matter enter into the main channel of the river and bring turbidity and hence reducing water clarity (Weilhoefer *et al*., 2008).

Considerable variations were observed in fish species composition and abundance in the sampling stations of the studied rivers. Highest number of fish individuals was collected at St3 and this may be due to relatively low human interference that brought optimum range of environmental conditions suitable for fishes. The smallest channel diameter and depth of this site appropriate for fish sampling might be the reason for catching many specimens. But, in both sampling sites of Shinfa River, lowest number of individuals was collected. This might be due to severe human interference and predation pressure posed by the high population of crocodiles in the river. Welcomme (1979) and Khalid *et al*. (2016) observed such variations in relative abundance of fish population of similar ecosystems. In terms of their relative abundance, a few species dominated the ichthyofaunal compositions of floodplain rivers in the ALNP.

The family Mochokidae represented by a single genus and 4 species was the most abundant. Species of this family form “species flock” in African inland water habitats (Le´veˆque *et al*., 2008) and some species of this genus are also common in the Ethiopian lakes and rivers. In the family, the genus *Synodontis* is endemic to the Sub-Saharan Africa and the Nile River (Wright and Page, 2008) and is the most abundant genus in fluvial habitats (Halim and Guma’a, 1989) and also forms a small radiation in lakes (Day *et al*., 2009). In the genus, *S. schall* which is a common food fish in the Nile (Luff and Bailey, 2000) was reportedly dominating the catch of many water bodies in Ethiopia (e.g., Vijverberg *et al*., 2012; Mulugeta Wakjira, 2016). Bony head plates and heavily serrated spines in *Synodontis* that serve as a locking function to deter gape-limited predators may attribute to the higher abundance of the species. Similarly in many rivers of the tropical Africa, for example in the Djiri River of Congo (Mikia *et al*., 2013) and Benue River in Nigeria (Akombo *et al*., 2016) found that *S. schall* was more abundant and available year round in local markets.

The African catfish *C. gariepinus* was also abundant in the present collection. This agrees with the study of Khalid *et al*. (2016) in which the catch of this species dominated the Dinder River in Sudan. This might be due to its well suited adaptation to oxygen poor habitats by possessing accessory breathing organs to utilize atmospheric oxygen (Van Neer, 2004). This species can tolerate high turbid water and low in dissolved oxygen, and is often the only last fish species found in remnant pools of drying rivers (Safriel and Bruton, 1984; Van Neer, 2004). The availability of different prey types and optimum foraging behavior (i.e., opportunistic feeding) of *C. gariepinus* in floodplain rivers might have also attributed for the high relative abundance. According to Bruton *et al*. (1984) fishes in larger and relatively stable water bodies showed feeding specialization, whereas those in the floodplain ecosystems are opportunistic feeders. *C. gariepinus* is a generalist feeder that can consume any prey (e.g., Demeke Admassu *et al*., 2015; Elias Dadebo *et al*., 2014; present study) and therefore food, will not be a limiting factor for the distribution and abundance of this species in the floodplain rivers of the ALNP. The relative abundance of *C. gariepinus* was higher during the dry season in the present study. In accordance with the present finding, Welcomme (1979) found that the feeding behavior of piscivorous fish is seasonal in river floodplains and their relative abundance increases during the dry season. The absence of competitive and top predators such as *Lates niloticus* in the Gelegu River might be also another possible reason for the higher abundance of *C. gariepinus*.

A small risk predation effect on *B. docmak* led the species to have a considerable abundance in the present catch. In contrast to the present study, the relative abundance of *B. docmak* in the Geba and Sor Rivers of the White Nile system (Ethiopia) were insignificant (Simagegnew Melaku *et al*., 2017). *L. bynni* and *H. niloticus* are swamp fishes and they frequently appeared in floodplain rivers during the present catch. These two species are opportunistic feeders (Beetz, 2004; present study) but preferably consume aquatic plants and detritus. These food types are frequently infested in floodplain rivers and provide suitable conditions for them to feed and breed (Welcomme, 1985). On the other hand, cyprinids belonging to the "floodplain dwellers" (Van Neer, 2004) have the haemoglobin for highest affinity for dissolved oxygen in oxygen poor river floodplains (Fish, 1956). Therefore, such intricate physiology for binding oxygen in water favored them to adapt to the constantly changing floodplain habitats. *H. niloticus*, which is the primitive Osteoglomorpha, can adapt oxygen poor environments by making nests down to sediments (Odo *et al*., 2009; Adite *et al*., 2006). In peculiarity, *H. niloticus* possesses externally projecting gill filaments with a respiration and a food absorption function (Hermens *et al*., 2007). Because of these features and behavioral responses, the species had a considerable abundance in the present catch. The other probable reason for higher abundance of *H. niloticus* might be due to its detritivore feeding habit which is always the available food in river floodplains (Present study).

Individuals of the Cichlidae and Mormyridae were less frequently observed in the catches of the present study and relatively less important in abundance. This may be due to the frequent predation posed by *C. gariepinus*, *Hydrocynus spp.* and *Bagrus spp*. in the rivers. Similar to the results of the present findings, in the work of Tesfaye Melak and Abebe Getahun (2012) and Simagegnew Melaku *et al*. (2017), the relative importance of *O. niloticus* was insignificant in floodplain rivers of the White Nile Basin (Ethiopia). However, in contrast to the present study, *O. niloticus* was more abundant in Koka Reservoir (Ethiopia) (Kassahun Asaminew, 2005), Lake Langeno (Ethiopia) (Mathewos Temesgen, 2017) and in the Dinder River (Sudan) Khalid *et al*. (2016). In fact, the gut content analysis of piscivorous species (*C. gariepinus*, *B. docmak* and *H. forskhalii*) in the present study confirmed more *B. nurse*, cichlids and *Synodontis spp*. as important fish prey than mormyrids (see chapter 4). However, Merron (1993) found that *C. gariepinus* practice pack-hunting on mormyrids when the floods cease in rivers and this led to the smaller relative abundance of mormyrids. This might be important when preferred prey items go down to a critical level and certain fish species alter their diets which enables them to minimize intraspecific competition (Zahorcsak *et al*, 2000; Rossi, 2001).

The occurrence and relative abundance of members of the Alestidae family, among the largest groups of the Nile fishes, was small in the present catch. This is supported by the study of Khalid *et al*. (2016) who reported small numbers of individual catches from representatives of this family in the Dinder River. Even though, variability of floodplain habitats provides a wide range of possible food organisms and substrates from allochthonous and autochthonous sources (Welcomme, 1979), however many fishes have been suffering for searching prey (Tiogué *et al*., 2014). Similar cases can be taken as a limiting factor for the distribution and abundance of the fast swimming carnivorous fishes of the Alestidae in the floodplain rivers of the ALNP. Their confinement to pool water sections may not support species of this family with sufficient food supplies and they migrate to riffle habitats to feed on other small fishes and insects (Khalid *et al*., 2016). Thus, sampling of such fishes in running waters usually needs special fishing equipments and our fishing gear might not be effective to sample these active swimmers in riffle habitats and thus small in numerical abundance. The relative abundance of *A. occidentalis* was considerable. A strong pectoral spine defends from any incidence of predation and attributed for the higher abundance of this species in the present catch. Members of the families Malapteruridae, Polypteridae, Citharinidae, Latidae, Distichodontidae, Cyprinidae (except *L. bynni* and *R. senegalensis*) and Schilbeidae (except *S. mystus*) were present relatively in small numbers and their numerical contribution in the present catch can be taken as insignificant. In contrast to the floodplain dwellers, "open water species" usually do not adapt floodplain habitats and only small specimens of these species can be captured from such water bodies (Van Neer, 2004).

The difference in individual fish numbers between rivers of the same basin in the present study may be attributed to the size of the river and its tributaries. Variability in water level also contributed for the differences in species abundance in river floodplains. Because of seasonal changes following rainy and dry season sequence, the group of rivers in the ALNP is characterized by a seasonal hydrology, in which water levels rise but fall gradually just after the rains. At the landscape scale, these events in floodplain rivers drive numerous critical ecological processes (Simasiku and Mafwila, 2017).

Fish stock biomass in temporary rivers is dynamic showing irregular variations induced by fishing, natural mortality and habitat modifications during the extended dry season. Therefore, it is not unusual to obtain varied abundance estimates for species in floodplain habitats depending on the stage of the flood cycle during which the samples are collected. The present survey was based on a seasonal sampling where dry season sampling revealed large species abundance over wet season sampling. This may be because when water level is reduced during the dry season, maximum number of individuals can be collected using any fishing gear since possible refuges that safeguard fishes can dry out. Environmental cues that trigger seasonal fish reproduction might have also attributed for the higher abundance of fishes during the dry months. According to the exclusive conclusion made by Welcomme (1979), abundance of fishes in floodplain rivers commonly varied seasonally but increases during the dry season.

### 3.6. Conclusion

In the present collection, *C. gariepinus* and some species of *Synodontis* were more abundant. However, the commonly dominant individuals of the cyprinids and cichlids in many Ethiopian water bodies were few in the studied rivers. Cluster analysis suggested possible differences between the BNB (Ayima and Gelegu Rivers) and the TAB (Shinfa River) fish communities, with 17 dominant species causing most of the variations among rivers. In SIMPER, it was also found that the Gelegu River fish community was largely composed of the most dominant species in terms of their relative abundance, followed by the Ayima, while the Shinfa River community was composed of relatively few important species. The main factors that explained most and statistically significant variance between the fish communities in the rivers were dissolved oxygen, river channel length, site depth, water transparency and nutrient levels of the sampling sites.

# CHAPTER FOUR

## 4. Length-weight relationship, fish condition factor and feeding habits of some major commercially important fishes of the Alitash National Park

### 4.1. Introduction

Length and weight are two basic parameters widely used in the study of fish biology. In fisheries science, the role of Length Weight Relationship (LWR) is an integral component to which size is more biologically relevant since ecological and physiological factors largely depend on size (Moata *et al*., 2005). Moreover, LWR in fish allow comparison of life history that undergoes morphological changes (Torres *et al*., 2012). Fishes grow in life and weight of fish increases as a function of length (Hadi *et al*., 2011). In any sampling occasion, length measurements can be taken easily at field, while weight cannot be measured accurately. Therefore, the LWR in fish allows the inter-conversion of these two parameters (Borges *et al*., 2003).

The concept of LWR is further employed in the estimation of fish condition factor (CF) and providing information on growth type (Freitas *et al*., 2017). Alternatively, CF serves as an indicator of fish general well-being based on the assumption that a heavier fish of a given length is in a better condition (Kumolu-Johnson and Ndimele, 2010). The analysis of fish CF measured in numerical terms has become a standard practice in fisheries management and estimated by comparing fish of a given length to its standard weight (Borges *et al*., 2003). CF index that reflects interactions between biotic and abiotic factors in fish physiology could be obtained from the relationship: $\mathbf{CF = \frac{TW}{(TL)b} x100}$ (Pauly, 1984).

Fish like other animals have a requirement for essential nutrients to promote proper physiology and growth. In the natural environment, food is available for the fish to forage and meet their body needs. Therefore, examining fish feeding habit in natural waters are among the important aspects of fish biology (Zerihun Desta, 2007). The study of food and feeding habits of freshwater fish species is becoming a subject of continuous investigation (e.g., Demeke Admassu and Elias Dadebo, 1997; Zenebe Tadesse, 1999; Liao *et al*., 2001; Elias Dadebo *et al*., 2015). This is because feeding habit studies help to design a successful management option for fish production (Shalloof and Khalifa, 2009).

In feeding relation, to maintain the balance of the aquatic ecosystem, fish utilize food and the adaptation for these requires the development of some morphological traits (Adite *et al*, 2013). Body size is one of the most important characteristic that affect food acquisition in organisms (Adite *et al*, 2013; Lucifora *et al*., 2009) and fish exhibit tremendous morphological changes for feeding (Adeyemi, 2009; Solomon *et al*., 2017). The development of gill rakers for filter feeders and increasing in gape size for piscivores are among the prominent changes in fishes (Scharf *et al*., 2000; Hermens *et al*., 2007). Bite force or ambush tactics (Huber and Motta, 2004) and suction force for predators (Carroll *et al*., 2004) are also feeding adaptations and abilities along with fish morphological changes.

The morphological changes and associated feeding adaptations encountered by fish often result in the onset of ontogenetic dietary shift (Adite *et al*., 2006; Hermens *et al*., 2007; Mosepele *et al*., 2009). Within fish species, small and large individuals often coexist and forage in the same environment thus potentially competing for common trophic resources. However, small individuals are competitively disadvantaged due to their absolute smaller size (Herrel and Gibb, 2006) and forced to follow another feeding track and forming ontogenetic dietary shift to reduce intraspecific competition (Schmitt *et al*., 2015; Blasina *et al*., 2017). Following an ontogenic dietary shift in fish, generally juveniles consume zooplankton or aquatic insects and switch over to fishes or other large animals and plants. Besides morphological changes, fish diet compositions also vary within a wide range of temporal and spatial scales.

The general objective of the present study is to provide information on the LWRs and condition factor of some selected commercially important fishes and to assess feeding habit, feeding strategy, seasonal and ontogenetic dietary variation among fishes of floodplain rivers in the ALNP for proper management of the riverine fisheries. The following specific objectives are designed to achieve results in this particular study:

The specific objectives are to:

- determine the LWRs and the respective body conditions of the different fish species in the rivers.
- identify prey organisms and examine dietary importance of prey items of some selected fish species of the ALNP.
- determine the feeding strategies, seasonal and ontogenetic dietary shifts of the major commercially important fish species of the rivers.

## 4.2. Materials and methods

### 4.2.1. Fish measurements

Length measurements (TL, FL, and SL) of each individual fish were taken using a digital caliper (Mitutoyo) at a precision level of 0.02 mm and using a measuring board to the nearest 0.1 cm. Body weight was measured to the nearest 0.1 g using a digital weighing balance (WEI-Ib 413C, Shanghai). Sex of each individual fish was identified and recorded for all species. Samples were later grouped as dry and wet season sample for seasonal diet analysis. For ontogenetic diet variation analysis, fish lengths were categorized into different size classes.

### 4.2.2. Estimation of fish LWR and CF

The LWRs of each individual fishes were examined based on the method of Bagenal and Tesch (1978):

$$\mathbf{TW = aTL^{b}}$$

Where, TW= total weight in grams; TL= total length in centimeters. The prefix <a> is the intercept and the exponent <b> is the regression coefficient (Le Cren, 1951). Values of the exponent <b> provide information on fish growth, when b= 3, increase in weight is isometric and if the value of b deviates from 3, weight increase is allometric (Bagenal and Tesch, 1978).

The average fish condition factor (CF) was estimated for both sexes to assess body condition of individual fishes (Bagenal and Tesch, 1978). CF was computed using the formula: $\mathbf{CF = \left({}^{TW}/_{TL}\,b\right)x100}$ (Pauly, 1984)

Where, CF= condition factor; TW= total weight (g) and TL= total length (cm).

### 4.2.3. Fish gut sampling

Five fish species representing five families with commercial scale of fishery importance and represented by relatively sufficient gut samples were used for diet analysis. These included *Bagrus docmak* (n=21, Ayima River) from the Bagridae family. *Clarias gariepinus* (n=74, Gelegu River), *Heterotis niloticus* (n=35, Gelegu River) and *Hydrocynus forskahlii* (n=39, Ayima and Gelegu Rivers) from the Clariidae, Arapaimidae and Alestidae families, respectively. The family Cyprinidae is represented by *Labeobarbus bynni* (n=83, Ayima and Gelegu Rivers). The numbers exclude stomachs that had no food. All selected species were not the subject of fish diet analysis at Shinfa River due to small sample size collected from the river. The separated intact stomachs were preserved in 5% formalin solution for analysis.

### 4.2.4. Gut content analysis

Preserved stomach contents were emptied into a petridish and prepared on a slide for microscopic examination and examined under a dissecting LEICA S8 APO and a compound LEICA DME microscope. The observed food types were identified to the lowest possible taxonomic level using keys (Needham and Needham, 1962; Vuuren *et al*., 2006). After categorizing the identified food items into respective groups, the water displaced by a group of items in each category was measured in a partially filled graduated cylinder to estimate the volumetric contribution of prey items as recommended by Hyslop (1980). Then percentage composition by volume (%V) and frequency of occurrence (%FO) were used to evaluate and quantify dietary items. %V is the proportion of the volume of a particular prey to the total volume of overall stomach contents (Persson and Hansson, 1999). %FO provides information on the proportion of fish stomachs containing a particular prey item despite amount (Hyslop, 1980). In this study, volume (ml) and frequency of occurrence were used to compute index of food preponderance (IFP) and geometric importance of index (GIIi) for each fish species. In GIIi, %V and %FO as Relative Measures of Prey Quantity (RMPQ) for each fish species were generated to estimate dietary importance indices of each prey.

Fishes feeding strategy (generalist vs specialist) based on the Costello's illustration (Figure 13) later modified by Amundsen *et al*. (1996) was used to assess the level of predator preference to a certain prey item and to estimate niche width.

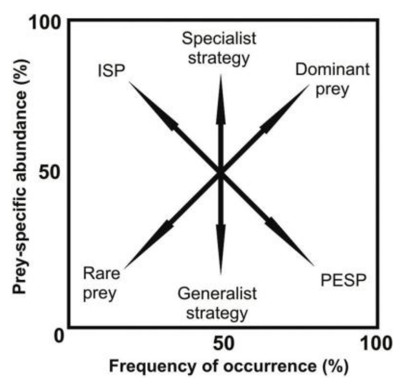


**Figure 13**. Explanatory diagram for interpreting of feeding strategy, niche width contribution and importance of prey items. ISP: individual specialization of predators; PESP: individuals in the population eating several prey items (modified from Amundsen *et al*., 1996)

Dietary overlap between fishes of different species was calculated using Schoener Diet Overlap Index (SDOI) (Schoener, 1974; Wallace, 1981):

$$\alpha = 1 - 0.5\left(\sum_{i=1}^{n} |pxi - pyi|\right)$$

Where, α is percentage overlap, SDOI, between predator species x and y, pxi and pyi are proportions of food category (type) *i* found in the stomachs of predator x and y, and n is the total number of food categories. The values that α can take for any pair of species examined can range from 0, for species that use different food resources, to 1, when the food resources are used in the same proportion. Overlap index values higher than 0.6 indicate biologically significant diet overlap (Wallace, 1981).

### 4.3. Seasonal variation and ontogenetic diet shift

Identified food items were calculated and comparisons between the dry and wet months were made by employing different indices. Food items that occurred frequently and accounted for the largest prey volume were regarded as the dominant food item for that month and vice versa. For ontogenetic dietary variation, length data and respective identified food items were recorded in Excel. The food items with larger volume in the diet of each fish for a given length category were dominant food types for that size class and vice versa.

### 4.4. Data analysis

The relationship between length and weight of fishes were computed by linear regression method. One-way analysis of variance (ANOVA) was used to check the statistical variation of the regression analysis among the different length groups. To test the significant difference between the ideal b values (3.0) Student's t was em0loyed. To test for possible significant differences between sexes ($P<0.05$), Tukey test was computed for comparison of the slopes and CF.

Descriptive statistics was employed to ascertain the percentage in volume and frequency of each prey item. The species level dietary variations were assessed using Geometric Index of Importance (GIIi) (Assis, 1996). GIIi for a particular prey category '*i*' was computed as: $\mathbf{GIIi} = (\sum \mathbf{RMPQi})/(\sqrt{\mathbf{n}})$; Where, RMPQ*i*= percentage of volume and frequency of occurrence (as a percentage of total occurrences) and n= total number of RMPQ parameters used to generate GIIi. GIIi index treats each dietary metric equally and some prey items were better represented by %N (e.g., smaller but countable prey) whereas others were better represented by %V (e.g., fish and other larger prey). Index of food preponderance in percent (%IFP) which incorporates %V and %FOi was also used to evaluate prey importance.

$$\mathbf{IFP} = \frac{\mathbf{Vi*FOi}}{\Sigma(\mathbf{Vi*FOi})} \boldsymbol{x100}$$ (Natarajan and Jhingran, 1961)

Where, Vi and FOi are percentage volume and frequency of occurrence of a particular diet in the total food items, respectively.

Ontogenetic and seasonal dietary variations were assessed using ANOVA with a significant level of, $p<0.05$. When ANOVA returned significant variations, Mann-Whitney U test was performed to identify specific prey categories that caused significant ontogenetic or seasonal variations in fish diet or prey importance along the season and size.

Diet specialization by the different fishes was calculated based on Levin's standardized diet breadth index according to Rosas-alayola *et al.* (2002) as follows.

$$\boldsymbol{Bn} = \frac{\mathbf{1}}{(\mathbf{n}-\mathbf{1})} + [\frac{\mathbf{1}}{(\Sigma \mathbf{jPij2})}] - \mathbf{1}$$

Where, *Bn* = Levin's standardized index of niche amplitude,

Pij = proportion of diet of predator i on prey j, and *n* = total number of food items (resources). *Bn* values vary from 0 (species consume a single item) to 1 (species exploits available items in equal proportion). Values of *Bn* are considered high or a generalist feeder when higher than 0.6, moderate or selective for some prey items when between 0.4 and 0.6 and low when below 0.4 (Novakowski *et al*., 2008). All statistical analyses were carried out in PAST version 3.20 (Hammer *et al.*, 2001), SPSS soft ware package version 20.0 and Microsoft Office Excel 2007.

## 4.5. Results

### 4.5.1. LWRs of fishes in the ALNP

A total number of 449 fish individuals were examined to provide estimates of LWRs and CF values. The results obtained in the estimation of LWRs along with several descriptive statistics are summarized in table 14. *C. gariepinus* (n=156) had a total length ranging from 29.7 to 82.3 cm and weight from 140 to 4200 g sampled from Gelegu River. The mean total length (TL) and mean total weight (TW) of *H. niloticus* collected from the Gelegu River were 48.98±5.96 cm and 1113.71±463.49 g, respectively. The LWR was separately evaluated for all individuals of species and grouped by sex (Table 14).

Figures 14 to 16 show the LWRs of the different fish species. For *C. gariepinus*, the growth coefficient (b) when both sexes are combined was 3.139 and 3.464 from Gelegu and Ayima Rivers, respectively which is higher than 3. The 'b' value differed significantly ($p < 0.05$) from 3, indicating positive allometric growth of *C. gariepinus* in both rivers. The 'b' value obtained for combined sexes of *B. docmak* in Ayima River (b=3.330), *H. forskahlii* for Gelegu and Ayima (b=3.753 and b=2.666, respectively), *L. bynni* from Ayima River (b=2.845), and *H. niloticus* from Gelegu River (b=2.826) all showed allometric growth. *L. bynni*, sampled from the Gelegu River attained an isometric growth (b=2.936) (Table 14; Figure 14). Only *H. forskahlii* showed significant difference in 'b' values between the sexes ($p<0.05$) and hence separate equations are provided for each sex (Figure 16).

**Table 14**. Descriptive statistics and LWR parameters for fish species of the Ayima and Gelegu Rivers (numbers in parenthesis are sample size): TW= weight (g); TL= length (cm); Av. =Average; S.D.= standard deviation; $r^2$=coefficient of determination or regression value; a= intercept, b = slope of the regression line; $A^-$ and $A^+$ = negative and positive allometry, respectively and IS= isometric.

| **Gelegu River** | **Sex** | **TL (cm)** | | **TW (g)** | | **TW= aTL$^b$** | | | **Growth type** |
|---|---|---|---|---|---|---|---|---|---|
| | | **Av. ±SD** | **range** | **Av. ±SD** | **range** | **A** | **b** | **r$^2$** | |
| *C. gariepinus* | Male (74) | 48.20±10.63 | 30.8-82.1 | 864.95±766.07 | 200-4000 | 0.003 | 3.134 | 0.947 | |
| | Female (82) | 48.91±11.11 | 29.7-82.3 | 913.40±779.94 | 140-4200 | 0.003 | 3.143 | 0.943 | A+ |
| | Pooled (156) | 48.57±10.86 | 29.7-82.3 | 890.42±771.28 | 140-4200 | 0.003 | 3.139 | 0.945 | |
| *H. niloticus* | Male (33) | 48.69±5.49 | 40.7-61.2 | 1028.48±362.21 | 650-1920 | 0.025 | 2.735 | 0.934 | |
| | Female (29) | 49.31±6.52 | 42.30-75.6 | 1149.24±561.79 | 550-3680 | 0.012 | 2.915 | 0.940 | IS |
| | Pooled (62) | 48.98±5.96 | 40.7-75.6 | 1113.71±463.49 | 550-3680 | 0.017 | 2.826 | 0.936 | |
| *L. bynni* | Pooled (22) | 32.33±7.73 | 17.8-47.2 | 425.91±256.63 | 60-1150 | 0.013 | 2.936 | 0.990 | IS |
| *B. docmak* | Male (17) | 59.62±13.24 | 32-77.4 | 1676.77±984.82 | 165-3400 | 0.001 | 3.365 | 0.978 | |
| | Female (15) | 57.53±16.51 | 32-87.2 | 1695±1565.09 | 165-5100 | 0.001 | 3.306 | 0.963 | A+ |
| | Pooled (32) | 58.64±14.65 | 32-87.2 | 1685.31±1267.64 | 165-5100 | 0.001 | 3.330 | 0.970 | |
| *H. forskahlii* | Pooled (27) | 44.30±7.71 | 27.6-67 | 964.74±712.32 | 120-3750 | 0.000 | 3.753 | 0.976 | A+ |
| **Ayima River** | | | | | | | | | |
| *H. forskahlii* | Male (19) | 30.76±13.79 | 17-75.2 | 370.89±549.24 | 85-2400 | 0.014 | 2.513 | 0.913 | |

| Gelegu River | Sex | TL (cm) | | TW (g) | | TW= aTL$^b$ | | | Growth type |
|---|---|---|---|---|---|---|---|---|---|
| | | Av. ±SD | range | Av. ±SD | range | A | b | $r^2$ | |
| | Female (25) | 38.88±17.66 | 15.8-73.4 | 684.80±762.67 | 70-2500 | 0.047 | 2.808 | 0.957 | A- |
| | Pooled (44) | 35.38±16.44 | 15.8-75.2 | 559.59±720.35 | 70-2850 | 0.026 | 2.666 | 0.940 | |
| *C. gariepinus* | Pooled (15) | 61.15±7.98 | 45.1-77.3 | 1813.40±780.09 | 530-3700 | 0.001 | 3.464 | 0.979 | A+ |
| *L. bynni* | Male (42) | 28.70±11.13 | 6.7-51.5 | 346.52±352.84 | 10-1250 | 0.020 | 2.785 | 0.973 | |
| | Female (49) | 30.17±9.38 | 11.8-56.5 | 373.16±333.95 | 25-1750 | 0.013 | 2.918 | 0.980 | IS |
| | Pooled (91) | 29.49±10.19 | 6.7-56.5 | 360.87±341.14 | 10-1750 | 0.017 | 2.845 | 0.975 | |
| *B. docmak* | Male (17) | 59.62±13.24 | 32-77.4 | 1676.77±984.82 | 165-340 | 0.001 | 3.365 | 0.978 | |
| | Female (15) | 57.53±16.50 | 32-87.2 | 1695±1565.09 | 165-5100 | 0.001 | 3.306 | 0.963 | A+ |
| | Pooled (32) | 58.64±14.65 | 32-87.2 | 1685.31±1267.64 | 165-5100 | 0.001 | 3.330 | 0.970 | |

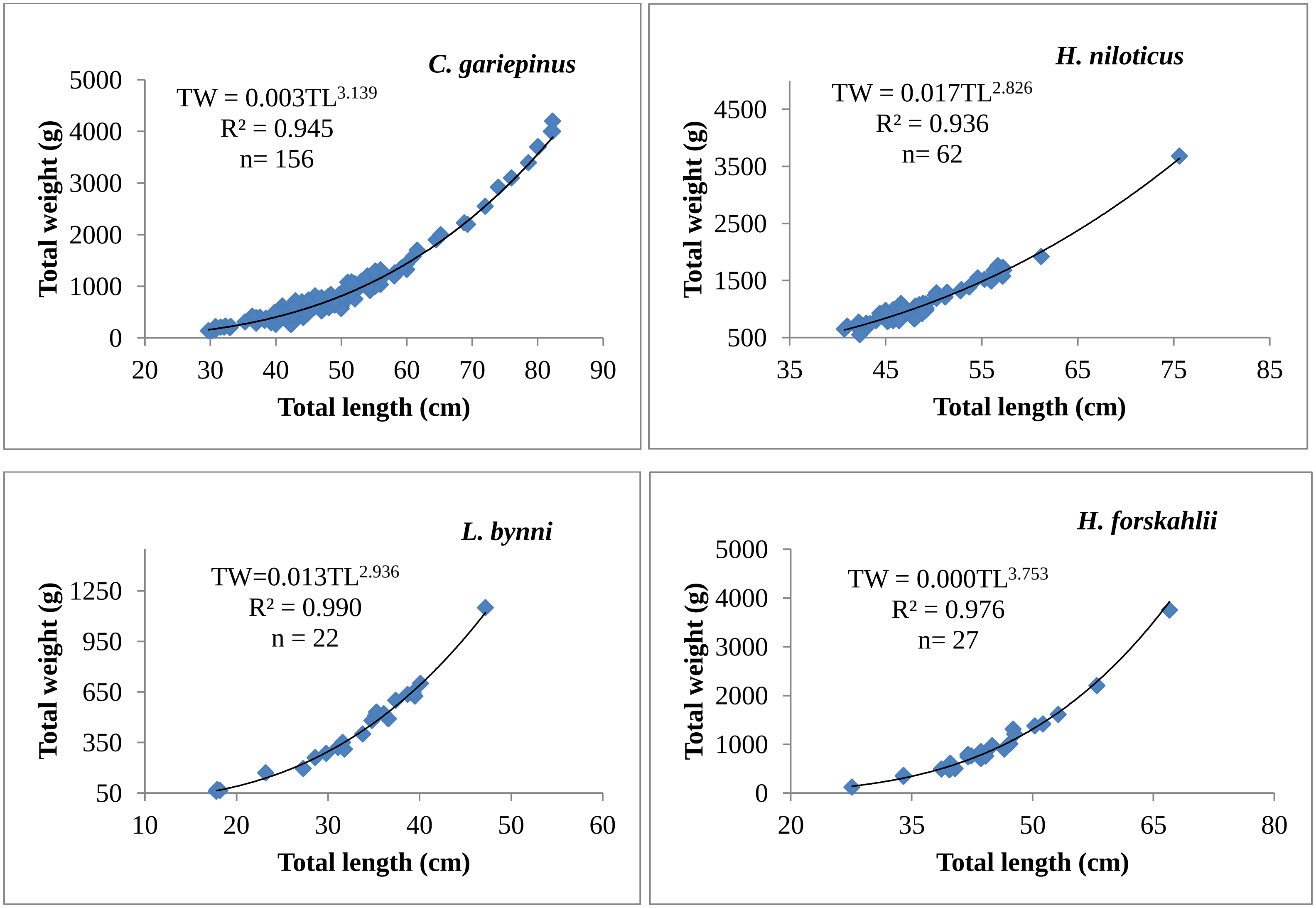


**Figure 14**. LWRs of fishes (sexes combined) sampled from the Gelegu River.

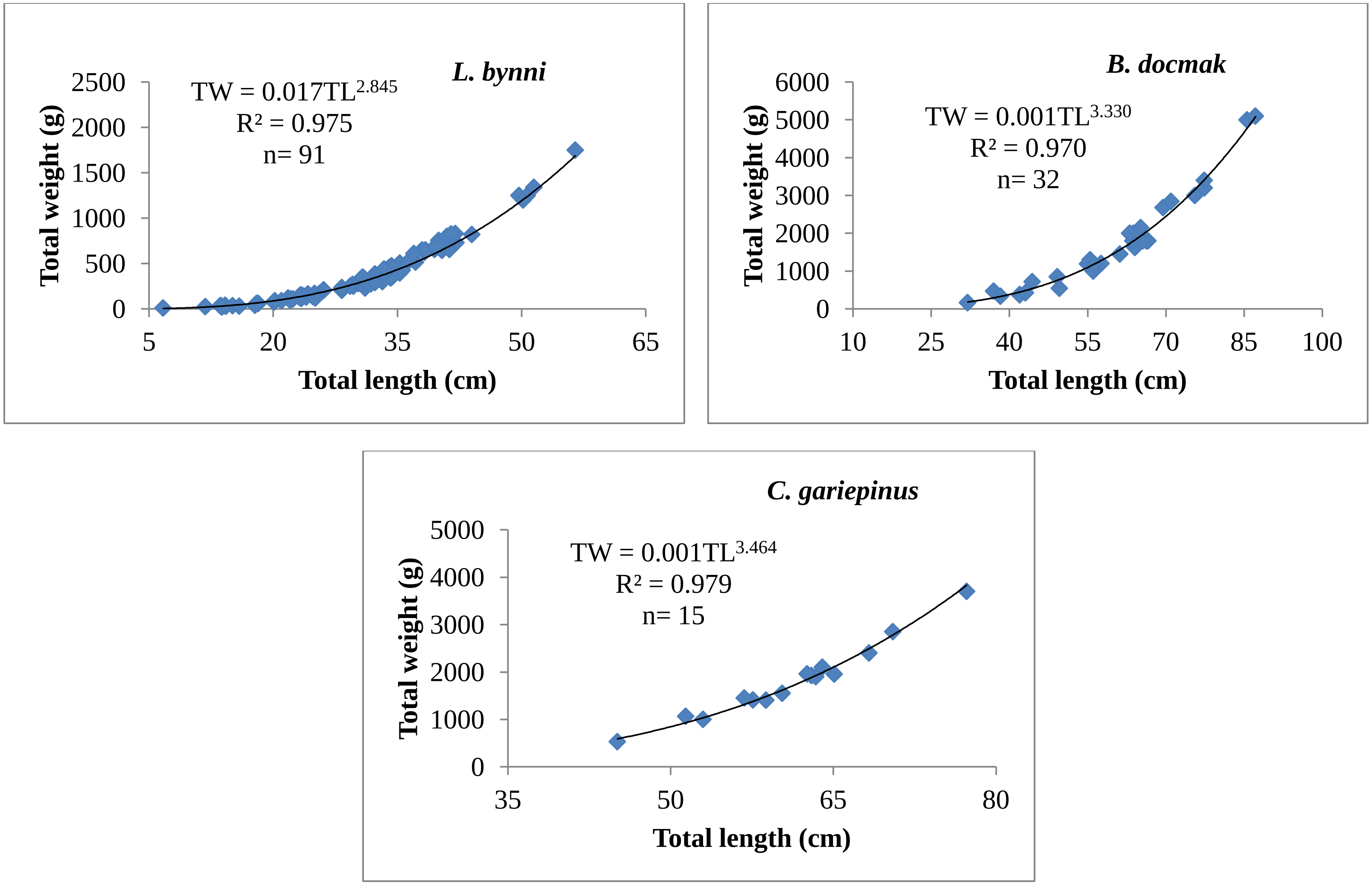


**Figure 15**. LWRs of fishes (sexes combined) sampled from the Ayima River.

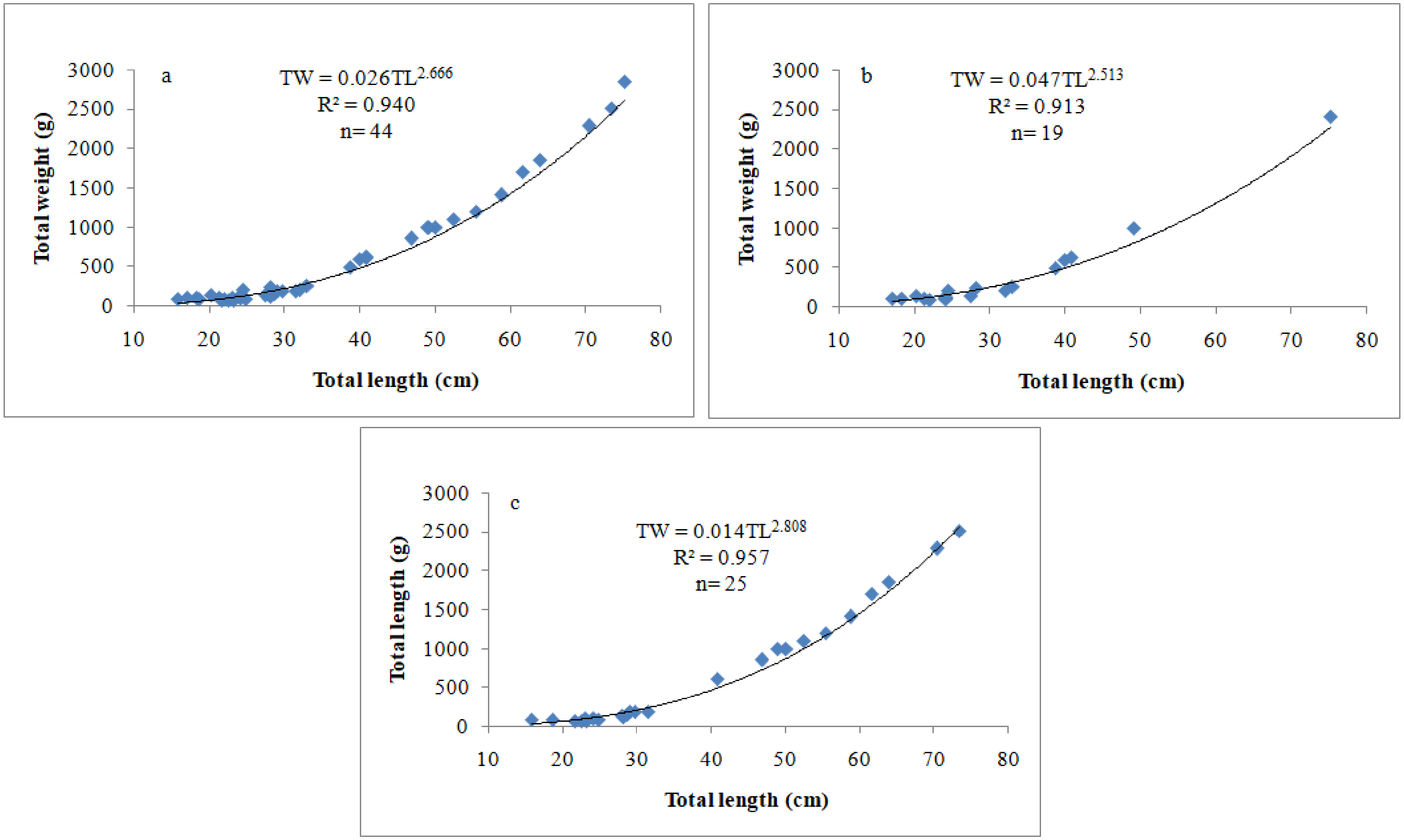


**Figure 16.** The LWR of *H. forskahlii* (a) sexes combined; (b) males; (c) females in the Ayima River.

### 4.5.2. Body conditions of fishes in the ALNP

The mean condition factor (CF) for the five selected fish species in the ALNP is summarized in table 15.

**Table 15**. Condition factor obtained for fishes sampled from Ayima and Gelegu Rivers.

| Species | Sex | Gelegu River CF Range | Gelegu River CF Average±SD | Ayima River CF Range | Ayima River CF Average±SD |
|---|---|---|---|---|---|
| *C. gariepinus* | Male | 0.344-0.901 | 0.652±0.096 | | |
| | Female | 0.365-0.906 | 0.657±0.107 | | |
| | Pooled | 0.344-0.906 | 0.655±0.102 | 0.58-081 | 0.74±0.06 |
| *H. niloticus* | Male | 0.727-1.069 | 0.911±0.082 | | |
| | Female | 0.727-1.082 | 0.915±0.079 | | |
| | Pooled | 0.727-1.082 | 0.913±0.078 | | |
| *L. bynni* | Male | | | 0.709-3.325 | 1.068±0.381 |
| | Female | | | 0.746-1.522 | 1.066±0.152 |
| | Pooled | 0.999-1.109 | 1.098±0.089 | 0.709-3.325 | 1.067±0.280 |
| *B. docmak* | Male | | | 0.49-0.83 | 0.67±0.10 |
| | Female | | | 0.45-0.93 | 0.68±0.14 |
| | Pooled | | | 0.447-0.928 | 0.675±0.117 |
| *H. forskahlii* | Male | | | 0.610-1.934 | 0.974±0.379 |
| | Female | | | 0.513-2.028 | 0.780±0.308 |
| | Pooled | 0.571-1.247 | 0.958±0.148 | 0.513-2.028 | 0.865±0.349 |

Except *L. bynni*, all species showed an average condition factor (CF<1.0) (Table 15). The results showed there was a significant variation in CF value among the studied fishes

($P<0.05$). Males of the *L. bynni* and *H. forskahlii* had a better body condition than females. However, in all species the results did not show a significant variation among sexes ($P>0.05$).

### 4.5.3. Fish diet composition, prey importance and feeding strategy

A total of 449 stomachs of which 252 (56.12%) that contained food were examined for fish diet analysis. Animal origin diets (e.g., fish and fish parts, aquatic insects, vertebrae, molluscs, zooplankton, nematodes, gastropods, etc), plant origin prey items (e.g., macrophytes, plant seeds, and phytoplankton), detritus and sand grains were the identified prey categories in the examined fish stomachs of the ALNP (see all tables and figures under this section).

***C. gariepinus* (Gelegu)**

156 samples of *C. gariepinus* were collected from the Gelegu River and 74 (47.5%) stomachs contained food. The list of food items that occurred in the stomachs of *C. gariepinus* is summarized in table 16. Fishes were the most preferred food items and had the highest grading index value (IFP=57.11%). In the fish prey category, *Brycinus nurse* and Tilapia largely contributed for the highest grading index value (Table 16). The percentage of geometric importance index value (%GIIi) also showed that fish was the primarily consumed prey type (Figure 17). For the frequency of occurrence, 54 (72.97%) consumed fish and fish parts and accounted for 76.45% of the total food volume, 37 stomachs contained insects (50%) and 28 stomachs had macrophytes (37.84%). Other food items identified were: detritus (22.97% = 17 fishes), sand (21.62% = 16 fishes), bivalves (8.11% = 6 fishes), vertebrae (4.05% = 3 fishes) and plant seeds (4.05% = 3

fishes). Detritus and macrophytes accounted for 5.63% and 3.86% respectively were the second and third most important food items of *C. gariepinus* by volume.

**Table 16.** Prey items found in the guts of *C. gariepinus* (n=74) from the Gelegu River (FOi-frequency of occurrence; V-volume; IFP-index of food preponderance; GIIi-geometric index of importance).

| **Prey items** | **Frequency of occurrence** | | **Volumetric contribution** | | **Prey importance indices** | |
|---|---|---|---|---|---|---|
| | **FOi** | **%FOi** | **V (ml)** | **%V** | **%IFP** | **%GIIi** |
| **Fish and their parts** | | | | | | |
| *Brycinus nurse* | 5 | 6.76 | 99.70 | 16.86 | 10.57 | 7.03 |
| Tilapia | 4 | 5.41 | 99.70 | 16.86 | 8.46 | 6.63 |
| *Synodontis spp.* | 3 | 4.05 | 88.10 | 14.89 | 5.61 | 5.64 |
| *Labeo spp.* | 3 | 4.50 | 46.80 | 7.92 | 2.98 | 3.69 |
| *Labeobarbus spp.* | 2 | 2.70 | 32.50 | 5.49 | 1.38 | 2.44 |
| *Alestes baremoze* | 1 | 1.35 | 6.50 | 1.09 | 0.14 | 0.73 |
| *Raiamas senegalensis* | 1 | 1.35 | 4.50 | 0.76 | 0.09 | 0.63 |
| Digested fish | 21 | 28.38 | 62.60 | 10.59 | 27.88 | 11.59 |
| Fish scale | 23 | 31.08 | 11.74 | 1.99 | 5.73 | 9.84 |
| Vertebrae | 3 | 4.05 | 39.75 | 6.72 | 2.53 | 3.21 |
| **Insects** | 25 | 33.78 | | | | |
| Odonata | 3 | 4.05 | 0.555 | 0.09 | 0.04 | 1.37 |
| Coleoptera | 14 | 18.92 | 12.06 | 2.04 | 3.58 | 6.24 |
| Belostomatidae | 1 | 1.35 | 1.50 | 0.26 | 0.03 | 0.48 |
| Butterfly | 1 | 1.35 | 0.05 | 0.01 | 0.00 | 0.40 |

| Prey items | Frequency of occurrence | | Volumetric contribution | | Prey importance indices | |
|---|---|---|---|---|---|---|
| | **FOi** | **%FOi** | **V (ml)** | **%V** | **%IFP** | **%GIIi** |
| Dermaptera | 1 | 1.35 | 3.00 | 0.51 | 0.07 | 0.56 |
| Diptera | 1 | 1.35 | 0.01 | 0.00 | 0.00 | 0.40 |
| Insect parts | 16 | 21.62 | 3.05 | 0.52 | 1.04 | 6.59 |
| **Bivalves** | 6 | 8.11 | 15.76 | 2.67 | 2.01 | 3.21 |
| **Plant parts** | 2 | 2.70 | | | | |
| Plant seeds | 2 | 2.70 | 0.41 | 0.07 | 0.02 | 0.83 |
| Root hair | 1 | 1.35 | 0.05 | 0.01 | 0.00 | 0.40 |
| **Macrophytes** | 28 | 37.84 | 22.81 | 3.86 | 13.54 | 12.41 |
| **Detritus** | 17 | 22.97 | 33.30 | 5.63 | 12.01 | 8.93 |
| **Sand** | 16 | 21.62 | 6.88 | 1.17 | 2.34 | 6.78 |

NB: Food items in ***bold*** summed up to 100% in volume, IFP and GII prey index.

Except for Coleoptera, insects constituted a small prey volume. Vertebrae (e.g., birds, mice, snake, etc), sand and bivalves were found in the stomach of *C. gariepinus* and their volumetric contribution was relatively small (Table 16). Plant seeds, root hairs and leaf litter of land plants were relatively insignificant in the diet of *C. gariepinus*. All prey items except fish were plotted below 30% of the volume axis while points of fish, insects and macrophytes were plotted above 30% of the occurrence axis (Figure 18).

***H. niloticus* (Gelegu)**

62 stomach samples of which 35 (56.45%) had food were examined for diet analysis of *H. niloticus*. A variety of food types were identified in the stomachs of this species (Table 17). Detritus and macrophytes which occurred in 74.29% and 71.43% and accounted for

52.65% and 10.75%, respectively of the total volume of food types were the most important food items, whereas insects, ostracods and seed grain were the intermediately consumed prey types (Table 17; Figure 17). Phytoplankton was the less utilized food item and observed only in 5.71% of the stomachs.

Based on the IFP, about 91% of prey importance was contributed by detritus (55.84, %IFP), sand (24.14, %IFP), and macrophytes (10.96, %IFP). According to this index, insects and seed grain constituted the next bulk of prey importance in *H. niloticus*. The %GII showed that only detritus was the preferential prey and *H. niloticus* consumed macrophytes and insects as a secondary prey, whereas seed grain, ostracods and phytoplankton were occasionally consumed food types (Figure 17). From the total prey types consumed by *H. niloticus,* only the %V contribution of detritus was plotted above 30% (Figure 18). Similarly, detritus, macrophytes and insects were also scored over 30% of the occurrence axis.

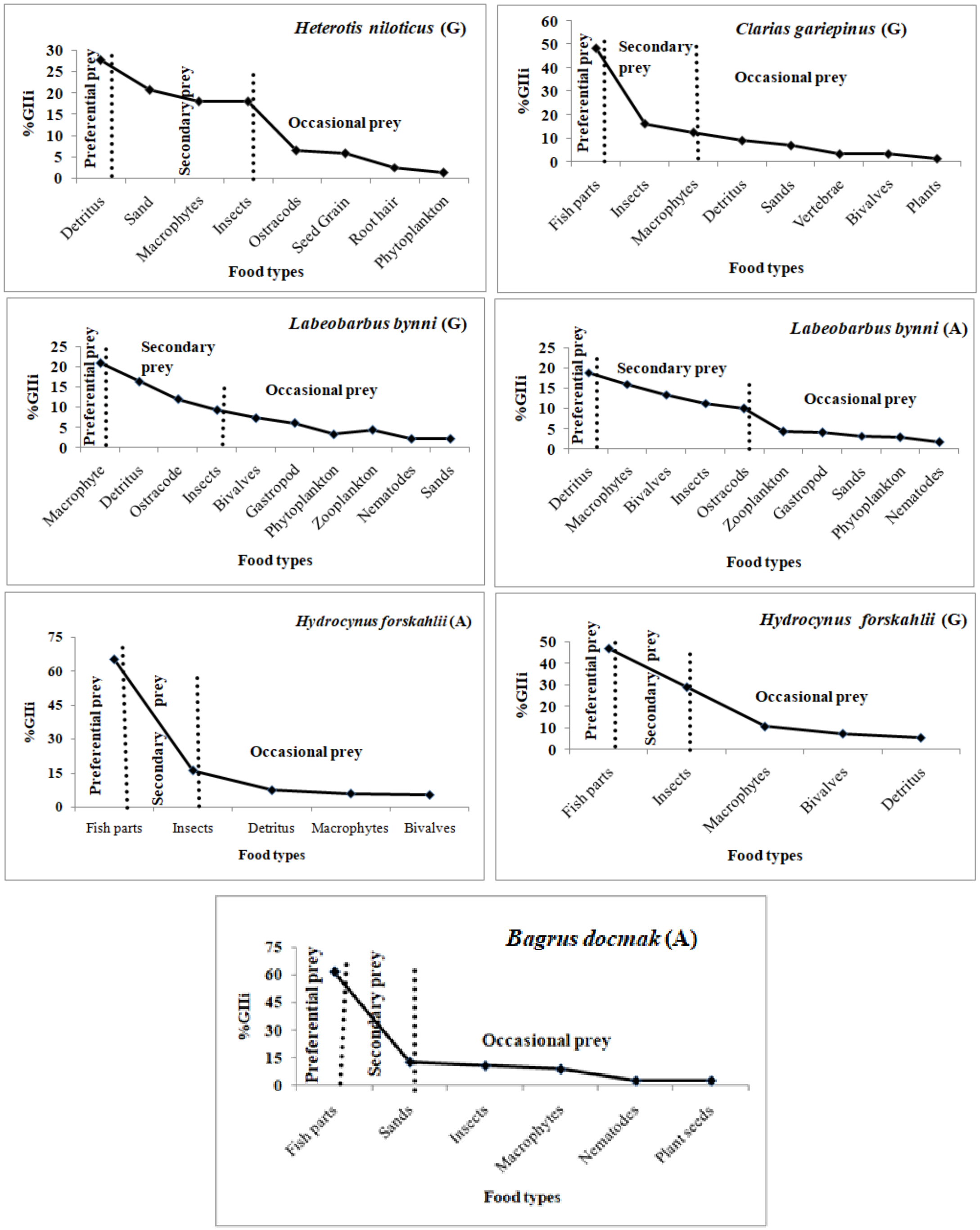


**Figure 17**. Graphical presentation of percentage geometric index of importance (%GIIi) for diets of the five selected fish species in the Ayima and Gelegu Rivers of the ALNP; A- Ayima and G- Gelegu; vertical lines separate the preferably consumed food items from the secondly or occasionally consumed prey types.

**Table 17**. Percentage Frequency, Volumetric contribution and IFP of different food items in the diet of *H. niloticus* from the Gelegu River (n=35).

| Prey items | Frequency of occurrence | | Volumetric contribution | | Prey importance indices | |
|---|---|---|---|---|---|---|
| | Foi | %FOi | V (ml) | %V | %IFP | %GIIi |
| **Detritus** | 26 | 74.29 | 71.25 | 52.65 | 55.84 | 27.59 |
| **Macrophytes** | 25 | 71.43 | 14.55 | 10.75 | 10.96 | 17.87 |
| **Sand** | 25 | 71.43 | 32.03 | 23.67 | 24.14 | 20.68 |
| **Insects** | | | | | | |
| Unidentified insect | 23 | 65.71 | 10.80 | 7.98 | 7.49 | 16.02 |
| Coleoptera | 1 | 2.86 | 0.15 | 0.11 | 0.01 | 0.64 |
| Diptera | 2 | 5.71 | 0.06 | 0.01 | 0.01 | 1.25 |
| **Ostracods** | 10 | 28.57 | 1.29 | 0.95 | 0.39 | 6.42 |
| **Phytoplankton** | | | | | | |
| Naviculla | 1 | 2.86 | 0.01 | 0.01 | 0.00 | 0.62 |
| Surirella | 1 | 2.86 | 0.25 | 0.19 | 0.01 | 0.66 |
| Seed grain | 8 | 22.86 | 4.82 | 3.56 | 1.16 | 5.74 |
| Root hairs | 4 | 11.43 | 0.11 | 0.08 | 0.01 | 2.5 |

***L. bynni* (Ayima and Gelegu)**

From the total of 113 (Ayima=91 and Gelegu=22) examined stomachs, for Gelegu 7 (31.8%) and Ayima 23 (25.3%) guts had no food. The food categories found in the guts of 83 individuals of *L. bynni* included bivalves, macrophytes, detritus, zooplankton, insects, ostracods, phytoplankton, and nematodes (Table 18). In the Gelegu River, macrophytes occurred in 93.3% of the examined stomachs and accounted for 38.5% of the total food volume was the most important prey.

For specimens obtained from Ayima, macrophytes which occurred in 82.4% of the guts and volumetrically accounted for 18.7% was the second most important food item. Detritus observed in 73.3% of the examined guts and contributed 29.2% of the total food volume, while ostracods and bivalves occurred in 66.7% and 40% of the examined guts and accounted for 8.8% and 5.7% of the total food volume, respectively in stomach samples collected from the Gelegu River. But, detritus which occurred in 85.29% of the total examined stomachs contributed 34.0% of the total food volume in gut samples collected from Ayima.

In contrast to specimens taken from Gelegu River, gut samples of *L. bynni* collected from Ayima River contained a large percentage volume of bivalves (Table 18). Phytoplankton, zooplankton, nematodes and sands rarely occurred in the guts of *L. bynni* and accounted for only 3.0% and 5.8% of the total food volume in samples obtained from the Gelegu and Ayima Rivers, respectively (Table 18). The volumetric contribution of insects in the dietary importance of *L. bynni* was relatively small in both rivers.

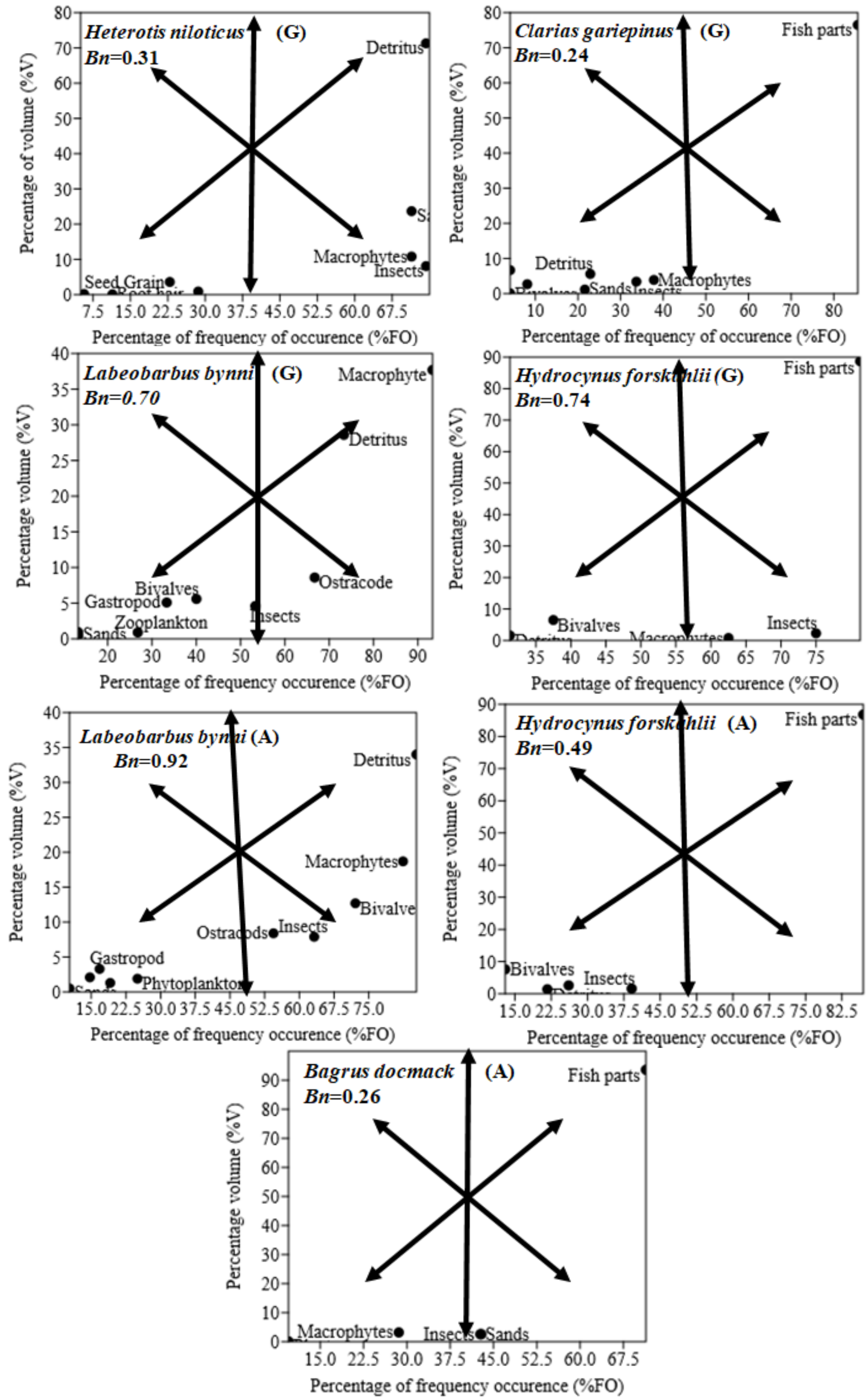


**Figure 18**. Feeding strategy diagram of the five selected fish species from the Ayima and Gelegu Rivers based on Costello's method; Bn= normalized (by R or resource number) Levin's dietary niche breadth index; A-Ayima; G-Gelegu.

In terms of the grading index, macrophytes and detritus were the most important and favored prey of *L. bynni* collected from Gelegu River (Figure 17). Based on this index, the dietary contribution of insects for gut samples collected from this river was small as compared to samples collected from the Ayima River (Table 18). For gut samples obtained from the Ayima River; detritus (42.9, %IFP), macrophytes (22.8, %IFP), bivalves (13.5, %IFP) and insects (12.1, %IFP) took the highest values of the grading index. These food items in the order contributed for 29.9, 50.2, 3.2 and 5.4% of the IFP of the food in *L. bynni* which were collected from the Gelegu River.

Ostracods which accounted for 8.2% of the grading index were a secondary prey for *L. bynni* in the Gelegu River (Table 18). This prey which contributed for 6.8% of the total IFP was relatively the least important prey in the Ayima River. Macrophytes, detritus, ostracods, bivalves and insects were plotted above 30% of frequency of occurrence for samples of both rivers and gastropod in the Gelegu River only (Figure 18). Macrophytes and detritus also plotted above 30% of the volume axis in samples collected from the Gelegu and Ayima Rivers, respectively (Figure 18).

**Table 18**. Frequency of occurrence, volumetric contribution and indices of prey importance of food items consumed by *L. bynni* (n=15-Gelegu and n=68-Ayima); AR-Ayima River and G-Gelegu River.

| | **Frequency of occurrence** | | | | **Volumetric contribution** | | | | **Prey importance indices** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Foi** | | **%FOi** | | **Vi** | | **%Vi** | | **%IFP** | | **%GIIi** | |
| **Prey items** | **GR** | **AR** | **GR** | **AR** | **GR** | **AR** | **GR** | **AR** | **GR** | **AR** | **GR** | **AR** |
| **Macrophytes** | 14 | 56 | 93.33 | 82.35 | 31.9 | 17.43 | 38.50 | 18.71 | 50.17 | 22.75 | 21.04 | 15.20 |
| **Detritus** | 11 | 58 | 73.33 | 85.29 | 24.2 | 31.7 | 29.21 | 34.04 | 29.91 | 42.86 | 16.36 | 17.95 |
| **Ostracods** | 10 | 37 | 66.67 | 54.41 | 7.3 | 7.83 | 8.81 | 8.41 | 8.20 | 6.76 | 12.05 | 9.45 |
| **Bivalves** | 6 | 49 | 40 | 72.06 | 4.75 | 11.8 | 5.73 | 12.67 | 3.20 | 13.48 | 7.29 | 12.75 |
| **Insect parts** | 8 | 43 | 53.33 | 63.24 | 3.9 | 7.32 | 4.71 | 7.86 | 3.51 | 7.34 | 9.26 | 10.69 |
| Coleoptera | 5 | 27 | 33.33 | 39.71 | 2.5 | 5.1 | 3.02 | 5.48 | 1.41 | 3.21 | 5.80 | 6.79 |
| Diptera | 3 | 19 | 20 | 27.94 | 1.5 | 3.52 | 1.81 | 3.78 | 0.51 | 1.56 | 3.48 | 4.77 |
| **Gastropods** | 5 | 11 | 33.33 | 16.18 | 4.3 | 3.03 | 5.19 | 3.25 | 2.42 | 0.78 | 6.15 | 2.93 |
| **Nematodes** | 2 | 7 | 13.33 | 10.29 | 0.4 | 0.43 | 0.48 | 0.46 | 0.09 | 0.07 | 2.20 | 1.62 |
| **Phytoplankton** | 2 | 17 | 13.33 | 25 | | | | | | | 2.13 | 3.76 |
| Green algae | 2 | 11 | 13.33 | 16.18 | 0.3 | 1.2 | 0.36 | 1.29 | 0.07 | 0.31 | 2.18 | 2.63 |
| BGA | 1 | 9 | 6.67 | 13.24 | 0.5 | 0.63 | 0.60 | 0.68 | 0.06 | 0.13 | 1.16 | 2.09 |
| **Zooplankton** | 4 | 10 | 26.67 | 14.71 | | | | | | | 4.26 | 2.21 |
| Daphnia | 4 | 10 | 26.67 | 14.71 | 0.8 | 1.1 | 0.97 | 1.18 | 0.36 | 0.26 | 4.41 | 2.39 |
| Moina | - | 7 | - | 10.29 | - | 0.8 | | 0.86 | 0 | 0.13 | 0 | 1.68 |
| **Sands** | 2 | 13 | 13.33 | 19.12 | 0.5 | 1.25 | 0.60 | 1.34 | 0.11 | 0.38 | 2.22 | 3.08 |

***B. docmak* (Ayima)**

From the total of 32 stomach samples of *B. docmak*, 21 (65.63%) stomachs contained food. Fish parts, insects and macrophytes which occurred in 71.4, 42.9 and 28.6% of the examined stomachs and accounted for 93.6, 2.6 and 3.2% of the total food volume, respectively were the most important prey. Fishes which contributed for 90.5% of the IFP were the most important prey. According to this index, the individual contribution of fish prey was in the order: *Bagrus spp*. (17.9%), *B. nurse* (4.1%), and *Synodontis spp*. (2.7%). *B. docmak* also occasionally consumed insects, macrophytes, and nematodes (Figure 17). In the diet of *B. docmak* only fish prey is plotted near to 100% both in the occurrence and volume axes of the feeding strategy diagram (Figure 18).

**Table 19**. Frequency of occurrence, volumetric contribution and prey importance indices in the food items consumed by *B. docmak* in Ayima River (n=21).

| **Prey items** | **Frequency of occurrence** | | **Volumetric contribution** | | **Prey importance indices** | |
|---|---|---|---|---|---|---|
| | **Foi** | **%FOi** | **V (ml)** | **%V** | **%IFP** | **%GIIi** |
| **Fish and parts** | 15 | 71.43 | | | | |
| *Bagrus spp.* | 3 | 14.29 | 51.30 | 28.29 | 17.95 | 12.09 |
| *Synodontis spp.* | 1 | 4.76 | 23.00 | 12.69 | 2.68 | 4.95 |
| *B. nurse* | 1 | 4.76 | 35.00 | 19.31 | 4.08 | 6.83 |
| *Mormyrus spp.* | 1 | 4.76 | 11.50 | 6.34 | 1.34 | 3.15 |
| Digested fish | 12 | 57.14 | 40.55 | 22.37 | 56.72 | 22.56 |
| Fish scale | 8 | 38.09 | 8.30 | 4.58 | 7.74 | 12.11 |
| **Insects** | 9 | 42.86 | | | | |

| Prey items | Frequency of occurrence | | Volumetric contribution | | Prey importance indices | |
|---|---|---|---|---|---|---|
| | Foi | %FOi | V (ml) | %V | %IFP | %GIIi |
| Coleoptera | 3 | 14.29 | 0.54 | 0.29 | 0.19 | 4.14 |
| Insect parts | 5 | 23.81 | 0.53 | 0.29 | 0.31 | 6.84 |
| **Nematodes** | 2 | 9.52 | 0.05 | 0.03 | 0.00 | 2.71 |
| **Macrophytes** | 6 | 28.57 | 5.82 | 3.2 | 4.07 | 9.02 |
| **Plant seeds** | 2 | 9.52 | 0.03 | 0.02 | 0.01 | 2.71 |
| **Sands** | 9 | 42.86 | 4.68 | 2.58 | 4.91 | 12.89 |

***H. forskahlii* (Ayima and Gelegu)**

In Ayima River, among the 44 examined stomachs, 23 (52.3%) contained food. About 40.7% stomachs collected from Gelegu had empty stomachs. Fishes which occurred in 86.9% and 81.3% stomachs and accounted for 86.8% and 88.8% of the total food volume were the most important food category and preferential prey for *H. forskahlii* in the Ayima and Gelegu Rivers, respectively (Table 20; Figure 17). Bivalves observed in 37.5% and 13.0% stomachs and accounted for 6.5% and 7.6% of the total food volume were the next most important prey only next to fish, for specimens obtained from the Gelegu and Ayima Rivers, respectively.

According to the index of Levin's trophic niche amplitude (*Bn*), higher dietary breadth index was calculated for *L. bynni* in both Ayima and Gelegu Rivers and for *H. forskahlii* in Gelegu River, while *H. forskahlii* had moderate niche amplitude in Ayima River (Figure 18). On the other hand, *C. gariepinus* and *H. niloticus* in the Gelegu River and *B. docmak* in Ayima River had a low niche breadth index (Figure 18).

**Table 20**. Frequency of occurrence, volumetric contribution and prey importance indices in the food items identified from *H. forskahlii* (n=23-Ayima and n=16-Gelegu); AR-Ayima River and GR-Gelegu River.

| **Prey items** | **Frequency of occurrence** | | | | **Volumetric contribution** | | | | **Prey importance indices** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Foi** | | **%FOI** | | **Vi** | | **%Vi** | | **%IFP** | | **%GIIi** | |
| | **AR** | **GR** | **AR** | **GR** | **AR** | **GR** | **AR** | **GR** | **AR** | **GR** | **AR** | **GR** |
| **Fish and parts** | 20 | 13 | 86.96 | 81.25 | | | | | | | | |
| *B. nurse* | 6 | 7 | 26.09 | 43.75 | 57.60 | 49.30 | 18.96 | 18.65 | 20.46 | 23.45 | 11.64 | 10.62 |
| *Labeo spp.* | 4 | 2 | 17.39 | 12.5 | 54.00 | 26.80 | 17.78 | 10.14 | 12.79 | 3.64 | 9.09 | 3.85 |
| *A. baremoze* | 2 | 4 | 8.69 | 25.00 | 35.80 | 53.13 | 11.79 | 20.1 | 4.24 | 14.44 | 5.29 | 7.68 |
| Tilapia | 3 | 2 | 13.04 | 12.50 | 34.60 | 28.50 | 11.39 | 10.78 | 6.14 | 3.87 | 6.31 | 3.96 |
| *Bagrus spp.* | 1 | | 4.35 | | 14.50 | | 4.77 | | 0.86 | | 2.36 | |
| *Labeobarbus spp* | 1 | 1 | 4.35 | 6.25 | 13.00 | 13.25 | 4.28 | 5.01 | 0.77 | 0.89 | 2.23 | 1.92 |
| *R. senegalensis* | 5 | 3 | 21.74 | | 9.80 | | 3.23 | | 2.9 | | 6.45 | |
| Digested fish | 16 | 11 | 69.57 | 68.75 | 44.30 | 63.80 | 14.58 | 24.03 | 41.79 | 40.03 | 21.75 | 18.99 |
| **Bivalves** | 3 | 6 | 13.04 | 37.5 | 23.05 | 17.08 | 7.59 | 6.46 | 4.09 | 6.96 | 5.33 | 7.48 |
| **Insects** | 9 | 12 | 39.13 | 75 | | | | | | | | |
| Coleoptera | 5 | 6 | 21.74 | 37.50 | 3.00 | 1.35 | 0.99 | 0.51 | 0.89 | 0.55 | 5.87 | 6.47 |
| Diptera | 1 | 8 | 4.35 | 50.00 | 0.20 | 1.80 | 0.07 | 0.68 | 0.01 | 0.98 | 1.14 | 8.63 |
| Butterfly | | 4 | | 25.00 | | 0.75 | | 0.28 | | 0.20 | | 4.30 |
| Insect remains | 8 | 9 | 34.78 | 56.25 | 1.65 | 2.25 | 0.54 | 0.85 | 0.78 | 1.37 | 9.13 | 9.72 |
| **Macrophytes** | 5 | 10 | 21.74 | 62.50 | 4.25 | 2.14 | 1.39 | 0.81 | 1.26 | 1.46 | 5.98 | 10.78 |
| **Detritus** | 6 | 5 | 26.09 | 31.25 | 8.00 | 4.25 | 2.63 | 1.61 | 2.84 | 1.45 | 7.41 | 5.59 |

### 4.5.4. Ontogenetic and seasonal dietary variation

There was a slight ontogenetic and seasonal dietary shift in *L. bynni*, *H. forskahlii* and *C. gariepinus* (Figures 19 and 20). Seasonal dietary variation was not a subject of the present study for *B. docmak* and *H. forskahlii* because samples were only collected during the dry season for the former and stomachs collected for the second species during the dry season were empty. Stomach samples of *L. bynni* from Gelegu River were collected only during the dry season.

Insects, especially that of Coleoptera showed a significant variation in the diet of *H. niloticus* and were highly significant during the wet months ($P<0.05$). Ostracods also showed a significant variation in the dietary contribution of *H. niloticus* and significant during the dry months (Figure 19). Macrophytes which were the most important food item during the dry season also showed a significant variation in the seasonal diet of *H. niloticus*. The frequency of occurrence did not show a significant temporal variation for detritus ($P>0.05$), but the variation was significant by its volumetric contribution ($P<0.05$). The seasonal contribution of detritus in the diet of *H. niloticus* was different and it was important during the dry season (Figure 19). An ontogenetic diet shift analysis was not done for *H. niloticus* because of the smaller size ranges (groups) collected.

In *C. gariepinus* the seasonal dietary variation was small. Only some fish prey and insects showed a significant variation in the seasonal diet of this predator (Figure 19). *B. nurse, Synodontis spp*., and *Labeobarbus spp*. were the most important prey during the dry months, while other fish prey categories were important during the wet months. The volumetric contribution of insects was higher during the wet months (Figure 19). Detritus also contributed highly in the diet of *C. gariepinus* during the wet months. Three arbitrarily grouped size classes were used to examine the ontogenetic dietary shift in *C. gariepinus* and the different diet composition was found to vary with size (Figure 20). The volumetric contribution of fish prey was important for the smaller (29-40 cm, TL) and intermediate (40-60 cm, TL) size classes (Figure 20). The contribution of insects showed no significant variation among the different size classes, but largely consumed by the intermediate size class. Bivalves and detritus significantly contributed for the smallest size class (Figure 20). The contribution of macrophytes showed no significant variation among the different size classes (P>0.05).

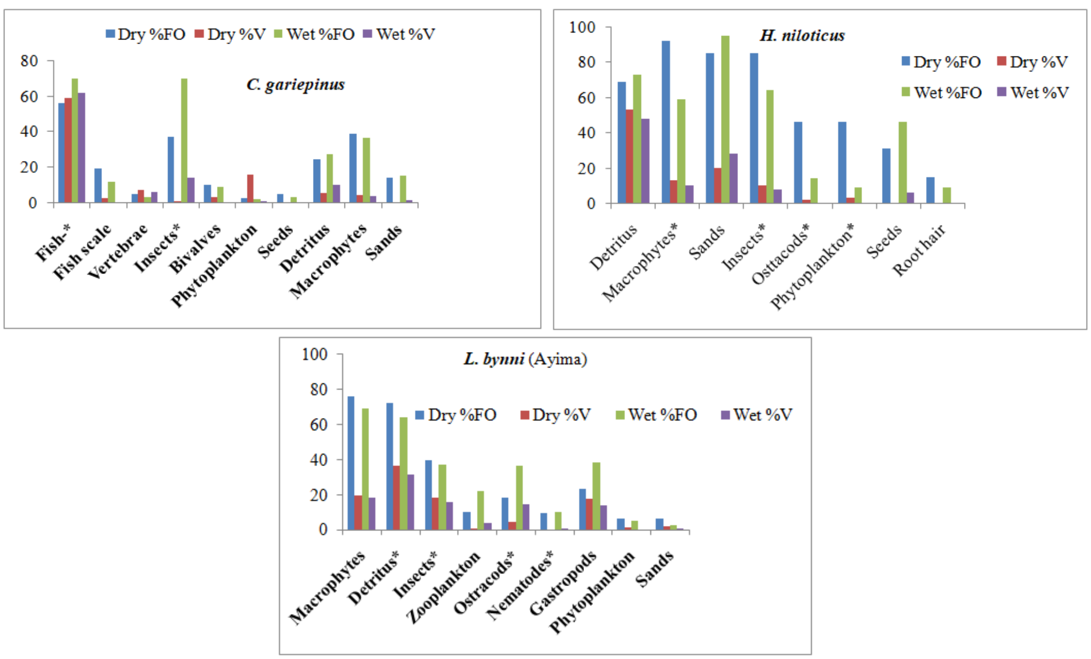


**Figure 19.** Relative contribution of different food items in the diet of the selected fish species of the ALNP during the dry and wet months; *- indicates food types that show significant difference in the two months.

No significant seasonality variation in dietary importance was observed in *L. bynni*. However, there was a slight ontogenetic dietary shift observed in only for some particular prey items. In the smaller size class (6-20 cm, TL) the contribution of insects and ostracods was important and differ significantly from other size categories ($p<0.05$). In the intermediate size class (21-30 cm, TL) the contribution of macrophytes showed a significant variation from the smaller size class. Generally, in the smaller and intermediate size classes of *L. bynni*, the contribution of food of animal origin was relatively high, whereas in adults (>31 cm, TL) plant origin diets were important (Figure 20).

Only two size classes (15-30 and >30 cm, TL for Ayima and 20-40 and >40 cm, TL for Gelegu Rivers) were considered for examination of the ontogenetic dietary shift in *H. forskahlii*. In the Gelegu River, the contribution of fish prey was important in the smaller size class but the difference was insignificant from the larger ones. However, there was a significant difference in the contribution of insects which was more important in the smaller size class (15-30 cm, TL). The volumetric contribution of bivalves and detritus differ significantly among the different size classes and the former was important for the smaller size, whereas the larger size class largely consumed the second (Figure 20). The volumetric contribution of fish prey, insects and bivalves differ significantly ($p<0.05$) for the different size classes of *H. forskahlii* sampled from the Ayima River (Figure 20). Insects and bivalves were largely consumed by the smaller size class (20-40 cm, TL), while fish prey was important for the larger size class (>40 cm, TL). *B. docmak* which was only collected from Ayima River was not considered in the assessment of both seasonal and ontogenetic dietary variations.

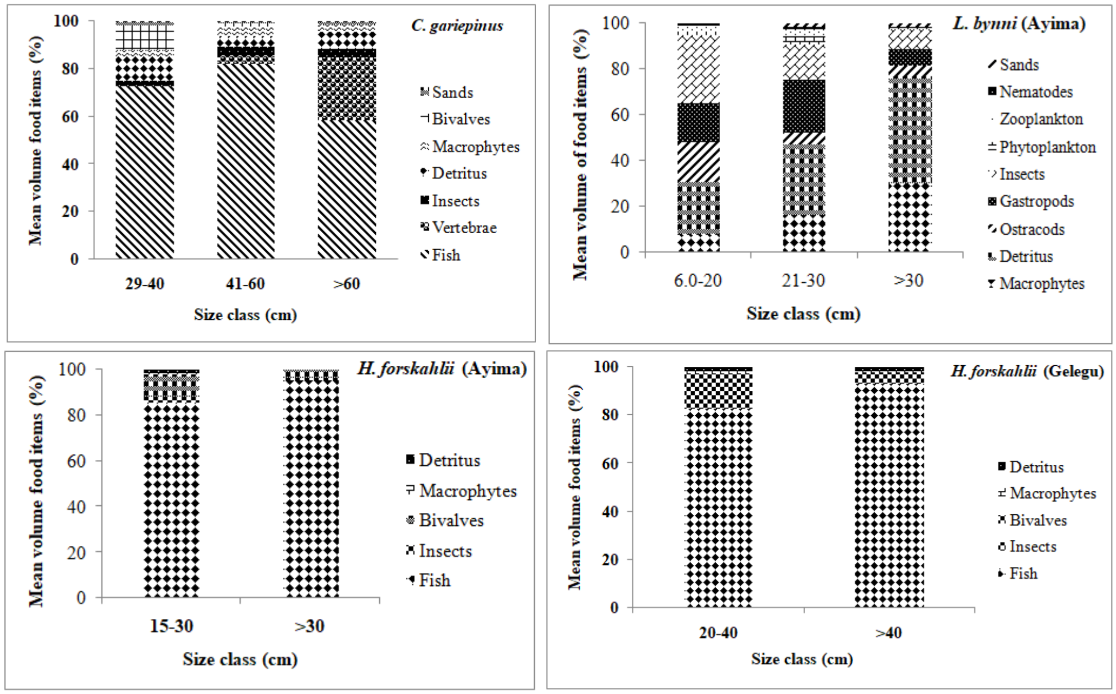


**Figure 20**. Volumetric contribution of food items consumed by different size classes of the selected fish species sampled from floodplain rivers of the ALNP.

### 4.5.5. Interspecific dietary niche overlap

The Schoener's (α) index of dietary niche overlap for the consumer fish species is summarized in table 21. For the investigation of the diet overlap for the examined species; 9 combinations were produced (Table 21). Out of those combinations, 6 (66.7%) were null, indicating no significant diet overlap. Values higher than the threshold value were only observed in 3 (33.3%) cases, which indicate significant overlap (Table 21). Based on the results of α index, there was no diet overlap for the four combinations (*H. niloticus* ▲*C. gariepinus*; *L. bynni* ▲ *C. gariepinus*; *H. forskahlii* ▲ *C. gariepinus* and *H. forskahlii* ▲ *B. docmak*). The first three combinations were from the Gelegu River. The species with the highest number of diet overlaps with other fishes was *H. niloticus*, which showed diet overlap with *L. bynni* and *C. gariepinus*.

**Table 21**. Summary of Schoener's (α) index of dietary niche overlap for the five selected predator fish species in the ALNP (Clg- *C. gariepinus*; Htn- *H. niloticus*; Lby- *L. bynni*; Bad- *B. docmak*; Hyf- *H. forskahlii*).

| | **Clg** (G) | **Htn** (G) | **Lby** (A) | **Lby** (G) | **Bad** (A) | **Hyf** (A) | **Hyf** (G) |
|---|---|---|---|---|---|---|---|
| **Clg** (G) | 1 | 0.51 | | 0.47 | | | 0.63 |
| **Htn** (G) | | 1 | | 0.91 | | | 0.27 |
| **Lby** (A) | | | 1 | | 0.37 | 0.29 | |
| **Lby** (G) | | | | 1 | | | 0.31 |
| **Bad** (A) | | | | | 1 | 0.73 | |
| **Hyf** (A) | | | | | | 1 | |
| **Hyf** (G) | | | | | | | 1 |

## 4.6. Discussion

### 4.6.1. LWR and body conditions of fishes of the ALNP

The results obtained for the LWR showed that *C. gariepinus*, *H. niloticus* and *L. bynni* in the Gelegu River conformed the cube law of Bagenal and Tesch (1978) which assumes the regression slope 'b' to be three or nearly three. *B. docmak* and *C. gariepinus* both from the Ayima River and *H. forskahlii* from the Gelegu River have shown a positive allometric growth. *H. forskahlii* had a negative allometric growth (b=2.666) sampled from the Ayima River.

The coefficient of LWR (b) recorded for *C. gariepinus* collected from Gelegu River (b=3.139) and Ayima River (b=3.464) corroborates a positive allometric growth. In agreement with this study, Elias Dadebo *et al*. (2011), David *et al*. (2010) and Keyombe *et al*. (2015) reported a positive allometric growth for *C. gariepinus* in Lake Chamo

(Ethiopia), in the Vimtim stream in Nigeria and in Lake Naivasha from Kenya, respectively. However, in contrast to the present study, this species showed a nearly isometric growth in Lakes Ziway and Babogaya (Ethiopia) (Lemma Abera *et al*., 2014) and Langeno (Ethiopia) (Leul Teka, 2001). Negative allometric growth was also reported for *C. gariepinus* from the Sô River in Bènin (Hazoume *et al*., 2017). Differences in the allometric coefficients between the present and previous studies can be attributed to the combination of one or more factors such as number of specimens, prey availability, gonad maturity and sex, health condition, habitat and seasonal effect (Wotton, 1979; Uneke, 2013). In addition, the availability of sufficient prey in floodplain rivers favored the successful growth of fishes. For the case of *C. gariepinus,* its general feeding behavior in ALNP coupled with the presence of accessory breathing organs privileged the species to accompany a successful growth.

The mean body condition factor (CF=0.65±0.1) obtained for combined sexes of *C. gariepinus* was higher than the findings of Getso *et al*. (2017) from the Wudil River in Nigeria (CF=0.52) and Keyombe *et al*. (2015) from Lake Naivasha (0.55), which showed that *C. gariepinus* in the ALNP had a better body condition. However, the combined sexes of *C. gariepinus* in the Cross River from Nigeria had a mean CF of 0.963 (Uneke, 2015), which was higher than the present study. The differences in body condition obtained in the present and previous studies might be due to differences in environmental condition, feeding rate, stress, season and water level fluctuation and water quality parameters. Fish CF is reportedly affected by food availability, water quality and level and environmental conditions (Khallaf *et al*., 2003). By considering the general principle, higher condition factor values revealed a better state and thus males of *C. gariepinus* were in a better condition than females in the Gelegu River. This might be due to females expending more energy during reproduction than males. The levels of energy investment appropriated towards aspects of reproduction differ between the sexes and affect body conditions of a fish (Morgan, 2004).

The primitive nest builder species from the family Arapaimidae, *H. niloticus*, in the Gelegu River had a nearly isometric growth (b=2.826). This agrees with the reports of Hazoume *et al*. (2017) from Sô River (b=2.999) for a sample size of 40 and Lalèyè (2006) in the Ouèmè River from Bènin (b=2.923) for a sample size of 101. *H. niloticus* also had an isometric growth in the Cross River (Offem *et al*., 2009). In contrast to the present study, this species showed a negative allometric growth (b=2.67) in a coastal river of the Iϋory Coast (Konan *et al*., 2007). *H. niloticus* had a mean CF of 0.91±0.08 from the Gelegu River for combined sexes and higher values of CF (0.98) for this species is reported by Ezekiel and Abowei (2013) from the Amassoma River in Nigeria. The mean CF value of the present study is also small as compared to values reported in other tropical floodplain rivers, like Lower River Benue in Nigeria (0.96) (Solomon *et al*., 2017) and Kaduna River in Nigeria (1.15) (Bake and Sadiku, 2005). The poor CF reported in the present study may be associated to the high fishing pressure coupled with the harsh environmental condition prevailing in floodplain rivers. This species is yet not a subject of any biological study in Ethiopia.

*L. bynni* in the present study attained a nearly isometric (b=2.845) and isometric (b=2.936) growth in the Ayima and Gelegu Rivers of the ALNP, respectively. In contrast to the present study, Elias Dadebo *et al*. (2014) reported that this species attained a positive allometric growth (b=3.25) in Lake Abaya (Ethiopia). Demeke Admassu and

Elias Dadebo (1997) noted a positive allometric growth for another species of the genus (*L. intermedius*) in Lake Hawassa (Ethiopia). This difference could be due to the differences in sample size which was smaller in the present study. Another probable reason for the disparity might be associated with water level stability differences between lakes and seasonally inundated floodplain rivers. The mean body condition value obtained for *L. bynni* both in Ayima and Gelegu Rivers was greater than 1.0. The high CF values of this species might be due to the presence of plenty macrophytes and detritus commonly infested in floodplain habitats that are the most important food types frequently occurring in the guts of *L. bynni*.

The value obtained for the allometric coefficient (b) was 3.3330 and revealed a positive allometric growth in *B. docmak* from the Ayima River. The finding is in agreement with the works of different authors. Hailu Anja *et al*. (2009), Offem *et al*. (2009) and El-Drawany and Elnagar (2015) obtained a similar growth type for this species from Lake Chamo (Ethiopia), in the Cross floodplain river and in Muess channel (Egypt), respectively. The presence of sufficient fish prey for this piscivorous species may attribute for attaining this growth type in Ayima River. The mean CF (0.67±0.12) obtained from the Ayima River in the present study revealed a poor status of *B. docmak* as compared to the reports made by Ikongbeh *et al*. (2012) in Lake Akata from Nigeria. However, a similar result was obtained for the mean CF value of a very similar species (*B. bajad*) (CF=0.668) in the Adofi River from Nigeria (Nwabueze and Garba, 2015). In Lake Chamo, *B. docmak* had CF values of 0.436 ± 0.011 to 0.489 ± 0.012 (Hailu Anja *et al*., 2009) which was much smaller than the present study. The difference in the mean body condition in the previous and present studies might be ascribed to the unfavorable environmental condition common in floodplain ecosystems, fishing pressure and feeding competition with other piscivorous fishes. Fishing intensity and regular competition for prey has been reported to affect fish body condition factor and growth pattern (Khallaf *et al.*, 2003).

The predatory Tiger fish, *H. forskahlii*, had a positive and negative allometric growth sampled from the Gelegu and Ayima Rivers, respectively. The difference in the allometric coefficient of the two rivers in the present study might be due to environmental factors and prey availability, because it might be easy to capture prey in the smaller Gelegu River. According to Elias Dadebo and Seyoum Mengistou (2008) this species attained isometric growth in Lake Chamo. The difference in the allometric coefficient values of the present and previous findings may be due to differences in sample size and food availability. The mean body condition of *H. forskahlii* was 0.96±0.15 and 0.86±0.35 (the difference was not significant, $p>0.05$) in the Gelegu and Ayima Rivers, respectively and higher than reported by Ahmed *et al*. (2017) (0.7018±0.1912) from the Roseires Reservoir in Sudan.

### 4.6.2. Fish diet composition, prey importance and feeding strategies

The analysis showed that fishes in floodplain rivers of the ALNP consumed a variety of food items. Not all prey items were equally important in the diet of each fish species. Generally, animal origin prey items were largely eaten by juveniles, whereas adults consumed both animal and plant origin diets.

***C. gariepinus* (Gelegu)**

The stomach content analysis indicated that *C. gariepinus* consumed a variety of food types in the Gelegu River. As compared to previous studies, the prey items identified from the guts of *C. gariepinus* was limited. The probable reason for this might be related to prey adaptability to the constantly changing floodplain habitats. In the present finding, *C. gariepinus* was omnivore but piscivory was more frequent.

A large percentage of *C. gariepinus* individuals (72.9%, FO) exploited higher quantity of fish prey (76.4%, V), which was the most important food for this fish. This notion agrees with the previous report made from Oluwa River in Nigeria disclosing that fish prey frequently occurred in the guts of *C. gariepinus* (Akegbejo-Samsons, 2005). In Lake Hawassa, 81.7% adults and 86.6% juveniles dietary contribution by volume was due to fish prey (Elias Dadebo, 2000). However, the present study contrasts with some reports made from other Ethiopian lakes. For example, in Lake Babogaya, *C. gariepinus* mainly fed on insects, zooplankton and plant origin diets (Demeke Admassu *et al*., 2015), while detritus constituted the largest prey bulk of the species in Koka Reservoir (Elias Dadebo *et al*., 2014). The disparity between the present findings and earlier ones could be due to the difference in sample sizes and sampling sites; the specimens for the present study were entirely obtained from a floodplain ecosystem as opposed to the previous studies which were conducted in relatively stable lakes. In contrast to many other studies, the present study confirmed no cannibalism in *C. gariepinus*. The most probable reason for this might be that Gelegu River is relatively minimally fished and no problem on prey availability that could prompt any cannibalism in the species. Fishing pressure has been reported to affect prey acquisition by fish (Garrison and Link, 2000; Garrison *et al*., 2010).

The most important fish prey in the diet of this species was constituted by *B. nurse*, Tilapia, and *Synodontis spp.* These prey contributed about 63% of the fish prey in volume. In agreement with the present study, Elias Dadebo (2000) also noted that the contribution of *O. niloticus* as fish prey of *C. gariepinus* was important in Lake Hawassa. However, this study contrasts with the findings of Elias Dadebo *et al*. (2014) in which *O. niloticus* was the least important fish prey in Koka Reservoir. The volumetric contribution of *B. nurse* in the diet of *C. gariepinus* was comparable to that of *O. niloticus* in Gelegu River. This is because *C. gariepinus* is a generalist feeder and largely consumes *B. nurse* which was more abundant in rivers of the ALNP (Table 7, chapter 3) and became the most available prey for this generalist predator. Although the contribution of allochthonous food resources is expected to be higher in floodplain rivers, insects were among the least important prey in the diet of this species. This may be associated with the harsh environmental condition that affects the adaptation of insect groups in the floodplain rivers.

In floodplain rivers, it is important to adapt diet breadth or exhibiting trophic plasticity, an ecological advantage that enabled fishes to switch from one food category to another in response to prey abundance fluctuation (Yatuha *et al.,* 2013). This mechanism is often followed by many fishes when a preferred food item is going down to a critical level. It could be also due to this reason that, *C. gariepinus* being a generalist feeder, selects its prey depending on availability rather than preference. This statement is further expounded by its unspecialized feeding habit illustrated by figure 18 following the

Costello's procedure and exhibited by the normalized Levin's diet breadth index (*Bn*). This means that there is a high within phenotype contribution to niche breadth, i.e., many individuals utilized most prey items simultaneously. This feeding behavior is an optimal strategy especially in habitats prone to change (Kaiser and Jennings, 2002). This feeding flexibility in *C. gariepinus* led not to have any distinct niche overlap with other piscivorous and non-piscivorous species living in the same habitat.

***H. niloticus*** **(Gelegu)**

The results of the present study showed that *H. niloticus* consumed a wide range of food items. Therefore, it confirmed a euryphagous and omnivorous feeding habit. Among the identified food categories, detritus, macrophytes and sands were the most dominant food types. From the published information describing the diet of *H. niloticus*, it is categorized as omnivore but detritus and sand particles accounted for the major food types (Adite *et al*., 2006; Odo *et al*., 2009; Adite *et al*., 2013; Edoghotu and Hart, 2014). The mouth shape and gill arrangement equipped with fine gill rakers in *H. niloticus* could aid to be bottom feeder (Bake and Sadiku, 2005). Hence, it can filter planktons and other food substances in the water and at the same time ingested large amounts of sands and mud. The high occurrence of detritus in the stomachs of *H. niloticus* also suggests its bottom feeding behavior on benthic invertebrates, which dominated the diet of this fish in rivers (Odo *et al*., 2009; Solomon *et al*., 2017). High quantity detritus also suggested that this fish species fed on dead organic matter.

In the present study, macrophytes also formed the dominant prey item in the diet of *H. niloticus*, which is third next to detritus and sand grains. This is because, floodplain rivers favored seasonal macrophytes and death in the dry season that led to detritus formation as a major diet for fishes. Wide food spectrum in this species and the significant contribution of plant material in its diet witnessed the possibility of *H. niloticus* as a candidate for aquaculture because it would not require expensive animal protein in its feed. A piscivory character was not noted for this species in the present and previous studies. The graphical illustration based on the Costello's (1990) method, the feeding strategy adapted by *H. niloticus* was more opportunistic. It was only the volumetric contribution of detritus plotted above 30% of the Costello's scatter plot and this attributed *H. niloticus* to have a small Levin's dietary breadth since the species showed a specialist feeding strategy for only this prey. It is also noted that, based on %GIIi, only detritus was the preferential prey and *H. niloticus* consumed macrophytes and insects as a secondary prey, whereas seed grains, ostracods and phytoplankton were occasionally consumed as illustrated in the lower hand right side of the GIIi diagram (Figure 17).

***L. bynni* (Ayima and Gelegu)**

Based on the present investigation, *L. bynni* adapted a polyphagous feeding habit in the Ayima and Gelegu Rivers. The most important food types identified from the guts of *L. bynni* were macrophytes and detritus. This is in agreement with the reports of Elias Dadebo *et al*. (2014) who reported that *L. bynni* consumed large amounts of macrophytes and detritus in Lake Abaya. Insects, molluscs and nematodes were also identified from the guts of this species with a different level of dietary importance. In a study made by Demeke Admassu and Elias Dadebo (1997), the diet of another *Labeobarbus spp.* (*L. intermedius*) comprised largely macrophytes, detritus, molluscs and insects in Lake

Hawassa. In Mbô floodplain river from Cameroon, *L. batesii* consumed many varieties of plant and animal origin diets as well as detritus (Tiogué *et al*., 2014).

Different morphotypes of the genus *Labeobarbus* revealed a piscivorous feeding habit (Nagelkerke *et al*., 1994; Demeke Admassu and Elias Dadebo, 1997; de Graaf, 2003). However, *L. bynni* did not show a piscivory feeding tactics in rivers of the ALNP and this assertion is supported by the study of Elias Dadebo *et al*. (2014) in which this species exclude pisces from its prey items. Since cyprinids lack teeth, stomach and hence the associated digestive enzymes, they are morphologically isolated to feed on fish, and thus, piscivory is rare in cyprinids (Matthes, 1963 cited in Demeke Admassu and Elias Dadebo, 1997). However, in the absence of specialized piscivorous behaviour, many *Labeobarbus* species may consume fish prey, especially at later stages during their ontogeny (Nagelkerke *et al*., 1994; Elias Dadebo *et al*., 2014). The presence of many piscivorous species in the Gelegu and Ayima Rivers might restrain *L. bynni* to consume on fish prey. In such ecological setups, therefore, *L. bynni* switch to fed on ostracods, molluscs, aquatic insects and macrophytes to reduce interspecific competition. This implies that the diet of fish depends on the availability of food in the environment and the relative differences in contribution of the major food items of *L. bynni* in its natural habitat could reflect seasonal variation in prey availability.

The feeding strategy plot (Figure 18) and Levin's diet breadth index suggests that *L. bynni* is unspecialized in its feeding habit and obtained prey from several trophic levels depending on prey availability. It has a high within phenotype contribution to niche breadth because many individuals utilized most prey items simultaneously. However, in contrast to other predator species, the general feeding strategy adapted by *L. bynni* in the

Gelegu River led to form a significant dietary overlap with other opportunistic feeder (*H. niloticus*) (Table 21).

***B. docmak* (Ayima)**

The food composition identified from stomachs of *B. docmak* in the Ayima River was dominated by fish prey. This finding agrees with the studies of Okach and Dadzie (1988) and Hailu Anja and Seyoum Mengistou (2001) who reported that this species was entirely piscivore during adult stages of its ontogeny in Lakes Victoria and Chamo, respectively. In areas where data are available about the feeding habits of *B. docmak* it has been reported that the dietary proportion and importance of fish prey was different (Okach and Dadzie, 1988; Hailu Anja and Seyoum Mengistou, 2001; El-Drawany and Elnagar, 2015). This implies that *B. docmak* is an opportunistic feeder and able to switch to any fish prey. The preference on available fish prey can be triggered by the predator distribution in the natural habitat. The individual contribution of *Synodontis spp*. was higher next to *B. nurse* and a similar report was made by Hailu Anja and Seyoum Mengistou (2001). This is because *B. docmak* which is a bottom dweller and prefers fish prey that live in the bottom such as *Synodontis spp.* (Hailu Anja and Seyoum Mengistou, 2001).

Cannibalism was noted in the present study. This result is in agreement with the findings of Hailu Anja and Seyoum Mengistou (2001) where large ones consume smaller specimens of the same in Lake Chamo. As suggested by the Costello’s graph later modified by Amundsens’ *et al*. (1996) illustration, the feeding strategy adapted by *B. docmak* was opportunistic, only fish prey plotted near to 100% of the occurrence and volume axes that attributed the small Levin's index of diet breadth in *B. docmak*. This flexible feeding habit followed by the species led *B. docmak* not to have any distinct dietary overlap with another piscivore species (i.e., *H. forskahlii*) in the Ayima River.

***H. forskahlii* (Ayima and Gelegu)**

*H. forskahlii* in the Ayima and Gelegu Rivers consumed varieties of food items including fish, insects, bivalves, macrophytes and detritus. Based on the GIIi of prey category, fish was a preferential prey followed by insects as a secondary prey, whilst bivalves, macrophytes and detritus were occasionally acquired food types. Similarly, insects constituted the largest volumetrical contribution of the food of *H. forskahlii* in Lake Chamo only next to fish (Elias Dadebo and Seyoum Mengistou, 2008). In the Zambezi River floodplain (Namibia), this species was largely piscivorous in its feeding habit (Winemiller and Kelso-Winemiller, 1994). According to the IFP, fish prey which accounted 90% of the total food consumed was the most important food type. Individually, the contribution of *B. nurse*, *Labeo spp.*, *A. baremoze* and Tilapia constituted the first list order of fish prey importance. However, in contrast to the present study, Elias Dadebo and Seyoum Mengistou (2008) reported that *O. niloticus* constituted the bulk of fish prey in *H. forskahlii* from Lake Chamo. Although the individual contribution of fish prey was high, *H. forskahlii* consumed a large variety of food categories and followed a generalist feeding strategy as suggested by the Costello's graphical illustration and notified by the Levin's index of dietary breadth. This feeding adaptation may be the cause for the species not to have any distinct niche overlap with fishes sharing the same habitat in the rivers.

### 4.6.3. Interspecific dietary niche overlap

The analysis showed that only three out of nine combinations (2 and 1, from Gelegu and Ayima Rivers, respectively) revealed significant dietary niche overlap in the studied fishes. The highest dietary niche overlap (91%) was estimated for the combination made between *L. bynni* and *H. niloticus* at the Gelegu River. This suggests that the two species in a combination use similar resources with a comparable proportion and there is a competitive coexistence of these species despite their extensive dietary overlap. Extensive dietary niche overlap has been suggested to occur between competitors that are similar in their skills to compete for resources (Di Prinzio and Casaux, 2012), such as when consumers differ in their foraging behavior towards the same abundant prey (Wilson *et al*., 1999). According to Di Prinzio and Casaux (2012), competitors can survive by segregating along a resource gradient if they have ample differences in their ecological niches, but they can also coexist under conditions of extensive overlap if they are highly similar in their niche utilization, and become equal competitors. Both species largely fed on plant matter especially on macrophytes and detritus. It was noted that the combinations between *C. gariepinus* vs *H. forskahlii* ($\alpha = 0.63$) and *B. docmak* vs *H. forskahlii* ($\alpha = 0.73$) reflected significant diet overlap in the Gelegu and Ayima Rivers, respectively.

It may be surprising that dissimilar species such as *H. niloticus* vs *C. gariepinus* ($\alpha = 0.51$) have diets not highly similar in the Gelegu River, but showed a nearly biologically significant dietary niche overlap. Similar to this result, two morphologically very different salmonids and a freshwater catfish had a niche overlap in Patagonian stream in Argentina (Di Prinzio and Casaux, 2012). This might be related to both species changing their food preferences during seasonal change in floodplain habitats and forced to forage almost exclusively on the other available but non preferential food types and niche overlap occurs. Their opportunistic or generalist feeding strategy followed by two coexisting fish species also attributed for the occurrence of niche overlap somewhere in the river. Generally, there was no any combination for the value of α which was 0.0 and 1.0, indicating no and complete overlap in fish diets, respectively.

### 4.6.4. Seasonal and ontogenetic dietary variation

The result indicated that the percentage in FO and volumetric contribution among the different predator size categories (small vs large) and season (dry vs wet) was not significant for all food categories. However, the contribution of some food types in the different size groups and season showed a significant variation (Figures 19 and 20). Both ontogenetic and seasonal dietary variations involved only small deviations in the relative amounts of particular prey groups eaten, and hence a complete ontogenetic or seasonal dietary variation was not clearly demonstrated in any of the species in the present study. However, there was a slight ontogenetic dietary shift in *L. bynni*, *H. forskahlii* and *C. gariepinus.*

Ontogenetic changes in prey choice and seasonal variation in the dietary importance of *C. gariepinus* was generally not very distinct. This study is supported by Yosef Tekle-Giorgis *et al.* (2016) who noted that the seasonal variation in the diet of *C. gariepinus* was slight in Lake Hawassa and Shallo Swamp (Ethiopia). Lack of dramatic ontogenetic dietary shifts in the present study, except variations observed in some particular food items may reflect that, very young stages were not captured in this study. Major prey categories occurred in the diet of all sizes and season but with a different proportion. For example, the volumetric contributions of fish were large in the smaller and intermediate size classes. Similarly insects contributed the largest food volume of the small size class and the difference with the rest of size classes was significant ($p<0.05$). In accordance with the present study, Yosef Tekle-Giorgis *et al*. (2016) observed that animal origin prey types were important for smaller size class and decreased with fish size. This may be associated with developing some physiologies related to food ingestion because plants' cellulose needs a large intestine and developed enzymatic action for digestion. However, the present study contrasts with the findings of Elias Dadebo *et al*. (2014) who reported that ontogenetic diet shift of *C. gariepinus* was clear in Koka Reservoir. The contribution of macrophytes along the different size classes was comparable. Detritus was the most important food for small size class and this finding is supported by Elias Dadebo (2009) who observed the importance of detritus in smaller sizes of *C. gariepinus* from Lake Chamo. This is because small sized fishes largely dwell in shore areas where floods load different plant materials and dead animal body parts enter to the rivers and undergoing partial decomposition.

Occurrence of major prey categories across all sizes also points to a possibility of intraspecific competition in *C. gariepinus*. Intraspecific competition is likely when a single prey occurrence is above 25% in two or more size classes of a species (Hyslop, 1980). This notion is further expounded in the present study when we consider fish prey in the diet of *C. gariepinus* (Figure 20). Seasonal fluctuation has great effect on the availability and emergence of different food items. On a seasonal observation to examine the feeding habits of *C. gariepinus*, the most important food categories that constituted the bulk food during dry season was macrophytes, whereas insects and detritus highly contributed to the dietary importance of this species during the wet season. This result is in line with the reports of Elias Dadebo *et al*. (2014) who reported the high contribution of detritus in the diet of *C. gariepinus* during the wet season and the lower contribution of fish prey in this season from Koka Reservoir.

There was no distinct variation in the diet of *H. niloticus* according to the seasons in the Gelegu River and similar report was also made by Kouakou *et al*. (2016) in Agneby River from Côte d'Ivoire. The contribution of macrophytes was higher during the dry season and this may be due to the nutrients entering into rivers during flooding, which support the rapid growth of macrophytes in the dry season. During flooding, dead plant and animal parts enter river channels and undergo partial decomposition and could provide a good feeding site for *H. niloticus* during the dry season.

Only a slight ontogenetic dietary variation was observed in some food items between the different size classes of *L. bynni*. Similarly, *L. bynni* did not show a distinct ontogenetic dietary variation in Lake Abaya (Elias Dadebo *et al*., 2014). Although some food items consumed by *L. bynni* did not vary significantly in the two seasons, however seasonal dietary variation was noted for food types like detritus, insects, and ostracods. This notion is supported by Elias Dadebo *et al*. (2014) who reported that only the contribution of some food types varied in the seasonal diet of *L. bynni* in Lake Abaya. For the smaller size class (6-20 cm, TL), only the contribution of insects and ostracods was much higher in the diet of *L. bynni*. In this size class, the contribution of gastropods was much higher and significantly different as compared to the larger size class (>31 cm, TL). This may be associated to the selective nature of small size groups towards animal origin prey types as they do not have well developed digestive structure for cellulose containing prey types. In the intermediate size range (21-31 cm, TL) the volumetric contribution of phytoplankton was significant. Large size class of *L. bynni* (>31 cm, TL) largely fed on macrophytes and detritus. These findings about the ontogenetic dietary shift of *L. bynni* are supported by Elias Dadebo *et al*. (2014) who observed a slight ontogenetic change in the diet of *L. bynni* from Lake Abaya.

### 4.7. Conclusion

The study of fish biology is very crucial for the development of successful fisheries. The LWR which is important to examine fish growth and to evaluate the fish condition because of ecological and physiological factors received a continuous attention in fisheries science. Fishing pressure coupled with harsh environmental conditions rendered by floodplain ecosystems attributed for the low wellbeing state in many fish species of the ALNP. Prey availability is not a problem in floodplain habitats. Assessment of feeding strategies of a particular fish species in an assemblage aids to investigate feeding habit of fishes and feed selection for successful aquaculture development. In the present assessment, the Costello's scatter plot and Levin's dietary breadth index suggested that all fish species examined for diet analysis showed an opportunistic feeding strategy. This flexible feeding adaptation favors many fish species to adapt the dynamic floodplain environment by reducing the onset of competition and dietary overlap between species. This feeding tactics adapted by fishes also intend to reduce an intraspecific competition and reduce the energy fishes invest for searching rare prey in their habitat. In the present assessment, only some food items in predator fishes showed variation in dietary importance due to season and size differences. However, no clear distinct dietary variation based on season and size class differences was apparent in the studied fishes.

# CHAPTER FIVE

## 5. Assessment and toxicity evaluation of the commonly used piscicide plant 'Desert date' *Balanites aegyptiaca* on adults of three different fish species

### 5.1. Introduction

The incidence of using piscicides to catch fish is part of the traditional fishing knowledge which is not 'environmentally friendly' to the aquatic ecosystem. Plant piscicides are among the widely used traditional fishing methods, which are biodegradable and less severe than synthetic piscicides (Onusiriuka and Ufodike, 1998; Neuwinger, 2004). This has proven that plant extracts used for poison fishing is considered advantageous when viewed against the persistent synthetic piscicides (Neuwinger, 2004; Fafioye, 2005). In tropical Africa over 325 poison fishing plant species are commonly used to catch fish (Neuwinger, 2004). In Ethiopia, 17 plants with piscicidal properties are included in the Neuwinger's catalog.

In developing countries, indigenous knowledge of fishers and fishing communities can be used as source of information to document piscicidal plants. Plant parts having active ingredients such as barks, roots, fruits, pods, etc identified by the local fishers may be pounded and used as poison fishing besides phytochemical extraction (Yumnam and Triphati, 2013). The active ingredients released by mashing the appropriate plant parts and introducing them into small stagnant pools or in slow flowing rivers are the usual fishing practices using piscicides. These active compounds are toxic to fish because they are absorbed directly into the blood stream via gills, whereas it can be easily detoxified in the gut by digestive enzymes in most organisms including humans, mammals and birds (Idris, 2012). As a function of secondary metabolites, toxin saponins and rotenones function in plant defenses, protecting the plants from phytopathogenic microorganisms (Pelah *et al*., 2002). However, the historical procedures in mankind lead people to use such toxins to stun, stupefy and eventually kill fish and other organisms. Fish caught using such methods are considered as safe by fishermen for consumption as they have no immediate associated health risks (Neuwinger, 2004; Fafioye, 2005; Mungenge *et al*., 2014).

Although prohibited, plant piscicides used to catch fish, are used throughout Africa (Abebe Ameha, 2004; Fafioye *et al*., 2004; Neuwinger, 2004; Fafioye, 2005; Ekpendu *et al*., 2014). Fishermen living in areas where gears are not available are very well aware that poisoning implies killing of many small fish, but often see it as an emergency method to alleviate hunger (Van Andel, 2000). Thinking the disadvantages of spending a long time for fishing in the rivers and the probability of back home with no catch while using recommended gears, fishers are deceived to use piscicides as effective fishing method in most areas of Ethiopia and the practice is now increasing alarmingly (Tesfaye Wudneh, 1998; Abebe Ameha and Alemu Assefa, 2002; Abebe Ameha, 2004). Fishermen of the ALNP use different piscicides for fishing. However, plant piscicides are largely used by the fishing communities as they are easily available and cost effective. This traditional and destructive fishing technique is exercised and effective during the dry season when floodplain rivers form small water sections or pools. In addition to be used as a piscicide, toxic plants are also used in making spears and arrows for hunting and warfare. An observation made for this study revealed that the Gumuz society in Ethiopia use these plants for making pointed arrows and spears for hunting, fishing and fighting.

Many researchers have worked on assessing and documenting plants used for fishing. For example, Kamalkishor and Kulkarni (2009) surveyed fish stupefying plants used by the Gond tribe in India, Van Andel (2000) assessed poison fishing plants in northwest Guyana, and Ekka (2016) accounted plant piscicides used by fishers of the Oraon Tribes of northeast India. Ekpendu *et al*. (2014) assessed and prepared a checklist for piscicide plants used by fishers in Nigeria. However, to the best of our knowledge no work has been done so far on the survey of these botanical piscicides in Ethiopia. Therefore, this research attempts to survey and document different plant and synthetic piscicides used for poison fishing in the ALNP area and to recommend some management options.

Studies have been conducted about the responses of different fish to some piscicide plants (Abebe Ameha, 2004; Singh and Yadav, 2010; Agbor and Okoi, 2014; Abalaka *et al*., 2015; Ekpendu *et al*., 2014), but the piscicidal effect of *B. aegyptiaca* is limited (Absalom *et al*., 2013; Alhou *et al*., 2016). The acute toxicity levels of *B. aegyptiaca* on fish has not been investigated in Ethiopia but extensively used by fishermen of the ALNP. Therefore, in the present study, documenting plants with piscicidal properties in the ALNP area was made and the median lethal concentration ($LC_{50}$) of the aqueous stem bark extract of *B. aegyptiaca* was evaluated on adults of different fishes and the result can be used for policy makers and authorities to enforce laws and regulations. Otherwise, its indiscriminate use could affect the biodiversity.

Specific objectives are to:

- identify potentially toxic piscicides used by fishers of the ALNP
- determine the level of toxicity responses of different fishes exposed to *B. aegyptiaca* stem bark extract

### 5.2. The 'Desert Date' *Balanites aegyptiaca*

#### 5.2.1. Taxonomy and description

*B. aegyptiaca* (L.) Del. is a dicotyledons fruit bearing perennial multi-branched spiny tropical plant that belongs to the family Balaniteceae. The genus was placed in different families by various taxonomists. However, today due to its peculiarity, Takhtajan (1969) placed the plant as the only genus in the abovementioned family. *B. aegyptiaca* has various names by different languages; 'desert date' and 'spiny tree' (English), "lallob" and "kudekuda" (Amharic) and "heglig" (tree) and "lallob" (fruit) (Arabic). The tree is widely grown in the Sudano-Sahielian region of Africa, the Middle East and South Asia (Hall and Walker, 1991). The plant also forms an open forest in the northwestern lowlands of Ethiopia adjacent to the Sudan border. The tree is single stemmed, dark brown to grey and deeply fissured (Plate 3, left). The leaves are alternate with broadly pointed petioles (Yadav and Panghal, 2010) and flowers are small, bisexual and greenish white in color (Chothani and Vaghasiya, 2011). The spines of this tree are simple, straight, rigid, alternate and supraaxillary. The fruit is long, narrow drupe and young ones are green and tormentose, while turning yellow and glabrous when mature (Plate 3, right). The fruit has a strong bitter taste at early ripe and becomes much tasty when ripe and consumed by local communities in the lowlands of northwestern Ethiopia (pers. obs.).

**Plate 3**. *B. aegyptiaca* tree (left) around Shinfa River and ripe fruit (right) collected from the Derhassen Village in the Gelegu River close to the ALNP (photo taken during surveying and collection).

### 5.2.2. Phytochemical constituents and pharmacological uses

The phytochemistry of different parts of *B. aegyptiaca* has revealed various ingredients. The aqueous extract of the fruit mesocarp has tannin, flavonoids and cardiac glycosides (Mariam *et al*., 2013). Saponins are also potential constituents of this xerophytic tree consisting of sugar residues (one or more units of glucose, galactose, etc) (Chapagain and Wiesman, 2007) linked through oxygen multiring compounds usually containing large amounts of carbon atoms (Yadav and Panghal, 2010). The root extracts of the plant yield Balanitin 1, 2 and 3, alkaloids and diosgenin (Elfeel, 2010; Hassan *et al*., 2017). The presence of potentially toxic extracts such as alkaloids and saponins which are equivalent to rotenone, show piscicidal properties of the plant (Absalom *et al*., 2013).

Different parts of the plant have been reported to posses various medicinal uses to treatment of syphilis, leucoderma, malaria, wounds, aches, liver and spleen diseases (Chothani and Vaghasiya, 2011; Hassan *et al*., 2017; Khalil *et al*., 2016). This plant is well known by the traditional herbal medicinal knowledge in Africa (Table 22). The boiled root of the plant can be used as a soup against stomach pain, anthrax, and the infusion of root also acts as an antidote to snake bite in Nigeria (Ojo *et al*., 2006). In the ALNP area, people use different parts of this plant (fruits and stem barks) for removing lice and other parasites from hair, body and clothes. The responsible toxicity for lice removal might be due to its soapy nature and produces whitish foam when soaked in water (Plate 4, right). The fruit and stem bark of this plant has been also used as poison fishing in considerable parts of Africa and Asia (Newinger, 2004; Kamalkishor and Kulkarni, 2009; Absalom *et al*., 2013; Alhou *et al*., 2016; Krishan, 2016). Fishermen of the ALNP use fruits and stem barks of *B. aegyptiaca* for poison fishing in the rivers during the dry season.

In developing countries, the plant is used for food preparation besides its traditional role in herbal medicine. In many parts of Africa, fruits of the 'Desert date' is mixed into porridge and eaten by nursing mothers to improve lactation (Chothani and Vaghasiya, 2011; Kamal, 2014). Fruits of *B. aegyptiaca* are a constituent of the diet among Gumuz ethnic groups in northwestern Ethiopia.

**Table 22**. The pharmacological activity of *B. aegyptiaca*, parts used and with sources of information in different parts of Africa.

| Country | Plant part | Use | Reference |
|---|---|---|---|
| Senegal, Nigeria, Morocco, Ethiopia | Fruit | purgative for colic and stomachache | Chothani and Vaghasiya, 2011; Kamal, 2014 |
| Egypt | fruit mesocarp | antidiabetic | Gnoula *et al*., 2008 |
| Sudan | fruit kernel | treat skin diseases | Albadawi, 2010 |
| Kenya | root infusion | emetic | Kamal, 2014 |
| Ethiopia | Fruit | treating mental illness, epilepsy, yellow fever, jaundice, syphilis and snake bite | Mr. Kaku; pers. comm. |
| Uganda | fruit | a therapy for sleeping sickness | Cushny, 1908 |

## 5.3. Materials and Methods

### 5.3.1. Description of the study area

The study was conducted along the river courses of the ALNP in Quara Woreda, in West Gondar (formerly North Gondar) Zone of ANRS, northwestern Ethiopia. Quara Woreda is located between 11°47′ to 12°41′ N latitude and 35°16′ to 36°30′E longitude in the northern part of the Great East African Rift Valley. The entire area is situated at the border line of the eastern Sudan with the average elevation range of 530-1900 m a.s.l. The annual average temperature ranges from 26°C to 42°C with an overall average of 32°C and rainfall of 500-1500 mm spreading over 4-5 (3 months effective rain). The large portion of the area is delineated as a national park by the ANRS in 2006 supported by the Council of Ministers Regulation No.541/2007. The ALNP is covered by a large forest that provides substantial bulk for livelihood ranging from food, fuel, fodder to medicine. Plants of this region are also used for poison fishing in the traditional fishing societies of the area. The study mainly includes plant collection, identification, individual and group discussion and observation of the fishing events on the rivers of the ALNP. Helped by elderly and fishers, along the river courses of the ALNP, major poison fishing piscicide plants used were identified and documented.

### 5.3.2. Experimental design

The experimental setup consisted of seven rectangular geo-membrane lined ponds with 1 m x 0.5 m and with a depth of 0.5 m; each filled with 100 L river water (Plate 4). Among the seven experimental ponds, one was left empty during toxicity commencement and used as a control.

**Plate 4**. Test ponds (left) and whitish foam appeared on pond water (right) after commencement of toxicity test.

To reduce the rate of evaporation and to eliminate direct sunlight exposure, the ponds were covered with geo-membrane, fresh plant leafs and dried grasses. The water was pre-aerated through stirring for some time to full oxygen saturation before addition of the different concentration grades of the plant extract.

### 5.3.3. Collection and preparation of plant extract

The stem barks of *B. aegyptiaca* were collected from the Derhassen Village following the Gelegu River course near the ALNP at Quara Woreda in December 2017. Pre-assessment questionnaires developed for fishermen about fishing activities using plants led us to select this plant for toxicity evaluation. Fresh stem bark maceration of the plant was exclusively followed as fishermen do in the ALNP area. Stem bark were obtained from the wild, sliced into smaller sizes using a knife, sickle and an axe and then ground to a fine powder using a stone and wooden mortar with pistil. Only river water was used for mashing and extraction. The extract and solid plant materials were separated by hand squeezing using cheesecloth. The plant extract was used immediately after extraction to ensure its freshness. The different test concentrations prepared from aqueous extracts of *B. aegyptiaca* and used for the experiment are summarized in table 25.

### 5.3.4. Test fish collection, acclimatization and test procedures

Beach seine, mosquito nets, traps and castnets were used to collect live and active fishes in the wild from the Gelegu River for the experiment. The candidate fish specimens were acclimatized for 4 days before toxicity commencement in a pond (2.5 m x 2.5 m with a depth of 0.5 m) having water diverted from the river for this purpose. Test fishes were selected based on pre-assessment questionnaire conducted on fishers about plant poison fishing and the prerequisite observation made at fishing grounds from April 2015 to December 2017 by the investigators. Therefore, based on the reconnaissance study proposed for the experiment, the most affected and easily stupefied fish groups, economically viable species, readily available for test individual and species with important ecological role (i.e., in feeding relation) were selected. 'Healthy' adults of *B. nurse*, *L. intermedius* and *L. bynni* were used for the experiment. During the experiment, pond water was changed and carefully washed to remove previous piscicide residue and ready for the next experiment for another test organism or individual. To reduce the effect of size, all test specimens of a species had comparable size. The individuals of *B. nurse* (n=77) with a mean of 165±0.18 g and 17.5±0.25 cm, total weight (TW) and total length (TL), respectively; *L. intermedius* (n=77) with a mean of 245±2.30 g and 22.3±1.26 cm, TW and TL, respectively and *L. bynni* (n=55) with a mean of 226±3.8 g and 21.2±2.6 cm, TW and TL, respectively were used for the experiment. 7 test individuals per extract were used but 5 with *L. bynni* due to a limited sample.

The acclimatized individuals were recollected using scoop nets and then distributed to the experimental pond and exposed to different level of concentration: C1=0.00 (control), C2=15.00, C3=17.50, C4=20.00, C5=22.50 and C6=25.00 $mgL^{-1}$ of the pounded and powdered *B. aegyptiaca* poison extract based on the Organization for Economic Cooperation Development (OECD) guideline No. 203 (OECD, 1992) in duplicates over a 96 h period. Pilot tests were carried out to establish range finding concentration grades used for the actual experiment along with the control as described by Environmental Protection Authority (EPA, 1996). The results of this pilot test led to preparing the abovementioned five serial concentration levels and a control (C1-C6) of *B. aegyptiaca* stem bark aqueous extract for a static bioassay acute toxicity test. Throughout the time of the whole experiment, changes on physical stress of test individuals were recorded. A fish is considered affected by the plant toxicant when it manifests erratic swimming, hyperactivity, hyperventilation and pronounced ataxia coinciding with decreased capacity to respond to visual stimuli.

### 5.3.5. Median lethal concentration ($LC_{50}$) estimation

As an end point of toxicity action, fish mortalities were observed and recorded at every 8 h throughout the 96 h toxicity test as recommended by OECD (OECD, 1992). When a fish did not respond to any mechanical prodding it is proven to be dead and removed from the pond after recording to prevent body decomposition and hence pond suffocations.

The median lethal concentration ($LC_{50}$) which is the concentration at which 50% of the test fish survived was calculated for each of the test species. The $LC_{50}$ which is the basis of most toxicity tests was determined using dose response mechanisms of the piscicide and test animal over the 96 h exposure period and calculated using the method of Karber adapted by Dede (1992):

$$\mathbf{LC50 = LC100 - \frac{\Sigma\ probit}{No.\ of\ fish\ per\ extract\ concentration}}$$

Where, $LC_{100}$= Extract concentration with 100% fish mortality occurred.

### 5.3.6. Pond water quality monitoring

Throughout the whole toxicity bio-assay experiment, pond water quality parameters such as EC, DO, pH, and temperature were measured before and after toxicity commencement in every 8 h using a multimeter probe (HQ 40d).

### 5.3.7. Ethical statements

Experimental procedures involving handling of experimental animal was in accordance with the standard practice as specified in the OECD and EPA guidelines (OECD, 1992; EPA, 1996). The present investigation was carried out in the field. Prior to the experiment, letter of permission to do the experiment was issued by the Quara Woreda Agriculture and Rural Development Office (QWARDO). The procedures and all tasks of the experiments were approved by the extension core process committee of the office declared and assigned as an ethical committee by stakeholders to evaluate the test procedure. The committee made intermittent observations throughout the whole experimental period. Test fishes used for this study are not in a red list category yet in the Ethiopian context.

### 5.3.8. Data analysis

Descriptive statistics were used to determine the total percentage mortality of the test fishes. Data were presented as means (±SD) and also subjected to one-way analysis of variance (ANOVA) for statistical significance at $p<0.05$. The mortality response of different fishes exposed to *B. aegyptiaca* stem bark extract was subjected to probit analysis for a linear regression method (Finney, 1971) to establish the $LC_{50}$ of the treatment effect on exposed fish using Microsoft Excel (Agresti, 1990). Physico-chemical parameters of water in each treatment and control pond were compared by one-way ANOVA. All the statistical tests were carried out using SPSS version 20.0 package software and Microsoft Office Excel 2007.

## 5.4. Results

### 5.4.1. Piscicides used by fishers of the ALNP

A total of 9 different piscicidal plants, 2 synthetic chemicals and other byproducts used for poison fishing in the ALNP are identified and presented in table 23.

**Table 23**. Botanicals and non botanical piscicides used by fishers of the ALNP.

| **I. Plant piscicides** | | | | |
|---|---|---|---|---|
| Name of the plant | Common name | Local name(s) | Habitat | Parts used |
| *Balanites aegyptiaca* | Desert date | Lallob/Kudekuda | Tree/shrub | Barks/ fruits |
| *Milletia ferruginea* | | Birbira | Tree | Seeds |
| *Combretum molle* | Velvet bushwillow | Chariya | Tree | Barks |
| *Tamarindus indica* | Tamarind | Kumer | Tree | Fruit/bark |
| *Euphorbia candelabrum* | Candelabra | Qulqual | Tree | Latex |
| *Adenia cissampeloides* | Monkey rope | Leza/Hareg | Shrub | Whole (crushed) |
| *Myrica salicifolia* | | Shinet/Kalava | Tree | Leaf |

| | | | | |
|---|---|---|---|---|
| *Aloe vera* | Indian Aloe/first aid plant | Erret | Shrub | Whole plant |
| *Datura stramonium* | Jimsonweed/devil's snare | Attefaris/Astenag ir | | Whole plant |

**II. Synthetic piscicides**

| Name of synthetic piscicide | Common name | Local name | Main use | Ways of using as piscicide |
|---|---|---|---|---|
| Dichlorodiphenyltrichloroet hane | DDT | Merz | Pesticide | Paint on sand or maize |
| Malathion | Carbophos/ mercaptothion | Merz | Insecticide | Paint on crushed maize |
| Goat manure | | Tifirfiriya | Fertilizer/ fire | mashed with kerosene |
| Traditional alcohol ("Tella") by product | | Attela | Animal food | Pouring into a water section |
| Fire remains | Ash | Amed | Fertilizer | Tide and soaked into water |

### 5.4.2. Pond water physico-chemical parameters

Measurements of pH range, temperature ($T^0$), dissolved oxygen (DO) and electrical conductivity (EC) of experimental ponds are provided in table 24. The test pond water physico-chemical parameters of the test ponds were measured and recorded before fish introduction and taken every 8 h throughout the exposure period (Table 24). Mean values of the parameters during acute exposure of different fish species to *B. aegyptiaca* stem bark have shown slight fluctuations (Table 24). In all the treatment ponds, DO values decreased slightly but insignificant ($p>0.05$) with increasing extract concentration. EC values were increased at higher concentrations of the toxicants and significantly different ($p<0.05$) compared to the control with the highest values at concentration of 25.00 $mgL^{-1}$.

Temperature values did not show a significant variation ($p>0.05$) but slightly increased with increasing concentration (Table 24). pH values showed changes and decreased at higher concentration with significant difference from the control ($p<0.05$). In all the treatment ponds, the water quality parameters determined showed no significant differences ($P>0.05$) between the concentration levels of *B. aegyptiaca* and the control but pH and EC.

### 5.4.3. Observed behavioral responses of fishes to test concentrations

Fish exposed to the different concentration levels of aqueous extract from stem bark of *B. aegyptiaca*, stirred into the water, exhibited hyperactivity characterized by darting, rapid opercular movement, held mouth wide open and kept the fins stretched laterally. These responses were species specific and on average, after 5 to 10 minutes, this restlessness subsided in all species and later the fish settled at the bottom. The first symptom of loss of sensitivity (response) was characterized by rising of the fins and was highly pronounced in the *L. intermedius* and *B. nurse*. Then, a rigorous and mostly superficial movement of the fins and rapid respiration was observed. Fish aggregated at the air-water interface gasping for air with their mouth permanently opened and this response was frequent in *B. nurse* and *L. bynni*.

On average after 6-10 h, there was discharge of mucus through the gills and a mucus layer was formed on eyes and all over the body. As time passed, normal colors of the fish were changed. *L. bynni* and *B. nurse* were discolored and remained in the state of exhaustion, did not respond to external stimuli and remained diagonally suspended in the water. Later on the fishes loss body equilibrium and have shown turning over the back.

Then, attempts were made to avoid the toxic medium by bumpy swimming, jumping out of water followed by accelerated and arrhythmic respiration, but slowly the movements were staggered, mouth was slightly opened, fins and tail become rigid. These behavioral deviations were more pronounced with increasing concentration and it was species specific and extreme on *L. bynni* followed by *B. nurse* and lastly by *L. intermedius*. Finally, fish died and mortality increased with increasing concentration (Table 24). No strange behavioral responses were observed on individuals kept in the control pond.

**Table 24**. Mean±SD (range in parenthesis; measured 12 times in the 96 h) of water physico-chemical parameters in the pond exposed for aqueous extract stem bark of *B. aegyptiaca* and the control.

| Parameter | After/ before toxic addition | Concentration level ($mgL^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.00 | 15.00 | 17.50 | 20.00 | 22.50 | 25.00 |
| pH | Before | 7.2 | | | | | |
| | After | | 7.9±0.44 (7.7-8.8) | 6.8±0.47 (6.2-8.7) | 7.41±0.37 (7-8.1) | 7.23±0.48 (6.9-7.3) | 7.08±0.6 (7-7.6) |
| Temp. ($^0C$) | Before | 27.4 | | | | | |
| | After | | 27.80±0.89 (27.2-30.2) | 28.65±0.89 (27.5-30) | 28.09±0.47 (27.8-29.1) | 28.38±0.74 (27.8-31.6) | 28.9±0.8 (28.6-31) |
| DO ($mgL^{-1}$) | Before | 7.60 | | | | | |
| | After | | 6.80±0.27 (6.6-7.2) | 6.9±0.26 (6.8-7.4) | 6.3±0.27 (6.0-6.6) | 6.0±0.34 (5.6-6.8) | 6.0±0.74 (5.6-6.5) |
| Cond. (µS/cm) | Before | 270 | | | | | |
| | After | | 280.17±11.13 (279-293) | 285.83±9.46 (280-300) | 289.42±7.1 (276-293) | 284.83±9.98 (270-300) | 291.46±12.31 (276-298) |

### 5.4.4. Average mortality and $LC_{50}$ of test individuals

There was complete (100%) mortality in fishes exposed to the highest concentrations of 25.00 $mgL^{-1}$ in the first 24 h, while the least mortality of 28 to 35% (species specific) was recorded in fishes exposed to the lowest extract concentration of 15.00 $mgL^{-1}$ (Table 25). The acute lethal concentration after 96 h showed that 40, 60, 80, 90 and 100% mortality of *L. bynni* occurred at concentrations of 15.0, 17.5, 20.0, 22.5 and 25.0 $mgL^{-1}$, respectively representing C2, C3, C4, C5 and C6. These concentration levels in the order brought mortality in *L. intermedius* by amounts of 36, 43, 64, 93, and 100%. The 29, 57, 71, 86 and 100% deaths in *B. nurse* were also due to these concentration levels. However, no mortality was recorded in the control (C1) of all test fishes during the 96 h test period (Table 25).

**Table 25**. Percentage mortality of fish species exposed to various acute concentrations of stem bark extracts of *B. aegyptiaca*; Conc. = concentration; **R1** and **R2** are duplicates of the experiment.

| **Test fish** | **Con. ($mgL^{-1}$)** | **Log of conc.** | **Treatment** | **Exposure time (hrs)** | | | | **Total mortality** | **% mortality** |
|---|---|---|---|---|---|---|---|---|---|
| | | | | **24** | **48** | **72** | **96** | | |
| | C6 | 1.39 | R1 | 3 | 4 | 0 | 0 | 7 | 100 |
| | | | R2 | 4 | 2 | 1 | 0 | 7 | |
| | C5 | 1.35 | R1 | 1 | 3 | 2 | 0 | 6 | 85.71 |
| | | | R2 | 1 | 0 | 3 | 2 | 6 | |
| | C4 | 1.30 | R1 | 2 | 1 | 4 | 0 | 7 | 71.43 |
| | | | R2 | 0 | 2 | 1 | 0 | 3 | |
| *B. nurse* | C3 | 1.24 | R1 | 0 | 1 | 2 | 1 | 4 | 57.14 |
| | | | R2 | 1 | 1 | 1 | 1 | 4 | |
| | C2 | 1.18 | R1 | 0 | 0 | 1 | 1 | 2 | 28.57 |
| | | | R2 | 0 | 1 | 0 | 1 | 2 | |
| | C1 | 0.00 | R1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | R2 | 0 | 0 | 0 | 0 | 0 | |

| Test fish | Con. ($mgL^{-1}$) | Log of conc. | Treatment | Exposure time (hrs) | | | | Total | % mortality |
|---|---|---|---|---|---|---|---|---|---|
| | C6 | 1.39 | R1 | 2 | 3 | 0 | 0 | 5 | 100 |
| | | | R2 | 3 | 1 | 1 | 0 | 5 | |
| | C5 | 1.35 | R1 | 1 | 1 | 2 | 0 | 4 | 90 |
| | | | R2 | 2 | 0 | 1 | 2 | 5 | |
| | C4 | 1.30 | R1 | 0 | 1 | 2 | 1 | 4 | 80 |
| *L. bynni* | | | R2 | 1 | 1 | 2 | 0 | 4 | |
| | C3 | 1.24 | R1 | 0 | 1 | 0 | 2 | 3 | 60 |
| | | | R2 | 1 | 1 | 0 | 1 | 3 | |
| | C2 | 1.18 | R1 | 0 | 1 | 0 | 1 | 2 | 40 |
| | | | R2 | 0 | 0 | 0 | 2 | 2 | |
| | C1 | 0.00 | R1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | R2 | 0 | 0 | 0 | 0 | 0 | |
| | C6 | 1.39 | R1 | 2 | 4 | 1 | 0 | 7 | 100 |
| | | | R2 | 2 | 2 | 3 | 0 | 7 | |
| | C5 | 1.35 | R1 | 2 | 1 | 3 | 0 | 6 | 92.86 |
| | | | R2 | 3 | 3 | 1 | 0 | 7 | |
| | C4 | 1.30 | R1 | 2 | 0 | 1 | 2 | 5 | 64.29 |
| *L.* | | | R2 | 1 | 2 | 0 | 1 | 4 | |
| *intermedius* | C3 | 1.24 | R1 | 0 | 0 | 1 | 2 | 3 | 42.86 |
| | | | R2 | 0 | 1 | 1 | 1 | 3 | |
| | C2 | 1.18 | R1 | 0 | 0 | 0 | 2 | 2 | 35.72 |
| | | | R2 | 0 | 0 | 2 | 1 | 3 | |
| | C1 | 0.00 | R1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | R2 | 0 | 0 | 0 | 0 | 0 | |

NB. Results of two replicate over 96 h.

Mean mortality increased significantly ($p<0.05$) with extract concentrations but changes were insignificant with exposure period. The highest mortality was recorded for all test fish species in C6 within the first two recording hours. The $LC_{50}$ of the aqueous extract of *B. aegyptiaca* for the test fish species over the 96 h exposure period was calculated to be: 18.832, 20.72 and 20.72 $mgL^{-1}$ for *L. bynni, L. intermedius* and *B. nurse,* respectively (Table 26).

**Table 26**. Lethal median concentration ($LC_{50}$) of *B. aegyptiaca* on a 96 h acute toxicity exposure of the different test fishes.

| Test fish | Concentration levels ($mgL^{-1}$) | Log of concentration | %Mortality | Probit | $LC_{50}$ ($mgL^{-1}$) |
|---|---|---|---|---|---|
| *B. nurse* | C1 | 0.00 | 0 | 0 | |
| | C2 | 1.18 | 28.57 | 4.43 | |
| | C3 | 1.24 | 57.14 | 5.18 | |
| | C4 | 1.30 | 71.43 | 5.55 | 20.724 |
| | C5 | 1.35 | 85.72 | 6.05 | |
| | C6 | 1.39 | 100 | 8.72 | |
| *L. intermedius* | C1 | 0.00 | 0 | 0 | |
| | C2 | 1.18 | 35.72 | 4.62 | |
| | C3 | 1.24 | 42.86 | 4.81 | |
| | C4 | 1.30 | 64.29 | 5.37 | 20.720 |
| | C5 | 1.35 | 92.86 | 6.44 | |
| | C6 | 1.39 | 100 | 8.72 | |
| *L. bynni* | C1 | 0.00 | 0 | 0 | |
| | C2 | 1.18 | 28.57 | 4.75 | |
| | C3 | 1.24 | 42.86 | 5.25 | |
| | C4 | 1.30 | 85.72 | 5.84 | 18.832 |
| | C5 | 1.35 | 85.72 | 6.28 | |
| | C6 | 1.39 | 100 | 8.72 | |

## 5.5. Discussion

### 5.5.1. Piscicides used by fishers of the ALNP

Different plants having piscicidal properties are used by fishers of the ALNP. Fabaceae is the most dominant plant family used as poison fishing in the ALNP area. This is in accordance with the findings of Neuwinger (2004) and Yumnam and Tripathi (2013) who reported large numbers of piscicidal plants belonging to this family. Plant piscicides as an easy method of fishing have been extensively used from time immemorial in Ethiopia (Tesfaye Wudneh, 1998; Neuwinger, 2004). According to Neuwinger (2004) about 17 species of plants are recognized as having piscicidal property in Ethiopia and used in coastal areas of the country. Among the different plant species used for poison fishing in

Ethiopia, *B. aegyptiaca* and *M. ferruginea* are the commonly used potentially active plant piscicides for fishing. Many of the piscicide plants used by fishers of the ALNP are also used by fishers of other African and Asian countries. For example, in Nigeria fishermen regularly used *Adenium obesum* and *B. aegyptiaca* for fishing (Amos and Ngadina, 2015). The tribal society of India used *M. ferruginea* and other plants for poison fishing (Das *et al*., 2018). Among the different piscicide plants used for fishing in the ALNP, *B. aegyptiaca* is grown near the river sides of the area and largely used as an effective poison fishing during the dry season. In accordance with the present finding, *B. aegyptiaca* is in the first listing order among the piscicide plants widely used in Africa and Asia (Neuwinger, 2004; Dominic and Ramanujam, 2012; Abalaka *et al*., 2015). Therefore, the efficacy of this commonly used plant piscicide was evaluated and found to be more toxic than other plant piscicides evaluated on different fish species (e.g., Neuwinger, 2004; Absalom *et al*., 2013; Alhou *et al*., 2016).

Indigenous knowledge of fishers from their forefathers led them to use plants for poison fishing. The use of various plant parts such as leaves, roots, barks, fruits, etc. irrespective of habit of the plant or even whole plant for poison fishing and hunting by various traditional communities is also reported (Van Andel, 2000; Abebe Ameha, 2004; Neuwinger, 2004; Kamalkishor and Kulkarni, 2009). Our personal observation indicated that, the stem barks of plants are the most commonly used plant part for poison fishing by the fishing communities of the ALNP. This may be due to that barks are available at anytime and anywhere, while leaves and fruits shed during the dry season. The plant part used for fishing is collected from the wild and pounded on a rock and the crushed pieces are then sprayed into small water hole or “Bahir” formed during dry season (see Figure

22, for detail fishing procedures using piscicides in the ALNP). Some of the easily stupefied fishes using piscicidal plants in the ALNP area are species of *Labeobarbus*, *Labeo* and some other Alestids. Sometimes, fruits of piscicidal plants are collected and fishers dig small holes near the river and soaked (for fermentation) for a few days and poured into a small water pool. After discharging or pouring the water soaked piscicide, fishes come out and stunned, then easily harvested by mosquito nets or hand (Plate 5).

Fishermen perceived that harvesting becomes very important using natural resources or plant piscicides. These activity needs sometimes a short cut way to reduce an intensive work force required during fishing. This is because fishing especially in small-scale fishery is a very labor intensive activity and people sometimes spent long time for fishing and they sometimes come back home with no catch. In this regard people intend to develop traditional knowledge of poison fishing using plants. In some traditional and tribal inhabitants all over the world, some botanicals collected from the wild are used to catch fishes are largely being practiced in remote areas (Das *et al*., 2018) and even some are purposely cultivated (Neuwinger, 2004). In Ethiopia, the ALNP region is amongst the remote areas where conservation activities are not always effective. This may be due to its remoteness coupled with road inaccessibility is difficult to provide fishing gears for fishers and conservation stakeholders cannot make regular follow up. Therefore, fishers of the peripheral and coastal areas of Ethiopia have no access of finding fishing gears and are with no option forced to use the traditional and banned fishing techniques.

Actually fishers of the ALNP can find and use old gillnets imported from the nearby markets of the Sudan (Ashagrie Fetene, pers. comm.). However, fishers blame that these nets have small mesh sizes and only catch small specimens while local markets need large sized fishes. These used nets are too weak and easily damaged by crocodile when set for an overnight (pers. obs.). These gears are imported illegally and very expensive that many fishers cannot afford. Therefore, arrows and poison fishing are being used largely by the local fishermen to harvest large sized fishes to sell with a good price in the local markets. Fishing using piscicides is prohibited and fishers add them into water during night or early in the morning. According to the perceptions of local fishermen, piscicide fishing is relatively easy to operate and only requires fishers to spend a short fishing time in rivers. This fishing practice is largely important for part time fishers of the ALNP where their major primary income depends on crop production. Thus piscicide fishing becomes more appropriate for such fishermen who did not need to waste much time for such additional business (i.e., fishing).

### 5.5.2. Pond water quality

The analysis showed that pH and EC in the test ponds differ significantly from the control. The pH of the water samples varied from concentration to concentration and the values obtained for the different treatments, however, were within the standard given by WHO (2004) for fish survival. The decline in pH with time and concentration may be due to the production of acidic products of metabolism by the plant material in water. EC increased across the different concentration level and this may be due to the chemical composition of *B. aegyptiaca* responsible for conductivity (Abalaka *et al.*, 2014).

In the present study, there was insignificant decline in DO within the 96 h experiment period. Treatments with higher concentration of the plant extract had lower DO which can be attributed to the chemical oxygen demand of the extract. Further drop in DO concentrations might be attributed to the oxygen consumption of the test fishes (Fafioye, 2005). Edafe and Vincent-Akpu (2016) reported that anoxic state or reduction in DO content in a bioassay media as toxicant concentration increase may be due to antioxidant property of the toxicant. The physico-chemical parameters monitored in this study have contributed little or none to the toxicity of *B. aegyptiaca*. This implies that it was only the piscicidal property of the plant independent of test condition which brought odd behavioral responses and death on test fishes.

### 5.5.3. Behavioral response of fishes to test concentrations

All the test fishes used for the current experiment showed a different degree of response against the acute concentration of *B. aegyptiaca* stem bark extract. Adults of *L. bynni*, *L. intermedius* and *B. nurse* when exposed to aqueous extract of *B. aegyptiaca* bark for short term exposure showed behavioral responses and finally followed by death. This has proven that the plant extract disrupted the normal behavior and physiology of test fishes. Toxicities of the plant extract for test fishes varied with concentration levels and with exposure time. All fishes subjected to higher concentration levels (C4, C5 and C6) appeared in a more distressed condition at first, jumping over the surface and gasping air then they became inactive followed by loss of balance and finally sank to the bottom. However, at lower concentrations (C2 and C3), such physical distress was recorded only for *B. nurse* within a short time of exposure and the other test fishes showed such behavioral actions after long exposure.

The respiratory distress in test fishes was characterized by frequent opercular movements and air gasping with the continuous exposure of snouts above pond water levels. These symptoms of respiratory distress might be happened due to excessive mucous coating of gill epithelia surfaces. The initial increase in opercular movement can be taken as index of the suffocation stress felt by the fishes exposed to toxicity levels (Ferdous *et al*., 2018) and attempted to increase ventilation rates to compensate for low oxygen uptake (Fernandes and Mazon, 2003) by passing large volume of water over gill surfaces at faster rates (Reebs, 2009). This is besides the engagement of aerial mode of respiration to disengage gill respiration and by implication, prevent continuous gill contact with the toxicant (Absalom *et al*., 2013). Fishes kept in the control were free from such type of behavioral responses and therefore only the plant extract was responsible for the altered behavior and fish mortalities.

The behavioral responses against acute concentration of *B. aegyptiaca* observed in the current studies are in tandem with earlier findings of Ufodike and Omoregie (1994), Absalom *et al*. (2013), Abalaka *et al*. (2014) and Alhou *et al*. (2016). In addition to respiratory distress, the test fishes exhibited increasing states of motionlessness, adoption of different postures, sudden darts, slow sluggish movements and ataxia. These might be due to the acetylcholinesterase inhibition property of the piscicide plant as similar hyperactivity, uncoordinated movements and inhibited acetylcholinesterase activity was reported in *O. niloticus* exposed to aqueous extract of *B. aegyptiaca* stem bark (Alhou *et al*., 2016). The tail fin beat increased as the fish swam faster to escape from the toxic area. The frequent tail fin beat observed in the present investigation may suggest that fish exposed to toxicants exhibited avoidance syndrome (Ufodike and Omoregie, 1994). Generally, as the exposure time increased, the fish became fatigued, hence revealed subsequent drop in opercular ventilation and tail fin beat. This is because of the direct toxic effect of the extract that finally brought death on test fishes.

### 5.5.4. Toxicity evaluation of *B. aegyptiaca*

In the present experiment, *B. aegyptiaca* was toxic for the different test fishes with a different level of $LC_{50}$. The $LC_{50}$ value was relatively small for *L. bynni* (18.832 $mgL^{-1}$), which showed that the extract was toxic to this fish as higher $LC_{50}$ values signify less toxicity of piscicides and vice versa (Eisler and Gardener, 1993). In the present study, dose responses of fishes against the aqueous extract of *B. aegyptiaca* depend on concentration levels and the test individual. At higher concentration levels, all fishes exposed in the treatment were dead within a short time exposure, while no death was recorded in the control. This observation agrees with the findings of Neuwinger (2004), Absalom *et al*. (2013) and Alhou *et al*. (2016) who reported the more toxicity nature of this plant extract as compared to other piscicide plants evaluated using fishes. In an experiment intended for comparing the lethal toxicity effect of *B. aegyptiaca* and *Kigelia africana* on *O. niloticus*, the former was found more toxic for this test fish (Ufodike and Omoregie, 1994).

*O. niloticus* exposed for an aqueous extract of *B. aegyptiaca* showed signs of toxicosis such as air gasping, reduction in tail fin beating rate and overturning before death and the $LC_{50}$ of the extract for this fish was 1.12 $mgL^{-1}$ (Okwuosa *et al*., 1993) and 26.22 $mgL^{-1}$ (Alhou *et al*., 2016). In another experiment tested on juvenile *C. gariepinus*, *B. aegyptiaca* fruit extract showed distress behavioral activities like surface erratic swimming, loss of reflex and hyperventilation and the 96 h $LC_{50}$ value was obtained at 12.59 $gL^{-1}$ for this species (Absalom *et al*., 2013).

The 96 h $LC_{50}$ value recorded for all species in the present study was lower than those earlier reports made by the aforementioned findings. This implies that the toxicity of *B. aegyptiaca* is depending on the test fishes and more toxic for the sensitive cyprinid than cichlids and clariids. It is, however, also imperative to note that the toxicity and $LC_{50}$ value differences encountered in the present and previous studies could be attributed to the differences in age, number of individuals per test medium or extract concentration, size of experimental pond or aquaria, and experimental conditions. This was what happened in the actual river when this plant was used for fishing in the ALNP area by fishers; the species that come out and stupefied easily, according to their rank, were from Cyprinidae, Alestidae, Distichodontidae, Schilbeidae, and Bagridae but finally Mochokidae, Clariidae and rarely Arapaimidae. This relative difference for piscicide tolerance may be associated with the presence of some elaborative breathing organs in the catfish families and an intricate physiology in some fishes that are able to detoxify plant piscicides to a level of insignificant toxicity (Abalaka *et al*., 2014). The other most probable reason might be due to the age of test fishes in which the older fish is more tolerant than younger ones for piscicide exposure. In the ALNP, cyprinids and alestids have more consumer preferences and fishers target to catch fishes of these groups to compete for the local market. This led for the overexploitation of the parent stock in these groups and subsequently only smaller sized fishes are available for fishing. In addition to age, length also matters the tolerance ability of piscicide exposure and thus the longer fishes (i.e., *L. intermedius*) tend to be more tolerant than fishes with smaller length (*L. bynni* and *B. nurse*).

### 5.6. Conclusion

The main objective of this study was to assess the availability of different piscicides and to evaluate the potential toxicity of *B. aegyptiaca* using adult fishes sampled from the wild (Gelegu River) along the ALNP. As part of the traditional fishing procedures, fishers of the ALNP have used a variety of piscicides categorized as plant and synthetic. Among the commonly used plant piscicides, fishers put *B. aegyptiaca* and *M. ferruginea* in the first listing order and the former was more effective and commonly used by fishers of this region. Based on personal observation and a pond experiment, *B. aegyptiaca* was more toxic to fishes of some groups and even our personal observation indicated that the plant is also toxic to the resilient catfish. Based on the present findings, *B. aegyptiaca* was much toxic to *L. bynni* since smaller values of $LC_{50}$ were calculated and found to be 18.832 $mgL^{-1}$ followed by *L. intermedius* and *B. nurse* with relatively higher $LC_{50}$ values. Fishing using *B. aegyptiaca* by local fishers in the rivers and pools or ‘Bahir’, is ill advised, as the resultant deleterious effects will subsequently led to death of not only target fish but other aquatic organisms, hence affect the biodiversity. If the present rate at which these extracts are being used by fishers of the ALNP is not checked, the sustainable existence of the aquatic fauna, including biologically important fish species, will be in serious jeopardy. Therefore, the indiscriminate use of *B. aegyptiaca* as a toxicant to catch fish should be discouraged and regulated to protect fish biodiversity in the ALNP. Thus, the Amhara regional environmental authority or any other concerned bodies responsible for conserving the ALNP biodiversity should look into banning the use of any piscicide for fishing in the natural water bodies.

# CHAPTER SIX

# 6. Socio-economic values and nature of small-scale fisheries in the Alitash National Park: a management perspective

## 6.1. Introduction

Although agriculture is one of Ethiopia's most promising resource mobilizer, the sector has been slowed down by periodic drought, increasing population and poor infrastructure that often make it hard and expensive to get goods in markets. In the situation of periodic drought that affects crop production, shifting to proper utilization of the water resources for alleviating hunger has no option. Thus, demand of fish consumption as a healthy protein and an alternative means for hunger alleviation is increasing in Ethiopia. However, due to lack of fishing and port facilities, fishing seem only possible for those living near water bodies and having fishing gears.

The fishery sector is entirely small-scale in Ethiopia and only dominated by inland capture fisheries. The total capture fisheries production potential is estimated to be about 94,500 tons/year of which only 20% of this potential is currently used (Gashaw Tesfaye and Wolff, 2014).The current low fish supply trends combined with ever-increasing population, the per-capita fish consumption in Ethiopia is stagnating and is the least in Sub-Saharan Africa which is only 1.3% of the average world consumption rate (FAO, 2014). Although, religion has traditionally been related to fish consumption patterns in Ethiopia, it is becoming evident that the level of fish consumption is influenced by the availability of regular supply of quality products (Mulugeta Wakjira *et al*., 2013; Assefa Mitike, 2014).

The relative contribution of small-scale fisheries (SSF) to a country's food and economic security dependents on its level of economic development and social context often higher in the developing world and emerging economies (Welcomme *et al*., 2010; De Silva, 2011). Despite of the role of artisanal fisheries in food security, fisheries of most lakes and all rivers in Ethiopia are unregulated which contributes to resource overexploitation, declining fish stocks and reduction in capture fisheries. An open access nature of fisheries resources (Brook Lemma, 2012), over dependency on capture fishery (Assefa Mitike, 2014) and illegal and poison fishing (Tesfaye Wudneh, 1998; Alamrew Eyayu and Abebe Getahun, 2019) contribute to the reduction of capture fisheries in Ethiopia. Intensive and unwise fishing was reported to have resulted in substantial changes in species composition and commercial catch productions of some lakes (Felegeselam Yohannes, 2003; Gashaw Tesfaye and Wolf, 2014).

In the lower tributaries of the BNB and TAB, many floodplain rivers drain the ALNP and are inhabited by different freshwater fishes which support the livelihoods of many economically marginalized riparian communities. However, lack of infrastructure, fishing facilities and market accessibility, illegal fishing and ethnic based conflict on resource utilization are causes for the low fisheries development in the region. In addition, the sector in the region did not receive due attention as it deserves from both development and scientific aspects in contrast to the main upper reaches of the two basins.

A reconnaissance study conducted in November 2014 and continuous sampling till the study period (until) December 2017 revealed that the fisheries potential is high in the rivers. However, the fisheries production in numerical terms, ways of exploitation or fishing, and the socioeconomic contribution of fisheries and fishers perception towards conservation and management strategies in the areas are not known. Therefore, this study was conducted to:

- determine socioeconomic contribution of the fisheries,
- identify factors affecting the development of the SSF in the ALNP, and
- determine fishers' perception related to sustainability of the riverine fisheries.

**6.2. Methodology**

**6.2.1. Study area**

The study was carried out in the riverine fishing communities of the Ayima and Gelegu Rivers in the BNB, northwestern Ethiopia (Figures 2 and 3). At the landing sites of the Gelegu River, a wide range of traditional fishing vessels and fishing communities were involved from the very upper part of the Gelegu town down to the border of the ALNP. Out of the seven major landing sites on the Gelegu River, sample populations were taken from three landing sites (Table 27). Fishers from these landing sites are producing a large catch for home consumption and for sell both in local markets and export to Gelabat market (Sudan). In Ayima River, five landing sites are known by the QWARDO that extend from the Farshaho town along the borders of the ANRS and BGNRS down to ALNP. Fishing practices in Ayima River are much smaller compared to Gelegu River and catches are largely being used for home consumption. In this river, fisher respondents were interviewed from three fishing sites (Table 27). In Shinfa River, only three landing sites were identified stretching along the southern part of the Shinfa town downwards to the Tumet village. None of these landing sites are recognized by the woreda agriculture office and they are producing only small products for home consumption, home sell and sometimes selling at Shinfa town. However, due to security problems socio-economic values of the fisheries in the Shinfa River were not assessed by this study. There is no functional fishery cooperative in the fishing communities of the ALNP and all fishers are working on individual basis.

### 6.2.2. Data collection

This study was mainly based on primary data gathered through structured questionnaire, focus group discussion (FGD) and personal observation at fishing sites. Fishers were grouped according to their category and then respondents were drawn using simple random sampling method. After interviewee's consent was obtained, potential interviewees were approached, usually at fishing sites and a brief account of the research mission was explained. From the unknown population of fishers, 67 (Ayima=24 and Gelegu=43) respondents consisting of 23, 29 and 15 full-time, part-time and occasional individual fishers, respectively were selected.

Data were collected with the assistance of local guides/enumerators who are familiar with the traditions and languages of the fishers. The FGD was held with staff from the QWARDO and selected fishers. With fishers, the interviewing process was carried out individually where only the interviewer and interviewee came together in an isolated table for confidential dialogue. During interview, effort was made not to interfere with respondent's fishing activity. For example, no fisher was requested to give an interview when setting fishing gears or collecting their catch.

Questionnaires were prepared in English (later translated into Amharic for ease of communication) and had three general parts (**Appendix 4**): (1) Fisher biodata and fishing experience (2) Quantity of fish production and per-capita fish consumption by the fishers, and the economic return fishers obtained from fishing, and (3) The fishers perception on factors affecting fisheries development and possible management strategies. Questionnaires were pre-tested among some groups, which were not the subject of the main sampling population.

Fisheries socio-economic values were assessed as the amount of fish consumed and income earned. Thus, annual fish consumption per fisher household was computed as:

FCons = FPr X FDays

Where,

FCons = Annual fish consumption per fisher (Kg/year and Fish/year)

FPr= Portion of fisheries production consumed per fisher household per day (Kg/day and Fish/day)

FDays = Number of days fishers spend at fishing per year

The annual gross income earned per fisher was computed as:

AnIncFr = IncFPro X FDays X FPri

Where,

AnIncFr = Annual income earned from fisheries in Ethiopian Birr (ETB/year)

IncFPro= Portion of fisheries production sold for income by a fisher per day (Kg/day, Fish/day)

FDays = Number of days at fishing per year (days/year)

FPri = Price of fish (ETB/kg, ETB/Fish)

The average annual total catch of fish from the rivers was also calculated as:

AnFPro= DFPr x FDays

AnFPro= Annual fisheries production at landing sites

DFPr= Fish production per day (summed out of year)

FDays= Fishing days

### 6.2.3. Data analysis

Descriptive statistics was used to examine the mean income values fishers obtained from different livelihood sources. One-way ANOVA was also used to test and compare the amount of fish catch variations among the different fisher categories along with their income from fisheries production only. The mean fish consumption variations among the interviewed respondents and fishing experience were also tested by one way ANOVA. All statistical analysis was carried out in Microsoft Excel 2007 and SPSS software package version 20.0.

## 6.3. Results

### 6.3.1. Fisher categories

Only 34.3% of the fishers in the ALNP were full time while 43.3% and 22.4% fishers were part-time and occasional, respectively. Majority of the full-time fishers (23.9%) were interviewed from the Gelegu River fishing sites. At the landing sites of Ayima River, only few fishers were full-time individuals while the vast majorities were part-time and occasional fishers (Table 27). Part-time and occasional individual fishers were also engaged in other alternative means of livelihoods such as cash crop farming, labor employment in large farms and cattle rearing and fattening. In Shinfa River, all fishers were in the category of part-time and occasional. However, due to the recurring civil war in the Shinfa area, socioeconomic assessment of the fisheries was impossible for this study.

**Table 27**. Sampling sites, fisher category and sample populations.

| River | Fishing site | Fisher category | Sample population |
|---|---|---|---|
| **Ayima** | Farshaho1 | Part-time and occasional | 5 (20.83%) |
| | Farshaho 2 | Full-time, part-time and occasional | 11 (45.83%) |
| | Abay Dar | Full-time, part-time and occasional | 8 (33.33%) |
| | | **Total** | **24** |
| **Gelegu** | St. George | Full-time and part-time | 16 (37.21%) |
| | Dildy | Part-time and occasional | 13 (30.23%) |
| | Shimel Egir | Full-time and part-time | 14 (32.56%) |
| | | **Total** | **43** |

The number of days fishers spend at fishing sites was different among fishers and fishing sites ($P<0.05$; Table 29). In the Gelegu River, fishers fish immediately after the main rainy months while in Ayima and Shinfa Rivers fishers fish in mid of November or December when rivers form small pools. The full-time fishers in the ALNP spend 130–180 days in fishing per year, while the part-time and occasional individual fishers spend only 60-124 days a year. The larger number of fishing days in a year was recorded in the Gelegu River fishing sites and was statistically significant with that of Ayima River fishing sites ($p<0.05$; Table 29).

### 6.3.2. Fishers' socio-demographic characteristics

The qualitative and quantitative socio-demographic characteristics, such as sex, marital status, age, household size, and educational background of the respondents are presented in table 28. A total of 67 fisher respondents of which 43 (64.2%) and 24 (35.8%) from Gelegu River and Ayima River fishing sites, respectively were interviewed for the present study. The fisher respondents comprised of 76.1% married, 19.4% single and 4.5% are in divorced, widowed or separated male. The size of family members in each household varies from one for those that are single with no dependents to nine head per family with the mean of 4.7. Households with family size of 3-6 were the highest with 62.7% and there was no significant difference among household size groups ($p>0.05$). The highest percentage (70.2%) of individuals was engaged in fishing and farming for their livelihood. The livelihoods of 23.9% of fisher respondents dependent on fishing and labor employment, while 5.9% fishers were engaged in fishing and petty trade.

The survey response revealed that all of the fishers were males, while females were involved in the value chain activity in fish processing at home or transporting catch from landing sites to storage sites (usually home) or to markets. The age of fisher respondents ranged from 14 to 60 with a mean age of 31.2 years. The age distribution of the fishers showed that most were within the age group of 23-50, forming 77.6% of the total respondents (Table 28).

**Table 28**. Number and percentage of fisher respondents according to their socio-demographic profiles in the ALNP fishing areas.

| Age range | Number | Percentage | Literacy level | Frequency | Percentage |
|---|---|---|---|---|---|
| 14-18 (teenagers) | 9 | 13.43 | Illiterate | 31 | 46.27 |
| 19-35 (young) | 38 | 56.72 | Adult education | 9 | 13.43 |
| 36-50 (adult) | 14 | 20.89 | Primary education | 19 | 28.36 |
| 51-60 (elder) | 6 | 8.96 | Secondary school | 7 | 10.45 |
| **Total** | **67** | **100** | Certificate | 1 | 1.49 |
| **Marital status** | | | **Total** | **67** | **100** |
| Married | 51 | 76.12 | **House hold size** | | |
| Single | 13 | 19.40 | <3 | 15 | 22.39 |
| Divorced/widowed | 3 | 4.48 | 3-6 | 42 | 62.69 |
| **Total** | **67** | **100** | 7-9 | 10 | 14.93 |
| | | | **Total** | **67** | **100** |

The literacy level of fishers revealed that 46.3% of the respondents were illiterate and the remaining 53.7% had formal and non-formal education from different schools and academic levels (Table 28).The majority of the respondents (76.1%) mentioned that their main reason for fishing was for home consumption as food but now they are fishing both for households and the market. All respondents indicated that their parents were farmers largely engaged in crop farming and or animal production. Fishing experience of sampled fishers ranged between 1 to 17 years and differs significantly among the different fishermen ($p<0.05$), with the mean of 7.3 years (Table 29). In fact, 23.9% of the fishers practiced fishing for about 1 to 5 years, while 58.2% had 6 to 11 years of experience and the remaining 17.9% fished for about 12 to 17 years.

**Table 29**. Fishing experience (years), annual fish production, consumption and income earned from fishing and related activities.

| Fishing experience | Number | Percentage | Fishing days per year (FDays) | Number | Percentage | P |
|---|---|---|---|---|---|---|
| 1-5 | 16 | 23.88 | 60-100 | 26 | 38.81 | 0.003* |
| 6-11 | 39 | 58.21 | 101-130 | 25 | 37.31 | |
| 12-17 | 12 | 17.91 | 131-180 | 16 | 23.88 | |
| Total | **67** | **100** | **Total** | **67** | **100** | |
| Fish production yearly basis (FPr) | **Fish/yr** | **Fishers** | **Range (no.)** | **Mean** | **SD** | |
| | | 11 | 562-1000 | 781 | 130 | 0.000* |
| | | 7 | 1000-1500 | 1260 | 203 | |
| | | 45 | 1501-2086 | 1786 | 177 | |
| | | 4 | Uncertain | - | - | |
| | **Fish Kg/yr** | **Fishers** | **Range (kg)** | **Mean** | **SD** | |
| | | 26 | 168-500 | 301 | 123 | 0.001* |
| | | 14 | 501-1000 | 711 | 181 | |
| | | 20 | 1001-1306 | 1145 | 265 | |
| | | 7 | Uncertain | **-** | **-** | |
| Annual fish consumption (FCons) | **Unit/group** | **Range** | **Mean** | **SD** | **P** | |
| | Fish/yr (family) | 100-1500 | 828 | 383 | 0.001* | |
| | Fish/yr/ individual (per capita) | 53-168 | 104 | 38 | 0.721 | |
| | Kg/yr (family) | 27-567 | 233 | 204 | 0.000* | |
| | Kg/yr (per capita) | 30-127 | 69 | 36 | 0.001* | |
| Fish price | ETB/Fish | 5-25 | 16 | 6 | 0.062 | |

| | | | | | |
|---|---|---|---|---|---|
| (FPr) | ETB/Kg | 20-50 | 35 | 9 | 0.075 |
| Gross annual income in ETB/yr from: | Fish sell | 15000-63000 | 44194 | 17399 | 0.000* |
| | Crop farming | 20000-76400 | 51858 | 17007 | 0.000* |
| | Labor employment | 5000-12000 | 8040 | 2234 | 0.071 |
| | Animal raising | 7480-15000 | 11837 | 2494 | 0.000* |
| | Petty trade | 3250-15000 | 8221 | 3332 | 0.054 |

**NB: 1 ETB~=0.043 USD, average exchange rate during data collection.**

The fishers in the ALNP on average spend 113 days in fishing per year and visit fishing grounds at least twice in a day (morning and evening). The average number of days fishers spend during fishing in the Gelegu River was much higher than those fishers fishing in the Ayima River, and the variation was statistically significant between the rivers (ANOVA, $p<0.05$; Table 29).

The per-capita fish consumption of individual fisher and fishers' family is summarized in table 29. According to the fishermen their annual income earned from different livelihood activities ranged between 3250 and 76400 ETB. The fishers' mean annual income only obtained from fishing was estimated to be 44194 ETB (Table 29). Fishers were also involved in another income generating activities and earned 5000-10000 ETB in labor employment, 7480-15000 ETB from animal production, 20000-76400 ETB when engaged in crop farming (including cash crop farming) annually.

### 6.3.3. Poison fishing related responses

Different destructive fishing techniques are used by fishers of the ALNP. Plant piscicides and potentially toxic synthetic chemicals are used for fishing. Figure 21 summarizes the responses of fishers about levels of different piscicides used for fishing in the ALNP.

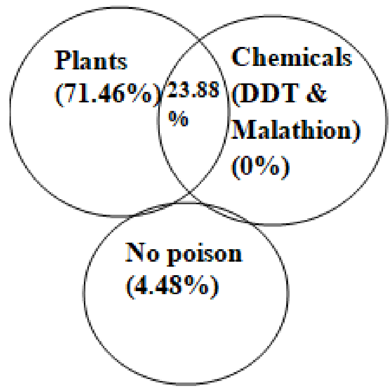


**Figure 21**. Percentage distribution of fishermen using plant and non plant poison fishing in the ALNP.

Fishers' response indicated that some critical procedures should be followed for effective poison fishing. Figure 22 depicts the general procedures adapted by fishers in the ALNP for poison fishing. During poison fishing procedure, painting DDT and Malathion over cereals or sands have two advantages: first for fishes to access poison easily when painted over bait and second the cereals settle down where fishes live. The fishers believe that when piscicide plant parts are soaked into water, the piscicide gets more toxic through fermentation. Fishers rated poison and illegal fishing second only next to lack of fishing facilities as a determinant factor for fisheries development in the ALNP.

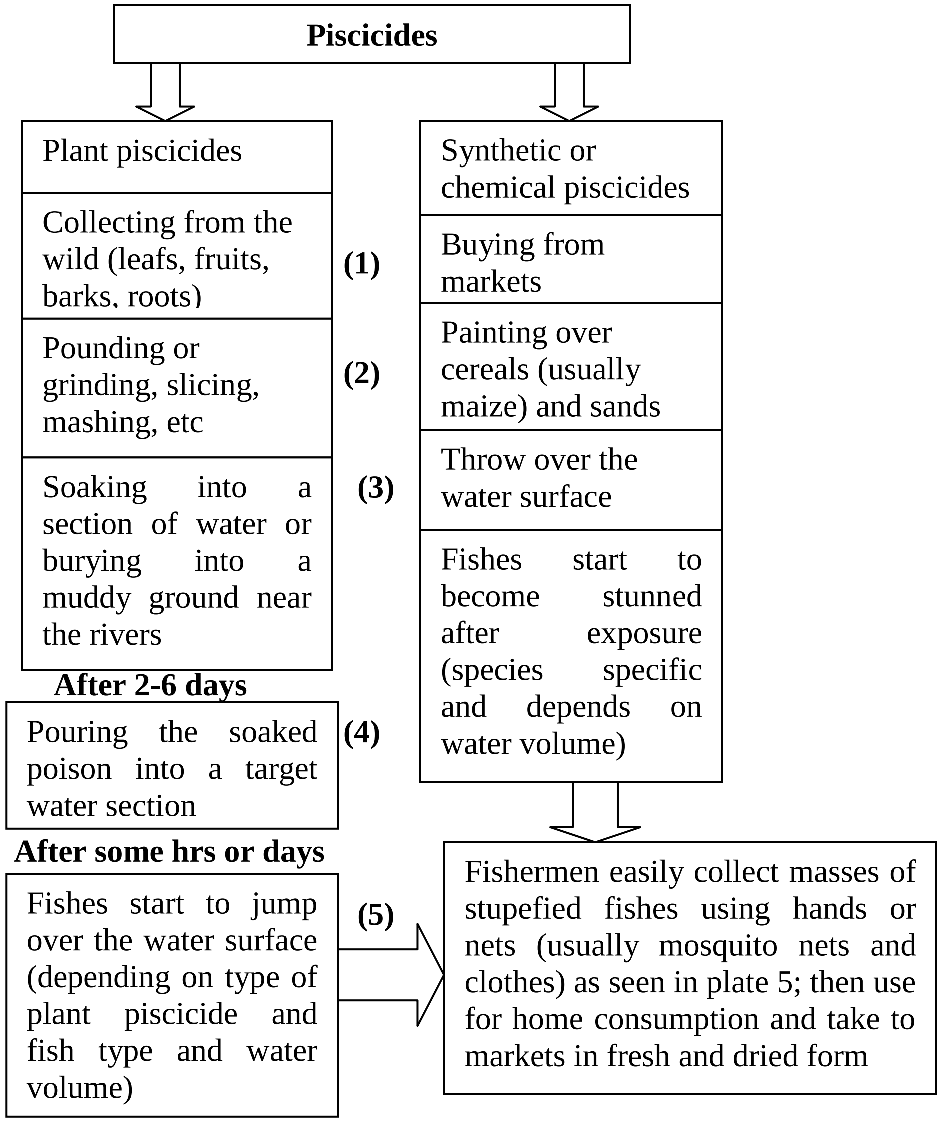


**Figure 22**. Schematic illustration of poison fishing procedures followed by fishers of the ALNP.

Plate 5 shows people collecting poisoned fishes using only hands in the Ayima River during the dry season.

**Plate 5**. Fishers collecting stupefied fishes from Ayima River.

### 6.3.4. Fishers' perception on fishing accessibility and management

Regarding fishing sites accessibility, 73.1% of the respondents indicated that the area is least accessible for fishing and 26.9% responded that the area is not accessible for fishing at all. About 86.6% of the respondents indicated that problems of accessibility resulted in the underdevelopment or underutilization of the fisheries sector in Quara Woreda. Fishers indicated that factors related to accessibility problems arose because of the low attention given for fishing by local government or agriculture officers, users and fishers. As a result, fisheries production is decreasing over the last 5-10 years and about 56 (84%) of the respondents supported this assertion. Poison fishing, reduction of the rivers' water volume and the ever-increasing number of illegal fishers are also attributing for the reduction in the fishing potential of the rivers. As a solution for supporting effective management, respondents' focused on the smooth relationship between fishers and agriculture officers, awareness should be created on fishermen about the significance of fisheries management and relevant bodies should make follow ups and monitoring around the fishing sites.

About 97% of the respondents confirmed that the fisheries of the studied rivers are not regulated. Although fishers are the immediate stakeholders expected to regulate the fisheries in the rivers, however respondents blame that the QWARDO must be responsible for the regulation. In view of fisheries management, only 7.5% of the respondents knew of fishery legislations that were in place for fisheries management. Respondents said that the regional office of agriculture offered few fishers to have training on concepts of fisheries management. However, no fisherman has heard about the Ethiopian fisheries development and utilization proclamation No. 315/2003 (1995 E.C.). According to the view of 59 (88.1%) respondents from the Ayima and Gelegu fishers, the delineation of the ALNP played a role for fisheries development and management. They asserted that the delineation, at least, reduced the number of fishers who used poison fishing.

Table 30 summarizes the perception of fishers on the different possible management strategies. All fishers condemned the use of destructive fishing practices exercised by the fishing communities of the ALNP. If appropriate management options are not taken and if poison fishing is not prohibited or if fishermen do not develop a habit of stewardship attitude on the fisheries resources, there will be drastic reduction of the fish production from the rivers. This could further be aggravated by the water level reductions of the rivers. About 76.1% of the interviewed fishers came to a general consensus on organizing fishers into cooperatives and they believe that cooperatives can do best on fisheries development and on sustainability.

**Table 30**. Fishers' reaction on banning poison fishing and the fate of future fisheries production in the ALNP.

| | Agree | Disagree | No idea | Respondents' remark |
|---|---|---|---|---|
| Prohibit poison fishing | 100% | - | - | First there should be appropriate fishing gears available for fishermen. |
| Licensing and organizing fishery cooperatives | 76.12% | 17.91% | 5.97% | Efforts and endeavors may differ among fishers in a cooperative, no legal documents on income sharing, no outlines for job description, etc. |
| If no fishing for some time | 43.28% | 46.27% | 10.45% | |
| Limit type, number, and gear size | 83.58% | 16.42% | - | |
| Future fisheries production fate | **Increased** | **Decreased** | **No idea** | |
| | 25.37% | 70.15% | 4.48% | |

### 6.3.5. Focus group discussions

Focus group discussions (FGD) and key informants interview largely focused on the management strategies of the fisheries resources. Participants indicated that the role of fisheries in the fishing communities of the Quara Woreda is too small. According to the respondents, fisheries production showed a fluctuating to decreasing trend from year to year in rivers of the ALNP. Accordingly, respondents put down the possible factors attributing for the perceived decreasing trend of fisheries production that include poison fishing, lack of fishing gears, lack of infrastructure (roads) and processing (storage) facilities, lack of adequate training for fishers, and water level reduction following intensive irrigation development along the river courses. According to the FGD, fishers possessed only a few monofilament gillnets, locally made traps named ‘Guramba’, hooks and castnets that contributed to the trends in fisheries reduction in the area.

Besides, lack of extension works, administrative problems related to licensing fish traders and fishers, and lack of infrastructure to effectively facilitate fish marketing were mentioned as impeding factors for the fisheries development. Although, economy and social setup matters the extension activities of the fisheries sector in the ALNP, due attention is required for development of the fisheries sector. Key informants emphasized the negative impact of poison fishing on fisheries development. Like fishers, participants of the FGD from the QWARDO also had no awareness about the Ethiopian fisheries development and utilization proclamation 315/2003. According to the FGD and key informants, there is no documented number of beneficiaries in the overall fishing activities of the Quara Woreda.

The QWARDO is considering the fishery sub-sector to meet the GTP-II within the agricultural sector. From the recognized and licensed traders, the woreda customs office is collecting 60000 to 80000 ETB annually. However, the market is not regulated and the office expects more than this value if there is proper control on the fish marketing system.

Both production and marketing of fishes in the ALNP are affected by factors including natural, social, political and policy related issues. These factors can alarm policy makers for proper regulation and sustainability of the fisheries sector. However, there is a need for coordination and collaboration among fishers, agriculture bureaus, local government and non-governmental organizations for effective regulation.

### 6.4. Discussion

### 6.4.1. Fisher categories and nature of fisheries

The analysis showed that many fisher respondents were part-time and occasional fishers. In the Gelegu River 62.8% fishers were part-time and occasional with an alternative occupation; whereas only 29.2% full-time fishers in the Ayima River were also engaged in other alternative means of livelihoods such as crop farming, labor employment in large investors' farm and cattle rearing. The engagement of part-time fishers in other livelihood activities has been reported among the Ethiopian fishing communities (Ayitegeb Anteneh, 2013; Shewit Gebremedhin *et al*., 2013; Dawit Garoma *et al*., 2013). In Africa and parts of Asia, part-time fishers often alternate seasonally between fishing and other occupations, such as agricultural laboring (Welcomme, 1985). It is also reported that part-time fishers usually combine fishing activity with other livelihoods and it is especially common in the floodplain rivers of the tropics (FAO, 2014). The reason for fishers' involvement in other livelihood activities in the ALNP may be due to the accessibility of fertile land and labor employment in large investors' farm. In addition, lack of fishing gears led fishers not to have enough income and forced them to search for other additional livelihood activities.

As a unique feature of the Ethiopian fisheries, fisheries in the ALNP are so small-scale (SS) that are predominantly activated by traditional fishing practices. Except fishers who own a few hooks and mono-filament gill-nets, the majority of the fishers are using poison fishing. There is no functional fishery cooperative in the ALNP and this lead fishers not to have a common voice to appeal to the local government to have access to fishing gears and facilities.

Despite the presence of 43 fish species, the fisheries depend largely on a few selected fish species for consumers' preference. These included *Bagrus bajad*, *Bagrus docmak*, *Lates niloticus*, *Hydrocynus spp*., and *Labeobarbus spp*. for local markets. On the other hand, fishers target only few large sized species for exporting, since markets require large specimens. These included *Clarias gariepinus, Bagrus spp*., large specimens of *Labeobarbus spp.*, and *Heterotis niloticus*. Other fishers are also largely involved in catching electric cat fishes (*Malapterurus minjiriya* and *M. electricus*) for traditional healing purposes. The traditional healers believed that products from these fish species can protect people from gun fires, relieve erectile dysfunction (ED) in men and protect and treat people from snake and scorpion bite. Fishers and the traditional healers also believe that consuming *Synodontis spp*. can relieve hypertension in humans. These selective fishing activities have impact in limiting the fisheries production potential of the ALNP.

Although, the fishery is SS and fishing only depends on a few selected species, the per-capita fish consumption of individuals in the area is much higher than the national per-capita consumption. This implies that the fishing activity is supporting many livelihoods and can pay a huge economic return for the fishing communities if extension activities are largely intended for scale up and condemning piscicide fishing. The income earned by fisheries is considerable only next to crop farming. Fishing can pay more than this value while management strategies also include furnishing fishing infrastructures. In the fisheries infrastructure development, controlling the pushing factor using piscicides, providing appropriate fishing gears will increase production potential and thereby increasing fishery values for local communities.

### 6.4.2. Fishers' socio-demographic characteristics

The fishing communities of the ALNP are only composed of male fishers. This agrees with the findings of Ayitegeb Anteneh (2013), Shewit Gebremedhin *et al*. (2013), and Ayalew Assefa *et al*. (2018) who reported the gender labor division in fishing and male dominance. This condition is not unusual because men in Ethiopia dominated most of the field in agricultural practices and hence there is no exception for fishing. In Ethiopia, gender based labor division is common especially in traditional communities who believe that females are less strong than males. Thus, fishing activities especially SSF are labor intensive and require a strong work force that females could not shoulder since many activities are operated by hand only.

Religious and cultural views of traditional societies also attribute for gender based labor division in fishing activity which is largely performed during the night and females would be exposed for sexual attacks. Females frequently encounter cultural proscriptions against taking on certain types of work and may lack control over their labor and incomes are also specific challenges women face in SSF of the ALNP. Therefore, in many traditional societies, women roles are embedded as housewife, accompanying her husband and taking care of the children. However, the close observation we made on labor division in gender revealed that women are largely involved in post- and pre-harvest fishing activities including repairing and cleaning nets and hooks, collecting plant barks and fruits for poison fishing, transporting nets to rivers and catches to home and sell in local markets.

The age of fishers in the ALNP ranged from 14-60 years where the larger age is in the active age range of 20-50. This is in agreement with the findings of Dawit Garoma *et al*. (2013), Shewit Gebremedhin *et al*. (2013), and Ayitegeb Anteneh (2013) who reported this age group composed of large population of the fisher categories in Lakes Ziway and Tana. Similarly, in the El-Mawrada and Jabel Awlia dams in Sudan, the fishing community is largely composed of this age group (Ahmed *et al*., 2015). High proportion of active age groups in fishing might be taken as a proof that fishing is an intensive activity that requires a strong work force. It seemed that as compared to the younger age groups, the aged ones show lesser tendencies to stay in fishing activities since fishing demands more energy and more time to stay along fishing grounds searching for fish.

The analysis of the present study showed that the larger fisher proportion in the ALNP comprises married men. Similar results were reported by Ayitegeb Anteneh (2013) and Shewit Gebremedhin *et al*. (2013) in the Lake Tana fishing communities. This may be associated with the reason that married social groups have family members that depend on productive parents and this social group endeavors to secure enough food for the family. Fishers fishing experience in the ALNP are small as compared to other studies and may be associated with lack of fishing infrastructure in the ALNP. The number of fishing equipment that a fisherman owns and availability of fishing gears determine the level of fishing experience of fishers. Migratory nature of floodplain fishers may be also a factor for the small fishing experience of fisherman (Welcomme, 1985).

The fishing communities in the ALNP were largely composed of illiterate fishers. Similarly, in all areas of Ethiopia where literacy levels of fishers were assessed it has been indicated that majority were illiterate (e.g., Ayitegeb Anteneh, 2013; Shewit

Gebremedhin *et al*., 2013; Tsegay Teame *et al.*, 2016). Although years of schooling enables fishers to understand the technical requirements of fish farming, however years of involvement in fishing are important to develop fishing skills and to achieve practical experiences. In agreement to this, Mwakubo *et al*. (2007) observed that the level of education is not likely to be a major determinant for the level of catch as it is not a source of the skills required in fishing. This implies that fishing is not necessarily requiring educated individuals, but skills developed as a result of experience are still mandatory to operate and manage fishing activities. Nonetheless, education may influence management of fishing practices through better understanding of policies, management implications and to facilitate collaboration with concerned bodies or with each other. Generally, key informants boldly suggested that education creates awareness among fishermen about fishery management strategies of the fishing sector where educated fishermen are more likely to use the recommended fishing gears.

The ethnic composition of fishers is largely dominated by Amharas, which agrees with the findings of Dawit Garoma *et al.* (2013) in Lake Ziway, who observed that the majority in the native ethnic groups dominate the fishing communities.

### 6.4.3. Poison fishing

According to fishers' responses, lack of fishing gears forced them to use poison fishing. A large proportion of fishers (71.5%) in the ALNP use plant piscicides for fishing, while 23.88% use both botanical and chemical (DDT and Malathion) piscicides and the remaining fishers use only gears for fishing. This may be associated with the availability and cost effectiveness of plant piscicides over synthetic ones. Some fishers also perceived that fishing using plants is not illegal. Fishers in the ALNP perceived that piscicide fishing is easy and it saves fishing time (Alamrew Eyayu and Abebe Getahun, 2019) and at least they will be back home with catches for consumption (Ashagrie Fetene, pers. comm.).

Although it is easy to fish using piscicides, fishers follow procedures for successful fishing to take place in rivers. Water soaked (fermented) fruits and barks of piscicide plants were poured into standing or slow flowing sections of rivers in the ALNP. On the other hand, fishers paint DDT and Malathion on sands or maize to settle the poison to the water columns to bottoms and accessible for fishes. This indigenous knowledge followed by fishers of the area was adapted and obtained from their forefathers. The details of piscicide types used by fishers and the toxicity evaluation of commonly used plant piscicide in the ALNP are presented in chapter 5.

The indiscriminate uses of piscicides among the different fishing communities of the ALNP area are affecting many of the sensitive cyprinids. In the present assessment the numerical relative importance of the endemic and other cyprinids were very small. This may be due to the effect of piscicides and that in the long run will lead the extinction of many of this fish groups. The application of piscicides resulted with mass killing of fishes are also affecting and killing cattle. These cumulative effects of piscicides call policy makers and stakeholders to develop a means to ban poison fishing.

### 6.4.4. Focus group discussion and fishers' perception on fisheries management

Several potential factors were mentioned by members of the FGD for the apparent decrease in fisheries production related to accessibility problems, water abstraction, lack of fishing facilities and market access, lack of training for fishers, river pollution and poison fishing, ethnic based conflict on resource utilization, etc. These all are negatively affecting the fisheries development in the ALNP.

Majority of the FGD participants emphasized on lack of institutional organization, regulatory framework on resource utilization, fishing facility, poor extension and lack of trained fishery personnel in the woreda to regulate and manage the fisheries sub-sector. Organizing the fisheries sub-sector with animal production is also presented as a factor for the decline in fisheries production since more emphasis is given to the non-fisheries sector by the QWARDO. Fishers' lack of awareness to organize themselves in fishery cooperatives is also another possible factor negatively affecting the fisheries development.

Fishers were not trained on sustainable resource utilization; all fishers, traders and agriculture officers did not know of the national fisheries proclamation No. 315/2003 (1995 E.C.) prepared by the Federal government and cascaded to regional and zonal bureaus to be implemented based on their own real situations, specific guidelines and management plans for the waters and the resources. The proclamation largely dictates on aquatic resources and adapting sustainable utilization. Although, ANRS has its own fishery proclamation, implementing it is not yet as expected and useful (Abebe Getahun and Eshete Dejen, 2012). Thus, the present assessment of fishers' perceptions on resource sustainability revealed the necessity of management intervention; the regional state should urgently take all the necessary steps towards implementing the proclamation, formulating and enforcing the management measures for the ALNP fisheries which is currently endangered due to a persistent poison fishing practices.

Assessment of fishers' attitudes towards the possible management strategies showed that most fishers had positive attitude towards most of the potential strategies but fishers concurrently set remarks (Table 28). Fishers mentioned weakness of law enforcement agents to enforce the laws when trespassers break set rules. The absence of alternative means of livelihoods is also another remark fishers recommended before implementing potential management strategies. All fishers agreed to ban poison fishing, licensing and organizing fishers in cooperatives, and limiting the type, number and mesh sizes of gears as a possible means of fisheries management strategy. However, majority of the fishers disagree on a closed fishing season and time as many of them are occasional and part-time fishers engaged in fishing intermittently or seasonally.

**Lack of infrastructure**

All fisher respondents, the FGD and key informants agreed to accessibility problem of landing sites as a limiting factor for developing the fisheries. Starting from lack of fishing gears to processing facilities and inaccessible market destinations are affecting the development of SSF in the ALNP. The reports from the QWARDO have shown that many fishers are shifting to other vibrant, sustainable and resilient agricultural sectors. This may be associated with the lack of landing site facilities, distant market destinations and inaccessibility of fishing areas.

**Piscicide fishing**

Majority of the fishers ascribed their perceived decrease in fisheries production to poison fishing. FGD and the key informants also concurred with the fishers' views on possible factors that might have contributed to their perceived decrease in fisheries production.

The FAO technical guideline for responsible fisheries and sustainable development (FAO, 1997 a) stated that the fishing method chosen for rivers is conditioned by three factors: the nature of the fish stock, the form of the river and development of the fishing community. According to the FGD, the second and third circumstances are being the determinant factors among the traditional fishing communities of the ALNP. Besides lack of fishing gears, the ease in operating process and less labor intensive nature led fishers to use piscicides for fishing. As a result, large types of synthetic chemicals are being used for fishing in the traditional fishing communities living far away from local administration areas. Among them, some notable ones are 2-4-D, thyadine and Malathion. These chemicals are unscrupulously used in pools and slow flowing river channels when the water level/discharge is very feeble.

**Seasonal grazing along the river sides**

In hot dry climatic zones like the Alitash, livestock regularly use stream sides adjacent to rivers as grazing and loafing areas. Cattle grazing affect the associated water quality and then interfere in the healthy functioning of the whole ecosystem. For example, the role of phytoremediation that intends to protect the entrance of pollutants into rivers is affected by grazing intensity. When river side riparian vegetation is exhaustively grazed by livestock, risk of erosion and associated turbidity affect the riverine ecosystem and primary productivity. Therefore, protecting the riparian vegetation from intensive cattle grazing becomes very important for biodiversity conservation and hence fisheries development.

**Ethnic conflict on the water resources' utilization**

The different ethnic groups in the region invariably use natural resources such as water, fish, wildlife, land and non-timber forest products to sustain their livelihoods. Largely the Amhara and Gumuz people are using the rivers and other resources in the ALNP. However, nowadays members of the two ethnic groups raise many questions on use of the rivers and they sometimes experienced conflicts. During the sporadic conflict, members of any ethnic group come to the rivers and add chemicals for revenge and kill the cattle of the other ethnic group. The chemicals used for such revenge would first affect the aquatic ecosystem and kill several fishes. The environmental degradation in different forms such as resource depletion, desertification and demographic pressure aggravate tensions and instability among ethnic groups and revenge continues.

## 6.5. Conclusion

The SSF largely activated by traditional fishing methods of the floodplain rivers in the ALNP contribute to livelihood, income and employment opportunities of the fishing communities. The fishing communities of the area are dominated by part-time individual fishers which constituted a livelihood that combines riverine fishing with crop farming, labor employment and cattle rearing. The lack of fishing facilities coupled with the greater tendencies of using piscicide for fishing is largely affecting the fisheries development in the ALNP. Therefore, to scale up the SSF and to sustain fisheries contribution to food security and livelihoods of the fishing communities, the Amhara regional government should address the major socioeconomic issues related to fisheries development and management strategies.

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## 8. Appendices

**Appendix 1**. Fish diagnostic description, catalogue numbers and sampling localities of voucher specimens identified from the floodplain rivers of the ALNP during the present study, and deposited at the Zoological Natural History Museum (**ZNHM**) of Addis Ababa University, Addis Ababa, Ethiopia:

**Order Polypteriformes**—F (1)

**Family Polypteridae**—G (1), Sp. (1)

1. ***Polypterus bichir*** Lacepède, 1803:340—Redeat Habteselassie (2012):57; Eschmeyer *et al*. (2016); Froese and Pauly (2018).
   - *Polypterus bichir* Geoffroy St. Hilaire, 1802:97—Günther (1896):218; Boulenger (1909):6; Sandon (1950):19; Shibru Tedla (1973):19; Bailey (1994):940; Golubtsov *et al*. (1995):10.
   - *Polypterus bichir* Geoffroy St. Hilaire, 1914—Boulenger (1916):149.

**Common name(s)**: Nile bichir.

**Local names**: "Ebabosh" (Amharic), "Yedildil" (Gumuz).

**Examined voucher specimen**: ZNHM-FAL-001-2, 50.8 cm SL; Appendix 2; Figure 1.

**Diagnosis**: Dorsal fin formed by a series of spines with several articulated rays supporting a membrane, forming 17 detached finlets; 63-70 lateral line scales (LLS); terminal mouth with small unicuspid teeth on jaws; body olive-green in colour (Appendix 2; Figure 1.

**Distribution**: Sampled from the Gelegu River (BNB).

**Order Osteoglossiformes**—F (2)

**Family Arapaimidae**— G (1), S (1)

2. ***Heterotis niloticus*** (Cuvier, 1829):328—Boulenger (1906):559; Boulenger (1909):149; Sandon (1950):21; Shibru Tedla (1973):21; Bailey (1994):941; Golubtsov *et al*. (1995):36; Redeat Habteselassie (2012):59; Eschmeyer *et al*. (2016); Froese and Pauly (2018).

**Common name**(s): African arowana, African bonytongue.

**Local names**: “Dulesie” (Amharic), “Paloluha” (Gumuz)

**Examined voucher specimen**: ZNHM-FAL-003-5, 63.5 cm SL; Appendix 2; Figure 2.

**Diagnosis**: Slender body covered with large and strong cartilaginous scales; no spine on both dorsal and anal fins; dorsal fin long and positioned closer to the short and rounded caudal fin; mouth terminal with unicuspid teeth (Appendix 2; Figure2).

**Distribution**: Sampled from the Ayima and Gelegu Rivers (BNB).

**Family Mormyridae**— G (5), S (6)

3. ***Hyperopisus bebe*** (Lacepède, 1803):619 —Sandon (1950):25; Bailey (1994):942; Golubtsov *et al*. (1995):37; Redeat Habteselassie (2012):66; Boulenger (1916):170; Eschmeyer *et al*. (2016); Froese and Pauly (2018).

**Common name**(s): Ngai.

**Local names**: “Ayit Assa” (Amharic), “Tsibilla” (Gumuz)

**Examined voucher specimen**: ZNHM-FAL-006-7, 27.2 cm SL; Appendix 2; Figure 5.

**Diagnosis**: Body colour varies from grey-olive to greenish-brown or purplish; possess very short dorsal and long anal fin in contrast to other congers of the genus by which the anal fin is five times more than the dorsal; snout round and short; mouth terminal equipped with very small teeth (Appendix 2; Figure 5).

**Distribution**: Sampled from the Gelegu and Shinfa Rivers, where the second river is in the TAB category.

4. ***Petrocephalus keatingii*** Boulenger, 1901:444—Sandon (1950):23; Bailey (1994):943; Golubtsov *et al*. (1995):39; Redeat Habteselassie (2012):70; Eschmeyer *et al*., (2016); Froese and Pauly (2018).

**Common name**(s): Not available.

**Local names**: “Ayit Assa” (Amharic), “Tsibilla” (Gumuz)

**Examined voucher specimen**: ZNHM-FAL-008-9, 19.3 cm SL; Appendix 2; Figure 8.

**Diagnosis**: Body rather short, strongly compressed; very narrow caudal peduncle with anal fin extension very slightly farther forwards than the dorsal fin; silvery in colour, darkening to grey on the upper surface; 25 and 37-39, rays in dorsal and anal fins, respectively; 42-43 LLS; mouth inferior (Appendix 2; Figure 8).

**Distribution**: Sampled from the Ayima and Gelegu Rivers (BNB).

5. ***Marcusenius cyprinoides*** (Linnaeus, 1758):327—Bailey (1994):943; Golubtsov *et al*. (1995):40; Redeat Habteselassie (2012):66; Eschmeyer *et al*. (2016); Froese and Pauly (2017).

**Common name**(s): Thick-lipped fish.

**Local names**: “Gurtosh Assa” (Amharic), “Tsibilla” (Gumuz)

**Examined voucher specimen**: ZNHM-FAL-010, 34.2 cm SL; Appendix 2; Figure 6.

**Diagnosis**: Terminal mouth with minute conical teeth; body silvery-darkening to grey in colour; 70-86 LLS; dorsal fin originating above anal fin with 25-30 rays; the latter with 30-37 rays (Appendix 2; Figure 6).

**Distribution**: Sampled from Ayima and Gelegu Rivers (BNB).

6. ***Mormyrus caschive*** Linnaeus, 1758:327—Golubtsov *et al*. (1950):38; Bailey (1994):942; Redeat Habteselassie (2012):64; Eschmeyer *et al*. (2016); Froese and Pauly (2017).
   - *Mormyrus caschive* Linnaeus, 1762—Sandon (1950):24, erroneous citation of year of original publication as 1762.
   - *Mormyrus caschive* Linnaeus, 1757:398—Boulenger (1909):136.

**Common name**(s): Eastern bottlenose; Elephant snout.

**Local names**: “Ayitosh” (Amharic), “Tsibilla” (Gumuz)

**Examined voucher specimen**: ZNHM-FAL-011-12, 42.7 cm SL; Appendix 2; Figure 4.

**Diagnosis**: Body grayish to bluish-purple in colour, darker above than below and more or less gleaming; snout or trunk long and bent downwards; dorsal fin more than five times as long as anal fin; 77-90 rays in dorsal fin; anal fin 18—21 rays; 97—128 LLS (Appendix 2; Figure 4).

**Distribution**: Sampled from Ayima and Shinfa Rivers.

7. ***Mormyrus kannume*** Forsskål, 1775: 74—Sandon (1950):24; Golubtsov *et al*. (1950):38; Boulenger (1916):169; Bailey (1994):942; Redeat Habteselassie (2012):64; Eschmeyer *et al*. (2016); Froese and Pauly (2018).

**Common name**(s): Elephant-snout fish; Bottle-nose.

**Local names**: “Ayitosh” (Amharic), “Tsibilla” (Gumuz)

**Examined voucher specimen**: ZNHM-FAL-013, 48.7 cm SL; Appendix 2; Figure 3.

**Diagnosis**: Snout or trunk shorter and less slender than apparent in *M. caschive*; body grayish in colour; dorsal fin 57-75 rays; anal fin 18—21 rays (Appendix 2; Figure 3).

**Distribution**: Sampled from the Ayima, Gelegu and Shinfa Rivers.

**8.** ***Mormyrops anguilloides*** (Linnaeus, 1758):327—Golubtsov *et al*. (1995):38; Redeat Habteselassie (2012):68; Eschmeyer *et al*. (2016); Froese and Pauly (2018).

- *Mormyrops anguilloides* Linnaeus, 1764—Sandon (1950):22, erroneous citation of year of original publication as 1764.
- *Mormyrops (Mormyrops) anguilloides* (Linnaeus, 1758) —Bailey (1994):943.

**Common name**(s): Cornish jack.

**Local names**: "Ayit Assa" (Amharic)

**Examined voucher specimen**: ZNHM-F-014, 55.3 cm SL; Appendix 2; Figure 7.

**Diagnosis**: Dark violet body is elongated and laterally compressed; snout relatively moderately long; nostrils distantly placed each other; head depressed; body less deep, anterior body tinged with dark reddish color; dorsal fin more or less as long as anal fin, both located near caudal; mouth sub-inferior (Appendix 2; Figure 7).

**Distribution**: Sampled in the Gelegu River.

**Order Characiformes**—F (3)

**Family Alestidae** — G (3), S (5)

**9.** ***Hydrocynus vittatus*** Castelnau, 1861:65—Bailey (1994):946; Eschmeyer *et al*. (2016); Froese and Pauly (2017).

- *Hydrocynus vittatus* (Castelnau, 1861)—Redeat Habteselassie (2012):75.
- *Hydrocyon lineatus* Bleeker, 1862:125—Boulenger (1909):182; Boulenger (1916):176; Shibru Tedla (1973):23.
- *Hydrocynus lineatus* Bleeker, 1862—Sandon (1950):27.

**Common name**(s): Tiger fish.

**Local names**: "Tirso" (Amharic), "Enza" (Gumuz)

**Examined voucher specimen**: ZNHM-FAL-015-16, 37.3 cm SL; Appendix 2; Figure 10.

**Diagnosis**: Unicuspid teeth arranged in a single row on each jaw and visible when mouth is closed; adipose eyelid present; two rows of scales between the scaly process at pelvic fins and lateral line; dorsal fin tip, adipose fin and caudal fin fork edges stripes deep black prominent; body silvery with slight black stripes (Appendix 2; Figure 10).

**Distribution**: Sampled in the Ayima and Gelegu Rivers.

10. ***Hydrocynus forskahlii*** (Cuvier, 1819):354—Bailey (1994):946; Golubtsov *et al*. (1995):28; Froese and Pauly (2017).

- *Hydrocynus forskahlii* Cuvier, 1819—Redeat Habteselassie (2012):74; Eschmeyer *et al*. (2016).
- *Hydrocynus forskalii* (Cuvier, 1819) —Paugy (1984):170.
- *Hydrocyon forskali* Cuvier, 1819 — Shibru Tedla (1973):22.
- *Hydrocyon forskalii* Cuvier, 1819 — Boulenger (1909):180; Boulenger (1916):175; Sandon (1950):27.

**Common name**(s): Elongate tigerfish.

**Local names**: “Tirso” (Amharic), “Enza” (Gumuz)

**Examined voucher specimen**: ZNHM-FAL-017-18, 38.6 cm SL; Appendix 2; Figure 9.

**Diagnosis**: Large mouth equipped with unicuspid caniniform teeth in one row on both jaws; upper dorsal part silvery; lower caudal lobe orange red; unlike in *H. vittatus* tip of dorsal fin, inner edges of caudal fin, and adipose fin uniformly grayish; small adipose fin; LLS 48-54 scales is nearer the ventral than the dorsal out line (Appendix 2; Figure 9).

**Distribution**: Sampled in the Ayima and Gelegu Rivers.

11. ***Alestes baremoze*** (Joannis, 1835):31—Eschmeyer *et al*. (2016); Froese and Pauly (2016).

- *Alestes baremoze* (de Joannis, 1835)—Bailey (1994):947; Golubtsov *et al*. (1995):29; Redeat Habteselassie (2012):76.

- *Alestes baremose* (Joannis, 1835)—Boulenger (1905):40; Boulenger (1909):195; Boulenger (1916):176; Sandon (1950):29; Shibru Tedla (1973):24.

**Common name**(s): Silversides.

**Local names**: "Beresho" (Amharic), "Lipka/Chilentie" (Gumuz)

**Examined voucher specimen**: ZNHM-FAL-019-21, 27.5 cm SL; Appendix 2; Figure 11.

**Diagnosis**: Body slightly laterally compressed; dorsal surface dark sliver; lower caudal lobe orange red; first ray of dorsal fin equidistant from last ray of pelvic and first ray of anal or a little nearer the latter; moderately large anal fin with 25—30 branched rays; 30—38 gill-rakers on lower part of first gill arch; edges of caudal fin only finely black; adipose eyelid present; more than 44 LLS (Appendix 2; Figure 11).

**Distribution**: Sampled in the Ayima, Gelegu and Shinfa Rivers.

**12. *Brycinus nurse*** (Rüppell, 1832):12—Bailey (1994):946; Golubtsov *et al*. (1995):29; Redeat Habteselassie (2012):77; Froese and Pauly (2016).

- *Brachyalestes nurse* (Rüppell 1832)—Eschmeyer *et al*. (2016).

- *Alestes rueppellii* (Günther, 1864):315—Günther (1896):223.

- *Alestes nurse* (Rüppell, 1832)—Sandon (1950):29; Boulenger (1905):40; Boulenger (1909):205; Boulenger (1916):179; Shibru Tedla (1973):24.

**Common name**(s): Nurse tetra.

**Local names**: "Nech Assa" (Amharic).

**Examined voucher specimen**: ZNHM-FAL-022-24, 16.7 cm SL; Appendix 2; Figure13.

**Diagnosis**: A black spot just behind gill-cover and another on caudal peduncle; dorsal-fin origin at about the same level as pelvic-fin insertions; a small adipose fin tipped with red colour; 11-16 branched rays on anal fin; 26-33 LLS (Appendix 2; Figure13).

**Distribution**: Sampled in the Ayima, Gelegu and Shinfa Rivers.

**13.** ***Brycinus macrolepidotus*** (Valenciennes, 1849):157—Bailey (1994):946; Golubtsov *et al*. (1995):29; Redeat Habteselassie (2012):76.

- *Alestes macrolepidotus* (Cuvier & Valenciennes, 1849)—Boulenger (1916):184; Sandon (1950):29; Shibru Tedla (1973):25.

**Common name**(s): True big scale tetra.

**Local names**: "Shimello" (Amharic)

**Examined voucher specimen**: ZNHM-FAL-025-27, 27 cm SL; Appendix 2; Figure 12.

**Diagnosis:** Dorsal fin originating well behind vertical of base of ventrals; head much flattened above; anal fin with 12-14 branched rays; first ray of dorsal fin midway between pelvics and anal and nearer to caudal fin than to occiput; 22-26 LLS; body olive-greenish in colour (Appendix 2; Figure 12).

**Distribution**: Sampled from the Ayima and Gelegu Rivers.

**Family Distichodontidae**—G (1), S (3)

**14.** ***Distichodus brevipinnis*** Günther, 1864:361—Boulenger (1916):193; Sandon (1950):32; Bailey (1994):948; Golubtsov *et al.* (1995):31; Redeat Habteselassie (2012):81; Eschmeyer *et al*. (2016); Froese and Pauly (2017).

**Common name**(s): Not available.

**Local names**: "Gosh Millas" (Amharic).

**Examined voucher specimen**: ZNHM-FAL-028, 44.3 cm SL; Appendix 2; Figure 15.

**Diagnosis**: Mouth small, somewhat inferior, with two rows of small, regular, bicuspid teeth in each jaw; nostrils very close together; scales rather small with very small ones covering the greater part of the caudal and adipose fins; dorsal fin rather long and situated vertically above the pelvics; adipose fin rather long than other congers in the genera (Appendix 2; Figure 15).

**Distribution**: Sampled in the Ayima and Gelegu Rivers.

**15.** ***Distichodus engycephalus*** Günther, 1864:361—Boulenger (1916):193; Sandon (1950):32; Bailey (1994):948; Golubtsov *et al.* (1995):31; Redeat Habteselassie (2012):81; Eschmeyer *et al*. (2016); Froese and Pauly (2017).

**Common name**(s): Perch.

**Local names**: "Gosh Millas" (Amharic).

**Examined voucher specimen**: ZNHM-FAL-029, 41.8 cm SL; Appendix 2; Figure 14.

**Diagnosis**: Mouth distinctly inferior, with two rows of small, regular, bicuspid teeth in each jaw; nostrils very close together; small ctenoid scales covering the whole body; dorsal fin rather long and situated vertically above the pelvics; adipose fin rather short than other congers in the genera; narrow head its unique feature in the genera; body generally gray, darker at back lighter at belly, upper portion of eye reddish, dorsal part with black spots, young with one black spot at caudal peduncle extending to central part of caudal fin; one orange spot followed by one black spot on lateral line at level of pectorals; sides with black vertically elongated spots (Appendix 2; Figure 14).

**Distribution**: Sampled in the Gelegu River.

**16.** ***Distichodus rostratus*** Günther, 1864:360—Boulenger (1916):194; Sandon (1950):32; Bailey (1994):946; Golubtsov *et al.* (1995):32; Redeat Habteselassie (2012):82; Eschmeyer *et al*. (2016); Froese and Pauly (2016).

**Common name**(s): Grass eater.

**Local names**: "Gosh Millas" (Amharic).

**Examined voucher specimen**: ZNHM-FAL-030, 46.3 cm SL; Appendix 2; Figure 16.

**Diagnosis**: Mouth somewhat inferior and equipped with two rows of small, regular, bicuspid teeth in each jaw; nostrils very close together; rather small ctenoid scales covering the body; dorsal fin rather long and situated vertically above the pelvics; 22–26 and 13–15 dorsal and anal soft rays, respectively; 83-90 LLS; 10-13 vertical dark bars on the body of young fish, which disappear with age gradually; juveniles with transverse black irregular bands on the sides; one black spot at extremity of caudal peduncle, one black humeral spot and sometimes one orange humeral spot (Appendix 2; Figure 16.

**Distribution**: Sampled in the Ayima and Gelegu Rivers.

**Family Citharinidae**—G (1), S (1)

**17.** ***Citharinus latus*** Muller & Troschel, 1845:9—Boulenger (1916):197; Sandon (1950):31; Bailey (1994):949; Golubtsov *et al*. (1995):28; Redeat Habteselassie (2012):86; Eschmeyer *et al*. (2016); Froese and Pauly (2016).

**Common name**(s): Not available.

**Local names**: "Sefedo" (Amharic), "Yambda" (Gumuz).

**Examined voucher specimen**: ZNHM-FAL-031, 33.4 cm SL; Appendix 2; Figure 17.

**Diagnosis**: Body very deep and strongly compressed, covered with smooth cycloid scales; mouth terminal and equipped with minute unicuspid teeth; rays in dorsal fin 20-22; rays in anal fin 23-26; dorsal and lateral upper half dark olive, lateral lower half white; pelvic, anal and lower lobe of caudal fin pinkish (Appendix 2; Figure 17).

**Distribution**: Sampled in the Ayima and Gelegu Rivers.

**Order Cypriniformes—F (1)**

**Family Cyprinidae —G (3), S (10)**

**18.** ***Labeobarbus bynni*** (Forsskål, 1775): 71—Redeat Habteselassie (2012):123; Eschmeyer *et al*. (2016); Froese and Froese & Pauly (2017).

- *Barbus bynni* (Forsskål, 1775)—Boulenger (1911):26; Sandon (1950):36; Bailey (1994):950; Golubtsov *et al.* (1995):15.
- *Barbus ruspolii* Vinciguerra, 1896:29—Shibru Tedla (1973):34.

**Common name**(s): Nile barb, Niger barb.

**Local names**: "Guanja" (Amharic), "Tsiwiya" (Gumuz).

**Examined voucher specimen**: ZNHM-FAL-032-33, 31.3 cm SL; Appendix 2; Figure 23.

**Diagnosis**: Body rather deep; mouth inferior with well developed lips; two barbells on each side; parallel striae on scales; the last unbranched dorsal ray is ossified into a straight massive spine; 8-10 branched rays in dorsal fin; 28-37 LLS (Appendix 2; Figure 23).

**Distribution**: Sampled in the Ayima, Gelegu and Shinfa rivers.

19. ***Labeobarbus crassibarbis*** Nagelkerke & Sibbing, 1997:131—Abebe Getahun & Eshete Dejen (2012): 81; Redeat Habteselassie (2012):131.

- *Barbus crassibarbis* Nagelkerke & Sibbing, 1997:131.

**Common name**(s): Not available.

**Local names**: "Guanja" (Amharic), "Tsiwiya" (Gumuz).

**Examined voucher specimen**: ZNHM-FAL-034-35, 21.3 cm SL; Appendix 2; Figure 25.

**Diagnosis**: Body rather deep; mouth inferior with well developed lips; two barbells on each side; parallel striae on scales; the last unbranched dorsal ray is ossified into a straight massive spine; 8-10 branched rays in dorsal fin; 28-37 LLS (Appendix 2; Figure 25).

**Distribution**: Sampled in the Ayima and Shinfa rivers.

20. ***Labeobarbus intermedius*** (Rüppell, 1835):7—Redeat Habteselassie (2012):123; Eschmeyer *et al*. (2016); Froese and Pauly (2017); erroneous year of publication of its first descriptor is available in Abebe Getahun and Eshete Dejen (2012):91—written as *Labeobarbus intermedius* (Rüppell, 1836).

- *Barbus intermedius* Rüppell, 1837—Boulenger (1910):59; Shibru Tedla (1973):43.

**Common name (s)**: African big barb.

**Local names**: "Kuba" (Amharic), "Tsiwiya" (Gumuz).

**Examined voucher specimen**: ZNHM-FAL-036-37, 36.3 cm SL; Appendix 2; Figure 24.

**Diagnosis**: Mouth terminal and protractile; lip variably develop; barbells small, 2 pairs on the upper jaw only; body covered with cycloid scales and variable in shape; 30-36 scales in the lateral line; dorsal fin originates immediately above the pelvic fin (Appendix 2; Figure 24).

**Distribution**: Sampled in the Ayima, Gelegu and Shinfa Rivers.

**21.** ***Labeobarbus degeni*** Boulenger, 1902:435—Abebe Getahun and Eshete Dejen (2012):85; Eschmeyer *et al*. (2016); Froese and Pauly (2017). The list of this species is missed from the ichthyofaunal accounts of Ethiopia compiled by Redeat Habteselassie (2012).

- *Barbus degeni* Boulenger, 1902—Boulenger (1902):435; Boulenger (1910):50.

**Common name**(s): Not available.

**Local names**: "Guanja" (Amharic), "Tsiwiya" (Gumuz).
**Examined voucher specimen**: ZNHM-FAL-038, 22.1 cm SL; Appendix 2; Figure 26.

**Diagnosis:** Body dark yellowish green in colour and fins steel-grey; lips very strongly developed, upper lip not curling back over the snout, lower lip produced into rounded median lobes; snout produced into triangular dermal flap over-hanging the lip; mouth inferior (Appendix 2; Figure 26).

**Distribution**: Sampled in the Ayima, Gelegu and Shinfa Rivers.

**22.** ***Labeobarbus nedgia*** (Rüppell, 1836):14—Abebe Getahun and Eshete Dejen (2012):98; Redeat Habteselassie (2012):138; Boulenger (1910):51; erroneously cited the original year of publication as 1837.

- *Barbus nedgia* (Rüppell, 1836):14 —Nagelkerke & Sibbing (2000):210.

- *Barbus nedgia* Günther, 1868:104—Boulenger (1902):426; Boulenger (1910):51.

**Common name**(s): Not available.

**Local names**: "Guanja" (Amharic), "Tsiwiya" (Gumuz).

**Examined voucher specimen**: ZNHM-FAL-039, 27.8 cm SL; Appendix 2; Figure 27.

**Diagnosis**: Mouth inferior with very thick lip, the lower with a fleshy median lobe, upper lip sometimes has a fleshy median flap that curls back over the snout (Appendix 2; Figure 27).

**Distribution**: Sampled in the Ayima and Shinfa Rivers.

**23.** ***Labeo cylindricus*** Peters, 1852:684—Boulenger (1916):204; Shibru Tedla (1973):29; Golubtsov *et al*. (1995):15; Redeat Habteselassie (2012):110.

**Common name**(s): Redeye labeo.

**Local names**: "Tikur Kuba" (Amharic), "Tsiwiya" (Gumuz).

**Examined voucher specimen**: ZNHM-FAL-040-41, 23.4 cm SL; Appendix 2; Figure 21.

**Diagnosis:** Lips plicate (folded); dorsal fin concave with 9-10 branched rays; eyes in supero-lateral position; body cylindrical, slightly elongated; snout truncate with deep transverse furrow and fleshy appendix directed upwards; mouth is large; general body colour is yellow-green with a darker band stretching horizontal over the body, older fish is a darker olive grey, eyes are typically red (Appendix 2; Figure 21).

**Distribution**: Sampled from Ayima, Gelegu and Shinfa rivers.

**24.** ***Labeo forskalii*** Rüppell, 1835:18—Boulenger (1916):205; Sandon (1950):35; Bailey (1994):952; Golubtsov *et al*. (1995):15; Redeat H/Selassie (2012):108.

**Common name**(s): Not available.

**Local names**: "Tikur Kuba" (Amharic), "Tsiwiya" (Gumuz).

**Examined voucher specimen**: ZNHM-FAL-042-43, 23.3 cm SL; Appendix 2; Figure 20.

**Diagnosis:** Horny tubercles on snout is big; eye position is somewhat dorsal, completely visible from above; Upper margin of dorsal fin concave; 9-11 branched rays in dorsal fin; no papillae on lips; body colour dark violet or bluish above and son the sides (Appendix 2; Figure 20).

**Distribution**: Sampled in the Ayima, Gelegu and Shinfa rivers.

**25.** ***Labeo horie*** Heckel, 1846:304—Boulenger (1909):306; Sandon (1950):35; Bailey (1994):952; Golubtsov *et al*. (1995):15; Redeat Habteselassie (2012):109.

- *Labeo horie* Heckel, 1847—Eschmeyer *et al*., (2016); Froese and Pauly (2017).

**Common name**(s): Not available.

**Local names**: "Kuba" (Amharic), "Tsiwiya" (Gumuz).

**Examined voucher specimen**: ZNHM-FAL-044-45, 25.6 cm SL; Appendix 2; Figure 19.

**Diagnosis**: Body strongly compressed; snout broadly round; no teeth on jaws; labial folds rather poorly developed in comparison to other Ethiopian congers; dorsal surface dark olive; 11-14 branched rays dorsal, upper edge straight or convex; one minute barbell on each side of head; papillae on lips rather elongated, forming a continuous fringe; 40—44 LLS (Appendix 2; Figure 19).

**Distribution**: Sampled in the Ayima, Gelegu and Shinfa rivers.

**26.** ***Labeo niloticus*** (Linnaeus, 1758): 322—Froese and Pauly (2016).

- *Labeo niloticus* (Forsskål, 1775):71—Boulenger (1909):304; CLOFFA-II: 316; Sandon (1950):35; Bailey (1994):952; Golubtsov *et al*. (1995):13; Redeat Habteselassie (2012):107.

**Common name**(s): Nile carp.

**Local names**: "Kuba" (Amharic), "Mangata" (Gumuz).

**Examined voucher specimen**: ZNHM-FAL-046-47, 31.2 cm SL; Appendix 2; Figure 18.

**Diagnosis:** Dorsal surface dark olive; no teeth on the jaws; inferior mouth with one minute barbell concealed under the folds of skin at the angle of mouth; 14-17 branched dorsal fin rays, its upper edge usually more or less distinctly concave; 41–45 LLS (Appendix 2; Figure 18).

**Distribution**: Sampled in the Ayima, Gelegu and Shinfa rivers.

**27.** ***Raiamas senegalensis*** (Steindachner, 1870):564—Bailey (1994):953; Redeat Habteselassie (2012):120; Eschmeyer *et al*. (2016); Froese and Pauly (2017).

- *Raiamas loati* (Boulenger, 1901):80—Golubtsov *et al*. (1995):12.
- *Barilius loati* (Boulenger, 1901):80;—Sandon (1950):38; Shibru Tedla (1973):57.
- *Barilius senegalensis* (Steindachner, 1870):564—Boulenger (1911):204.

**Common name**(s): Silver fish, Senegal minnow.

**Local names**: “Worka-Workit” (Amharic).

**Examined voucher specimen**: ZNHM-FAL-048-50, 46.3 cm SL; Appendix 2; Figure 22.

**Diagnosis:** Dorsal III 8 rays, second half of its base above anal fin with III 14 rays, notched and produced into a convex anterior lobe; 12-14 bluish-black vertical bars along their body; 50-64 LLS (Appendix 2; Figure 22)); terminal mouth.

**Distribution**: Sampled in the Ayima River.

**Order Siluriformes**—F (6)

**Family Auchenoglanididae**— G (1), S (1)

**28.** ***Auchenoglanis occidentalis*** (Valenciennes, 1840):303—Redeat Habteselassie (2012):141; Eschmeyer *et al*. (2016); Froese and Pauly (2017).

- *Auchenoglanis occidentalis* (Cuvier &Valenciennes, 1840)—Boulenger (1905):48; Boulenger (1911):369; Sandon (1950):44.

**Common name**(s): Black spotted catfish.

**Local names**: “Lemlem Kuri” (Amharic), “Jejumma” (Gumuz).

**Examined voucher specimen**: ZNHM-FAL-051-53, 46.3 cm SL; Appendix 2; Figure 28.

**Diagnosis:** Body colour olive or brown, uniform or spotted with dark brown or blackish spots; these spots when present are larger than in the *A. biscutatus*, often very large on the dorsal and caudal fins, where they are separated by a narrow network of the pale ground-color; scales absent on the body; inferior mouth yellowish, with three pairs of barbels; maxillary barbels short not reaching the posterior edge of eye; caudal truncate; moderate size black spots on body, small black spots on caudal fin; caudal fin orange red; maxillary barbells are white-yellow and reaching at least to hind margin of eye; in contrast to *A. biscutatus* the snout in *A. occidentalis* is more pointed and by the shortness of its maxillary barbel which is distinctly shorter than the outer mandibular barbel and cannot extend back beyond the eye (Appendix 2; Figure 28).

**Distribution**: Sampled in the Ayima, Gelegu and Shinfa rivers.

**Family Clariidae**— G (2), S (2)

**29.** ***Clarias gariepinus*** (Burchell, 1822):425—Boulenger (1911):228; Bailey (1994):957; Golubtsov *et al*. (1995):19; Abebe Getahun & Eshete Dejen (2012):114; Redeat Habteselassie (2012):151; Eschmeyer *et al*. (2016); Froese and Pauly (2017).

- *Clarias lazera* Cuvier & Valenciennes, 1840:372—Boulenger (1911):232; Sandon (1950):40; Shibru Tedla (1973):63.

**Common name**(s): North African catfish, African catfish.

**Local names**: “Bermut/Bermuts” (Amharic), “Bilbutsie” (Gumuz)

**Examined voucher specimen**: ZNHM-FAL-054-56, 46.3 cm SL; Appendix 2; Figure 31.

**Diagnosis:** Elongated naked body; subinferior mouth with 4 pairs of barbells; dorsal fin long, extending to the base of caudal; anal fin long extending near to the caudal fin; no adipose fin; caudal fin round; olive to blackish above, white beneath in colour (Appendix 2; Figure 31).

**Distribution**: Sampled in the Ayima, Gelegu and Shinfa Rivers.

**30.** ***Heterobranchus longifilis*** Valenciennes, 1840:395—Bouleneger (1911):274; Bailey (1994):957; Golubtsov *et al*. (1995):20; Redeat Habteselassie (2012):154; Eschmeyer *et al*. (2016); Froese and Pauly (2017).

- *Heterobranchus longifilis* Cuvier and Velenciennes, 1846: Shibru Tedla (1973):65.
- *Heterobranchus longifilis* Cuvier and Velenciennes, 1842: Sandon (1950):41.
- *Heterobranchus laticeps* Peters, 1852:682;—Boulenger (1901):265.

**Common name**(s): Sampa, Vundu.
**Local names**: "Sorz" (Amharic), "Bedena" (Gumuz).
**Examined voucher specimen**: ZNHM-FAL-057-58, 46.3 cm SL; Appendix 2; Figure 32.
**Diagnosis**: Head long, broad and somewhat rectangular in dorsal outline; snout broadly rounded; eyes with supero-lateral position; 29-34 rays on dorsal fin; adipose fin as long as or a little shorter than the rayed dorsal fin; four pairs of barbells; spine on pectoral fin feebly serrated (Appendix 2; Figure 32).

**Distribution**: Sampled in the Ayima, Gelegu and Shinfa Rivers.

**Family Bagridae**—G (1), S (2)

**31.** ***Bagrus bajad*** (Forsskål, 1775): 66—Golubtsov *et al*. (1995):21; Redeat Habteselassie (2012):142; Eschmeyer *et al*. (2016); Froese and Pauly (2017).

- *Bagrus bayad* (Forsskål, 1775)—Boulenger (1911):305; Sandon (1950):42.

**Common name(s)**: Bayad.
**Local names**: "Ambazza" (Amharic), "Besessie" (Gumuz).
**Examined voucher specimen**: ZNHM-FAL-059, 48 cm SL; Appendix 2; Figure 29.
**Diagnosis**: Scales absent on the body; maxillary barbell very long, extending to tip of ventral fin or beyond in contrast to *B. docmak*; mouth subinferior with 4 pairs of barbells; dorsally brownish, laterally silvery; some specimens dark brownish;; body relatively grayish in contrast to *B. docmak* which is pale red; caudal fin strongly forked, with the upper and lower lobes extending into long filaments or grow equally usually with extending filaments (Appendix 2; Figure 29).

**Distribution**: Sampled in the Shinfa (TAB).

**32. *Bagrus docmak*** (Forsskål, 1775):65—Golubtsov *et al*. (1995):2; Redeat Habteselassie (2012):143; Eschmeyer et al. (2016); Froese and Pauly (2017).

- *Bagrus docmac* (Forsskål, 1775)—Boulenger (1906):559; Boulenger (1911):308; Boulenger (1916):298; Sandon (1950):42; Shibru Tedla (1973):60.

**Common name**(s): Semutundu.
**Local names**: "Ambazza" (Amharic), "Besessie" (Gumuz).
**Examined voucher specimen**: ZNHM-FAL-059-60, 43 cm SL; Appendix 2; Figure 30.
**Diagnosis**: Body slightly elongated and without scale; body pale red in colour on fresh specimens; caudal fin forked, but only the upper lobe extending into long filament; maxillary barbells do not reach extremities of ventral fine; mouth subinferior with 4 pairs of barbells (Appendix 2; Figure 30).

**Distribution**: Sampled in the Ayima and Gelegu (BNB) and Shinfa (TAB).

**Family Mochokidae**—G (1), S (4)

**33. *Synodontis clarias*** (Linnaeus, 1758):306—Boulenger (1911):469; Bailey (1994):959; Golubtsov *et al*. (1995):23; Redeat Habteselassie (2012):165; year of original publication erroneously cited as 1762 in Sandon (1950):46.

- *Synodontis clarias* Geoffroy Saint-Hilaire, 1818:299.
- *Synodontis callarias* Bloch & Schneider, 1801:379.
- *Synodontis macrodon* Geoffroy Saint-Hilaire, 1827:295.

**Common name**(s): Mandi/Squeaker.
**Local names**: "Kurri" (Amharic), "Baquqo" (Gumuz)
**Examined voucher specimen**: ZNHM-FAL-061-62, 43 cm SL; Appendix 2; Figure 35.
**Diagnosis:** Scales absent on the body; maxillary barbells barbed or branched but without any marginal membrane; movable mandibular teeth; eye with free border; humeral process is pointed (Appendix 2; Figure 35).

**Distribution**: Sampled in the Gelegu River (Blue Nile basin).

**34.** ***Synodontis schall*** (Bloch & Schneider, 1801):385—Boulenger (1911):404; Boulenger (1916):316; Sandon (1950):47; Shibru Tedla (1973):66; Bailey (1994):960; Golubtsov *et al*. (1995):26; Redeat Habteselassie (2012):170; Eschmeyer *et al*. (2016); Froese and Pauly (2016).

**Common name**(s): Wahrindi/Shield-head fish.

**Local names**: “Kurri” (Amharic), “Baquqo” (Gumuz).

**Examined voucher specimen**: ZNHM-FAL-063-65, 43 cm SL; Appendix 2; Figure 36).

**Diagnosis:** Scales absent on the body; maxillary barbells longer than head, unbranched and with no basal marginal membrane on maxillary barbel; outer mandibular barbells with few, rather short and simple ramifications; dorsal fin spine feebly serrated behind; body dark (brown) color; mandibular teeth moderately developed; humeral process sharply pointed and granulose; adipose fin well developed, rather close to rayed dorsal fin; caudal deeply forked, upper lobe is longer than lower (Appendix 2; Figure 36).

**Distribution**: Sampled in the Ayima, Gelegu and Shinfa Rivers.

**35.** ***Synodontis serratus*** Rüppell, 1829:8—Boulenger (1911):457; Sandon (1950):46; Bailey (1994):960; Golubtsov *et al*. (1995):26; Eschmeyer *et al*. (2016); Froese and Pauly (2017).

- *Synodontis serrata* Rüppell, 1829—Redeat H/Selassie (2012):168.

**Common name (s)**: Squeaker-shield-catfish.

**Local names**: “Kurri” (Amharic), “Baquqo” (Gumuz).

**Examined voucher specimen**: ZNHM-FAL-066-67, 43 cm SL; Appendix 2; Figure 37.

**Diagnosis**: Dorsal spine distinctly serrated in front, feebly serrated behind; strongly serrated pectoral spine; humeral process flat or keeled; 12-13 anal fin rays; maxillary barbell slightly broadly margined; mandibular barbel with slender branches (Appendix 2; Figure 37).

**Distribution**: Sampled in the Ayima, Gelegu and Shinfa Rivers.

**36.** ***Synodontis sorex*** Günther, 1864:110—Boulenger (1911):465; Boulenger (1916):322; Sandon (1950):46; Bailey (1994):959; Golubtsov *et al*. (1995):25; Redeat Habteselassie (2012):167; Eschmeyer *et al*. (2016); Froese and Pauly (2016).

- *Synodontis geledensis* Günther, 1896:56—Shibru Tedla (1973):67; Boulenger (1916):322.

**Common name**(s): Squeaker.
**Local names**: "Tengallo Kurri" (Amharic), "Baquqo" (Gumuz).
**Examined voucher specimen**: ZNHM-FAL-068-69, 43 cm SL; Appendix 2; Figure 38.
**Diagnosis**: Maxillary barbels with a broad marginal membrane at the base; mandibular barbels with rather numerous, long, simple and tuberculate ramifications; denticulations on pectoral-fin spines finer and more close-set on outer than on inner margin; humeral process flat, rounded or obliquely truncate behind, it's lower margin convex, ending in a blunt point and not keeled; adipose fin normally developed and distinctly separated from rayed dorsal fin, its posterior margin truncate; caudal fin strongly developed as compared to that of other species; dorsal fin with I7 rays; spine strong finely serrated in front, coarsely serrated behind; anal fin with IV8 rays (Appendix 2; Figure 38).
**Distribution**: Sampled in the Gelegu River (Blue Nile basin).

**Family Malapteruridae**—G (2), S (2).

**37.** ***Malapterurus electricus*** (Gmelin, 1789):1354—Bailey (1994):958; Golubtsov *et al*. (1995):18; Redeat Habteselassie (2012):155; Eschmeyer *et al*. (2016); Froese and Pauly (2017).

- *Malapterurus electricus* (Forsskål, 1775) —Sandon (1950):50.

**Common name**(s): Electric catfish.
**Local names**: "Assa Adenziz" (Amharic), "Bamdandi" (Gumuz).
**Examined voucher specimen**: ZNHM-FAL-070, 43 cm SL; Appendix 2; Figure 33.
**Diagnosis**: No scales on the body; anal fin with III6-10 rays; 14-22 (usually more than 15); pectoral fin placed near body mid-depth; caudal fin usually well-spotted in adults; caudal saddle and bar pattern poorly developed in all ages; 7-8 branched caudal fin rays;

adults and young marked with large spots and blotches; anal fin short; gill membranes grown to the isthmus; no hard bony plates on head (Appendix 2; Figure 33).

**Distribution**: Sampled in the Ayima and Gelegu Rivers.

**38.** ***Malapterurus minjiriya*** Sagua, 1987:78—Golubtsov *et al*. (1995):18; Redeat Habteselassie (2012):156; Eschmeyer *et al*. (2016); Froese and Pauly (2017).

**Common name(s)**: Not available.

**Local names**: "Assa Adenziz" (Amharic), "Bamdandi" (Gumuz).

**Examined voucher specimen**: ZNHM-FAL-071, 43 cm SL; Appendix 2; Figure 34.

**Diagnosis**: Scales absent on the body; anal fin with 9-12 soft rays; without spinous rays. 6-15 (usually no more than 15); 8-12 anal-fin rays; 19 caudal-fin rays; pectoral fin placed ventrally; caudal fin round or slightly truncate; rayed dorsal fin absent; fleshy adipose fin sloped posteriorly; body and head marked with large blotches; spotting and blotching concentrated posterior; caudal and anal fins unmarked or lightly spotted; paired fins rarely spotted (Appendix 2; Figure 34).

**Distribution**: Sampled in the Gelegu River (BNB).

**Family Schilbeidae**—G (1), S (2)

**39.** ***Schilbe mystus*** (Linnaeus, 1758):305—Golubtsov *et al*. (1995):20; Redeat Habteselassie (2012):174; Eschmeyer (2014).

- *Schilbe mystus* (Linnaeus, 1762)—Boulenger (1916):293; Sandon (1950):49; erroneous citation of year of publication as 1762 in both cases.

**Common name**(s): African butter catfish.

**Local names**: "Liben/Liven" (Amharic).

**Examined voucher specimen**: ZNHM-FAL-072-74, 43 cm SL; Appendix 2; Figure 40.

**Diagnosis**: Body naked; very small adipose fin is present far behind the small rayed dorsal fin; body strongly compressed; head profile rises gradually to dorsal fin; mouth terminal with 4 pairs of barbels; anal fin very long (Appendix 2; Figure 40).

**Distribution**: Sampled in the Gelegu River (BNB).

**40.** ***Schilbe uranoscopus*** Rüppell, 1832:4—Boulenger (1911):296; Sandon (1950):49; Bailey (1994):956; Golubtsov *et al*. (1995):18; Redeat Habteselassie (2012):174; Eschmeyer *et al*. (2016); Froese and Pauly (2017).

**Common name**(s): Not available.

**Local names**: "Liben/Liven" (Amharic).

**Examined voucher specimen**: ZNHM-FAL-075-77, 43 cm SL; Appendix 2; Figure 39.

**Diagnosis**: No scales on the body; no adipose fin; body strongly compressed; upper profile of head nearly horizontal; mouth terminal with 4 pairs of barbels; anal fin very long (Appendix 2; Figure 39).

**Distribution**: Sampled in Gelegu (BNB) and Shinfa (TAB).

**Order Perciformes**—F (2)

**Family Cichlidae**— G (2), S (2)

**41.** ***Oreochromis niloticus*** (Linnaeus, 1758):290—Golubtsov *et al*. (1995):35; Redeat Habteselassie (2012):195; Eschmeyer *et al*. (2016); Froese and Pauly (2016).

- *Labrus niloticus* Hasselquist, 1757:346—Günther (1896):218.
- *Tilapia nilotica* (Linné, 1757):346—Boulenger (1915):162.
- *Tilapia nilotica* (Linnaeus, 1757): Sandon (1950):56; Shibru Tedla (1973):70.
- *Oreochromis niloticus cancellatus* (Nichols, 1923):2—Trewavas and Teugels (1991):330

**Common name**(s): Nile tilapia.

**Local names**: "Koroso" (Amharic).

**Examined voucher specimen**: ZNHM-FAL-078-80, 43 cm SL; Appendix 2; Figure 42.

**Diagnosis**: Body yellowish brown or greenish grey to dark olive above, whitish below, caudal fin with narrow vertical stripes; pectoral fin relatively shorter rarely extends to anal fin origin; dorsal fin XVI-XVIII 11-15 rays (rarely XV simple rays); anal fin with III8-11 rays; scales on body distinctly smaller than flank scales; mouth terminal with bicuspid teeth on the outer jaws; dark spots on the dorsal and anal fins and numerous narrow cross bars on the caudal fin (Appendix 2; Figure 42).

**Distribution**: Sampled in Ayima, Gelegu (BNB) and Shinfa Rivers (TAB).

**42. *Coptodon zillii*** (Gervais, 1848): 203.

- *Tilapia zillii* (Gervais, 1848)—Boulenger (1915):197; Bailey (1994):966; Golubtsov *et al*. (1995):34; Sandon (1950):56; Shibru Tedla (1973):70; Redeat Habteselassie (2012):197; Eschmeyer *et al*. (2016); Froese and Pauly (2017).

**Common name**(s): Red belly tilapia.

**Local names**: "Koroso" (Amharic).

**Examined voucher specimen**: ZNHM-FAL-081-82, 43 cm SL; Appendix 2; Figure 43.

**Diagnosis**: Body brownish-olivaceous with an iridescent blue sheen; chest pinkish; lips bright green; dark longitudinal band appears on flanks when agitated; no bifurcated dark vertical bars on flanks; dorsal and caudal fins not or feebly blotched; upper profile of head not convex; median pharyngeal teeth not broadened; dorsal fin with 14-16 spines, 10-14 soft rays and anal spines (3). 8-11 lower gill rakers; dorsal and anal fins outlined by narrow orange band; "tilapian" spot large, extending from last spine to $4^{th}$ soft ray and always bordered by yellow band (Appendix 2; Figure 43)**.**

**Distribution**: Sampled in the Ayima, Gelegu and Shinfa Rivers.

**Family Latidae**— G (1), S (1)

**43. *Lates niloticus*** (Linnaeus, 1758):290—Golubtsov *et al*. (1995):32; Redeat Habteselassie (2012):189; Eschmeyer *et al*. (2016); Froese and Pauly (2017).

- *Lates nilotica* Linnaeus 1762 Sandon (1950):53.
- *Lates niloticus* (Linnaeus, 1762):404—Boulenger (1915):105.
- *Lates (Lates) niloticus* (Linnaeus, 1758)—Bailey (1994):963.

**Common name**(s): Nile perch.

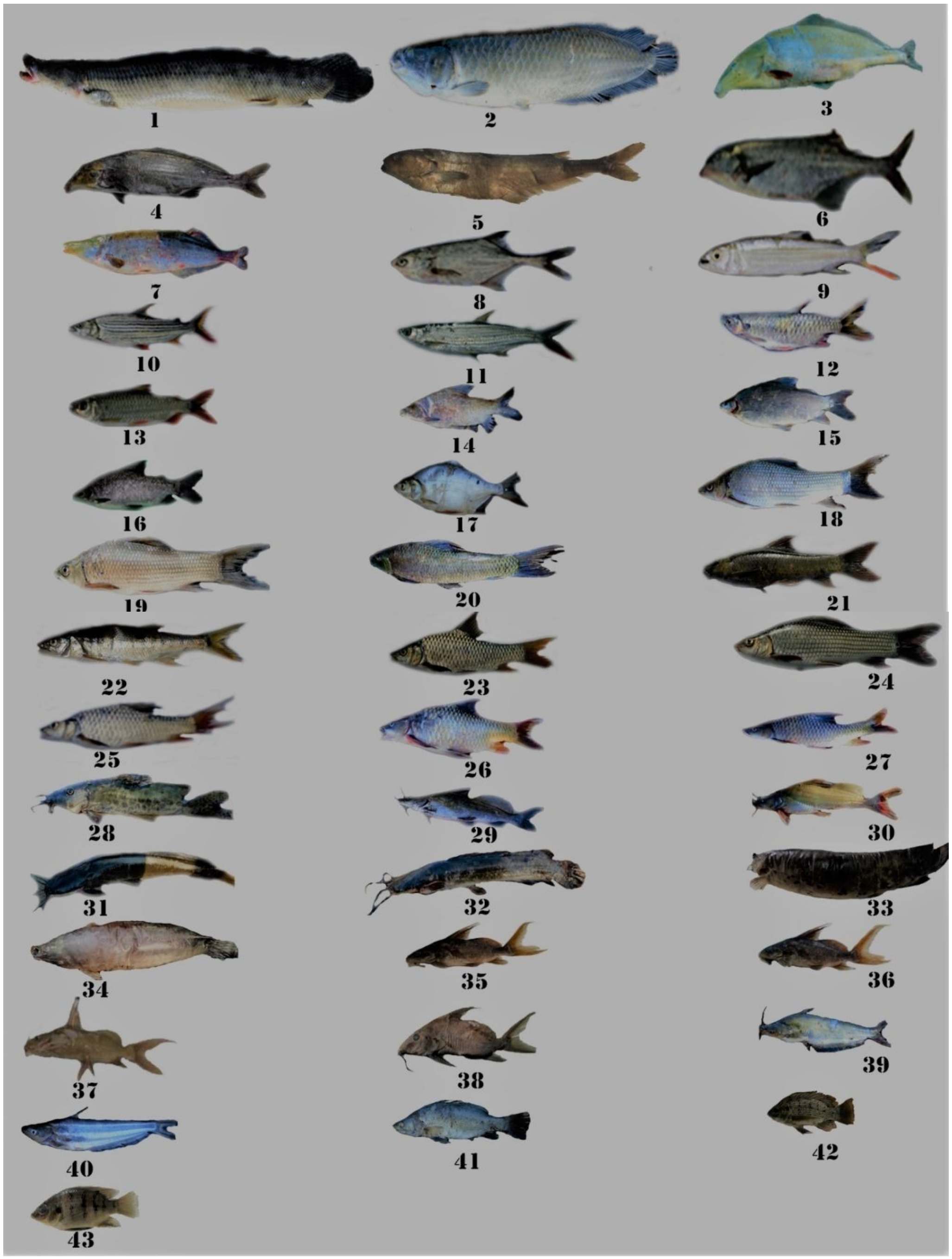
**Local names**: "Ayilla" (Amharic), "Burwa" (Gumuz).

**Examined voucher specimen**: ZNHM-FAL-083-84, 31.5 cm SL; Appendix 2; Figure 41.

**Diagnosis**: Deep body, covered with small ctenoid scales; mouth terminal with villiform teeth lateral line (single) continuous; dorsal fin notched into anterior spiny and posterior soft-rayed sections: anal fin with 3 spines; pelvics with a spine and situated close to the pectorals; dorsal spines and soft rays; 7-8 and 10-14, respectively; caudal fin rounded (Appendix 2; Figure 41).

**Distribution**: Sampled in the Ayima River.

**Appendix 2**. Images of fish species identified from the floodplain rivers of the ALNP during the present study (**Appendix 1** should be referred for detail description of all photos and for specific occurrence of the species).




**(1) *P. bichir* (2) *H. niloticus* (3) *M. kannume* (4) *M. caschive* (5) *H. bebe* (6) *M. cyprinoides* (7) *M. anguilloides* (8) *P. keatingii* (9) *H. forskahlii* (10) *H. vittatus* (11) *A. baremoze* (12) *B. macrolepidotus* (13) *B. nurse* (14) *D. engycephalus* (15) *D. brevipinnis* (16) *D. rostratus* (17) *C. latus* (18) *Labeo niloticus* (19) *L. horie* (20) *L. forskalii* (21) *L. cylindricus* (22) *R. senegalensis* (23) *L. bynni* (24) *L. intermedius* (25) *L. crassibarbis* (26) *L. degeni* (27) *L. nedgia* (28) *A. occidentalis* (29) *B. bajad* (30) *B. docmak* (31) *C. gariepinus* (32) *H. longifilis* (33) *M. electricus* (34) *M. minjiriya* (35) *S. clarias* (36) *S. schall* (37) *S. serratus* (38) *S. sorex* (39) *S. uranoscopus* (40) *S. mystus* (41) *Lates niloticus* (42) *O. niloticus* (43) *C. zillii*.**

**Appendix 3**. A bracketed artificial identification key for the fish species in Blue Nile and Tekeze-Atbara Basins within the limit of Ethiopia. Numbers in parenthesis with English letters refer to the lead characters from which the respective couplets follow; this key is intended for identification of fishes in the Blue Nile and Tekeze-Atbara Basins only in the limits of Ethiopia and thus its application outside this range may not be complete.

**Abbreviations:** ED- eye diameter; SnL- Snout length; IoW- Interorbital width; SL-Standard length; BD- Body depth; LLS- Lateral line scales; HW- Head width; HL- Head length

| | | |
|---|---|---|
| 1 | a | Closely spaced membrane supported finlets on the dorsal fin, continuous with caudal; caudal fin bluntly pointed or more or less truncate; scales thick, bony and rhomboid; body elongate; dorsal fin truncate…………………………… 2 |
| | b | No dorsal finlets; scales soft and large, body more or less elongated ............13 |
| 2 (1a) | a | 14-18 spines (usually 17) dorsal finlets; 63–70 (often 67 scales) in the lateral line; head slightly convex between the eyes......................... ***Polypterus bichir*** |
| | b | No spine on both dorsal and anal fins; dorsal fin long and positioned closer to the rounded caudal fin; no adipose fin; large and strong cartilaginous scales cover the body; mouth terminal with unicuspid teeth ......... ***Heterotis niloticus*** |
| 3 | a | Body covered with various types of overlapping scales, or with small thinner spines instead of scales………..……………………………………………. 20 |
| | b | Body naked, without scale or spines …………………………………....…. 62 |
| 4 | a | Various types of teeth on jaws; barbels absent; fleshy adipose fin present or absent; caudal fin forked, truncate or round….…………......…...………… 14 |
| | b | No teeth on jaws; barbels present or absent; no adipose fin; caudal fin forked…………………………………………………………………… 22 |
| 5 (4a) | a | Mouth small and restricted gape openings, elongated snout; body covered with thin cycloid scales; caudal fin deeply forked; no adipose fin……………..… 6 |
| | b | Mouth large with wide gape openings; rounded snout; scales cycloid or ctenoid cover the body; caudal fin forked/truncate or round; fleshy adipose fin |

present (usually) or absent………………………………………………….. 15

6 (5a) a Snout much elongated resembling proboscis; dorsal fin base twice longer than anal fin base, its origin nearer to head than to caudal……………..…………. 7

b Snout not elongated and not proboscis-like; dorsal fin base is as long as, or even shorter, than anal fin base, both located on the posterior body nearer to caudal...…...………..……………………………………………......……... 8

7 (6a) a Proboscis-like snout straight, not curved downward; dorsal originating well in advance of base of ventral fins, with 76-90 rays; 100-130 LLS....………. ***Mormyrus caschive***

b Proboscis-like snout slightly curved downward; dorsal originating above slightly in advance of base of ventral fins, with 57-75 rays; 115 lateral line scales (LLS)............. ***Mormyrus kannume***

8 (6b) a Anal fin more than 5 times the length of dorsal fin; snout round and short...…. ***Hyperopisus bebe***

b Dorsal fin more or less as long as anal fin……………………...……….. 10

9 a Well developed chin with a globular dermal appendage; mouth terminal; 70-86 LLS…………......….…….. ***Marcusenius cyprinoides***

b Chin absent; mouth sub-inferior; 87-96 LLS…………………….…………… 11

10 (8b) a Body elongated and less deep; mouth sub-inferior; nostrils distant from each other and remote from the eye; 25-28 rays in dorsal fin; 39-42 rays in anal fin; teeth more than 10 and 14, on the entire of upper jaw, and lower jaws, respectively…………………………………… ***Mormyrops anguilloides***

b Body short; mouth inferior; nostrils close together and close to the eye 38-39 rays in anal fin; 25 rays in dorsal fin; 41-44 LLS ….. ***Petrocephalus keatingii***

11 (9b) a Snout much shorter than post orbital part of head; 65-75 rays in dorsal fin; 17-20 rays in anal fin; 88-98 LLS….…..............….. ***Mormyrus hasselquistii***

b Snout pointing straight forwards; 83-90 rays in dorsal fin; 17-18 rays in anal fin; 100-120 LLS…………….………….................. ***Mormyrus niloticus***

12 a Small fleshy adipose fin behind the rayed dorsal fin; dorsal and anal fins with soft rays only; caudal fin forked ……………..……………….……………… 16

b No adipose fin; caudal fin truncate or round; dorsal and anal fins with or without spiny rays …….……..……………………………………..… 21

13 (1b) a Body more or less elongate, less deep; mouth terminal, with unicuspid or pluricuspid teeth on both jaws; ……………………………..………………… 63

b Body rather deep; mouth terminal, inferior or subinferior, with teeth on the lip or jaw; small ctenoid scales cover the body……......................................... 19

14 (4a) a Teeth unicuspid, in a single row on each jaw, visible when mouth is closed; adipose eyelid present …….………………………………………………….. 15

b Teeth largely pluricuspid, in two rows on each jaw, not visible when mouth is closed; inner row of the lower jaw only with two small conical teeth; inner row of premaxilla teeth molariform; adipose eyelid present or absent …..…16

15 (14a) a Tip of dorsal fin, inner edges of caudal fin, and adipose fin black; two rows of scales between the scaly process at pelvic fins and lateral line ……………………………………………………….. ***Hydrocynus vittatus***

b Tip of dorsal fin, inner edges of caudal fin, and surface edges of adipose fin uniformly grayish; two rows of scales between the scaly process at pelvic fins and lateral line………………………….***Hydrocynus forskahlii***

16 (14b) a Adipose eyelid present; black humeral spot or caudal blotch absent; scales in the lateral line more than 38……………………………………….………17

b Adipose eyelid absent or rudiment; black humeral spot usually and caudal blotch always present; scales in the lateral line fewer than 35; gill rakers moderately long ......................................................................................... 18

17 (16a) a Dorsal fin equidistant between ventral and anal fins or nearer to the latter; gill rakers on the lower half of first gill arch no less than 30; anal fin relatively moderately long, with 25–30 branched rays; body less deep; edges of caudal fin only finely black……..***Alestes baremoze***

b Dorsal fin slightly behind the origin of the ventral fin; gill rakers on the lower half of first gill arch no more than 27; anal fin relatively short, with 22–26 branched rays; body more deep; edges of caudal lobes (both) black …………………………….. ***Alestes dentex***

18 (16b) a Dorsal fin originating well behind vertical of base of ventrals; head much flattened above; no blackish spot on lateral line and on behind gill-opening; teeth in outer row of premaxilla 8–14; anal fin with 12-14 branched rays; 22-26 LLS…………… ***Brycinus macrolepidotus***

b Dorsal fin originating above base of ventrals or just behind them; head not much flattened or round; blackish spot present above lateral line, behind gill-opening and another on caudal peduncle; teeth in outer row of premaxilla 8; anal fin with 11-16 branched rays; 26-33 LLS..………… ***Brycinus nurse***

19 (13b) a Mouth small, terminal, with unicuspid teeth on the lip; body highly deep, covered with cycloid scales; base of adipose fin longer than its distance from the dorsal fin..................................................................... ***Citharinus latus***

b Mouth small, subinferior or inferior, with bicuspid teeth on the jaws; body less deep, covered with ctenoid scales covering a body; adipose fin base shorter than its distance from the rayed dorsal fin…………..……………………...22

20 (3a) a Snout feebly compressed; mouth strongly inferior; sides with numerous dark spots; 23-25 rays in dorsal fin; adipose fin small; 75-85 LLS; teeth small, bicuspid usually in two rows in each jaw; dorsal fin long with more than 22 rays; more than 90 scales in the lateral line........... ***Distichodus engycephalus***

b Snout broad and rounded; mouth terminal or slightly inferior; adipose fin rather large, its base as long as or a little shorter its distance from dorsal; 20-26 rays in dorsal fin; ……………………. ***Distichodus brevipinnis***

21 (12b) a Dorsal and anal fins with no spiny rays; lateral line absent; caudal fin truncate to round……..……. ***Distichodus rostratus***

b Dorsal and anal fins with spiny rays; two contiguous dorsal fins, the 1st with VII-VIII spines, the second I-II 10-14; lateral line present and not interrupted; caudal fin truncate or round…....…………………………… ***Lates niloticus***

22 (4b) a Mouth sub inferior; head feebly compressed behind; 3 pairs of barbels; 8-9 branched dorsal-fin rays; the anterior and posterior nares (nostrils) closely spaced (vs. well separated in a congener); body naked or with minute scales; bar-like spots on flanks usually of similar size………………….. ***Afronemacheilus abyssinicus***

b Mouth terminal with bicuspid teeth on the outer jaws; spinous dorsal fin long and continuous; body scales often cycloid; 2 short, incomplete lateral lines; caudal fin truncate; blackish opercular spot ……………..……...……… 23

23 (22b) a Gill rakers relatively short and thick, fewer, 8-12 on the lower half of the first gill arch; body scales often cycloid or feebly denticulate; scales between pectoral and pelvic fins same size as scales on the body side; a black spot (tilapia mark) at the junction of the spinous and soft dorsal rays present……..………………… ***Coptodon zillii***

b Gill rakers relatively thin and long, many, 14-27 on the lower half of the first gill arch; body scales cycloid; scales between pectoral and pelvic fins smaller in size than those on the body side; dorsal fin with 29–33 total rays; dark vertical bars or stripes on the body and caudal fin …… ***Oreochromis niloticus***

24 a Mouth typically inferior, with well developed sucker-like lips, 1or 2 pairs of minute barbels; dorsal fin origin well in advance of the origin of ventral fins……………………………………………………………….. 25

b Mouth inferior, subinferior or terminal; lips thin or thick but never sucker-like; barbels 2 pairs; dorsal fin origin above or slightly behind or in advance of the origin of the ventral fins………………………………...… 26

25 (24a) a Lower lip modified posteriorly into a well developed round mental disc, with free lateral and posterior margins; 2 pairs (nasal and maxillary) of small barbels………....  29

b Both upper and lower lips well developed into a sucker-like structure, but not forming a mental disc; 1 pair of small maxillary barbels………………..... 30

26 (24b) a Disc well developed with free posterior end……………… ***Garra dembeensis***

b Disc little or not developed with no posterior end……………….……… 28

27 (25a) a Rostral fold covering the upper lip; post-pelvic region naked………… 27

b Rostral fold not covering the upper lip; post-pelvic region scaled……. ***Garra regressus***

28 (26b) a Caudal peduncle thin and elongated (20.4-22.3%, standard length, S%L); 39-40 LLS……….. ***Garra tana***

b Caudal peduncle thick and short (13.3-20.7% SL); 37-38 LLS………***Garra dembecha***

29 (25b) a Eye lateral, visible both from bottom and above; rostral flap attached at sides and its free margin smooth; transverse plicae of papillae present or absent on the inner sides of the lips; dorsal fin with more than 10 branched rays..... 30

b Eye supero-lateral visible only from above; rostral flap detached at sides and its free margin feebly denticulate; transverse plicae of papillae present on the inner sides of the lips; dorsal fin with 9–10 branched rays…………….…32

30 (29a) a Branched dorsal fin rays more than 14, its upper edge often more or less concave; 41–45 scales in the lateral line; no transverse plicae of papillae on the inner sides of the lips............................................. ***Labeo niloticus***

b Branched dorsal fin rays not more than 14, its upper edge convex or slightly straight; scales in the lateral line 36 or more………………...… 31

31 a Labial folds rather poorly developed; light colors prevalent in live fish; 40–44

(30b) LLS; no transverse plicae of papillae on the inner sides of the lips……....... ***Labeo horie***

b Labial folds well developed; dark colors prevalent in live fish; 36–40 LLS; transverse plicae of papillae present on the inner sides of the lips ……………… ***Labeo coubie***

32 a Eye relatively large (often OD, orbit diameter > 18% HL, head length);
(29b) transverse groove above the snout present; scales in the lateral line 38–42...…….. ***Labeo forskalii***

b Eye relatively small (often OD < 18% HL); transverse groove above the snout absent; scales in the lateral line 35–39………… ***Labeo cylindricus***

33 a Dorsal spine serrated …………………… ***Enteromius pleurogramma***

b Dorsal spine non-serrated ………….. 34

34 a Large ED (34%, HL); smaller anterior barbel length (4.7%,
(33b) HL)……………… ***Enteromius tanapelagius***

b Smaller ED (32.1%, HL); bigger anterior barbell length (12.9%, HL)…………… ***Enteromius humilis***

35 a Lower lip with a distinct median lobe…………………..37

b Lower lip interrupted or continuous, but not forming a distinct median lobe.38

36 a Upper lip lobe not curling back over the snouts; snout produced into a
(35a) triangular dermal flap over-hanging the lip; lower lip produced into rounded median lobes …………………… ***Labeobarbus degeni***

b Upper lip lobe curls back over the snout; snout produced into a triangular dermal flap over-hanging the lip; lower lip not produced into rounded median lobe ……… ***Labeobarbus nedgia***

37 a Mouth inferior with downward protrusion; HL shorter than BD…….. 42

(35a) b Mouth sub-terminal with no protrusion; HL longer than BD………… 41

38 a ED at least 1.6X in SnL and IoW; anterior barbell longer than 1.1X ED…….
(35b) ***Labeobarbus gorgorensis***

b ED less than 2x in SnL and IoW; anterior barbell length < 1.3x in ED……..39

39 a HL <4.2x in SL; head longer than pectoral-ventral length; 32 LLS…………
(38b) ***Labeobarbus tsanensis***

b HL >4.2x in SL; head shorter than pectoral-ventral length; 38 LLS………. 40

40 a HW<1.8x of HL; HL more than 1.3x of BD…. ***Labeobarbus surkis***

(39b) b HW>1.8 of HL; HL less than 1.3x of BD……. ***Labeobarbus brevicephalus***

41 a Lower and upper lips well developed; no clear nuchal hump………………….
(37b) ***Labeobarbus dainellii***

b Lower and upper lips feebly developed; nuchal hump clearly developed….. 43

42 a Mouth inferior; body very deep (31–38% SL); more angular body profile ;
(37a) considerably long dorsal fin, longer than head, the last unbranched non-serrated ray ossified into a massive spine, and upper fin border concave; 28–37 scales in the lateral line …......................... ***Labeobarbus bynni***

b Mouth terminal; body rather shallow (19–32% SL); less angular body profile; considerably short dorsal fin, shorter than head; 30–36 scales in the lateral line……………… ***Labeobarbus intermedius***

43 a ED<IoW; well developed nuchal hump (Nhu>3) ……….. ***Labeobarbus***
(41b) ***macrophtalamus***

b Usually ED<IoW nuchal hump feebly developed……… 44

a Head is relatively long and narrow, with a small head depth and narrow snout; lower jaw relatively long and is equal to upper jaw; oral gape is large and sub-
44 terminal…. ……….. ***Labeobarbus acutirostris***

(43b) b Head is rather short and deep with straight dorsal profile; lower jaw falls within upper jaw; oral gape small and inferior……… 45

45 a Nuchal hump present (Nhu>3)…………… 46

(44b) b No clear nuchal hump (Nhu<2)…………… 49

46 a Small sized fish (max. 26 cm SL)……. ***Labeobarbus ossensis***

b Usually large fish (>30cm SL)………. 47

47 a Lower jaw extending anteriorly of upper jaw…… ***Labeobarbus megastoma***

(46b) b Lower and upper jaws close equally……. 48

48 a Nuchal hump steeply rising at occiput………. ***Labeobarbus gorguari***

(47b) b Nuchal hump starts gradually at occiput…….. ***Labeobarbus platydorsus***

49 a Anterior barbell very thick and dark; oral gape inferior; dorsal head profile
(45b) convex behind………. ………………………. ***Labeobarbus crassibarbis***

b Anterior barbell thin; oral gape terminal………….. 50

50 a Body slender; BD>4SL…………. ***Labeobarbus longissimus***

(49b) b Body rather deep; BD<4SL………. ***Labeobarbus truttiformes***

51 a No barbells; body elongated; no adipose fin; caudal fin forked …...... 52

b 3 pairs of babells; body cylindrical or little depressed; adipose fin moderate; caudal fin truncate to round …………...……53

52 a Mouth terminal; 10-116 (usually 12) black vertical blotches or bars on each

(51a) sides of the body 50-64 LLS…………. ***Raiamas senegalensis***

b Mouth inferior, surrounded by extended circular lip; no scales on the body...57

53 a Rayed dorsal fin absent; caudal fin nearly truncate; spinous rays absent.....54

(51b) b Rayed dorsal fin present; caudal fin emarginate or deeply forked; spinous rays in dorsal and pectoral fins…………………………………………………55

54 a Pectoral fins placed low on the body, obliquely oriented; broad tooth patches

(53a) on jaws……………….....… ***Malapterurus minjiriya***

b Pectoral fins placed more dorsally, near the body mid-depth, vertically oriented; narrow crescent shaped tooth patches on jaws ……………….. ***Malapterurus electricus***

55 a Caudal fin emarginate……………….……………………56

(53b) b Caudal fin deeply forked…………………………….. 57

56 a Relatively long and more pointed snout; maxillary barbels always shorter than

(55a) the outer mandibular barbel, not extending beyond the posterior border of eye….. ………………***Auchenoglanis occidentalis***

b Relatively short and less pointed snout; maxillary barbels always longer than the outer mandibular barbel, extending beyond the posterior border of eye....…….***Auchenoglanis biscutatus***

57 a Mandibular barbels non-branched; eyes without free border; mouth inferior,

(52b) surrounded by extended circular lip..……………… ***Chiloglanis niloticus***

b Mandibular barbels branched; eyes with free border; mouth inferior, sucker-like but lips not as extended as in *Chiloglanis niloticus* …………..………58

58 a Dorsal fin spine smooth in front except for a few apical or basal serrations;

(57b) basal marginal membrane on maxillary barbel narrow or none; caudal fin forked but not very deeply………………………………………… 59

b Dorsal fin spine with fine serration in front; basal marginal membrane on maxillary barbel broad; caudal fin very deeply forked, with longer upper lobe often ending in filament…………………………………………… 60

59 (58a) a Maxillary barbel not branched; humeral process very obtusely keeled and sharply pointed behind; dorsal fin spine feebly serrated behind…....……… ***Synodontis schall***

b Maxillary barbel branched or ramified, with a distinct marginal membrane at base; humeral process nearly triangular in shape and flattened; dorsal fin spine feebly serrated behind …………..…. ***Synodontis clarias***

60 (58b) a Dorsal fin spine coarsely serrated behind; maxillary barbells with a broad marginal membrane at base; humeral process rounded or obliquely truncate.……………… ***Synodontis sorex***

b Dorsal fin spine finely serrated behind ……..……… ***Synodontis serratus***

61 a Caudal fin round; dorsal fin long; anal fin long extending near to the caudal fin ………..……………..…………….……….…….…… 62

b Caudal fin forked; dorsal fin short; anal fin short, or long extending up to caudal …………..………………..……………………….. 63

62 (61a) a Fleshy adipose fin absent; dorsal fin long, with more than 50 rays; 24–110 long and thin gill rakers on the first gill arch in adult fishes of 60 cm SL or more ……….....… ***Clarias gariepinus***

b Fleshy adipose fin present; caudal fin with a whitish cross bar...............***Heterobranchus longifilis***

63 (61b) a Anal fin very long, with more than 50 rays; body strongly compressed; adipose present or absent …………………… 64

b Anal fin short, with no more than 15 rays including no more 10 branched; body feebly depressed small or moderate adipose fin always present . …. 65

64 (63a) a Fleshy adipose fin present; sloped upper head profile, with gradually ascending nape from occiput to the dorsal fin………… ***Schilbe mystus***

b Adipose fin absent; horizontal upper head profile, with abruptly ascending nape from occiput to the dorsal fin………… ***Schilbe uranoscopus***

65 (63b) a Maxillary barbels short, not extending beyond head; caudal fin lobes not extending into long filaments; dorsal fin with 16 non branched rays………………. ***Clarotes laticeps***

b Maxillary barbels extremely long, extending beyond head, reaching ventral or anal fins; upper caudal lobe extending into long filament, but the lower lobe may or not……….66

66 (65b) a Both upper and lower caudal fin lobes extending into long filament; the first branched dorsal fin ray extending into short filament; dorsal fin with I 9–11 (usually 10) branched rays……...……………… ***Bagrus bajad***

b Upper caudal fin lobe extending into long filament but the lower lobe not; the first branched dorsal fin ray not extending into short filament; dorsal fin with I 8–10 (usually 9) branched rays…………………… ***Bagrus docmak***

**Appendix 4**. Questionnaire prepared to gather some socio-economic and fishing related data on fishery activities from the Blue-Nile and Tekeze Basins.

Addis Ababa University
College of Natural Sciences
Department of Zoological Sciences (FASS)

I am **Alamrew Eyayu Zeleke**, PhD student in the Department of Zoological Sciences (FASS) at Addis Ababa University. Currently I am doing my dissertation on "**Fish biology and fisheries of the floodplain rivers in the Alitash National Park, northwestern Ethiopia**" under the supervision of **Professor Abebe Getahun**. Hence, the very objective of this project is to study the fish species diversity with their respective biology and ways of exploitation and socio-economic values of Rivers Ayima, Gelegu and Shinfa.

Dear respondents, all the genuine information you provide are very important for the success of my work and confidential too, only used for this research activity and will be published only in summary statistical form. I guarantee your full anonymity!

- You can use **English** or **Amharic** language to provide your information as you want.
- In the alternative part you can select more than one (if necessary).
- Above all, I thank you in advance, for giving me your valuable time and answering the questions genuinely for the success of the study.

**Part I: Demography questions (For selected fishermen respondents)**

1. Respondent Name (optional).....................................
2. Age....... 3. Sex....... 4. Residence Woreda………… Kebele............ Village…….
5. Region/ethnicity ……………
6. Marital status Married......... Single......... Divorced …………
7. Your academic level
    a. Illiterate/uneducated
    b. Formal education (between grades: 1-8…… 10/12 completed…… Certificate……. Diploma……….. Degree……
8. Employment

a. Government employee b. NGO employee c. Self employed d. Other (Please mention it) ……………………

9. Household/family size…………..

10. Family background (father/mother): a. Fisher b. Farmer c. Animal producer d. Trader e. Laborer f. Others……

**Part II: General information about the fishermen, ways of fishing and management options and roles of the fisheries.**

11. For how long and why you fish

12. Have you engaged in other agricultural or non-agricultural activities besides fishing? If any, please, list down.

12.1. Put in rank because of importance for your income and or livelihood improvements generation of the above activities?

13. Which kind of fishing are you involved in? a. Individual fisherman b. Organized/cooperative member c. Occasional d. Part-time e. Full time (regular fisherman)

13.1. What ways/materials have you used for fishing?

a. Poison fishing b. Guramba fishing c. Gillnets d. hooks e. Others (specify)

Guramba fishing is a type of fishing exercised by native Gumuz ethnic groups (**seldom by Amhara and Agew**) through which canals/ditches will be constructed along river sides or fencing parts of rivers where one side closed traps set and disturb the water from the top and the fish will move to the fence and then close it so the fish does not return back and they may live inside the Guramba for a period of time.

14. Do you use poison fishing techniques (more confidential response)? a. Yes b. No

14.1. If your answer for question 14 is “a” which poison materials you used?

a. Plant poison b. Synthetic poisons c. Any other (please, specifies it)

14.1.1. If your answer for question 14.1. is “a” or “b” please, try to list the plants and/or chemicals you used?

14.1.2. Which plant parts have you used and where did you find them?

14.1.3. Please write the procedures how you prepare plant parts for fishing?

- **For respondents!** Please note that, your response for Q"14" and on wards will be handled confidential and thank you in advance for your genuine responses once again.

**NB**. "Plant poison" here refers to the naturally occurring/cultivated plant parts from time immemorial fishermen considers having piscicidal activity and they used for fishing and the ways they process or extract is based on their indigenous knowledge and "Synthetic piscicides" refers to the industrial products produced for other purposes but (seldom) used for fishing.

15. How many gears (gillnets) you used per one fishing activity ……………… Please write the mesh size(s), length and width of gillnets you used as much as possible (if you know) ………… and for how long (at least and at most) you will stay in fishing when you use gillnets ……… and how often you go for fishing per day…………

16. Amount of fish harvested by a fisherman per day (Kg/day) (estimated)?

16.1. Amount of fish consumed per family of a fisherman (Kg per day)

16.2. Amount of fish (number or Kg) brought into the market and the income earned by you from selling fish (Birr per day)? …………. and …………Birr.

16.3. Market price of fish (Birr per Kg)? ...........................

16.4. Where is the market you sell your catch or fish product?

16.5. How far do you travel to sell your fish/fish products (you can list in hours or kms)?

16.6. How do you sell your fish?

a. Whole fish (unprocessed) b. Processed c. Smoked d. Dried e. others (specify)

- Please give the list of your processing activities and procedures here (gutting, filleting, deheading …)
- What materials you used for fish processing?

17. Where and how did you acquire fishing gears?

18. How many fish species do you think are/were found in the river? a. While you start fishing ………………. b. In the last 5/10 years……………… c. currently…………

19. How do you think the fisheries production has changed since you have started fishing on the river? a. Increased b. Decreased c. No change (Same amount) d. No idea
20. What do you think are the reasons for the change? Please list them down.
21. How do you rate accessibility of the river for fishing/as site of landing? a. entirely accessible b. moderately accessible c. least accessible d. Not accessible altogether
    - Do you think that this might relate to the development or underutilization of fisheries in the area? ………………………………..
22. If the river is not accessible or only partly accessible for fishing, what do you think are the factors that cause this?
23. What are the major threats to sustainability of the fishes and developing fisheries in the river? (Illegal fishing, water abstraction, overfishing, etc)
24. A. Is the fishery of the river regulated?

a. yes always b. yes sometimes c. yes often d. yes occasionally e. not at all

B. If yes, who regulates fisheries of the river? …………………………..

C. If no who do you think should be concerned? …………………………

D. Do you know of any fishery legislation or law of the country which is meant to regulate the fisheries of the river? Yes/No ………………………

25. Have you got any training concerning about Ethiopian fisheries legislation or other related resources exploitation ways? Yes/No ……………………………

a. If your answer is yes for Q’’25’’ how do you see fisheries development and utilization proclamation No. 315 of 2003 (1995 EC)?

b. Have you ever received any awareness or training on wise use of fisheries resources, especially on impacts of poison fishing? By Whom?

c. Who do you think should be involved in the proper and effective management of the fishes and fisheries to ensure sustainability? (e.g. local people/fishers, Woreda/Zonal/Regional agriculture bureaus, fishermen (both individual and cooperatives), the local Government, NGOs, etc). Please list them in order of involvement?

d. Are there any fishery extension attempts in the Quara Wereda's agriculture bureau that would assist in the development and management of fisheries of the river?

26. Do you think that the Alatish National Park (ANP) delineation have a role on the development and sustainable management for fisheries of the rivers? (For Ayima and Gelegu respondents) only: If yes, how; If no why?

27. In your (opinion) what are the possible solutions or management options to conserve the fishes and sustain the fisheries productions of the area?

Which problems you listed do you think are most significant?

28. As part of an effort to manage the fisheries of the river (s) to ensure sustainability, how do you evaluate about implementation of the following management strategies?

A. Ban poison and other destructive fishing and if there are trespassers bring them into justice? a. agree b. disagree c. no idea

B. Licensing, prioritizing and organizing fishermen in cooperatives?

a. agree b. disagree c. no opinion

C. Closed season when fishing is prohibited for some times

a. agree b. disagree c. no opinion

- If you agree to the area closure/temporal, please suggest any such areas that require and time closure?

D. Limiting the type, number and mesh sizes of the gears used

a. agree b. disagree c. no opinion

29. How do you think is the fate of fisheries production of the future in the river (s)?

a. increase b. decrease c. remain same as the present production d. no idea

30. What are your reasons for your answer for Q. No. 29 above?

**Part III: Interview and Focus group discussions**

- **For the Woreda agriculture officers and concerned bodies**

**1**. Name (optional) ……… Sex ……..

**2**. Educational level:

a. Certificate b. Diploma c. BSc d. DVM

d. Other levels of education (Please list it) …………..

3. Your position and responsibility in the office ………….

4. What looks like the role of fisheries at ground in the Quara Woreda?

5. Do people in the Woreda consider fish and its products in their daily meal? Yes/no

If **No** what do you think are the reasons?

Does females and children involved in fishing activities in the rivers? Yes/No

6. Do you think that the people feel stewardshipnes (considering as their own property) on fisheries of the area? Yes/no………

- If No what do you think the reasons?

7. Are there any fishery proclamations in your office (cascaded) from the Zone/Region? Yes/No…………
    - If yes does emphasizes for Females and Children?
    - Do you have some insight about the Ethiopia's fishery proclamation No. 315 of 2003 (1995 E.C)? Does your office implement this proclamation?
    - Does your office consider the fishery sector to meet the GTP within the agricultural sector? Yes/no……….., if yes what activities your office mandated to cope the sector and needs to meet the intended objectives?
8. Are there any major conservation threats to the fishes of the rivers because respondents (some fishermen) indicated that illegal fishing is common (e.g. poisons fishing). As an officer, do you know fishers use the ban fishing activities in these rivers? Yes/no____,

- If yes, what your office did for this illegal activity and/or what your office will do for the future to ban poison fishing and others that may restrain the development of the fishery sector of the area?

9. Have the fishermen ever been given awareness or training on wise use of fisheries resources by a concerned Woreda or Zonal Bureau? If yes, please give details about the awareness creation/training they are concerned.
10. Benefits of the fisheries activities to the local people in terms of:

Production:

Number of beneficiary fishermen-organized or individuals: ___________

Urban/rural beneficiaries: ___________

Male/Female/Children beneficiaries: ___________

Social status of the beneficiaries (poor/others): ___________

Marketing:

Number of beneficiary fishermen-organized or individuals: ___________

Urban/rural beneficiaries: ___________

Male/Female/Children beneficiaries:___________

Social status of the beneficiaries (poor/others):___________

Gear/hook making:

Number of beneficiary fishermen (organized or individuals):___________

Urban/rural beneficiaries: ___________

Male/Female/Children beneficiaries:___________

Social status of the beneficiaries (poor/others):___________

11. Annual estimation of the contribution of fishery income from the rivers to the economy of the Woreda or Zone or Region (Birr per year)? ____________________

12. Is the fishery activity regulated? If yes, who regulates the fishing activities in Rivers (Ayima, Gelegu and Shinfa) (both production and marketing)?

- If NOT regulated, why?

13. What regulatory framework (rule or direction) is available? How does the availability or unavailability of regulatory framework affect management of fishery in the area?

14. Are there any external factors beyond the woreda's agriculture office mandate/authority that affect the regulation of Ayima/Gelegu/Shinfa River fisheries production?

If yes, what are these factors related to? Natural factors, Social factors, Political factors, Institutional factors, policies, laws, others (specify)

15. Who do you think should be involved in the proper and effective management of the fishes and fisheries to ensure sustainability (e.g. local people/fishers, agriculture bureaus, local government, NGOs, etc)?

16. Is there any fishery extension in the Quara Wereda's agriculture bureau that would assist in the development and management of fisheries of the river? If yes, please give details.

- If no what matters your office not involved in the extension programmes, economy related or others. Please mention some reasons?

17. How do you think the fisheries production from the river has changed in the last 10 years/or after you were employed here? a. increased b. decreased c. same amount d. no opinion

18. What are the main constraints to the development of fish production in the river?

**Fishing gears** (locally manufactured or imported)

**Storage facilities** (deep freezers, generators, etc)

**Lack of marketing links** (local market or export)

**Lack of training for fishermen**

**Illegal fishing**

**Illegal fish marketing**

19. What are your suggestions to improve the conservation of the fishes and to develop and sustain fisheries development in the area?

20. Is there any fish catch statistics data in your office? If yes, please, attach a copy.