Bahir Dar University

College of Agriculture and Environmental Sciences

Spawning Migration of *Labeobarbus* species of Lake Tana to Arno-Garno River, Lake Tana sub-basin, Ethiopia

By

Shewit Gebremedhin Kidane

A Thesis Submitted to the Graduate Program in Partial Fulfillment of the Requirements for the Degree of Master of Science in Agriculture and Environmental Sciences (Fisheries and Wetlands Management)

June, 2011

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Declaration

This is to certify that this thesis entitled "*Spawning migration of Labeobarbus species of Lake Tana to Arno-Garno River, Lake Tana sub-basin, Ethiopia, s*ubmitted in partial fulfillment of the requirements for the award of Degree of Master of Science in Fisheries and Wetland Management to the Graduate Program of the College of Agriculture and Environmental Sciences, Bahir Dar University by Shewit Gebremedhin Kidane (ID. No. CAES/R/288/2002) is an authentic work carried out by him under our guidance. The matter embodied in this project work has not been submitted earlier for award of any degree or diploma to the best of our knowledge and belief.

Shewit Gebremedhin Kidane: ____________________ ______________

Signature Date

Dr. Minwyelet Mingist (Major advisor) ___________________ ____________

Signature Date

Dr. Abebe Getahun (Co-advisor) ___________________ ____________

Signature Date

Wassie Anteneh (Co-advisor) ________________________ ____________

Signature Date

Thesis Approval Sheet

This thesis entitled "*Spawning migration of Labeobarbus species to Arno-Garno River, Lake Tana sub-basin, Ethiopia,* by Shewit Gebremedhin Kidane has been evaluated by the board of examiners and was accepted in partial fulfillment of the requirements of Degree of Masters of Science in Fisheries and Wetland Management.

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ABSTRACT

The spawning migration of Lake Tana's Labeobarbus species to Arno-Garno River and its tributaries was studied from July to December 2010. Abiotic parameters such as dissolved oxygen, temperature, pH, total dissolved solids, conductivity and water transparency were measured from all sampling sites. Fish were sampled monthly in the non-peak spawning season (July, November and December) and twice in the peak spawning season (August to October) using 6,8, 10,12 cm stretched mesh size poly filament gill net. A total of 1077 Labeobarbus specimens were collected within the six sampling months (July to December 2010) from all sampling sites. Out of the total catch of Labeobarbus the four dominant species contributed 93.03%. From the index of relative importance L. intermedius was the most important species. The monthly gonad-somatic indicated that the spawning season for Labeobarbus species was from August to October. Four species (L. intermedius, L.brevicephalus, L. nedgia and L. tsanensis) aggregated at the river mouth. Labeobarbus intermedius and L. tsanensis were the first species to aggregate in the river mouth starting from July and L. brevicephalus and L. nedgia had similar aggregation period in the river mouth starting from September. However, L. intermedius was the first to migrate to the upstream sites starting from the end of July followed by L. tsanensis at the second week of August. The last migrant was L. brevicephalus starting from the fourth week of August. Pair wise comparison of the Labeobarbus species showed temporal segregation in all sampling months, except these L. intermedius and L. brevicephalus that did not show temporal segregation with L. nedgia. To manage these migrating species, closing season should be strictly implemented at least at the peak spawning season from August to October.

Keywords:, Closed season, Condition factor, Reproduction, Sex ratio, Spatial and temporal segregation,

1. INTRODUCTION

Human population is highly increasing in Ethiopia, so it is difficult to support the population with only cereals and livestock production as a source of protein. Therefore, it is necessary to sustainably utilize the aquatic resources, particularly the fishery resources as an inexpensive source of animal protein (Shibru Tedla, 1973; Tesfaye Wudneh, 1998). Although Ethiopia is a land-locked country, it is the water tower of East Africa and has a number of lakes and rivers, from where a great deal of aquatic food resources could be produced. The lakes cover a total area of about 7400 km^2 and the rivers cover a total length of about 7700 km (Wood and Talling, 1998). Lake Tana, which is the largest lake in the country, constitutes almost half of the freshwater bodies of the country (Reyntjes *et al*., 1998; de Graaf *et al*., 2004).

Ethiopia is rich in its fish fauna, having a diversified species in the inland water bodies (Shibru Tedla, 1973; Abebe Getahun, 2002). Lake Tana which is found in the north-western highlands of Ethiopia contains three main families of fish: Cichlidae, Clariidae and Cyprinidae. Cichlidae and Clariidae are represented by single species each: *Oreochromis niloticus* and *Clarias gariepinus*, respectively. The largest family, however, is Cyprinidae and it is represented by four genera:

I. *Barbus* represented by three species: *B. humilis, B. pleurograma* and *B. tanapelagius* (Eshete Dejen *et al*., 2003)
II. *Garra* represented by four species: *G. dembecha*, *G. tana*, *G. regressus* and *G.* small mouth (unidentified species) (Akewake Geremew, 2007)
III. *Labeobarbus* which is the most abundant genus of the family and consists of 15 species forming a unique species flock in Lake Tana (Nagelkerke and Sibbing, 2000).
IV. *Varicorhinus* represented by one species, *V. beso*

The family Cyprinidae is the most widespread and has the highest diversity (>2000 species) among all freshwater fish families and even among vertebrates (Nelson, 1994). Although cyprinid fishes are the most abundant fishes throughout the world’s freshwater systems, the *Labeobarbus* species of Lake Tana become the only remaining intact species flock of large cyprinid fishes, after the one in Lake Lanao in the Philippines, has practically disappeared because of anthropogenic activities (Kornfield and Carpenter, 1984).

The *Labeobarbus* species of Lake Tana had been previously classified under the genus *Barbus*, by adding the prefix ‘large’. However, large, diverse, hexaploid African *Barbus* are renamed as *Labeobarbus* (Skelton, 2001; Berrebi and Tsigenopoulos, 2003; Snoeks, 2004). This genus name better reflects their phylogenetic distance from other members of the overly lumped genus *Barbus* such as the three diploid ‘small barbs’ of Lake Tana. *Labeobarbus* of Lake Tana constitutes a combination of some distinct species and several phenotypically plastic species. Nagelkerke and Sibbing (2000) revised their taxonomy recently, which revealed 15 biologically distinct *Labeobarbus* species that form a species flock.

Species flock is a group of closely related species all living in the same ecosystem. Strictly speaking, the species assemblage must have monophyletic origin. The clear implication, then, is that a species flock evolved within the ecosystem from a single ancestral species by repeated speciation events. Thus, for an assemblage to merit the term species flock, theoretically it should be possible to point to one or more synapomorphies (shared specialized characters) in all members of the fish but not in relatives outside the flock. The common arguments for the species status of *Labeobarbus* of Lake Tana are: their distinct morphometrics (Nagelkerke *et al*., 1994, 1995; Nagelkerke, 1997; Nagelkerke and Sibbing, 2000); their segregation in food niches (Nagelkerke *et al*., 1994; Nagelkerke, 1997; Sibbing and Nagelkerke, 2001; de Graaf, 2003); their spatial distribution patterns (Nagelkerke *et al*., 1994; de Graaf, 2003); the maximal body size they attain (Nagelkerke and Sibbing, 1996); different immuno-genetics (Dixon *et al*., 1996; Kruiswijk *et al*., 2002); and indications of spawning segregation (Nagelkerke and Sibbing, 1996, Palstra, *et al*., 2004). Lake Tana and its *Labeobarbus* species flock provide a unique opportunity to study the selective forces driving speciation and diversity, because (1) it involves an intact species flock; (2) the *Labeobarbus* evolved in a genetically and geographically isolated system (Lake Tana is separated from the lower Blue Nile basin by 40 m high Tisisat Falls); and (3) this *Labeobarbus* species flock is of manageable size (15 species) so all components can be studied simultaneously (de Graaf *et al*., 2008)

The *Labeobarbus* species flock is hypothesized to have radiated from an ancestral riverine benthivorous *Labeobarbus* species resembling the *Labeobarbus intermedius* complex (Banister, 1973) that is common in the Ethiopian highlands and is present along the shores of Lake Tana (Nagelkerke *et al*., 1995; Sibbing *et al*., 1998; de Graaf *et al*., 2005, 2007).

Labeobarbus species are hexaploid and well diversified in their distribution and feeding ecology (Nagelkerke *et al.*, 1994; Nagelkerke, 1997; Sibbing and Nagelkerke, 2001; de Graaf, 2003). Sibbing and Nagelkerke (2001) distinguished five trophic groups based on gut content analysis and morphological prediction: zooplanktivore-insectivore (*L. brevicephalus*), molluscivore (*L. gorgorensis*), macrophytivore (*L. surkis*), four species feed on benthic invertebrates (mainly insect larvae) (*L. crassibarbis*, *L. nedgia*, *L. tsanensis, and L. intermedius*), and eight piscivores (*L. macrophthalmus, L. megastoma, L. longissimus, L. gorguari, L. dainellii, L. truttiformis, L. acutirostris*).

One of the most curious aspects of this species flock is the large number (eight) of piscivores species (de Graaf *et al*., 2000). Cyprinids do not seem well designed for piscivory; they lack teeth in the oral jaws, have a small slit shaped pharyngeal cavity and all lack a stomach with low pH for digesting large prey. The reason why piscivores are common in Lake Tana is due to the absence of other common African piscivorous (like perciform fishes) as competitors. So this allows the *Labeobarbus* of Lake Tana to use their potential for trophic diversification to the fullest (de Graaf *et al*., 2000; de Graaf, 2003).

Cyprinids are riverine in their origin and they are adapted to live in lakes or lacustrine environments. However, most of these species still migrate upstream to spawn in tributary rivers (Tomasson *et al*., 1984; Skelton *et al*., 1991) which indicates that they are not still fully adapted to the lake environment. Different studies conducted in some tributary rivers of Lake Tana such as Gelgel Abay, Gelda and Gumara (Nagelkerke and Sibbing, 1996; Palstra *et al*., 2004; de Graaf *et al*., 2005) and Ribb, Dirma and Megech Rivers (Wassie Anteneh, 2005; Abebe Getahun *et al*., 2008) showed the upstream spawning migration of some lacustrine *Labeobarbus* species.

From previous studies, at least eight *Labeobarbus* species (*L. acutirostris, L. brevicephalus, L. intermedius L. macrophtalmus, L. megastoma, L. platydorsus, L. truttiformis, and L. tsanensis*) of the 15 endemic *Labeobarbus* species of Lake Tana are reported as riverine spawners. But, the remaining seven 'missing' *Labeobarbus* species (*L. dainellii, L. surkis, L. gorgorensis, L. crassibarbis, L. gorguari, L. nedgia, L. longissimus,*) have been assumed either migrating or spawning in Arno-Garno River, or they might be lacustrine spawners (Nagelkerke and Sibbing, 1996; Palstra *et al*., 2004; de Graaf *et al*., 2005; Abebe Getahun *et al*., 2008).

Due to their aggregation over the river mouths, most of the large African cyprinids are vulnerable to fishing activities (Ogutu-Ohwayo, 1990). Unregulated modern fishing has proven to have severe impact on the stocks of lake dwelling or riverine spawning cyprinids. Usually gill nets are set near the river mouths to effectively block upstream spawning migrations. In addition, fish fences are constructed. The most plausible explanation for the decline of the *Labeobarbus* stock in Lake Tana is thought to be recruitment overfishing by the commercial gill net fishery that targets the riverine spawners (de Graaf *et al*., 2004) and poisoning of the spawning stock in rivers using the crushed seeds of Birbira (Nagelkerke *et al.,* 1996; Abebe Amha, 2004). In addition to this, habitat degradation, which is the alteration of breeding ground and/or separation of the river from the lake, which block the returning of juveniles into the lake, can be also the cause for the decline of *Labeobarbus* stock in Lake Tana. Therefore, it is important to provide a good management option so as to prevent those species from such kind of impact. Regarding the *Labeobarbus* species spawning migration, the only unstudied permanent river flowing to Lake Tana is Arno-Garno. Therefore, it was found necessary to carry out detailed investigation of the *Labeobarbus* species in this river for the rational exploitation and conservation of this unique species flock. Thus, the aim of this study was to investigate whether or not the *Labeobarbus* species of Lake Tana migrate to spawn in Arno-Garno River. In this study the reproductive biology of *Labeobarbus* species as well as the presence or absence of spatial and temporal spawning segregations among the species were assessed which helpful in unraveling lacustrine and migratory assumption dilemmas about the eight missing *Labeobarbu*s species. The results of this study are useful for the management of the declining stocks of the unique *Labeobarbus* species.

2. OBJECTIVES

2.1. General objective

The general objective of this study was to collect and establish baseline scientific information about the spawning migration and the reproductive biology of *Labeobarbus* species of Lake Tana. These data are important for the proper utilization of fishery resources of Lake Tana.

2.2. Specific objectives

- To identify *Labeobarbus* species migrating to spawn in Arno-Garno River
- To assess some biological aspects of *Labeobarbus* species migrating to Arno-Garno River for spawning.
- To assess the main spawning season of the *Labeobarbus* species of Lake Tana migrating to Arno-Garno River
- To estimate fecundity and its correlation with fork length, body weight and gonad weight for Arno-Garno River spawning *Labeobarbus* species
- To investigate the pattern of spatial and temporal segregation of *Labeobarbus* species of Lake Tana migrating to Arno-Garno River
- To propose appropriate management option for sustainable utilization of the fishery

3. MATERIALS AND METHODS

3.1. Description of the study area

Lake Tana is the largest lake in Ethiopia with an area of about 3200 km^2 and is situated in the northwestern highlands at an altitude of about 1800 m (Serruya and Pollingher, 1983; Wood and Talling, 1988). The Lake is believed to have originated two million years ago by volcanic blocking of the Blue Nile River (Mohr, 1962) and it is the headwater of the Blue Nile River. It is an oligo-mesotrophic shallow lake with an average depth of 8 m and maximum depth of 14 m and it is turbid, well-mixed and has no thermo cline (Serruya and Pollingher, 1983; Wood and Talling, 1988; Eshete Dejen *et al*., 2004). The catchment area of Lake Tana (16,500 km^2) has a dendritic type of drainage network (Rzoska, 1976). Lake Tana has a temperature of 20.2 to 26.9 °C, total dissolved solids 163.6 $mgl^{-1,}$ pH 6.8-8.3 and conductivity 132.8 µS. cm^{-} (Eshete Dejen *et al*., 2004).

Seven big perennial rivers flow into Lake Tana (Arno-Garno, Dirma, Gelda, Gelgel Abay, Gumara, Rib, and Megech). But, the only out flowing river from Lake Tana is the Blue Nile. Arno-Garno River (Figure 1) is located in the northeastern part of Lake Tana and originates from the north Gonder highlands (Mikael Debir). During the rainy season, Arno-Garno River is on average about 5-10 m wide in the upstream sampling sites. Boulders, pebbles and gravel beds characterize the bottom of the main channel of the river. Before 20 years the river used to join the lake about 1.5 km north of the current river mouth (pers. comm. with farmers). Two temporary rivers (Gramtit and Dobit) join Garno River 6 and 8 kilometers below the main asphalt road to Gonder from Bahir Dar, respectively. One temporary river (Wombha) joins the Arno River near the main asphalt road from Bahir Dar to Gonder.

Currently, during the dry season (starting from February up to June) the river completely separates from the lake due to high sand mining activities and water diversion by the local farmers for irrigation purposes. So, these activities are serious problems for both Arno and Garno

Rivers and their tributaries. However, during the spawning season both rivers recover in volume due to the heavy rains in the area.

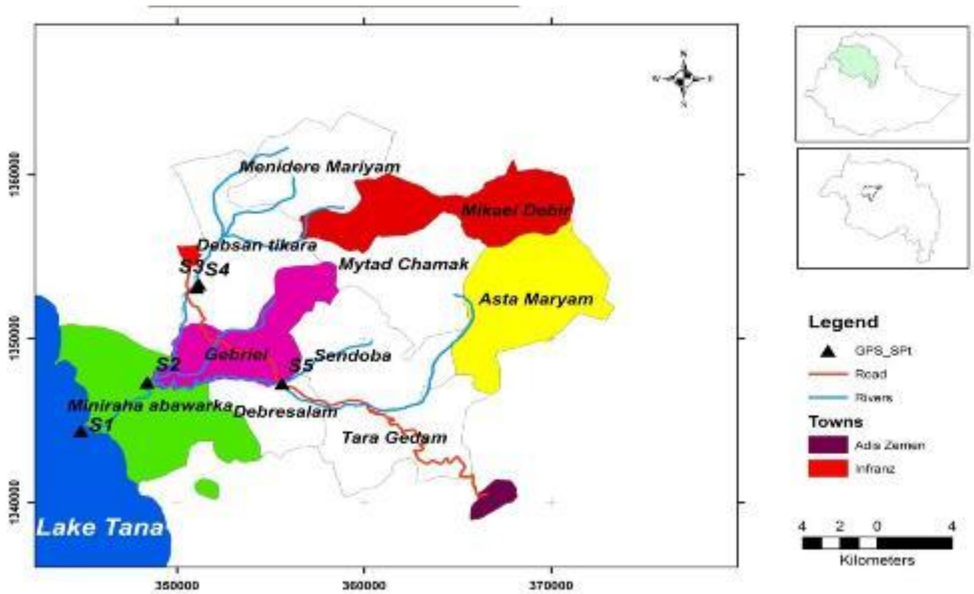


Figure 1: Map of Lake Tana and the sampling sites in Arno-Garno River

The monthly average minimum and maximum temperature and average rainfall at Enfranz starting from 2004-2007 is presented here below in Figures 2 and 3, respectively.

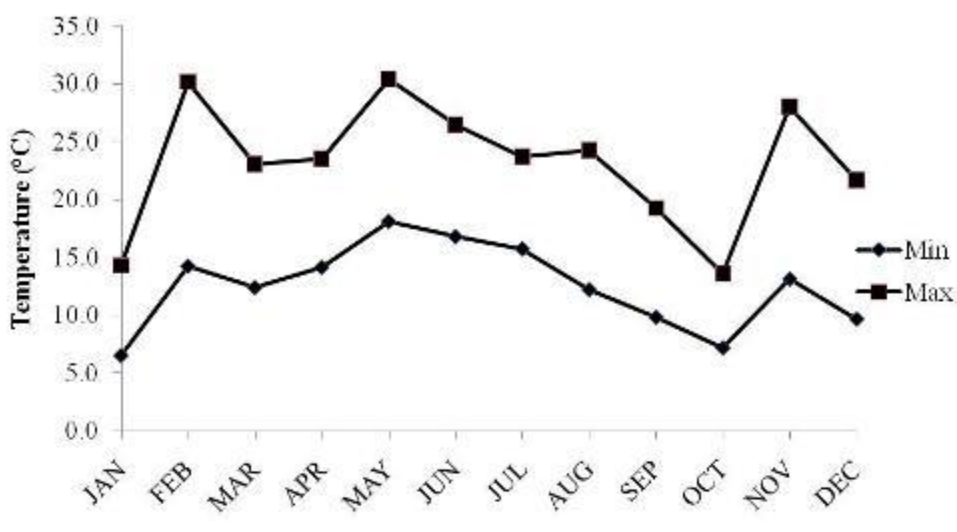


Figure 2: The monthly minimum (Min) and maximum (Max) temperature at Enfraz from 2004

2007 (National Meteorological Agency, Bahir Dar Branch, 2011).

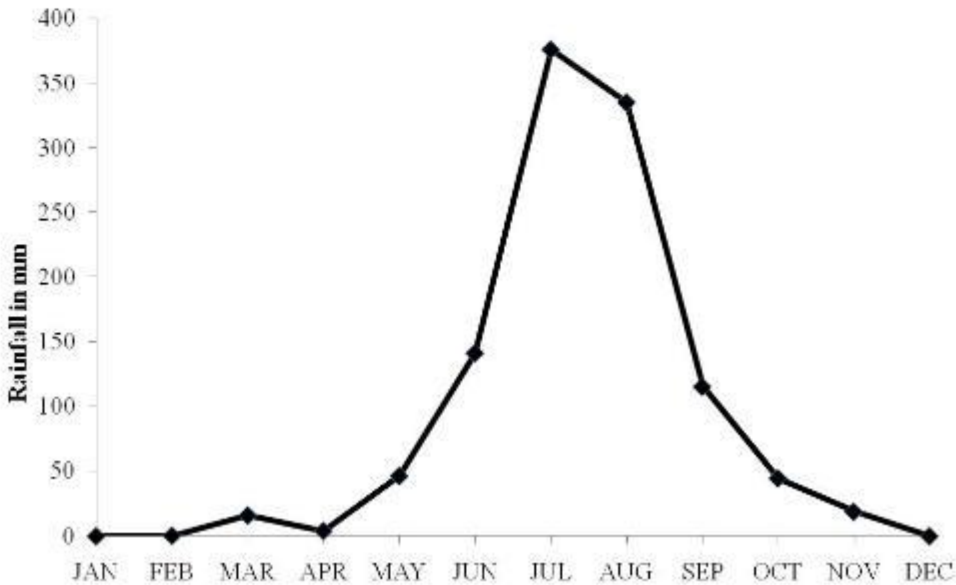


Figure 3: Monthly average rainfall distribution at Enfraz from 2004-2007 (National Meteorological Agency, Bahir Dar Branch, 2011).

3.2 Flora and fauna

During the rainy season the river mouth of Arno-Garno River was covered by dense vegetation such as grass and shrubs. But the Cyprus papyrus, which is common in Gumara and Gelda River mouths and Typha, which is common in Megech and Dirma River mouths were absent in this river (Nagelkerke and Sibbing, 1996; Wassie Anteneh, 2005). The upper part of the river was covered with many shrubs, a few big trees and some Eucalyptus. Besides the fishes there are also other vertebrates around the Arno-Garno river mouth. The most common vertebrates at the river mouth are bird species such as great white pelican (*Pelecanus onocrotalus*), African fish eagle (*Haliacetus vocifer*), Egyptian goose (*Alopochen aegytiaca*), King fisher and common crane. The only mammal, which is found at the river mouth, is Hippopotamus (*Hippopotamus amphibious*).

3.3. Field sampling

Five sampling sites based on the nature, velocity of the flowing river, human interference, suitability for fish spawning, and availability of fishes were selected by preliminary assessment/survey, and sampling sites were fixed using GPS (Table 1). Fish samples were collected monthly in July, November and December 2010. However, samples were collected twice per month from August to October 2010 at all selected sites of Arno-Garno River.

Gill nets of 6, 8, 10 and 14 cm stretched bar mesh, having a length of 25 m and depth of 1.5 m were used to sample fish**.** Gill nets were set in the river mouth at a depth of 2.5-3.5 m overnight. But in the upstream fish were sampled during day time since it is difficult to set gill nets overnight due to the usual heavy rainfall in the afternoon in the area. Fish were identified to species level using keys developed by Nagelkerke and Sibbing (2000) and experienced fish technical assistant from the laboratory of Bahir Dar Fisheries and Other Aquatic Life Research Center. Some fish samples from each species were preserved in 5% formalin solution, and put in plastic jar and transported to the laboratory to serve as reference specimens. Then, fork length (0.1 cm), total weight (0.1g) and gonad weight (0.01g) of each specimen of *Labeobarbus* species were measured at the sampling sites. After dissection, gonad maturity of each fish specimen was identified using a seven-point maturity scale (Nagelkerke, 1997; Table 2) and at the same time each fish was sexed. Samples of eggs from some ripe female *Labeobarbus* species having different fork lengths were preserved using 5% formalin solution for fecundity estimation.

Table 1. Sampling sites, estimated distance from the mouth, gear used and coordinates in the Arno-Garno River

Site	Code	Distance	Coordinate (GPS)
River mouth	RM	____	12°09´29.6´´N; 037°34´31.8´´E
Arno-Garno confluence	AGC	2 km	12°11´07.6´´N; 037°36´30.5´´E
Arno	Arno	30 km	12°10´13.7´´N; 037°43´03.8´´E
Garno	Garno	24 km	12°14´09.7´´N; 037°37´38.7´´E
Wombha	Wombha	28 km	12°09´29.6´´N; 037°40´22.3´´E

Note: Gear used were Gill nets in all sampling sites

Table 2: Gonad maturity stages and descriptions for cyprinids (Nagelkerke, 1997)

Gonad stages	Male	Female
I	Immature, impossible to distinguish females from males. Gonads are a pair of transparent strings running along the body cavity.	Immature, impossible to distinguish females from males. Gonads are a pair of transparent strings running along the body cavity.
II	Unambiguously male, very small testes, white-reddish, not lobed, tube-shaped strings.	Unambiguously female, very small ovaries, tube-shaped and reddish, eggs not visible.
III	Larger testes, white-reddish, somewhat lobed starting to flatten sideways.	Ovary somewhat larger and starting to flatten sideways, eggs visible, but very small.
IV	Large testes, white-reddish, lobed, flattened sideways.	Large ovary, flattened sideways and almost covering body cavity wall, eggs yellowish.
V	Large, white testes, some sperm runs out when testis is cut	Large and full ovary, completely covering body cavity wall, yellowish eggs run out when ovary is cut
VI	Large white testes, running, large amount of sperm runs out when testis is cut	Running, yellow eggs can be extruded by putting pressure on the abdomen
VII	Spent, empty testes, reddish and wrinkled	Spent, wrinkled ovary, reddish, containing a few yellow eggs

3.4. Abiotic factors

The physico-chemical parameters (water temperature, pH, total dissolved solutes, and conductivity) were measured in all sampling sites and time using conductivity meter. Water transparency (Secchi-depth) was measured using Secchi-disc.

Oxygen content was measured using oxyguard portable probe but after 3 samplings the instrument failed to function and complete measurement was not available.

3.5. Relative abundance

Relative abundance is the number of organisms of a particular kind as a percentage of the total number of organisms of a given area or community. Estimation of relative abundance of fishes in Arno-Garno River was made by taking the contribution in number and biomass of each species in the total catch for each sampling effort. An Index of Relative Importance (IRI) was used to evaluate relative abundance.

IRI is a measure of the relative abundance or commonness of the species based on number and weight of individuals in catches, as well as their frequency of occurrence (Kolding, 1989; 1999). IRI was used to find the most important species in terms of number, weight and frequency of occurrence in the catches from the different sampling localities. IRI gives a better representation of the ecological importance of species rather than the weight, numbers or frequency of occurrence alone (Sanyanga, 1996). Percent of IRI was calculated as follows:

$$\%\,\mathrm{IRI} = \frac{(\%W_i + \%N_i) \times \%F_i}{\sum_{j-1}^{s-1}(\%W_j + \%N_j) \times \%F_j} \times 100$$

Where, % W_i and % N_i are percentage weight and number of each species of total catch, respectively; % F_i is percentage frequency of occurrence of each species in total number of settings. % W_j and % N_j are percentage weight and number of total species of total catch, respectively. % F_j is percentage frequency of occurrence of total species in total number of settings.

3.6. Length-weight relationship

The relationship between fork length and total weight of the dominant *Labeobarbus* species of the Arno-Garno River were calculated using power function of $Tw = aFL^b$ as in Bagenal and Tesch (1978), Where; Tw – total weight (g), FL- fork length (cm), a and b are intercept and slope of regression line, respectively. The line fitted to the data was described by the regression equation for each species.

3.7. Condition Factor (Fulton's factor)

The well-being of each dominant *Labeobarbus* species of the Arno-Garno River was studied by using Fulton's condition factor (Lecren, 1951; Bagenal and Tesch, 1978). Fulton's condition factor (%) was calculated as,

$$FCF = \frac{TW}{FL^3} \times 100$$

Where, Tw- total weight (g) and FL- fork length (cm).

3.8. Sex-ratio

Sex ratio, is the proportion of females to males, was determined using this formula

$$\text{sex ratio} = \frac{\text{number of females}}{\text{number of males}}$$

Chi-square (χ^2) was used to test significant difference in sex ratios.

3.9. Gonado-Somatic Index (GSI)

GSI is the ratio of fish gonad weight to body weight. The graphs of the mean monthly GSI against months were used to determine the period and frequency of spawning of the species during the year (Bagenal, 1978). The GSI was determined using the following formula:

$$\text{GSI (\%)} = \frac{\text{Gonad weight (g)}}{\text{Body weight (g)}} \times 100$$

3.10. Fecundity

Fecundity is the number of eggs in ovary before spawning and it was estimated using gravimetric method (MacGregor, 1957) by weighing all the eggs from each of the ovaries of gravid fish species. Samples of eggs were taken from different size classes of each fish species on various ovary areas. These eggs were preserved in a labeled plastic bag containing 5% formalin solution for fecundity estimation (Bagenal, 1978). After ovarian membranes were removed mechanically using tap water from the preserved ovaries, eggs were counted and ova diameter was measured. Three sub-samples of 1 g eggs were taken from different parts of ovary and counted and the average was calculated. The total number of eggs per ovary was calculated by extrapolation from the mean calculated. For random measurement of ova diameter, every 1 g of eggs counted was poured into a Petri dish, calibrated by a grid every 5 mm. The water from the Petri dish was carefully removed without disturbing the eggs distribution in the dish.

Then only those eggs, which touched the grid lines, were measured to the nearest 0.05 mm using an ocular micrometer in a dissecting microscope. But for some ova which did not have circular shape, an average ovum diameter was taken by measuring the largest and smallest dimensions (Heins and Rabito, 1986). The correlation of fecundity with total length, total weight and ovary weight were done to determine the relationship of fecundity with morphometrics measurements. This was done according to the following formula:

$F = aFL^b$; $F = aTw^b$ and $F = a\ GW^b$, where F- Fecundity; FL-Fork length (cm); Tw- Total weight (g); GW- Gonad weight; a- constant and b- exponent.

3.11. Data analysis

SPSS version 16 software was used to compute regression, correlation analyses and some other descriptive statistics. One-way ANOVA was used to analyze length weight relationship and spatial and temporal segregation and Mann-Whitney U test to analyze abiotic parameters and condition factor.

4. RESULTS

4.1. Physico-chemical parameters

Physical and chemical parameters such as dissolved oxygen, temperature, pH, TDS, conductivity and water transparency (secchi depth) from all sampling sites were analyzed using Mann-Whitney U test and there was no significant difference (P>0.05) except secchi depth at all sampling sites (Table 3 and 4). However, water transparency (secchi depth) showed significant variation (P<0.05) between river mouth and Garno and between Arno-Garno confluence and Wombha. It also showed highly significant variation (P<0.01) between river mouth and Wombha at the same time between river mouth and Arno.

Table 3: Abiotic parameters in the river mouth and upstream areas with their Mean ± SE (standard error), total dissolved solids (TDS) and N is number of observation and N= 3 for oxygen and 9 for the rest.

Site	Oxygen (mgl^{-1})	Temperature (^0c)	pH	TDS (ppm)	Conductivity ($\mu s\ cm^{-1}$)	Secchi depth (cm)
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
RM	6.71 ± 1.07	22.82 ± 0.75	6.69 ± 0.33	82.48 ± 11.32	160.34 ± 23.33	17.44 ± 6.33
AGC	7.01 ± 0.50	22.57 ± 0.66	7.04 ± 0.15	94.44 ± 6.85	189.33 ± 13.55	49.00 ±15.02
Garno	7.46 ± 0.69	20.48 ± 1.04	7.48 ± 0.17	86.41 ± 6.08	173.47 ± 12.23	82.56 ± 20.01
Wombha	5.53 ± 1.77	20.13 ± 2.58	6.47 ± 0.84	86.58 ± 11.69	167.76 ± 21.95	98.48 ±18.12
Arno	7.53 ± 0.62	21.96 ± 0.75	7.38 0.23	97.24 ± 3.11	195.72 ± 4.43	100.13 ± 22.43
Average	7.78 ± 0.44	21.59 ± 0.61	7.01 ± 0.19	89.43 ± 3.70	177.33 ± 7.36	69.52 ± 8.81

NB. Average (mean of mean)

Table 4: Pair wise comparison of water transparency (secchi depth in cm) at all sampling sites

Sampling sites	RM	AGC	Arno	Garno	Wombha
RM	X				
AGC	ns	X			
Arno	**	ns	X		
Garno	*	ns	ns	X	
Wombha	**	*	ns	ns	X

** (P<0.01), * (P<0.05), not significant (ns) (P>0.05)

4.2. Species composition in the river mouth and upstream areas

A total of 1159 fish specimens were collected within the six months of (July to December 2010) sampling from all sampling sites (Table 5). Out of the total catch, 11 species are from the genus of *Labeobarbus* and contributed about 93.0% of the catch. From the 11 *Labeobarbus* species, four species contributed about 93.0% of the total *Labeobarbus* catches in the Arno-Garno River (Figure 4). From the total catch of *Labeobarbus* species in the River during the sampling time, *L. intermedius* contributed about 44% by number. *Labeobarbus brevicephalus* was the second most abundant species in the spawning season (28.8%). *Labeobarbus tsanensis* (13.7%) and *Labeobarbus nedgia* (6.6%) were the third and fourth abundant species, respectively. Other species, which were rare in the river mouth includes: *L. platydorsus* (2.1%), *L. truttiformis* (1.2%), *L. surkis* (0.4%), *L. megastoma* (0.6%), *L. crassibarbis* (1.2%), and *L. gorgorensis* (0.5%). No specimens of *L. dainellii*, *L. gorguari*, *L. macrophtalmus*, and *L. longissimus* were caught over the sampling months. From the total of 1077 specimens of *Labeobarbus* species 491 were collected in the upstream sites. Those species that were abundant in the river mouth were also abundant in the upstream sites. However, *L. acutirostris* (0.9%), which was not found in all other sites including the river mouth, found only in Arno site at the first sampling time (July).

From the species that were found rarely in the river mouth, *L. surkis* was totally absent in the upstream areas whereas *L. truttiformis, L. gorgorensis and L. platydorsus* were represented by one specimen each. *Labeobarbus megastoma* and *L. crassibarbs* were represented by 3 and 6 specimens, respectively. In the catch of *Labeobarbus* from Arno-Garno River and its tributaries (n = 1077), four species contributed over 93% of the catch. Therefore, analyses were restricted to these four most abundant species. The other fish species captured in all sampling sites of the river includes *O. niloticus* (1.1%), *C. gariepinus* (3.4%) and *V. beso* (2.6%).

Table 5: Total species composition in Arno-Garno River.

Species	Number (N)	Family
L. intermedius	474	Cyprinidae
L. brevicephalus	310	
L. tsanensis	148	
L. nedgia	71	
L. platydorsus	23	
L. megastoma	6	
L. truttiformis	13	
L. gorgorensis	5	
L. crassibarbis	13	
L. surkis	4	
L. acutirostris	10	
Varicorhinus beso	30	
Clarias gariepinus	39	Clariidae
Oreochromis niloticus	13	Cichlidae
Total	1159	

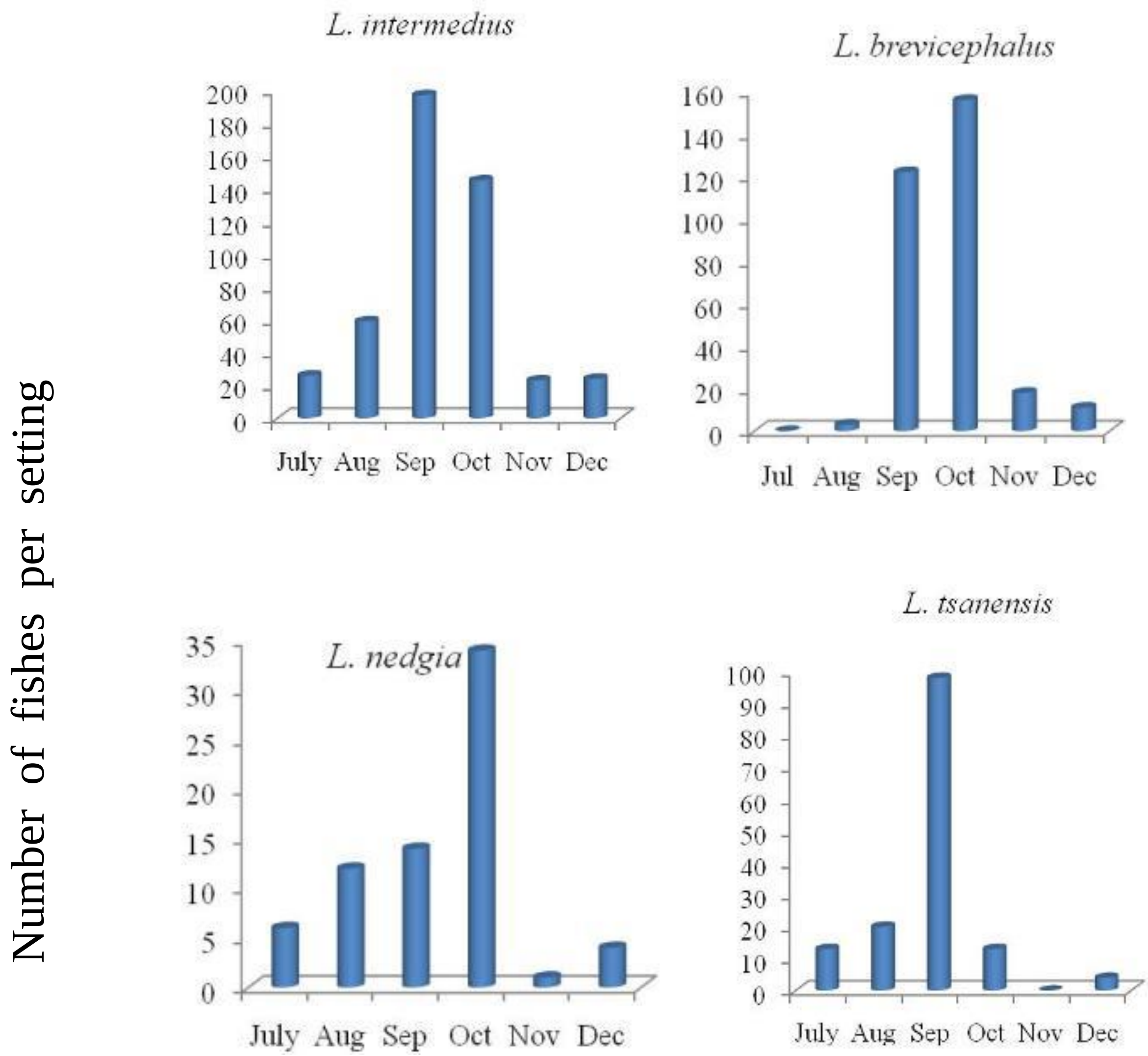


Figure 4: Abundance of the four *Labeobarbus* species (number of fish per settings) in Arno Garno River over the sampling months (July to December).

4.3. Relative abundance

The species composition of gillnet catch from all of the sampling sites and breeding seasons were ranked based on the index of relative importance (IRI) (Tables 6 and 7). *Labeobarbus* *intermedius* was the most important species at all sampling sites. Except at the river mouth and Arno in which *L. tsanensis* and *L. nedgia* were important, *L. brevicephalus* was the second most important species at all the other sampling sites. In addition to this, *L. intermedius* was the most important species in both peak spawning season and non-peak spawning season and *L. tsanensis* was the second important species.

Table 6: Percentage IRI of *Labeobarbus* species in Arno-Garno River in both peak spawning months (August to October) and non-peak spawning months (July, November and December)

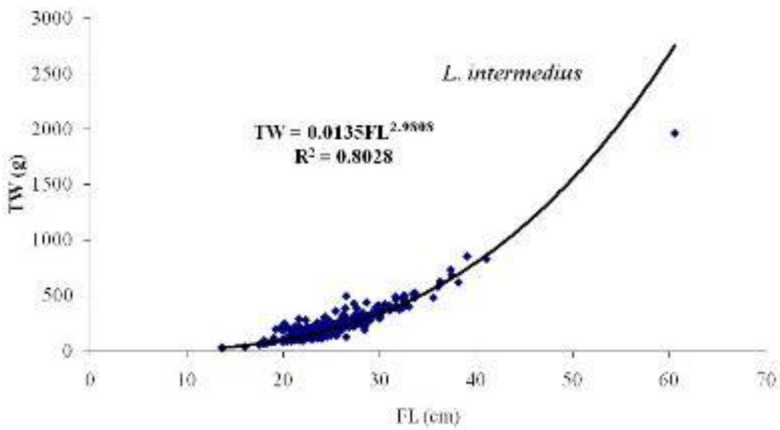
Peak spawning months (August to October)								
Fish	N	%N	W	%W	F	%F	IRI	%IRI
L. intermedius	401	45.93	81359.3	49.12	5	100	9505.51	53.28
L. brevicephalus	281	32.19	36160.1	21.83	3	60	3241.19	18.17
L. nedgia	60	6.87	18111.4	10.93	5	100	1780.78	9.98
L. tsanensis	131	15.01	29997.8	18.11	5	100	3311.72	18.56
Total	873		165629				17839.2	
Non peak spawning months (July, November and December)								
L. intermedius	73	56.15	14721.8	57.55	4	80	9095.93	69.46
L. brevicephalus	29	22.31	3204.1	12.52	1	20	696.64	5.32
L. nedgia	11	8.46	3043	11.89	2	40	814.25	6.22
L. tsanensis	17	13.08	4614.1	18.04	4	80	2489.02	19.01
Total	130		25583				13095.8	

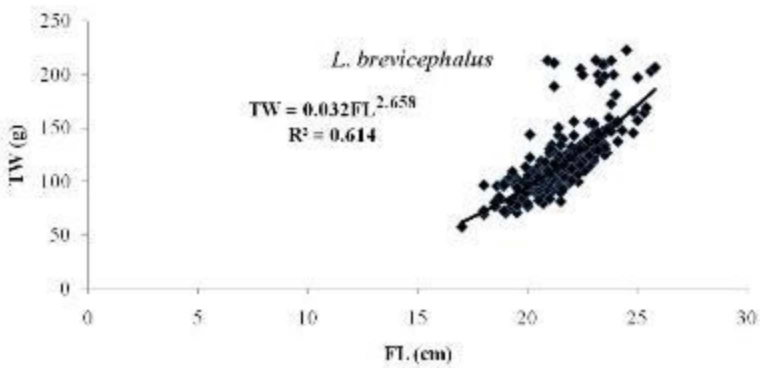
Table 7: Percentage IRI of *Labeobarbus* species in Arno-Garno River at all sampling sites

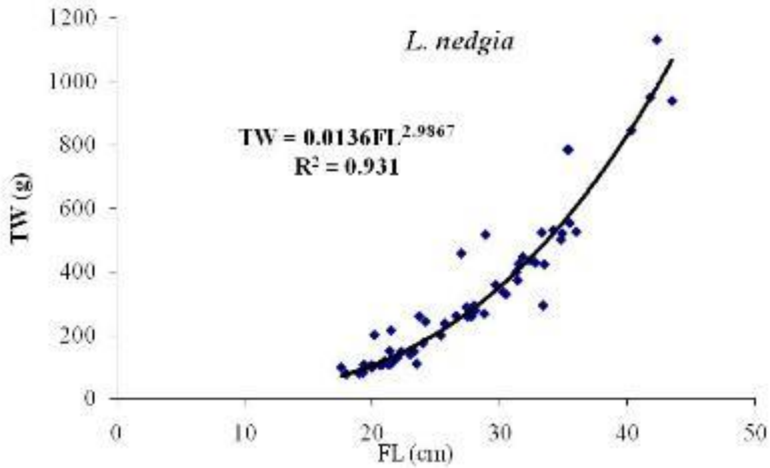
site	fish	N	%N	W	%W	F	%F	IRI	%IRI
RM	*L. intermedius*	272	50.5	53423.1	50.4	5	100	10087.0	54.8
	L. brevicephalus	113	21.0	14636	13.8	3	60	2086.4	11.3
	L. nedgia	24	4.5	6691.6	6.3	4	80	861.3	4.7
	L. tsanensis	130	24.1	31235.1	29.5	5	100	5359.0	29.1
	Total	539		105985.8				18393.7	
AGC	*L. intermedius*	65	42.5	13736.7	55.4	3	60	5875.4	61.4
	L. brevicephalus	74	48.4	8484.9	34.2	2	40	3304.4	34.5
	L. nedgia	0	0	0	0	0	0		
	L. tsanensis	14	9.2	2555.8	10.3	1	20	389.3	4.1
	Total	153		24777.4				9569.2	
Arno	*L. intermedius*	63	43.4	14896.3	47.8	4	80	7301.5	50.9
	L. brevicephalus	55	37.9	6794	21.8	2	40	2389.7	16.7
	L. nedgia	24	16.6	8862.7	28.5	5	100	4500.3	31.4
	L. tsanensis	3	2.1	597.3	1.9	2	40	159.5	1.1
	Total	145		31150.3				14350.9	
Garno	*L. intermedius*	40	40.8	7845.7	44.8	4	80	6853.1	50.0
	L. brevicephalus	45	45.9	6361.8	36.4	3	60	4937.0	36.0
	L. nedgia	13	13.3	3286.9	18.8	3	60	1923.2	14.0
	L. tsanensis	0	0	0	0	0	0		
	Total	98		17494.4				13713.3	
Wombha	*L. intermedius*	34	50.7	6179.3	52.8	3	60	6215.1	62.0
	L. brevicephalus	23	34.3	3087.5	26.4	2	40	2429.2	24.2
	L. nedgia	9	13.4	2313	19.8	2	40	1328.4	13.3
	L. tsanensis	1	1.5	114.9	1.0	1	20	49.5	0.5
	Total	67		11694.7				10022.2	

4.4. Length-weight relationship

Total Weight of the four dominant *Labeobarbus* species showed curvilinear relationship with fork length (FL) and was statistically significant (P<0.001) (one-way ANOVA) and the line fitted to the data was described by the regression equation (Fig. 5).







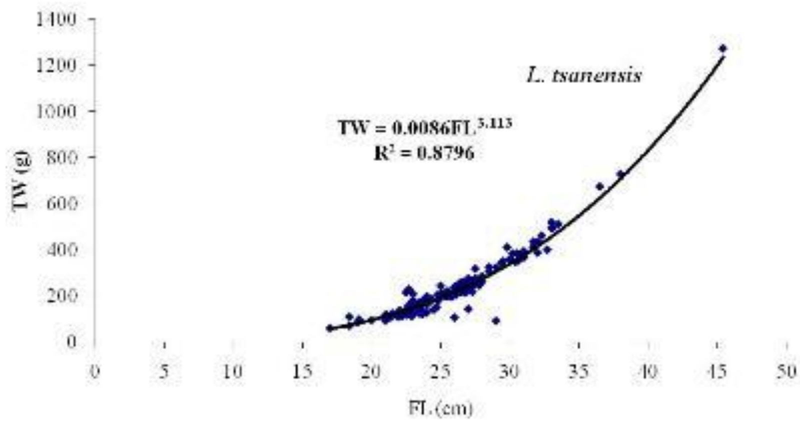


Figure 5: Length-weight relationship of the four dominant *Labeobarbus* species of Lake Tana (N= 474, 310, 71, and148, respectively). Note: N is sample size.

4.5. Fulton's condition factor

Fulton's condition factor for two *Labeobarbus* species (L. *intermedius* and *L. brevicephalus*) both by sex and spawning season in the Arno-Garno River was done. Thus, it was lower for females than males for both species (Table 8). Fulton's condition factor showed significant variation for *L. intermedius* during the peak spawning months (August to October) and non-peak spawning months (July, November and December) ($P<0.001$). However, it was not significant for *L. brevicephalus* ($P>0.05$) (Table 9)

Table 8: Mean ± SE of Fulton's condition factor for the most dominant *Labeobarbus* species in the river by sex. N is sample size, P is significant difference (Mann-Whitney U test).

Species	Sex	N	Mean±SE	P
L. intermedius	M	1139	1.3574 ± 0.03057	0.001
	F	333	1.2762 ± 0.01759	
	Average		1.3001 0.01541	
L. brevicephalus	M	68	1.4948 0.05886	0.000
	F	240	1.2113 ± 0.02113	
	Average		1.2746 ± 0.02203	

NB. Average (mean of mean)

Table 9: Mean ± SE of Fulton's condition factor for the most dominant *Labeobarbus* species of Lake Tana migrating to Arno-Garno River by season. N is sample size, P is significant difference (Mann-Whitney U test).

Species	Months	N	Mean±SE	P
L. intermedius	Peak spawning months (August-October)	399	1.2831 ± 0.01639	0.000
	Non peak spawning months (July, November and December)	73	1.3931 ± 0.04136	
	Average (mean of mean)		1.2998 ± 0.01535	
L. brevicephalus	Peak spawning months (August-October)	281	1.2763 ± 0.02392	0.197
	Non peak spawning months (July, November and December)	27	1.2309 ± 0.03193	
	Average (mean of mean)		1.2721 ± 0.02189	

4.6. Sex ratio

From the total catch of 1077 *Labeobarbus* species in Arno-Garno River in the study period 747 (69.4%) were females and 323 (30.0%) were males. Seven (0.7%) species were unsexed. Generally, females were more numerous than males. Except *L. intermedius, L. brevicephalus*, and *L. tsanensis* the eight *Labeobarbus* species were not significantly different (χ^2, P>0.05) from the theoretical 1:1 ratio (Table 10).

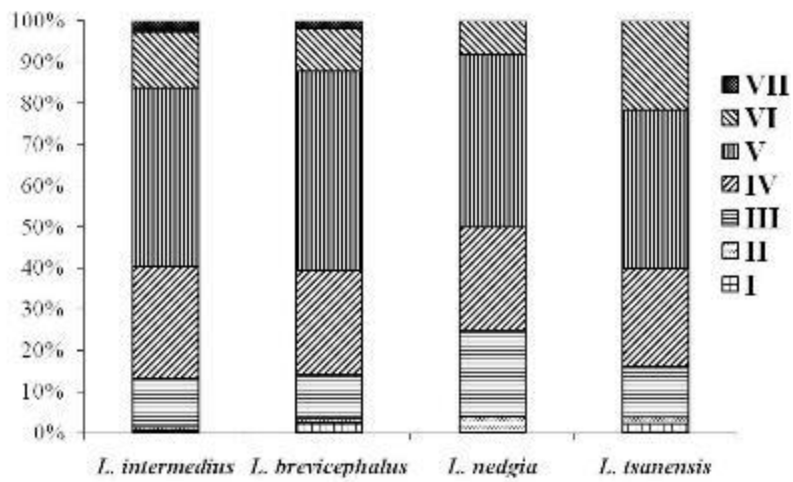
Table 10: Number of males, females, χ^2 values and the corresponding sex ratios in the *Labeobarbus* species in Arno-Garno River (pooled data from all sampling sites).

Species	Males	Females	Sex ratio (Male: female)	χ^2	P
L. intermedius	140	334	1:2.4	79.74	0.000***
L. brevicephalus	68	240	1:3.5	96.05	0.000***
L. tsanensis	56	89	1:1.6	7.51	0.006**
L. nedgia	27	42	1:1.6	3.26	0.072$^{(ns)}$
L. platydorsus	12	11	1:0.9	0.04	0.835$^{(ns)}$
L. megastoma	3	3	1:1	0.00	1.000$^{(ns)}$
L. truttiformis	3	9	1:3	3.00	0.083$^{(ns)}$
L. gorgorensis	1	4	1:4	1.80	0.180$^{(ns)}$
L. crassibarbis	7	9	1:1.3	0.25	0.782$^{(ns)}$
L. surkis	1	3	1:3	1.00	0.564$^{(ns)}$
L. acutirostris	6	4	1:0.67	0.40	0.527$^{(ns)}$

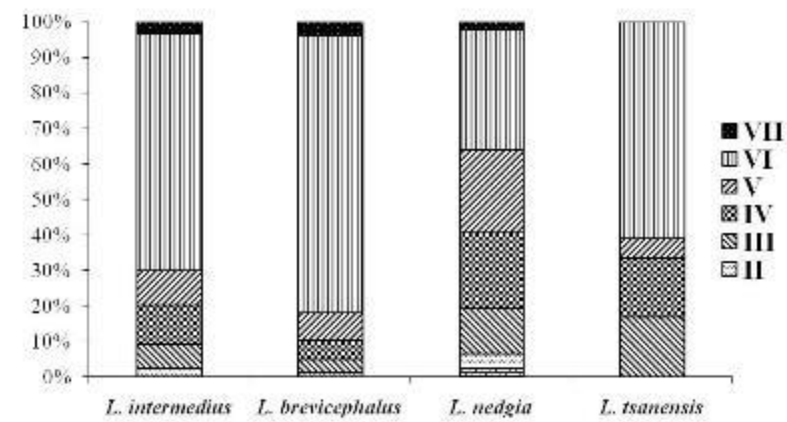
*** (P<0.001), ** (P<0.01), not significant (ns) (P>0.05)

4.7. Gonado Somatic Index (GSI)

The gonad proportion of mature *Labeobarbus* species (gonad stage IV, V), running (gonad stage VI), and spent (gonad stage VII) together was higher (about 86.4%) than the immature gonads (gonad stages I-III) in the samples collected during the peak spawning season (August to October) (Fig. 6). Sixteen (3 in river mouth and 13 in upstream sites) *Labeobarbus* specimens with spent gonads were caught and they were numerous at the end of October. From the total catch of specimens with spent gonad *L. intermedius* and *L. brevicephalus* were represented by 8 specimens each, 2 and 1 in the river mouth and 6 and 7 in the upstream sites, respectively. *Labeobarbus megastoma* had the highest individual GSI (39%) measured in September, but the maximum mean monthly GSI was highest for *L. surkis* (11.4%) in October (Table 11).



(a) River mouth



(b) River upstreams

Figure 6: Proportion of gonad maturity stages (I to VII) of the most dominant *Labeobarbus* species during peak spawning season (August to October) in the River mouth (a) and upstream areas (b) in the Arno-Garno River.

Table 11: *Labeobarbus* species with max. mean monthly GSI (%) and individual fish with max. GSI (%) in Arno-Garno River. N is number of fish used for calculating max. mean GSI (%)

Species	Max. mean Monthly GSI (%)	Monthly mean GSI calculated	N	Max. Individual GIS (%)	Monthly max. individual GSI observed	FL (cm) of individual fish with max. GSI	Site of fish with max. GSI caught
L. intermedius	6.51	Sep	195	16.44	Aug	31	Garno
L. brevicephalus	8.03	Aug	3	17.00	Oct	23.4	AGC
L. tsanensis	4.18	Jul	13	13.27	Sep	22	RM
L. nedgia	2.73	Sep	14	9.58	Aug	35.5	Garno
L. surkis	11.37	Oct	2	12.72	Oct	22.8	RM
L. megastoma	9.62	Sep	2	16.89	Sep	39	AGC
L. gorgorensis	-	-	-	10.97	July	33.2	RM
L. truttiformis	6.52	Sep	8	11.33	Sep	22.9	AGC
L. platydorsus	2.59	Aug	2	5.02	Sep	35	RM
L. crassibarbis	3.74	Sep	4	9.46	Oct	21.5	Arno
L. acutirostris	-	-	-	12.53	Aug	22	Arno

4.8. Fecundity

Fecundity of the most dominant *Labeobarbus* species (*L. intermedius* and *L. brevicephalus*) was done from the total sample taken from Arno-Garno River. *Labeobarbus intermedius* with fork length of 20.1 to 60.5 cm, mean and SE of 27.49 and 1.988 had absolute (total) fecundity ranged from 1935 to 11224 and average fecundity was about 4607. *Labeobarbus brevicephalus* with fork length of 19.4 to 23.6 cm, mean and SE of 21.47 and 0.392 had absolute fecundity ranged from 2305 to 4085 and average fecundity was about 3414. The relationship of absolute fecundity (AF) with FL, TW, and GW of the two species was linear (Figures 7 and 8). There was strong relationship between AF and FL, TW, and GW in both the *L. intermedius* and *L. brevicephalus* species (ANVA, $P<0.05$).

The egg diameter of the most dominant *Labeobarbus* species is presented in figure 9. The size frequency distribution of eggs had shown one modal diameter for both *L. intermedius* (1.86 mm) and *L. brevicephalus* (1.40 mm).

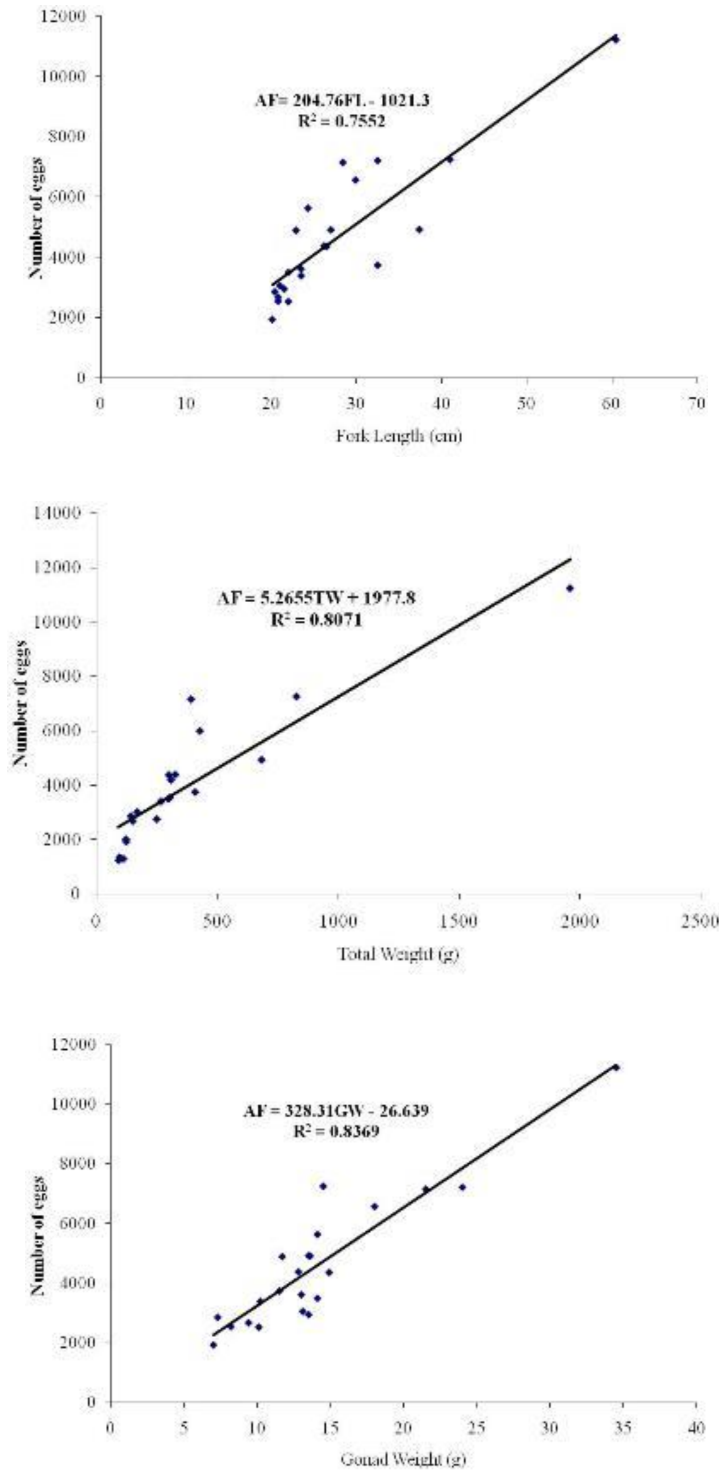


Figure 7: The relationship between absolute (total) fecundity and fork length, total weight, and gonad weight of *L. intermedius* in Arno-Garno River (N = 27, Where N is sample size).

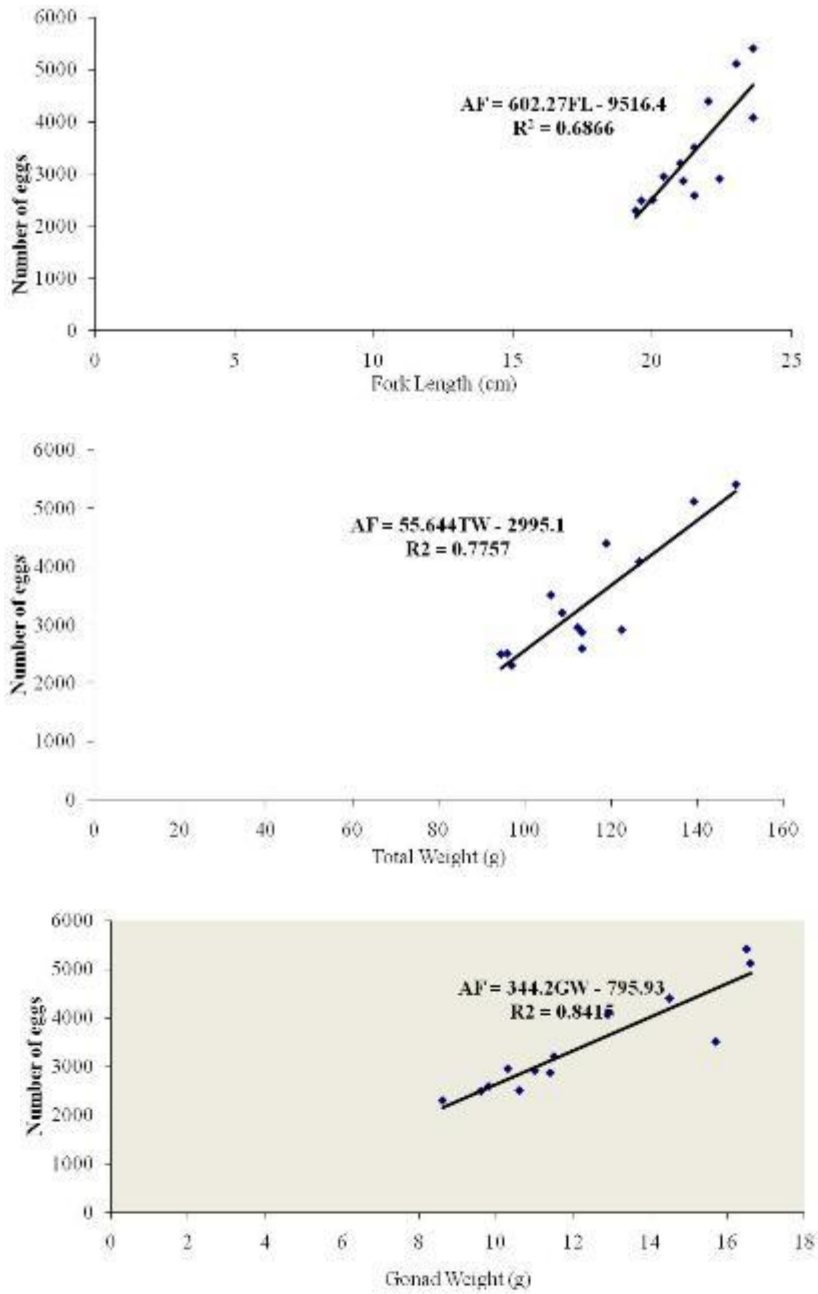


Figure 8: The relationship between absolute (total) fecundity and fork length, total weight, and gonad weight of *L. brevicephalus* in Arno-Garno River (N = 27).

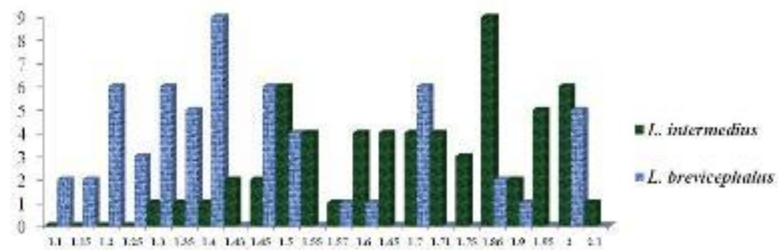
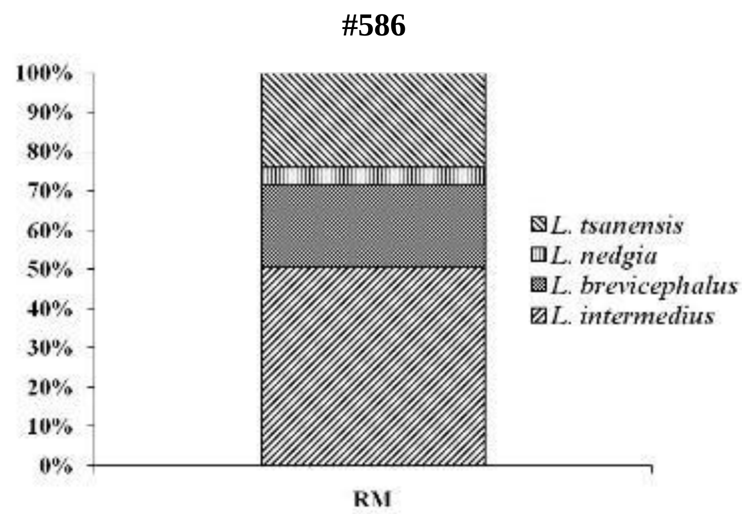


Figure 9: Ova diameter frequency distributions of *L. intermedius* and *L. brevicephalus* in Arno Garno River

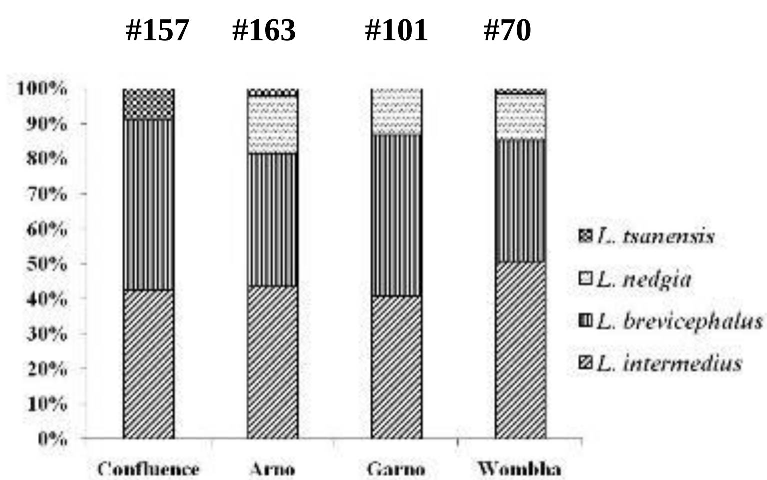
4.9. Segregation of *Labeobarbus* spp. in Arno-Garno River

4.9.1. Spatial segregation

Composition of the most abundant *Labeobarbus* species (temporally and spatially) in all sampling site of Arno-Garno River was revealed bellow (Table 12). There was no significant difference in the distribution patterns of the four most abundant species of *Labeobarbus* over the five sampling sites in Arno-Garno River (one-way ANOVA, P >0.05). Relative contribution of the most dominant *Labeobarbus* species within the sampling site is illustrated in figure 10. *Labeobarbus nedgia* were equally abundant both at Garno, Wombha and Arno but totally absent in the AGC (Fig. 10b). *Labeobarbus intermedius* and *L. brevicephalus* were almost all equally distributed in all sampling sites (Fig.10b).



(a) River mouth



(b) Upstream area sites

Figure 10: Contribution of *Labeobarbus* species at different sampling sites in Arno-Garno River during the sampling months (July-December) (pooled data from river mouth (a) and upstream areas (b)).

4.9.2. Temporal segregation

The aggregation patterns of the *Labeobarbus* species in the river mouth differ over the spawning months (July to November). Proportions of *Labeobarbus* species during the peak spawning season both in the river mouth and upstream sites were revealed in Figure 11 and 12. The aggregation patterns in the river mouth and migration patterns in the upstream sites on monthly basis for the non peak spawning months and bimonthly basis for the peak spawning months are given in figure 13. *Labeobarbus intermedius* and *L. tsanensis* were the first species to aggregate in the river mouth starting from July and reached their peak in the third week of September (Fig. 13a). *Labeobarbus brevicephalus* starts to aggregate in the river mouth on the third week of August and reached its peak at the third week of September. *L. nedgia* was the last species to aggregate in the river mouth starting from the first week of September and reached its peak on first week of October (Fig.13a). All *Labeobarbus* species showed a declining pattern in catch from October to November (Fig. 13b). The first migrant to upstream sites was *L. intermedius*, start to ascend at the end of July, but its catch was higher on August in both Arno and Garno sites (Fig. 13b). *Labeobarbus tsanensis* was the second migrant species starting from the second week of August. The last migrant was *L. brevicephalus* starting from the fourth week of August. Catch of *L. brevicephalus* and *L. tsanensis* reached its peak on October and September, respectively. Pair wise comparison of the four dominant *Labeobarbus* species in Arno-Garno River showed significant variations in temporal segregation ($P<0.001$) except between *L. intermedius* and *L. nedgia* and *L. brevicephalus* and *L. nedgia* (Table 13).

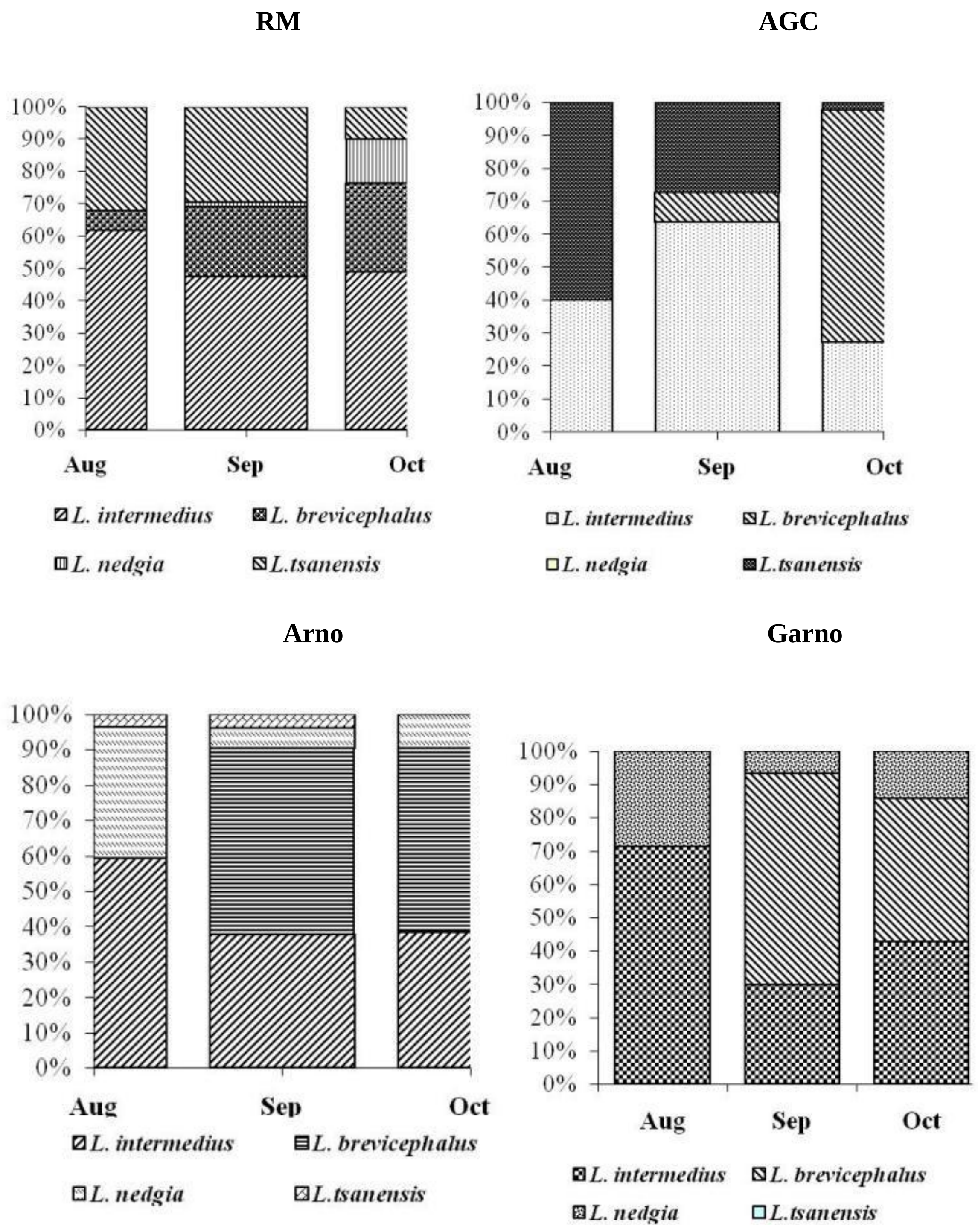


Figure 11: Proportions of *Labeobarbus* species during the peak spawning season in RM, AGC, Arno and Garno sites as a function of time.

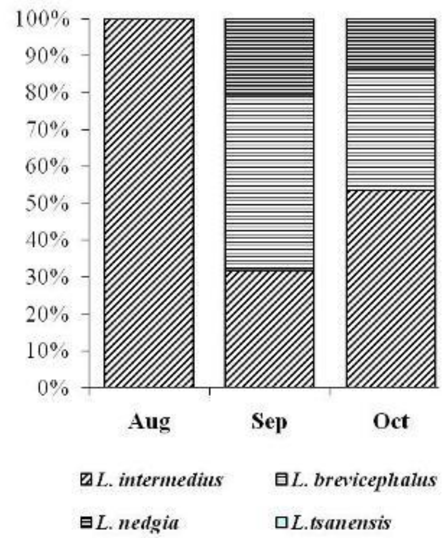
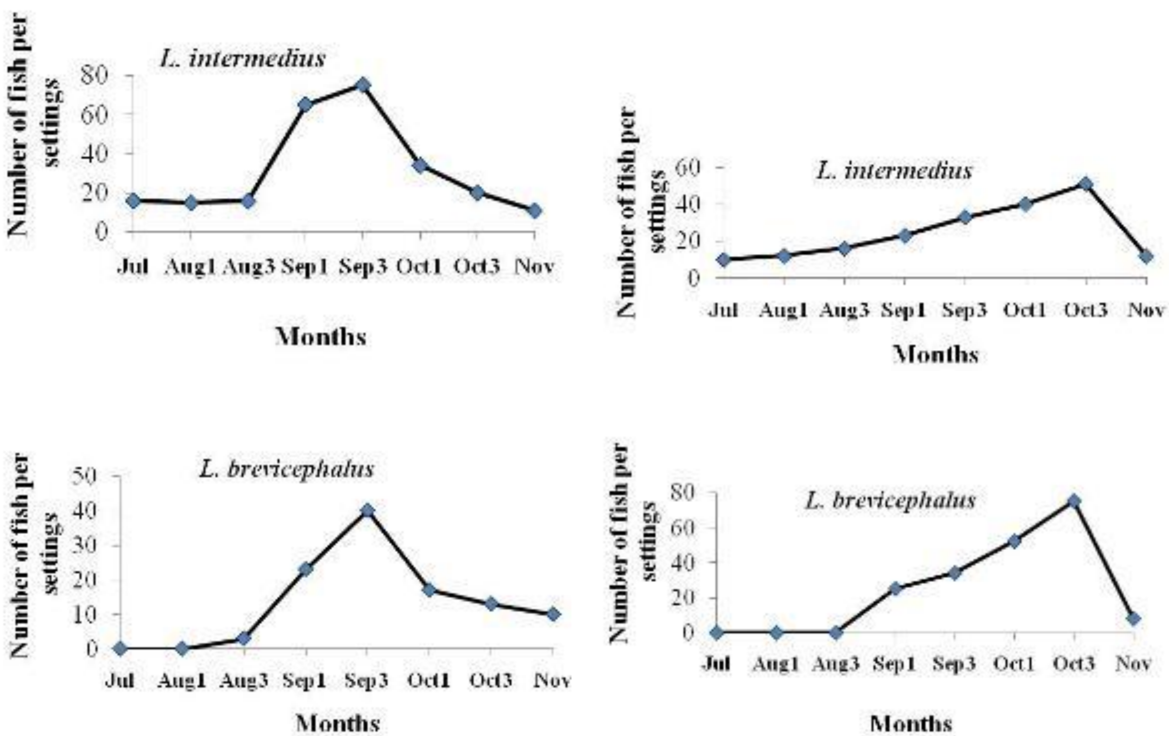
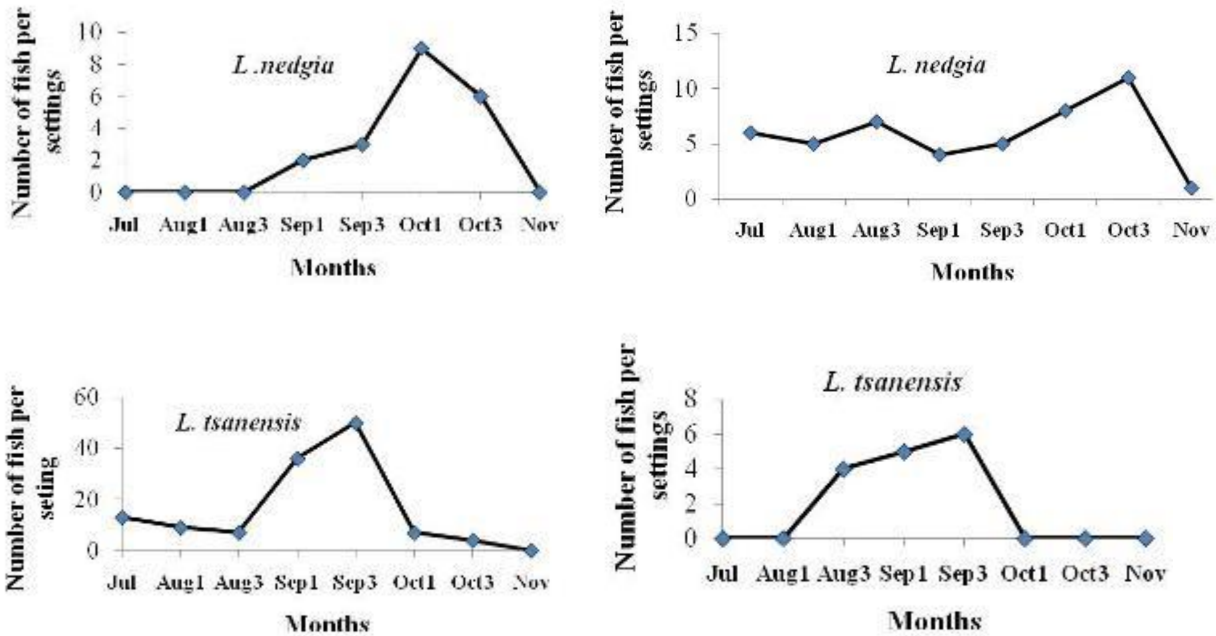


Figure 12: Proportions of *Labeobarbus* species during the peak spawning season at Wombha site as a function of time.





(a) River mouth (b) Upstream sites

Figure 13: Temporal variation in abundance of *Labeobarbus* species in the breeding season (July to November) in the river mouth (a) and upstream sites (b). NB. 1 represents first week of the month and 3 represents third week of the month.

Table 12: Composition of the most abundant *Labeobarbus* species (temporally and spatially) in all sampling site of Arno-Garno River. Data represents absolute number of specimens

	Temporal variation				Spatial variation			
Species	**Aug**	**Sep**	**Oct**	**RM**	**AGC**	**Garno**	**Wombha**	**Arno**
L. intermedius	59	195	145	226	44	38	35	56
L. brevicephalus	3	122	156	96	64	43	23	55
L. tsanensis	20	100	13	115	14	0	1	3
L. nedgia	12	14	34	20	0	12	10	18

Table 13: Pair wise comparisons of temporal segregation of *Labeobarbus* species during the peak spawning season (August to October) in all upstream sites.

Temporal	*L. intermedius*	*L. brevicephalus*	*L. nedgia*	*L. tsanensis*
L. intermedius	X			
L. brevicephalus	***	X		
L. nedgia	ns	ns	X	
L. tsanensis	***	***	***	X

*** (P<0.001), not significant (ns) (P>0.05)

5. DISCUSSION

5.1 Abiotic factors

Like other land organisms, aquatic populations are also highly dependent upon the characteristics of the aquatic habitat, which supports all their biological functions (reproduction, growth, feeding and sexual maturation). Thus, abiotic factors are the controlling factors for the aquatic life, since they shape most of the biological functions of aquatic life (Murdoch and Martha, 1999). Cyprinids (e.g. *Labeobarbus*) as they lack parental care, fast flowing, clear and highly oxygenated water, and gravel-bed streams or rivers are generally their spawning ground requirements (Rodriguez-Ruiz and Granado Lorencio, 1992; Baras *et al*., 1996; Baras, 1997), due to their critical importance in the development of eggs and larvae (Tómasson *et al*., 1984). Deposition of eggs in the gravel or pebble beds protects them from being washed away by riffle, and clear water will not cover them with a film of sediment obstructing the diffusion of oxygen (Lowe-McConnell, 1975).

Arno-Garno River serves as a best spawning area for *Labeobarbus* species since it has fast flowing, clear and highly oxygenated water, gravel beds and absence of clear waterfalls that affect fish migration. The abiotic parameters such as oxygen, temperature, water transparency (secchi depth), conductivity and total dissolved solids (TDS) taken from all sampling sites were analyzed using Mann-Whitney U test and there was no significant difference ($P>0.05$) except secchi depth at all sampling sites. However, water transparency (secchi depth) showed significant variation ($P<0.05$) between river mouth and Garno and Arno- Garno confluence and Wombha and highly significant variation ($P<0.01$) between river mouth and Wombha and between river mouth and Arno. This might be due to the fact that the river mouth gets more turbid due to sediment deposition from various sources. Adequate concentrations of dissolved oxygen (DO) are critical factor for the survival of fish species. Fish have evolved very efficient physiological mechanisms for obtaining and using oxygen in the water to oxygenate the blood and meet their metabolic demands (Washington State Department of Ecology, 2002). Reduced levels of dissolved oxygen can influence growth and development of different life stages of fishes, including eggs, alevins, and fry, as well as the swimming when they migrate, feeding and reproductive ability of juveniles and adults (Washington State Department of Ecology, 2002). Such impacts can affect fitness and survival, by decreasing the size of fry, increasing the likelihood of predation, and decreasing feeding activity. Reduced concentrations of dissolved oxygen can negatively affect the swimming performance of migratory fish (Bjornn and Reiser, 1991). Even if the requirement of DO varies according to species and life stage, DO levels below 3 mgl^{-1} are stressful to most aquatic organisms and levels 5 to 6 mgl^{-1} are usually required to perform their biological functions (Campbell and Wildberger, 1992). The mean DO level of the Arno-Garno River was 7.78 mgl,$^{-1}$ that is greater than 6 mgl,$^{-1}$ which is the required DO level for fish to perform their biological functions. Measurements were taken only on July and August from all sampling sites because of the failure of instrument. The pH value of the River was almost neutral at all sampling sites. A similar observation was made by Wassie Anteneh (2005) in Megech and Dirma Rivers which are thought to be ideal breeding ground for the *Labeobarbus* species of Lake Tana. The specific conductance in natural surface water has been found to range from 50 to 150 µS cm^{-1} but in seawater, it is usually expressed in terms of salinity (American Public Health Association, 1992). The average conductivity of Arno-Garno River was 177.33 µS cm^{-1} and the TDS was 89.43 ppm.

5.2. Relative abundance

Relative abundance is a measure of the relative commonness of the species based on number and weight of individuals in catches, as well as their frequency of occurrence (Kolding, 1989, 1999). The species composition of gillnet catch in all of the sampling sites and the breeding seasons were ranked based on the index of relative importance (IRI). *Labeobarbus intermedius* was the most important species at all sampling sites. *Labeobarbus brevicephalus* was also the second important species at all the sampling sites except at the river mouth and Arno in which *L. tsanensis* and *L. nedgia* was important, respectively. In addition to this, *L. intermedius* was the most important species in both peak spawning season and non-peak spawning season with IRI value of 53.3% and 69.5%, respectively and *L. tsanensis* was the second important species with almost all similar IRI values (i.e. 18.6% and 19%) in both peak and non-peak spawning seasons, respectively.

5.3. Length-weight relationship

The relationship between Fork length and total weight of the dominant *Labeobarbus* species was curvilinear and the line fitted to the data was described by the regression equation as shown in Figure 5. The regression coefficients for most of the dominant species were near to the cube value (b = 3). In fishes, the regression coefficient b = 3 describes isometric growth, which mean that weight increases at a rate of about a cube of increase in length (Allen, 1938 cited in Demeke Admassu, 1990 and Ricker, 1975 cited in Assefa Tessema, 2010). However, fishes may also have “b” value less than or greater than 3, a condition of allometric growth (Bagenal and Tesch, 1978). In agreement with Wassie Anteneh (2005) in Megech and Dirma Rivers, Nagelkerke *et al* (1994) in Lake Tana, most of the dominant *Labeobarbus* species showed nearly isometric growth. Similar results have been reported in Lake Awassa (Demeke Admassu and Elias Dadebo, 1997), in River Sanja (Genanaw Tesfaye, 2006), in Gendewuha, Guang, Shinfa and Ayima Rivers (Dereje Tewabe, 2008), in Borkena and Mille Rivers (Assefa Tessema, 2010) and in the head of Blue Nile River (Mohammed Omer, 2010) for *L. intermedius*.

5.4. Fulton’s condition factor

The measure of fish condition can be linked to various factors such as environment, quality and quantity of food, rate of feeding, reproductive potential, water level fluctuation and disease (Payen, 1986; Getachew Teferra, 1987). Generally, higher condition is associated with higher energy content, adequate food availability, reproductive potential and favorable environmental conditions (Pauker and Coot, 2004). The mean Fulton’s condition factor showed significant variation for *L. intermedius* during the peak spawning season (August to October) and non-peak spawning season (July, November and December) (Mann-Whitney U test, P<0.001), which is similar to result obtained in Megech and Dirma Rivers (Wassie Anteneh, 2005). However, it was not significant for *L. brevicephalus* (Mann-Whitney U test, P>0.05).

In agreement to the result obtained in Megech and Dirma Rivers by Wassie Anteneh (2005), Fulton's condition factor of the most dominant *Labeobarbus* species was lower for females than males in the Arno-Garno River and showed significant variation (Mann-Whitney U test, P<0.001).. This might be due to the energy requirement for egg development in females is higher than sperm production in males. The mean Fulton's condition factor values reported.

by Assefa Tessema (2010) in Borkena and Mille Rivers for *L. intermedius* were 1.23 and 1.31, respectively, greater than the values obtained by Genanaw Tesfaye (2006) in River Sanja, Zeleke Berie (2007) in Beles and Gelegel Beles Rivers and Mohammed Omer (2010) in the head of Blue Nile River. However, the mean Fulton's condition factor of *L. intermedius* in Arno-Garno River was 1.299 higher than the one mentioned in Assefa Tessema (2010) in Borkena River and almost similar to the result obtained in Mille River. This might be due to different in environment, quantity and quality of food, feeding rate, and water level fluctuation.

5.5. Sex ratio

Females were most numerous than males for the *Labeobarbus* species migrating to Arno-Garno River and the variation is higher during peak spawning season. Similar results were obtained for other cyprinid fishes like *Labeo horie* in Lake Chamo (Elias Dadebo *et al*., 2003), *Carassius carassius* in Lake Ziway (Elias Dadebo, 2004), and *Labeobarbus* species in Megech and Dirma Rivers (Wassie Anteneh, 2005). The chi-square test showed that there was significant difference between the number of males and females for *L. intermedius, L. brevicephalus, and L. tsanensis* in Arno-Garno River. Different biological mechanisms such as differential maturity rates, differential mortality rates and differential migratory rates between the male and female sexes may cause unequal sex ratios (Sandovy and Shapiro, 1987; Matsuyama *et al*., 1988). In addition to this Al-kholy (1972) reported females of cyprinid *Putius barberinus* in Lake Lanao live longer time in the spawning areas than males. Hence, living longer time in spawning areas and increased ovarian development as suggested by Tayler and Villoso (1994) may also cause the deviation from 1:1 sex ratio. Therefore, the combination of the above factors might be the cause for the sex ratio variations of *Labeobarbus* species migrating to Arno-Garno River.

5.6. Gonado Somatic Index (GSI)

GSI is the ratio of fish gonad weight to body weight. The graphs of the mean monthly GSI against months used to determine the period and frequency of spawning of the species during the year (Bagenal, 1978; De Silva *et al*., 1985). The mean GSI of a stock tends to increase as the species, reach maturity that is before spawning. Although some specimens of the *Labeobarbus* in Arno-Garno River start to reproduce in July, the peak spawning activity was from August to October. *Labeobarbus megastoma* has the highest individual GSI (39%) measured in September, but *L. tsanensis* (32.52%) was in Megech and Dirma Rivers (Wassie Anteneh, 2005), however, the maximum mean monthly GSI was highest for *L. surkis* (11.37%) in October, similar to the result obtained in Megech and Dirma Rivers (Wassie Anteneh, 2005). Both the appearance of high number of spent females in October and low abundances in the catch may indicate the end of spawning season. de Graaf *et al*. (2005) reported the peak-spawning season for the *Labeobarbus* species in Lake Tana that is August to October. Therefore, the peak spawning season of *Labeobarbus* species, migrating to Arno-Garno River were also similar to this report.

5.7. Fecundity

Information about fecundity of *Barbus* species in Africa is limited (Marshal, 1995). The few data on the fecundity of *Labeobarbus* are from the recent studies by Alekseyev *et al*. (1996) and Wassie Anteneh (2005) from Lake Tana and its tributaries. According to Oliva-Paterna *et al*. (2002) fast growth, high fecundity and early maturity are the characteristics of unstable environments. The absolute (total) fecundity of *L. intermedius* and *L. brevicephalus* ranged from

1935 to 11224 and 2305 to 4085 eggs, and had an average fecundity of 4607 and 3414 eggs, respectively. The result in this study for *L. brevicephalus* was almost similar to the result obtained by Wassie Anteneh (2005) in Megech and Dirma Rivers. The absolute fecundity of *L. intermedius* in Borkena and Mille Rivers ranged from 2736 to 12124 (Assefa Tessema, 2010) and in Beles and Gelegel Beles Rivers ranged from 1535 to 13864 (Zeleke Berie, 2007), which is somewhat higher than the result obtained in this study and this difference might be due to the difference in size at maturity stages or the difference in environment. Fecundity of *Labeobarbus* in other African Lakes is moderately high (Skelton *et al*., 1991).

A female *Labeo aeneus* with 30 cm fork length in Vaal-orange River drainage system carries about 30,000 eggs on average (Gaigher, 1976 cited in Zeleke Berie, 2007) whereas *L. intermedius* in Arno-Garno River with fork length of 60.5 cm which was much larger than this species carries about 11,224 eggs on average. This may be due to the reasons mentioned above.

Generally, the relationship of absolute fecundity (AF) with FL, TW, and GW of the two species was linear and there was strong relationship between AF and FL, TW, and GW in both the *L. intermedius* and *L. brevicephalus* species (ANOVA, $P<0.05$). The fecundity of *L. intermedius* in Beles and Gelegel Beles Rivers (Zeleke Berie, 2007), in Gelda and Gumara Rivers (Alekseyev *et al*., 1996), in Borkena and Mille Rivers (Assefa Tessema, 2010) and in the head of Blue Nile River (Mohammed Omer, 2010) was strongly and positively correlated with its gonad weight, fork length and body weight. Similar result was also obtained in this study.

5.8. Spawning aggregation and segregation

African *Labeobarbus* species predominantly occur in rivers, and although some species are lacustrine, all are riverine spawners (Tomasson *et al*., 1984). All these *Labeobarbus* perform a single annual mass upstream breeding migration, and spawning occurs on gravel beds in clear, small, fast flowing, and well-oxygenated shallow streams (Skelton *et al*., 1991). This ancestral reproductive strategy appears characteristic for at least seven of the *Labeobarbus* species in Lake Tana (Palstra *et al*., 2004; de Graaf *et al*., 2005; Abebe Getahun *et al*., 2008).

Migration of the tropical freshwater fish to the breeding ground is mainly triggered by rainfall patterns and water level variations (Lowe-McConnell, 1975). Although some of the fish species in Lake Tana spawns throughout the year, their peak spawning season, like the tropical freshwater fishes is during the rainy season (de Graaf *et al*., 2005). *Clarias gariepinus* flocks to the flooded areas of Fogera and Dembea from June to July (Tesfaye Wudneh, 1998), *O. niloticus* peak spawning season occurs from June to July (Zenebe Tadesse, 1997) and the small Barbus: *B. humilis* and *B. tanapelagius* spawn starting from March to September (Eshete Dejen *et al*., 2003). The *Labeobarbus* species in Lake Tana also aggregate in the river mouths to spawn in the rainy season (Nagelkerke and Sibbing, 1996; Dgebuadze *et al*., 1999; Palstra *et al*., 2004; de Graaf *et al*., 2005).

In this study four *Labeobarbus* species, (*L. intermedius*, *L. brevicephalus*, *L. nedgia* and *L. tsanensis*) aggregates at the river mouth of Arno-Garno River starting from mid July to the end of October. Those *Labeobarbus* species aggregating at the river mouth of Arno-Garno River were caught with gonad stage IV and V but gonad stage VI was very rare. This implies that *Labeobarbus* species do not spawn at the river mouth and they migrate to the upstream areas of Arno-Garno River.

A total of 491 specimens of *Labeobarbus* species were collected from the upstream sites. Those species that were abundant at the river mouth were also abundant in the upstream sites. However, ten specimens of *L. acutirostris*, a species which was not found in all other sites including the river mouth, were found in Arno River during the first sampling time (July) only.

Unlike the river mouth, the dominant *Labeobarbus* species in the upstream areas were caught with gonad stage VI. *Labeobarbus acutisrostris, L. macrophtalmus, L. megastoma, L. tsanensis,* and *L. truttiformis* were riverine spawners in Gumara River and its tributaries but *L. intermedius* was absent (Dgebuadze *et al*., 1999; Palstra *et al*., 2004). In contrast to this, *L. intermedius* was the dominant species in Arno-Garno River. Wassie Anteneh (2005) also reported similar result from Megech and Dirma Rivers. In agreement to de Graaf *et al*. (2005) in Gelda, Gelgel Abay, Gumara and Rib Rivers *L. surkis* did not aggregate at the river mouth of Arno-Garno River. However, it aggregated in Megech and Dirma Rivers (Wassie Anteneh, 2005). *Labeobarbus megastoma* and *L. truttiformis* which were riverine spawners in Gumara River and Megech and Dirma Rivers (Palstra *et al*., 2004; Wassie Anteneh, 2005) were found rarely in Arno-Garno River. The possible explanation for this might be the size dependent removal of those species by the fishermen who are setting gill nets near the river mouth or this might be due to the river specific spawning behavior of the species. I observed a large number of *L. megastoma* catch starting from July to end of September and *L. truttiformis* catch starting from September to end of August by the local fishermen. Therefore, this evidence strengthens that the reason why these species found rarely in the river.

In addition to this, *L. macrophtalmus* was found to migrate in Gumara River (Palstra *et al*., 2004) but not found in Arno-Garno River. This is similar to what has been reported by Wassie Anteneh (2005) for Megech and Dirma Rivers. This might be due to the river specific spawning behavior of the species.

L. nedgia that was not found in Gelda, Gelgel Abay, Gumara and Rib Rivers (Palstra *et al*., 2004; de Graaf *et al*., 2005), was found in Arno-Garno River. *Labeobarbus nedgia* could not show clear aggregation at the river mouth as the other species but it was found in all of the upstream areas with running gonad stage of both females and males. Its catch also showed a declining pattern starting from the end of October like other *Labeobarbus* species, which probably indicates the end of spawning period. Thus, *L. nedgia* might be one of the migratory *Labeobarbus* species of Lake Tana to Arno-Garno River and/or river dweller as Wassie Anteneh (2005) suggested. Therefore, this needs further investigation to know whether this species is migratory or river dweller.

There was no significant difference in the distribution patterns of the four most abundant species of *Labeobarbus* (one-way ANOVA, P >0.05) over the five sampling sites in Arno-Garno River. *Labeobarbus nedgia* were equally abundant both at Garno, Arno and Wombha but totally absent in the AGC. *Labeobarbus intermedius* and *L. brevicephalus* were almost equally distributed in all sampling sites.

Pair wise comparison of the four dominant *Labeobarbus* species in Arno-Garno River showed significant variations in temporal segregation (P<0.001) except *L. intermedius* with *L. nedgia* and *L. brevicephalus* with *L. nedgia*.

The monthly and bimonthly basis distribution patterns of *Labeobarbus* species during the non peak and peak spawning month's showed that they aggregated at the river mouth of the river. *Labeobarbus intermedius* and *L. tsanensis* were the first to aggregate starting from July and reach their peak in the third week of September, whereas *L. brevicephalus* and *L. nedgia* were the last which aggregates on third week of August and first week of September and peaked in the third week of September and third week of October, respectively. All the four dominant *Labeobarbus* species showed a declining pattern in catch from October to November, which is the indication of the end of spawning period. Different studies conducted in other tributaries of Lake Tana also revealed temporal segregation in *Labeobarbus* species. Palstra *et al*. (2004), de Graaf *et al*. (2005) and Wassie Anteneh (2005) reported the aggregation of *Labeobarbus* species at different time during the spawning season in Gumara, Gelgel Abay, Gelda, Rib, Megech and Dirma River mouths.

Similar results were obtained by de Graaf *et al*. (2005) for *L. tsanensis* and *L. brevicephalus* which were the first and the last species to aggregate in Gelgel Abay, Gelda, Gumara, and Rib River mouths, respectively. However, *L. megastoma* was the first to aggregate in Megech and Dirma River mouths (Wassie Anteneh, 2005). The reason for this difference might be due to heavy exploitation of this species by the fishermen before aggregating at the river mouth because of its large size.

The migration patterns to the upstream areas were determined, on monthly basis, for non spawning months and bimonthly basis, for peak spawning months on the four upstream sites. The first species to migrate to the upstream sites were *L. intermedius* starting from the end of July with highest running species in third week of October and the last migrant was *L. brevicephalus* starting from the first week of September with high running species in third week of October.

5.9. Missing species

From the previous studies on spawning migration of *Labeobarbus* species of Lake Tana, seven species (*L. dainellii*, *L. nedgia*, *L. surkis*, *L. gorgorensis*, *L. gorguari*, *L. crassibarbis,* and *L. longissimus*) were reported as missing species from both river mouths and upstream areas of Gumara, Gelgel Abay, Gelda, Ribb, Megech and Dirma Rivers (Nagelkerke and Sibbing, 1996; Dgebuaze *et al*., 1999; Palstra *et al*., 2004; de Graaf *et al*., 2005; Wassie Anteneh, 2005), Except the *L. surkis,* that was found to aggregate at the river mouths of Megech and Dirma Rivers (Wassie Anteneh, 2005). Two assumptions were also given by the previous studies in the other tributaries of Lake Tana (i.e. the missing species either migrate and spawn in Arno-Garno River, which is the tributary of Lake Tana or they might be lacustrine spawners). In this study, out of the seven species reported above as missing species *L. surkis*, *L. gorgorensis*, and *L. crassibarbs* were caught rarely at the river mouth of Arno-Garno River. In the upstream areas, *L. gorgorensis and L. crassibarbs* were represented by one and six specimens, respectively but *L. surkis* was completely absent. Apparently *L. nedgia* aggregated at Arno-Garno River mouth might be the migratory riverine spawner in Arno-Garno River.

Although lacustrine spawning is a novelty among large African *Labeobarbus* species, very few information have been reported on the lacustrine spawners (*Barbus longiceps Valenciennes*) among large cyprinids from the Middle East (Fishelson *et al*., 1995). The spawning grounds of *Barbus sharpeyi* are confined to the lakes and marshes in the alluvial plain and, to a lesser extent, to the lower reaches of the Tigris and Euphrates Rivers (Al-Hamed, 1972 cited in de Graaf *et al*., 2005). This species deposits eggs on submerged parts of aquatic vegetation or other objects, from the surface down to a depth of 1 m. Besides, Elias Dadebo *et al*. (2003) suggested that *L. horie* spawns in the shallow, littoral zone of Lake Chamo. Generally, the missing *Labeobarbus* species most probably breed in the lake and adjacent floodplains and deposit their eggs on sand or rocks, near roots of plants or on aquatic or flooded terrestrial vegetation as is common in many other cyprinid genera (Mills, 1991). Therefore, like the large African *Labeobarbus* species mentioned above and reasons probably given for missing *Labeobarbus* species which is common in other cyprinid genera, these missing *Labeobarbus* species of Lake Tana may also spawn in the lake itself or migrate and spawn in the other smaller temporary tributaries (like Enfraz River) of the Lake.

5.10. Implications for fisheries management

The susceptibility of large African cyprinids to overexploitation has been proven repeatedly in the previous century, as attested by the collapse of *Labeo mesops* fisheries in Lake Malawi (Skelton *et al*., 1991), *L. victorianus* and *Barbus altianus* in Lake Victoria (Ogutu-Ohwayo, 1990; Ochumba and Manyala, 1992) and *Labeo altivelis* in Lake Mweru (Gordon, 2003). Their reproductive strategy makes these large African cyprinids vulnerable to fishing activities (Skelton et al., 1991). The decline of the African *Labeobarbus* stocks was attributed primarily to increased fishing pressure after the introduction of more efficient gillnets compared to artisanal fishing gear, targeting ripe females during breeding migration (Ogutu-Ohwayo, 1990; Skelton *et al*., 1991; Ochumba and Manyala, 1992).

The migratory *Labeobarbus* species of Lake Tana also are facing the same problem to the above and show dramatic reduction (75%) in abundance (both in number and biomass) of adults and (90%) of the juveniles within ten years (1991-2001) (de Graaf *et al*., 2004). The most important explanation for this is recruitment overfishing. Recruitment overfishing is the exploitation of aggregating species for spawning using unregulated materials that brings a series reduction of recruits for the next year (Gabriel *et al*., 1989; Craig, 1992).

Before 1986, Lake Tana fisheries was made up by a predominantly subsistence reed boat fishery, operated by the Woito people and this type of fishery is limited to the shore areas and targets the native Nile tilapia, *O. niloticus*, using locally made fish traps and small gillnets (length 15–20 m) (Tesfaye Wudneh, 1998). However, after 1986 motorized boats and modern, more efficient, nylon gillnets were introduced in Lake Tana as part of Lake Fisheries Development Project (LFDP) which was initiated by the Ethiopian Ministry of Agriculture and two Dutch NGOs (ISE-Urkt and ICCO-Zeist) (Reyntjes *et al*., 1998). Even though this modern fishery restricts more to the Bahir Dar area that is southern part of the lake, currently this expands all over the Lake and it causes a serious impact on the fish resources by creating opportunity for local fishermen to extend their fishing areas even to distant river mouths.

The fishing activity in the northern part of Lake Tana, particularly in the shore areas of Arno-Garno River is traditional (using reed boats) and there are about 320 fishermen with 5 nylon gillnets having 50 m length each on average (pers. comm. with fishermen). Due to the lack of motorized boats, the local fishermen mostly the Woito ethnic groups target their fishing activity at the river mouth of the river (pers. obs.). *Labeobarbus* species were preferred fishes during the rainy season (July to September) because its price is relatively good (6-8.5 Birr/kg for fresh fish) (pers. Obs.; pers. comm. with the fishermen). Therefore, except the *L. brevicephalus* that has smaller size, all the three aggregating species at the river mouth and the two species (*L. megastoma* and *L. truttiformis*) which are found rarely at the river mouth are highly vulnerable for reed boat fishing in this river.

Before ten years, 1000 kg fish per day was harvested through traditional methods including the fencing activity in the upstream areas of the river but currently it is quite limited. The reason is due to the reduction of production and the fishes migrating to the river have small sizes (pers.comm. with fishermen). The most plausible explanations for the above are probably: increasing number of fishermen fishing at the river mouth and using small mesh sized gillnets, diversion of the river for irrigation by local farmers, and sand mining which is practiced more seriously than on any other tributary of Lake Tana (pers. obs.; pers.com. with farmers). Even though the current fishing activity in the upstream areas in Arno-Garno River is quite limited, I observed some people who used cast nets to harvest fish. The migratory *Labeobarbus* species of Lake Tana may be endangered like the large African Cyprinids in other lakes unless the gill net fishery in the river, at least during the peak spawning months (August to October), is prohibited and the river degradation problems such as sand mining and water diversion should be reduced reasonably to the extent of having less impact on migratory fishes. Therefore, for any policy to be effective the full participation of the various stakeholders is very important. Hence, the executive bodies at the federal level generally and at the regional level (Amhara Region for this case) particularly should create awareness in places where destructive fishing activities are practiced and they should take into consideration the recommendations given by the researchers. Closing gillnet fishery during the spawning months (July to October) which is recommended by de Graaf *et al*. (2004) for Gumara River and Wassie Anteneh (2005) for Megech and Dirma Rivers is also an important management measure for Arno-Garno River. This management measure is preferred due to its simplicity to practice, cheap to implement, enforce and control and its advantage to manage all *Labeobarbus* species, since all spawn from August to October. In addition it will not create total loss of income and food for the fishermen; they can still fish in the non-spawning areas during the spawning months. Closing spawning seasons (at least from August to October) from any kind of activities in the river, like fishing activities, diversion of the river and sand mining (which has a serious impact on the habitat) than other tributaries of Lake Tana is the most appropriate measure. Further, assessing the number of fishermen around the shore areas, the impact of different activities on the river, monitoring commercial catch continuously, and conducting regular exploratory sampling programs are important to evaluate the outcomes of implemented regulations.

6. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

The following are conclusions made from this study:

- Out of the total 1159 fish specimens collected during the study period from all sampling sites, 11 species belong to the genus *Labeobarbus* and the other species were *O. niloticus*, *C. gariepinus*, and *V. beso*.

- From the index of relative importance (% IRI) *L. intermedius* was the most dominant species in Arno-Garno River.

- The relationship between fork length and total weight of the dominant *Labeobarbus* species was curvilinear.

- FCF showed significant variation for *L. intermedius* during the peak spawning season and non-peak spawning season. However, it was not significant for *L. brevicephalus*. FCF of the most dominant *Labeobarbus* species was lower for females than males and showed significant variation.

- Females were most numerous than males for the *Labeobarbus* species migrating to Arno-Garno River and this is high in the peak spawning season. The highest individual GSI measured in September was for *L. megastoma* but the maximum mean monthly GSI calculated in October was highest for *L. surkis*.

- *Labeobarbus intermedius* had both high number of eggs and large ova diameter than *L. brevicephalus* and the relationship of AF with FL, TW, and GW of the two species was linear.

- The spawning season for *Labeobarbus* species was from August to October. Mainly four species (*L. intermedius*, *L.brevicephalus*, *L. nedgia* and *L. tsanensis*) aggregated at the river mouth.

- *L. intermedius* and *L. tsanensis* were the first species to aggregate at the river mouth starting from July and *L. brevicephalus* and *L. nedgia* have similar aggregation period in the River mouth in September. However, the first species to migrate to the upstream sites was *L. intermedius* starting from the end of July and followed by and *L. tsanensis* and the last migrant was *L. brevicephalus* at the end of August.

- Pair wise comparison of the dominant *Labeobarbus* species showed temporal segregation in all sampling months, except those *L. intermedius* and *L. brevicephalus* that did not show temporal segregation with *L. nedgia*.

6.2. Recommendations

- Awareness creation on the migratory *Labeobarbus* species for the public or users should be done to promote conservation of these migratory fish species and their habitats.
- The previous studies in Lake Tana mainly were using traditional methods like CpUE, resulting blurred pictures of migration. Therefore, studies by using modern tagging and tracking techniques such as radio-tracking are urgently needed.
- The impact of habitat degradation due to dam construction, sand mining and water extractions on the migratory *Labeobarbus* species was not examined in Lake Tana area, so emphasis should be given to these factors as they affect the breeding and nursery grounds of the species.
- There is no any management measure in the Arno-Garno River. Hence, it is necessary to put in place the closing season at least during the spawning season (July to October) to reduce recruitment overfishing of the migratory *Labeobarbus* species.
- Distance of the riverine spawners and actual breeding ground of the lacustrine spawners of *Labeobarbus* species should be studied to set in place sound management decisions.
- Excessive sand and water extractions should be reduced.
- The temporary tributaries of Lake Tana (like Enfraz River) should be studied to know whether or not those *Labeobarbus* species migrate to them for spawning.
- As it is very important aspect for fisheries management Size at first maturity for *Labeobarbus* species should be done for the future.
- Generally, this study provides useful information on spawning migration of *Labeobarbus* species for other researchers to study fish migration in Lake Tana and other Ethiopian lakes and rivers.

7. REFERENCES

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