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Some Biological Aspects of *Labeobarbus* spp. (Pisces: Cyprinidae) at Arno-Garno River, Lake Tana Sub-Basin, Ethiopia

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ABSTRACT

The reproductive biology of *Labeobarbus* species in Arno-Garno River was studied from July 2010 to June 2011. Fish were sampled monthly in the non-peak spawning season and twice in the peak spawning season using 6, 8, 10, 12 and 14 cm mesh size gill net. A total of 1077 *Labeobarbus* specimens were collected within the six sampling months 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 dominant species which contributes 44%. Length-weight relationship of the four dominant *Labeobarbus* species was curvilinear and statically significant ($p<0.001$). Fulton's condition factor was lower for females than males for *L. intermedius* and *L. brevicephalus* and showed significant variation for *L. intermedius* during the peak and non-peak spawning months ($p<0.001$). Except, *L. nedgia*, the remaining *Labeobarbus* species were significantly different (χ^2, $p<0.05$) from the theoretical 1:1 ratio. The average fecundity for *L. intermedius* and *L. brevicephalus* were 4607 and 4085, respectively. The relationship of absolute fecundity with Fork length, total weight and gonad weight of the two species was linear and significant ($p<0.05$). The monthly gonad-somatic indicated that the spawning season for *Labeobarbus* species was from August to October. Hence, closing season should be strictly implemented.

Key words: Condition factor, closed season, gonado somatic index, length-weight, sex ratio

INTRODUCTION

Sustainable utilization of the aquatic resources, particularly the fishery resources is necessary so as to support the increasing Ethiopian human population through inexpensive source of animal protein (Tedla, 1973; Wudneh, 1998). Ethiopia which is a land-locked country 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, 1988). Ethiopia is rich in its fish fauna, having a diversified species in the inland water bodies (Tedla, 1973; Getahun, 2002).

Lake Tana, the largest lake in the 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.

Cyprinid fishes are the most abundant fishes throughout the world's freshwater systems (Nelson, 1994). However, *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 revised taxonomy revealed 15 biologically distinct *Labeobarbus* species that form a species flock (Nagelkerke and Sibbing, 2000). 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).

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; Nagelkerke and Sibbing, 1996; Palstra *et al*., 2004; Anteneh, 2005; De Graaf *et al*., 2005; Getahun *et al*., 2008) which indicates that they are not still fully adapted to the lake environment.

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 and Sibbing, 1996; Ameha, 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 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 the reproductive biology of *Labeobarbus* species which helpful in sustainably using the fish resources. The results of this study are useful for the management of the declining stocks of the unique *Labeobarbus* species.

MATERIALS AND METHODS

Description of the study area: Lake Tana is the largest lake in Ethiopia with an area of about 3200 km^2, catchment area of 16,500 km^2 and shallow lake with an average depth of 8 m and maximum depth of 14 m (Vinkenborg *et al*., 2010). 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. 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 (Fig. 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

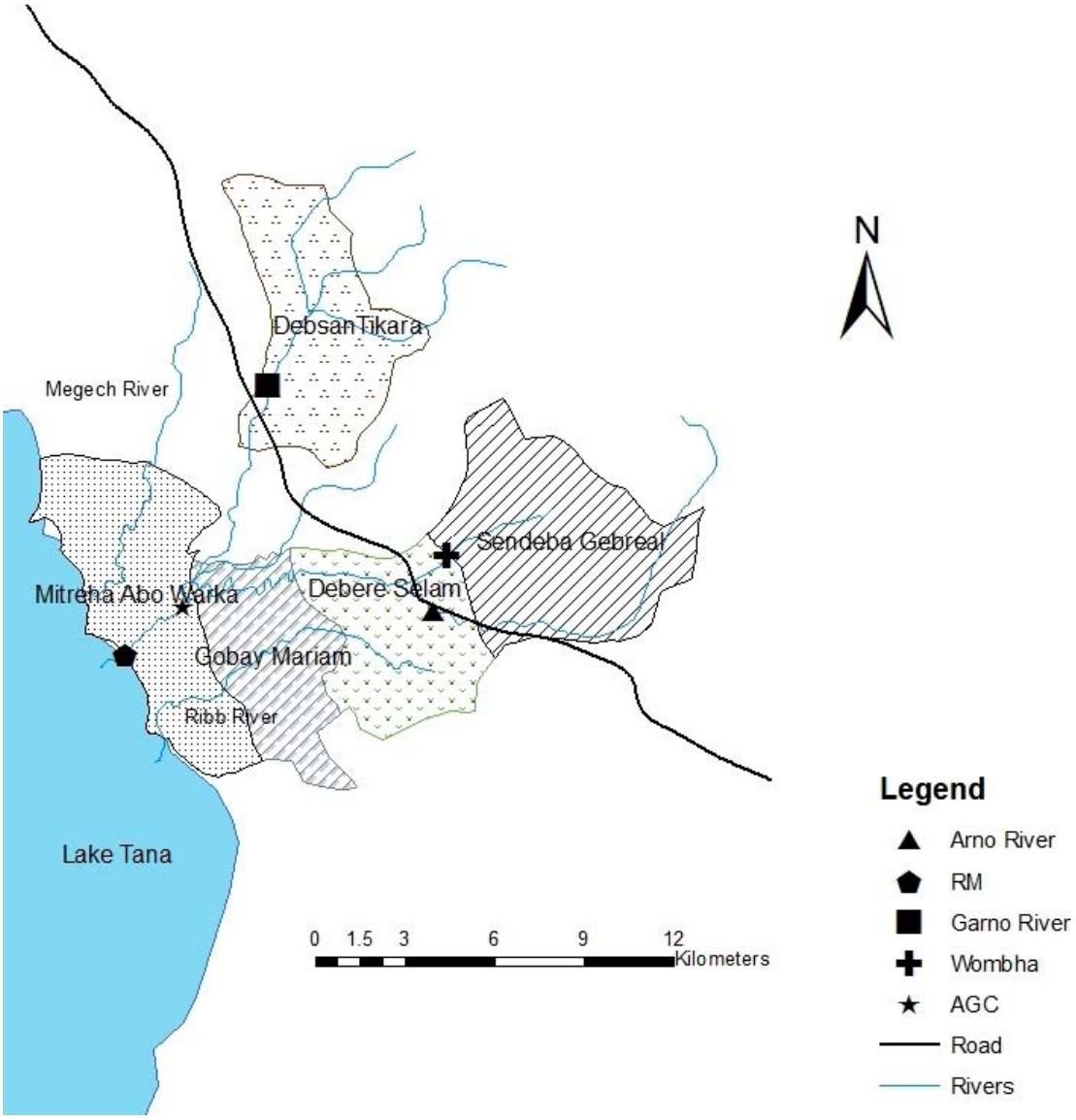

Fig. 1: Map of Lake Tana and the sampling sites in Arno-Garno River

main asphalt road from Bahir Dar to Gondar. 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.

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 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.

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

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

Gill nets were used in all sampling sites

Gill nets of 6, 8, 10, 12 and 14 cm stretched bar mesh, having a length of 25 m and depth of 1.5 m were used to sample fish. Fish were identified to species level using keys developed by Nagelkerke and Sibbing (2000). Then, fork length (0.1 cm), total weight (0.1 g) and gonad weight (0.01 g) 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) 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.

Relative abundance: 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. Percent of IRI was calculated as follows (Sanyanga, 1996):

$$\text{IRI}(\%) = \frac{(\%w_i + \%N_i \times \%F_i)}{\sum_{j-1}^{s-1}(\%w_i + \%N_i) \times \%F_i} \times 100$$

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.

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.

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 (Bagenal and Tesch, 1978). Fulton's condition factor (%) was calculated as:

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

where, Tw is total weight (g) and FL is fork length (cm).

Sex-ratio: Sex ratio, is the proportion of females to males, was determined using this equation:

$$\text{Sex ratio} = \frac{\text{No. of female}}{\text{No. of male}}$$

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

Gonado-somatic index (GSI): GSI is the ratio of fish gonad weight to body weight. The GSI was determined using the following equation (Bagenal, 1978):

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

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. 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. The correlation of fecundity with total length, total weight and gonad weight were done to determine the relationship of fecundity with morphometric measurements. This was done according to this equation:

$$F = aFL^b;\ F = aTw^b \text{ and } F = a\ Gw^b$$

where, F is Fecundity, FL is fork length (cm), Tw is total weight (g), GW is gonad weight a is constant and b is exponent.

Data analysis: SPSS version 16 software was used to analyze the data. One-way ANOVA was used to analyze length weight relationship and Mann-Whitney U test to analyze condition factor. Sex ratio was tested using Chi-square (χ^2).

RESULTS

Species composition in Arno-Garno river: A total of 1159 fish specimens were collected within the six months (July to December 2010) from all sampling sites. Out of the total catch, 11 species (1077 specimens) were 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. *Labeobarbus intermedius* was the most abundant 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. 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 2: 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)

Fish	N	N (%)	W	W (%)	F	F (%)	IRI	IRI (%)
Peak spawning months (Angnst to October)								
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		165629.0				17839.20	
Non peak spawning months (July, Novemnber and Decemnber)								
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	3043.0	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		25583.0				13095.80	

Table 3: 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	14636.0	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	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	6794.0	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	0.0	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	2313.0	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	

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) (Table 2 and 3). *Labeobarbus intermedius* was the most dominant species at all sampling sites. Except at the river mouth and Arno in which *L. tsanensis* (29.1%) and *L. nedgia* (31.4%) were abundant,

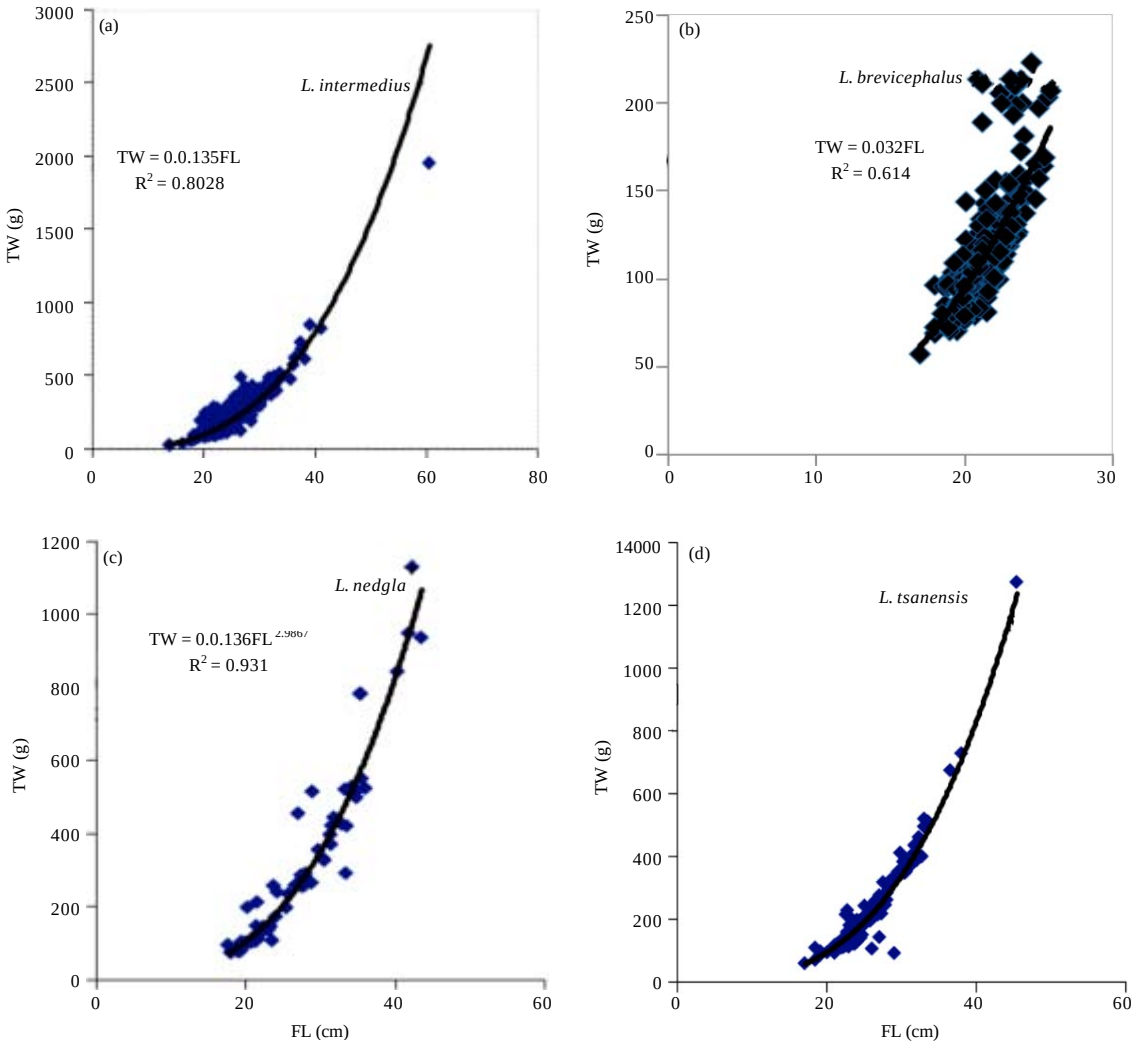

Fig. 2(a-d): Length-weight relationship of the four dominant *Labeobarbus* species of Lake Tana (N = 474, 310, 71 and 148, respectively). Note: N is sample size (a) *L. intermedius*, (b) *L. brevicephalus* (c) *L. nedgia* and (d) *L. tsanensis*

L. brevicephalus was the second most dominant species at all the other sampling sites. In addition to this, *L. intermedius* was the most dominant species in both peak spawning season and non-peak spawning season and *L. tsanensis* was the second dominant species.

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. 2).

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,

Table 4: Mean±SE of Fulton's condition factor for the most dominant *Labeobarbus* species in the river by sex

Species	Sex	N	Mean±SE	P
L. intermedius	M	139	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), N is sample size, P is significant difference (Mann-Whitney U test)

Table 5: Mean±SE of Fulton's condition factor for the most dominant *Labeobarbus* species of Lake Tana migrating to Arno-Garno River by season

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	

N is sample size, P is significant difference (Mann-Whitney U test)

Table 6: 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	$0.072^{(ns)}$

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

it was lower for females (1.2762±0.01759) than males (1.3574±0.03057) for both species (Table 4). Fulton's condition factor showed significant variation for *L. intermedius* during the peak spawning months (August to October) (1.2831±0.01639) and non-peak spawning months (July, November and December) (1.3931±0.04136) ($p<0.001$). However, it was not significant for *L. brevicephalus* ($p>0.05$) (Table 5).

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 (705 in number) were more numerous than males (291 in number). Except *L. nedgia*, the remaining *Labeobarbus* species were significantly different (χ^2, $p<0.05$) from the theoretical 1:1 ratio (Table 6).

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. 3). 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

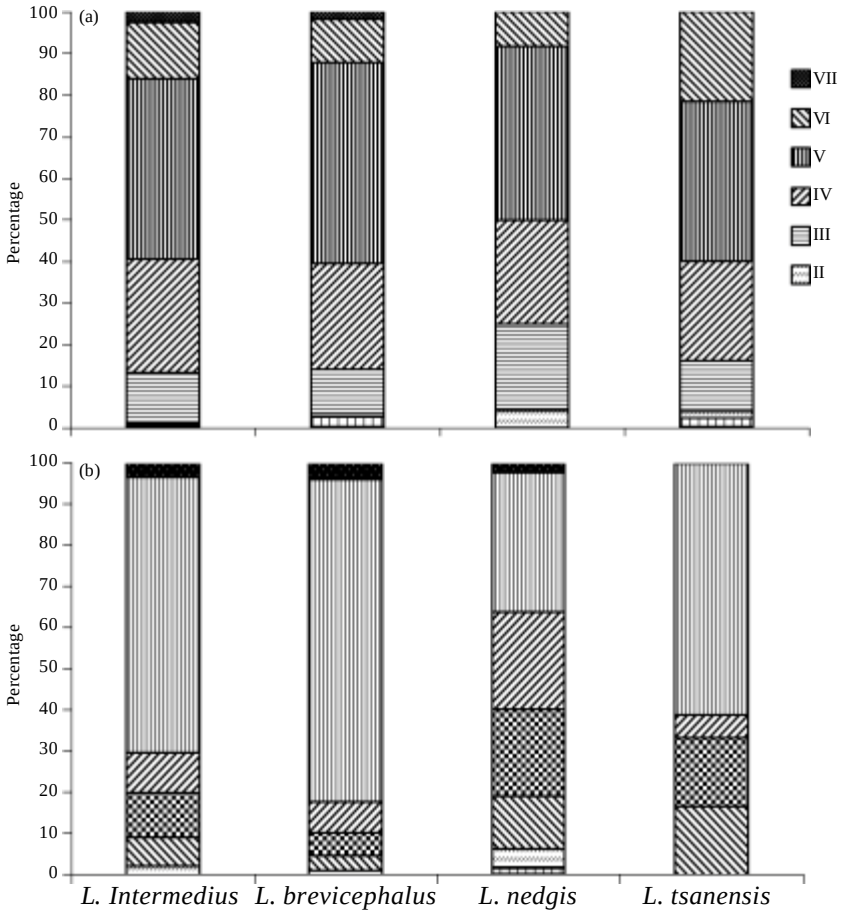

Fig. 3: Proportion of gonad maturity stages (I to VII) of the most dominant *Labeobarbus* species during peak spawning season (August to October) in the (a) River mouth and (b) Upstream areas in the Arno-Garno River

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.

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 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 (Fig. 4 and 5) and the relationship was strong (ANOVA, $p<0.05$).

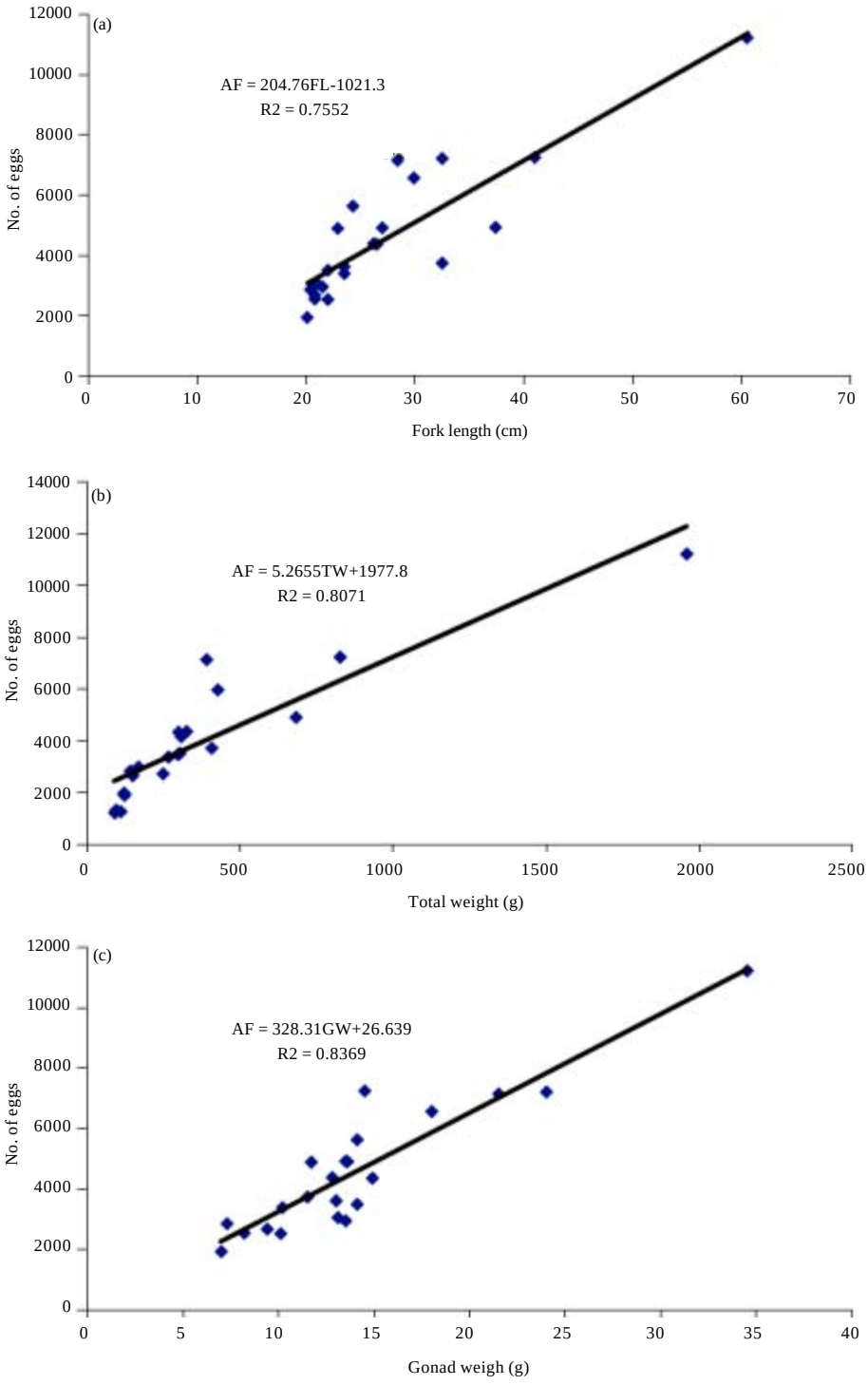

Fig. 4(a-c): Relationship between absolute (total) fecundity and (a) Fork length, (b) Total weight and (c) Gonad weight of *L. intermedius* in Arno-Garno River (N = 27, where, N is sample size)

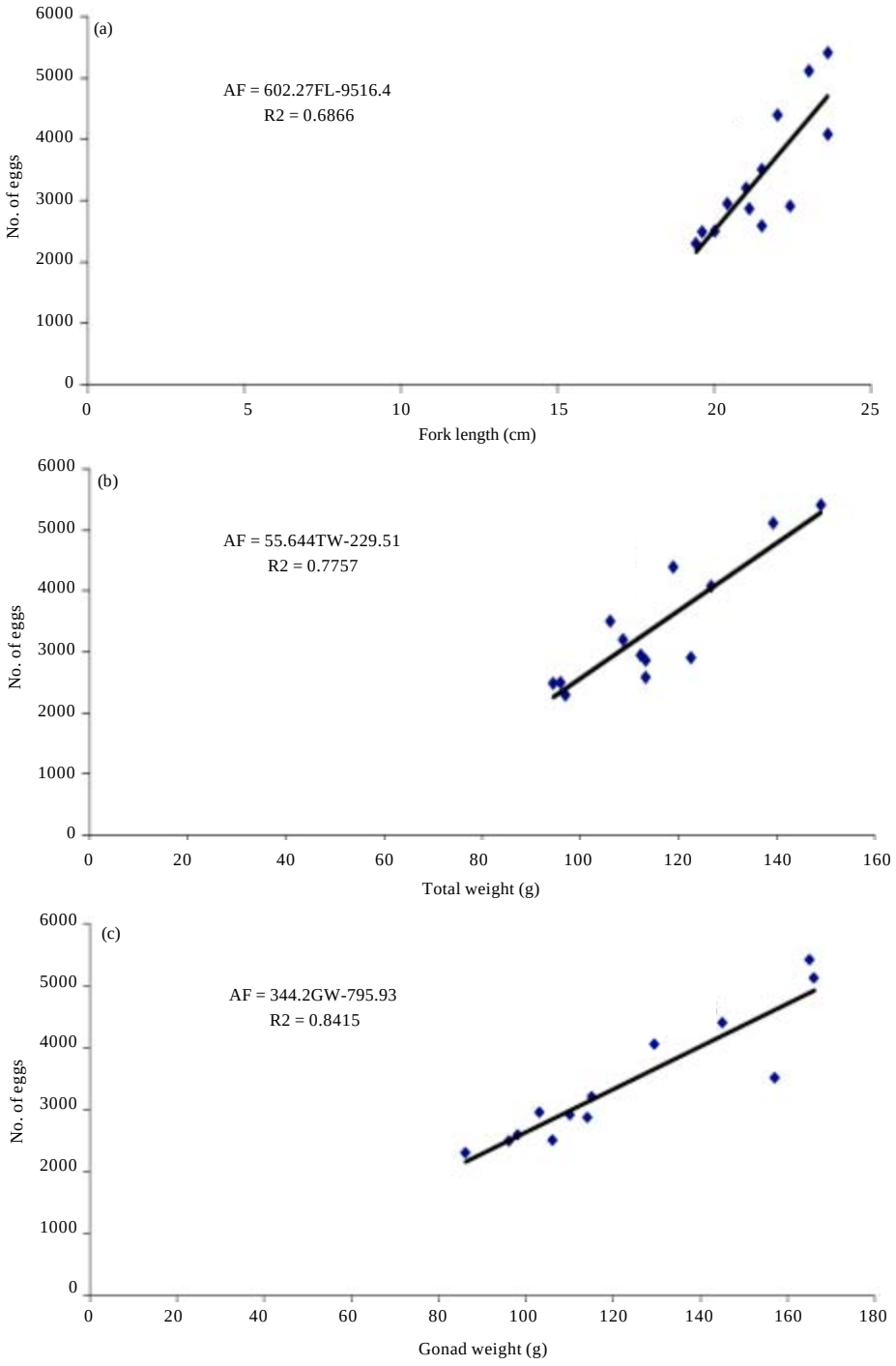

Fig. 5(a-c): Relationship between absolute (total) fecundity and (a) Fork length, (b) Total weight and (c) Gonad weight of *L. brevicephalus* in Arno-Garno River (N = 27)

DISCUSSION

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.

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. 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 (Admassu, 1994). 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 Anteneh (2005) in Megech and Dirma Rivers, Nagelkerke *et al.* (1994) in Lake Tana, most of the dominant *Labeobarbus* species in Arno-Garno River showed nearly isometric growth. Similar results have been reported in Lake Awassa (Admassu and Dadebo, 1997), in River Sanja (Tesfaye, 2006), in Gendewuha, Guang, Shinfa and Ayima Rivers (Tewabe, 2008), in Borkena and Mille Rivers (Tessema *et al.*, 2012) and in the head of Blue Nile River (Omer, 2010) for *L. intermedius*.

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 (Payne, 1986; Teferra, 1987). Generally, higher condition is associated with higher energy content, adequate food availability, reproductive potential and favorable environmental conditions (Pauker and Rogers, 2004). For *L. intermedius* the mean Fulton's condition factor showed significant variation during the peak spawning season and non-peak spawning season which is similar to result obtained in Megech and Dirma Rivers (Anteneh, 2005). However, it was not significant for *L. brevicephalus*.

In agreement to the result obtained in Megech and Dirma Rivers by 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. 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 Tessema *et al.* (2012) in Borkena and Mille Rivers for *L. intermedius* were 1.23 and 1.31, respectively, greater than the values obtained by Tesfaye (2006) in River Sanja, Berie (2007) in Beles and Gelegel Beles Rivers and 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 Tessema *et al.* (2012) 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.

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 (Dadebo *et al.*, 2003),

Carassius carassius in Lake Ziway (Dadebo *et al.*, 2003) and *Labeobarbus* species in Megech and Dirma Rivers (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 (Sadovy 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 Taylor 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.

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 but *L. tsanensis* (32.52%) was in Megech and Dirma Rivers (Anteneh, 2005), however, the maximum mean monthly GSI was highest for *L. surkis*, similar to the result obtained in Megech and Dirma Rivers (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.

Fecundity: Information about fecundity of *Barbus* species in Africa is limited (Marshal, 1995). The few data on the fecundity of *Labeobarbus* are from studies by Alekseyev *et al.* (1996) and 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 average fecundity of *L. intermedius* and *L. brevicephalus* were 4607 and 3414 eggs, respectively. The result in this study for *L. brevicephalus* was almost similar to the result obtained by Anteneh (2005) in Megech and Dirma Rivers. The absolute fecundity of *L. intermedius* in Borkena and Mille Rivers (Tessema *et al.*, 2012) and in Beles and Gelegel Beles Rivers (Berie, 2007), was 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 (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 ($p<0.05$). The fecundity of *L. intermedius* in Beles and Gelegel Beles Rivers (Berie, 2007), in Gelda and Gumara Rivers (Alekseyev *et al.*, 1996), in

Borkena and Mille Rivers (Tessema *et al*., 2012) and in the head of Blue Nile River (Omer, 2010) was strongly and positively correlated with its gonad weight, fork length and body weight. Similar result was also obtained in this study.

CONCLUSION

From the total 1159 fish specimens collected during the study period from all sampling sites, 11 species (1077 specimens) belong to the genus *Labeobarbus* and the other species were *O. niloticus*, *C. gariepinus* and *V. beso*. Results from index of relative importance (% IRI) showed *L. intermedius* as the most dominant species in Arno-Garno River. The relationship between fork length and total weight of the dominant *Labeobarbus* species was curvilinear. Fulton's condition factor showed significant variation for *L. intermedius* during the peak spawning season and non-peak spawning season. Fulton's condition factor was lower for females than males and showed significant variation. Females were the most numerous than males for the *Labeobarbus* species at Arno-Garno River and this is high in the peak spawning season. The spawning season for *Labeobarbus* species was from August to October. Therefore, closing season (June to October) should be strictly implemented so as conserve the unique species and to sustainably manage the fish resource in the river.

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