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Length-weight Relationship, Gonado Somatic Index and Fulton Condition Factor of the Dominant Fishes at Aveya River, Blue Nile Basin, Ethiopia

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ABSTRACT

The main purpose of this study is to generate scientific information about some biological aspects of fishes in Aveya River. The study was conducted in 2011/12 both in dry and wet seasons. Sampling sites were selected by considering, nature and velocity of the flowing river, accessibility, fishing activity and human interference. Abiotic parameters were measured using standard multi-meter. Fishes were collected using gillnets of stretched mesh size 6, 8, 10, 12 and 14 cm and monofilaments of different mesh sizes. Identification of fishes was made at species level using standard taxonomic keys. A total of 806 fish specimens were collected during the study period. Varicorhinus beso, Labeobarbus nedgia and Labeobarbus intermedius were the most dominant species in both seasons and most of the sites. Length-weight relationships for *V. beso* (R^2 = 0.991), *L. nedgia* (R^2 = 0.990), *L. intermedius* (R^2 = 0.996) and *L. forsakalii* (R^2 = 0.992) were curvilinear, significant at $p<0.00$ and isometric for all specimens. Fulton's condition was significantly higher during the dry season than wet season for *L. intermedius* (1.21±0.024 wet and 1.05±0.014 dry season) and *L. nedgia* (1.19±0.018 wet and 1.07±0.009 dry season) at $p<0.001$. Fulton's condition between female (1.17±0.018) and male (1.10±0.013) of *L. intermedius* was significant ($p<0.01$). Overall sex ratios of all specimens except *L. nedgia*were significant between seasons ($p<0.05$). Fecundity was related curvilinear and linearly to fork length and body weight and gonad weight, respectively. For sustainable use of aquatic resources catchment rehabilitation and minimizing the massive seasonal fishing is necessary.

Key words: Aveya river, species composition, condition factor, sex ratio, fecundity

INTRODUCTION

Ethiopia is the water-tower of East Africa and has a number of inland water bodies, in which the majority of the rivers and lakes are situated in Rift Valley of Africa. There are nine major river basins in Ethiopia (Abbay, Tekeze, Baro-Akobo, Omo-Ghibe, Afar or Denakil, Awash, Ogaden, Wabi-Shebelle and Genale-Dawa) many of which are transboundary. From these water bodies which harbor about 200 fish species, the country can exploit about 30,000-40,000 metric tons per year (FAO, 1995). The Blue Nile watershed is the largest basin in Ethiopia. Rivers of this basin like Aveya, Gumara andassa, Gelgel Abay, Beles, Dabous, Dedessa, Anger, Fincha and Muger, drain the great central and north-west plateau and it is the most important drainage basin in Ethiopia.

Ethiopia contains very high diversity of ichthyofauna in its inland water bodies (Getahun and Stiassny, 1998). The fish species in the inland water bodies of Ethiopia contains a mixture of Nilo-Sudanic, East African and Endemic of the Ethiopian highland fish fauna (Getahun and Stiassny, 1998). In Ethiopia, fish species diversity decreases with increasing altitude. This is especially pronounced because of the steep altitude gradients and occurrence of rich lowland fauna in most basins (Golubtsov and Mina, 2003).

Studies on some biological aspects of fish are very important to obtaining information on the quality and quantity of the available habitat. Since the 20th century, many fish species have suffered with different activities. This includes many of the smaller fish species as well as all the species targeted by inland commercial and recreational fisheries. As in many parts of the world population growth, agricultural development and industrialization contribute to the loss of species of inland water fishes (Getahun and Stiassny, 1998). Widespread deforestation and degradation of the pristine environment and other human induced factors might have left many Ethiopian streams, especially the northern ones, devoid of fish but the apparently resilient cyprinids (Getahun and Stiassny, 1998).

Knowledge on diversity, population structure distribution and biology of the Ethiopian ichthyofauna has been poorly known; relatively a large number of small, medium and even some large rivers have not been well studied and explored including the ones to be explored in this study (Abebe, 2005). Aveya (NB: in literatures this river is mentioned as ‘Abaya’, in so far it is called ‘Aveya’), Ginbara, Gumara and Yeka Rivers originate from the Central Gojjam Highlands, occupying a larger catchment area near the borders between East and West Gojjam Administrative zones. These rivers become one (main Aveya River) at the lower catchments and finally enter to Blue Nile River. Physical observations and simple reports indicated that all these rivers do have substantial fish resources in earlier times. In all these rivers, no formal research reports have been made with regard to biology of the fish fauna probably due to the presence of some harsh geographical features, inaccessibility for transportation, security and logistic problems. Therefore, the absence of fishery data on this river triggers the necessity to conduct this study. The major objective of the study is to investigate some biological aspects of fishes in Aveya River for sustainable use and management of the fish resources in the river.

MATERIALS AND METHODS

Description of the study area: Blue Nile River, draining the southwestern parts of the western highlands of Ethiopia, consists of Didissa, Dabus, Beles, Gelgel Beles, Beshilo, Dura and Ardi Rivers as major tributaries (Getahun and Stiassny, 1998). There are a number of other medium sized tributary rivers joining to Blue Nile River in its longest course in Ethiopia. Most of these medium sized tributary rivers arise from Gojjam, Gondar and Showa highlands. The study was conducted in lower catchment areas of the major river, arising from the central Gojjam highlands and having the largest watershed/catchment area (Fig. 1). It lies in those Kebeles within and adjoining between Woredas of East Gojjam and West Gojjam Administrative zones. Aveya River arises from Eastern side of Gojjam highlands; join the main Blue Nile River after the Fall of the Blue Nile River at about 30 km away from Motta Town, East Gojjam Administrative zone.

In terms of water volume, Aveya River contributes a largest share, since it is formed from a large of spring waters spilling/arising from the Choke and Wabirr peaks and forming a number of tributaries of this river. This river sourced from Choke mounts to Sihede side of Hulet Eju Enese Woreda and Wabirr mount and Kuchit Bahitay hills of Bibugn Woreda in East Gojjam

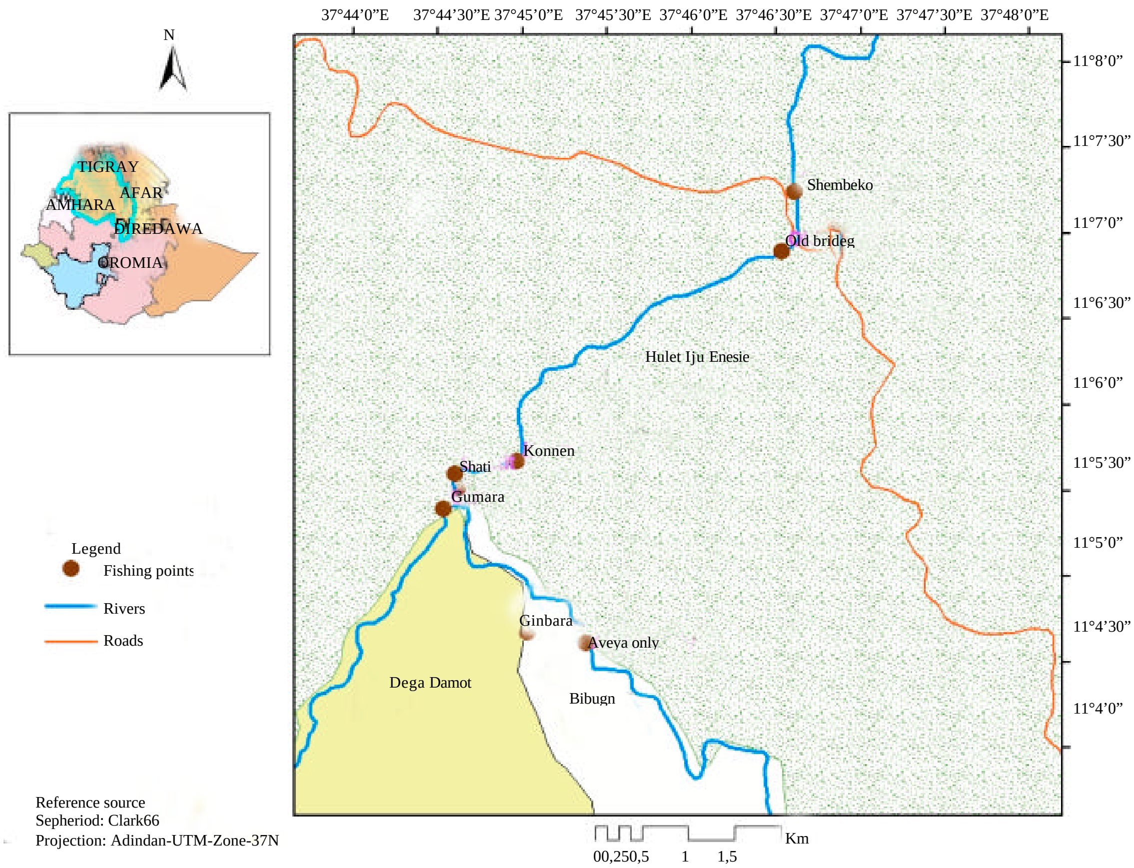

Fig. 1: Map showing representative sampling sites in the study area

Administrative Zone. A lot of tributary rivers are found in this big watershed. Most of the rivers in these two Woredas join this river. Except at the highlands, this river has slow course with wider areas river banks. At the lower catchment of this river, deep gorges, big rocks and rock beds and deep caves are common (personal observation).

Field sampling: The following characteristics were taken into consideration to select sampling sites; nature and velocity of the flowing river, accessibility, human interference, substrate type, suitability for gillnet setting and previous experience of traditional fishing. Sampling sites were fixed using GPS (Fig. 1 and Table 1).

Data was collected both in dry and wet seasons. Conductivity, pH and temperature were measured using standard multi-meter and water transparency, using secchi disc 20 cm in diameter. Gillnet of mesh size of 6, 8, 10, 12 and 14 cm stretched bar mesh, having a length of 25 m and depth of 1.5 m was used to sample fish by an overnight setting of gillnets. Monofilament with mesh size of 5-55 mm were also used by setting for 2 h to sample fish in the sampling sites of the river. Immediately after capture, a gentle pressure was applied on the abdomen to check whether spermiation or ovulation has occurred or not. Fish were identified to the species level using the keys developed by Nagelkerke (1997). Forked Length (FL) and Total Weight (TW) of all specimens of

Table 1: Sample sites and their codes, estimated distance from the old bridge, habitat, width of the sites and coordinates

Sites	Rivers	Distance (km)	Elevation (m)	Habitat	Width (m)	Coordinate (GPS)
Site 1	Seytan Bahir	16.0	1548	Clear water and rocky, sandy, forest cover at the right bank	250	39P03642981224807
Site 2	Aveya Ginbara confluence	15.0	1739	Very rocky, turbid water, forest cover on both sides	200	37p03635611224740
Site 3	Aveya Gumara confluence	11.0	1730	Very rocky, clear water and forest covered	150	37p03626591226062
Site 4	Shatit	10.0	1709	Clear water, forest cover	150	37p03627821226438
Site 5	Konnen	8.5	1718	Clear water, trees and small shrubs	70	37p03634481226575
Site 6	Old Bridge	0.0	1669	Clear water, rocky	160	37p03663001228837
Site 7	Shenbeko Bahir	1.0	1640	Clear water, rocky	110	37p03656431229480

fish were measured on field using standard measuring bored and sensitive balance, respectively. Picture of fish specimen was taken for each species. After dissection, gonad maturities of each fish specimen were identified using a seven-point maturity scale Nagelkerke (1997). Gonad weights were measured to the nearest 0.1 g using sensitive beam balance. Samples of eggs from some matured female fish (stage VI) were preserved in 5% alcohol for fecundity estimation (Bagenal, 1978). After taking the entire necessary information, individual specimen were preserved with 4% formalin and put in plastic jar and was transported to the laboratory of Bahir Dar Fisheries and other Aquatic Life Research Center for further identification and to serve as a reference specimen.

Length-weight relationship: The relationship between Fork length and total weight of most dominant fish was calculated using power function as in Bagenal and Tesch (1978) procedures:

$$TW = aFL^b$$

where, TW is Total Weight (g), FL is Fork Length (cm), a is intercept of regression line and b-slope of regression line.

Condition factor (Fulton factor): The well-being of each dominant species was studied by using Fulton condition factor (Bagenal and Tesch, 1978). Fulton condition factor (%) was calculated as:

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

where, TW is Total Weight (g), FL is Fork Length (cm).

Sex ratio: Sex ratio was determined using the equation:

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

where, difference among male and female species was tested using Chi-square (χ^2).

Gonado-somatic index (GSI): The breeding season was determined from the percentages of fish with ripe gonads taken each month. Gonado-Somatic Index (GSI), gonad weight as a percentage of total body weight was calculated for both sexes (Bagenal and Braum, 1978). A seven point maturity scale was used to determine the gonadal maturity stages Nagelkerke (1997).

Fecundity: Fecundity is the number of eggs in ovary prior to spawning and it was determined through gravimetric method (MacGregor, 1957). Three sub-samples of 1 g eggs was taken from different parts of ovary and counted and the average was calculated. Then, the total number of eggs per ovary was calculated by extrapolation. The relative fecundity was calculated by dividing the number of eggs with the total body weight. The relationships between fecundity with fork length, total weight and ovary weight was also made.

Data analysis: Descriptive statistical analysis was used to analyze the mean and standard error of the abiotic and biological data. ANOVA was used to analyze the biological data. But Kruskal Wallis test was used to analyze the abiotic parameters. SPSS version 16 was used to analyze the data.

RESULTS

Abiotic parameters: Physico-chemical parameters (conductivity, total dissolved solids, temperature, pH and secchi depth) were taken from all sites in both seasons and analyzed using non-parametric test (Kruskal Wallis test). The result of the analysis showed that there was significant difference in conductivity and total dissolved solids between seasons (Table 2). However, the physico-chemical parameters did not show significant variation among sampling sites ($p>0.05$). The higher conductivity and total dissolved solids in dry season may be because of the higher concentration of ions in the pools of sampling sites due to less speed and volume of water in dry season. The little rain in the dry season did not seem to affect these parameters. The water pH was more or less alkaline (mean pH = 8.40±0.15) in all sampling sites.

Table 2: Physico-chemical parameters in the sampling sites with their means ±SE for both dry and wet seasons (Kruskal Wallis test)

Abiotic parameter	Season	Mean±Std. Error	Sig.
Conductivity (μs cm^{-1})	Wet	206.79±13.21	0.018*
	Dry	267.66±10.61	
	Total	237.22±11.73	
Total dissolved solids (PPT)	Wet	103.29±6.700	0.013*
	Dry	132.86±5.760	
	Total	118.07±5.900	
Temperature (°C)	Wet	22.60±0.770	0.225
	Dry	23.95±0.750	
	Total	23.28±0.550	
pH	Wet	8.27±0.160	0.522
	Dry	8.51±0.270	
	Total	8.40±0.150	
Secchi depth (cm)	Wet	61.50±20.31	0.749
	Dry	49.93±12.42	
	Total	55.71±11.55	

*Significant

Length-weight relationship: The relationship between fork length and total weight for *V. beso*, *L. nedgia*, L. *intermedius* and L. *forskalii* was curvilinear and showed significant variation ($p<0.001$) (Fig. 2). The line fitted to the data was described by the regression equation as shown in Fig. 2.

Fulton's condition factor (FCF): The mean Fulton Condition Factor of *L. intermedius* (1.25±0.017 wet season, 1.23±0.006 dry season) and *L. nedgia* (1.19±0.018 wet season, 1.07±0.009 dry season) showed significant variation in season (Table 3, $p<0.001$). However it did not show significant variation ($p>0.05$) for *V. beso* and *L. forskalii* but values were higher in wet season for both sexes. All specimens showed higher values of FCF or better conditions in wet season (Table 3).

The mean Fulton condition factor for male (1.10±0.013) and female (1.17±0.018) of *L. intermedius* showed significant variation at $p<0.05$ whereas, for *V. beso*, *L. nedgia* and *L. forskalii* didn't show significant variation (Table 4, $p>0.05$).

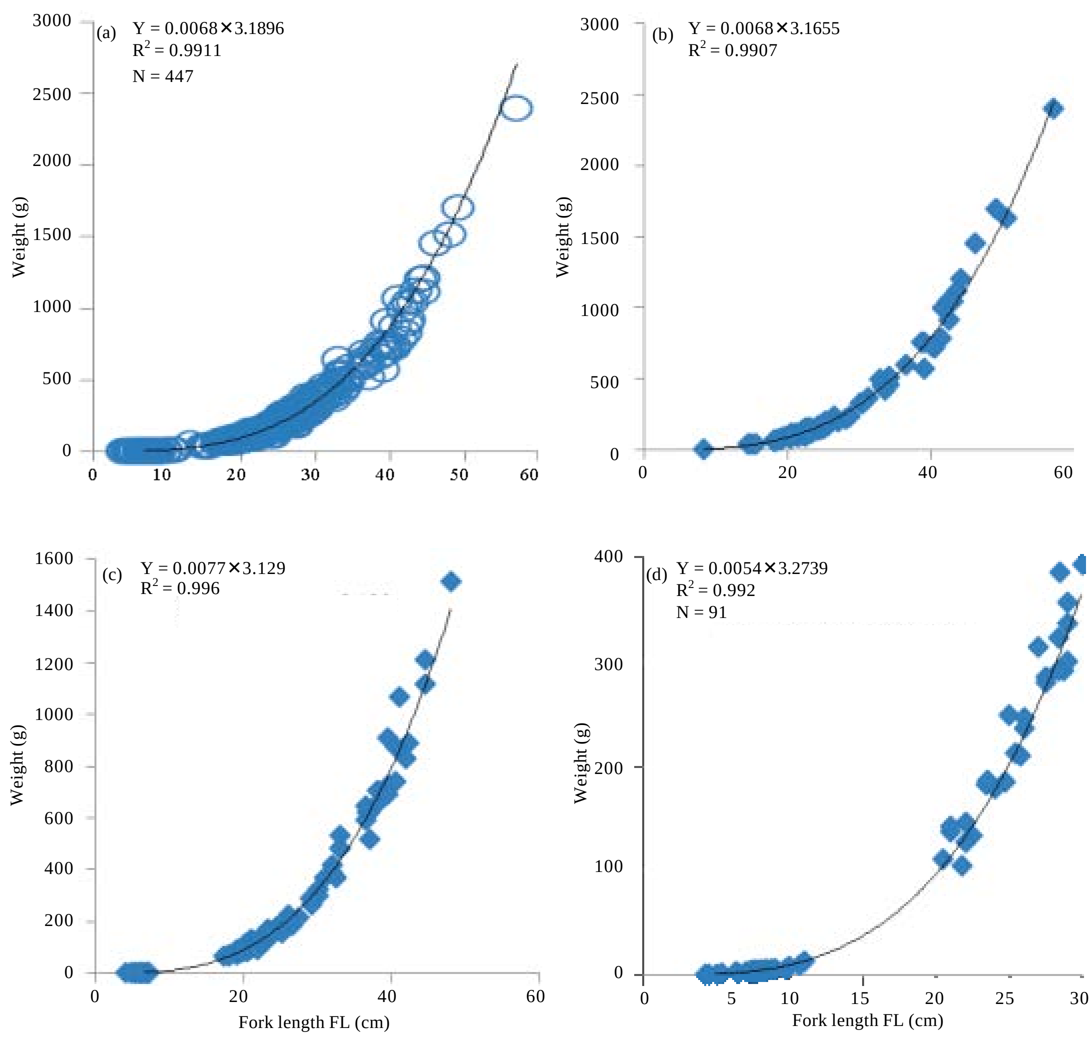

Fig. 2(a-d): Length-weight relationship of (a) *V. beso*, (b) *L. nedgia*, (c) L. *intermedius* and (d) *L. forskalii* $p<0.001$

Table 3: Fulton condition factor of sampled fishes by season (Mann-Whitney U test)

Species	Season	N	FCF (Mean ±SE)	Sig.
V. beso	Wet	105	1.25±0.017	0.089^{ns}
	Dry	342	1.23±0.006	
L. intermedius	Wet	38	1.21±0.024	0.000***
	Dry	91	1.05±0.014	
L. nedgia	Wet	41	1.19±0.018	0.000***
	Dry	98	1.07±0.009	
L. forskalii	Wet	9	1.13±0.087	0.149^{ns}
	Dry	82	1.00±0.028	

***Very highly significant (p<0.001), ^{ns}Not significant (p>0.05)

Table 4: Fulton condition factor (Mean and standard error) of sampled fishes by sex (Mann-Whitney U test)

Species	Sex	N	FCF (Mean ±SE)	Sig.
V. beso	Female	322	1.24±0.008	0.476^{ns}
	Male	122	1.23±0.010	
L. intermedius	Female	43	1.17±0.018	0.003**
	Male	66	1.10±0.013	
L. nedgia	Female	58	1.12±0.016	0.389^{ns}
	Male	76	1.10±0.011	
L. forskalii	Female	9	1.38±0.040	0.087^{ns}
	Male	22	1.06±0.113	

**Highly significant (p<0.01), ^{ns}Not significant (p>0.05)

Table 5: Number of males and females and the corresponding sex ratios (pooled from all sites)

Species	Season	F	M	Ratio	χ^2	Sig.
V. beso	Wet	90	13	6.9:1	57.56	0.000***
	Dry	232	109	2.1:1	44.37	0.000***
	Total	322	122	2.6:1	90.09	0.000***
L. *intermedius*	Wet	19	15	1.27:1	0.47	0.493^{ns}
	Dry	24	51	0.47:1	9.72	0.002**
	Total	43	66	0.65:1	4.85	0.028*
L. nedgia	Wet	21	19	1.11:1	0.10	0.752^{ns}
	Dry	37	57	0.65:1	4.26	0.039*
	Total	58	76	0.76:1	2.42	0.120^{ns}
L. *forskalii*	Wet	2	2	0.1:1	0.00	1.000^{ns}
	Dry	7	20	0.44:1	6.26	0.012*
	Total	9	22	0.5:1	5.45	0.020*

*Significant (p<0.05), **Highly significant (p<0.01), ***Very highly significant (p<0.001), ^{ns}Not significant (p>0.05)

Some aspects of reproductive biology

Sex ratio: From total number of 806 specimens of fish collected from the present study, 88 (11%) specimens were unsexed, hence excluded from sex ratio study. Totally, 718 (89%) specimens were sexed of which 432 (60%) were females and 286 (40%) were males. In general, females were more numerous than males. The chi-square test showed that there were significant variations (χ^2, $p<0.05$) between number of females and males of *V. beso* (322 female and 122 male), *L. intermedius* (43 female and 66 male) and *L. forskalii* (9 female and 22 male) (Table 5). However, *L. nedgia*did not show significant variation between males and females. There was also a significant variation in sex ratio during the two seasons, too (Table 5). During the study period, the highest deviation in sex ratios was observed in *V. beso* (2.6:1). There was a significant variation (p<0.05) in sex ratio among the different size classes and maturity stages for *V. beso*, indicating size and maturity based sex segregation in this specie (Table 6).

Gonado-somatic index (GSI): The GSI values indicated that a large number of *V. beso* were found at breeding condition (stage VI) during the wet season (Fig. 3). Few numbers of *L. nedgia*

Table 6: Sex ratio by size class and maturity stages for *V. beso* (One way ANOVA)

Parameter	F	M	Ratio	χ^2	Sig.
Size class					
13-19.4	64	32	0.2:1	10.67	0.001***
19.5-25.4	198	79	2.51:1	51.12	0.000***
25.5-31.4	53	10	5.3:1	29.35	0.000***
>31.4	7	1	0.7:1	4.50	0.034*
Maturity stage					
Immature	207	99	2.1:1	38.12	0.000***
Mature	115	23	0.5:1	61.33	0.000***

*Significant (p<0.05), ***Very highly significant (p<0.001), [ns]Not significant (p>0.05)

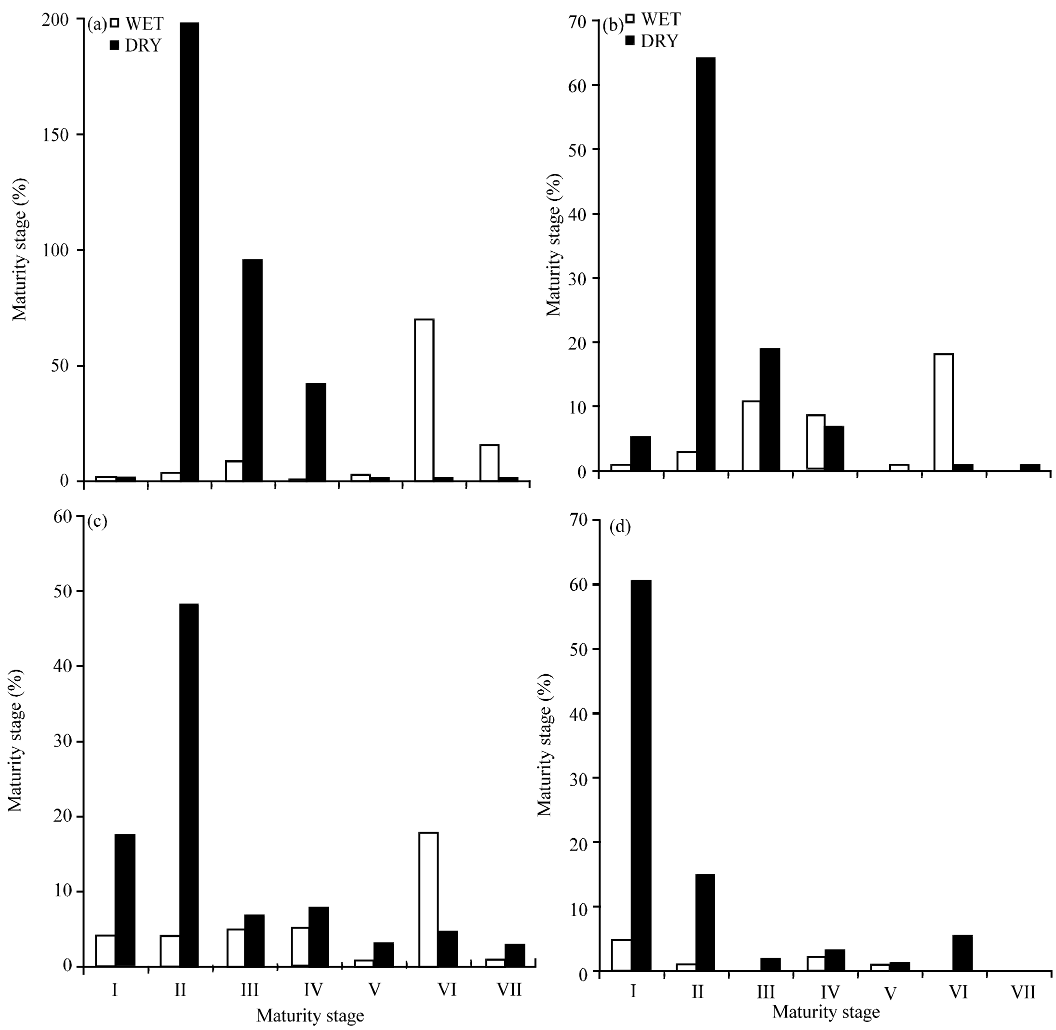

Fig. 3(a-d): Sexual maturity stages for (a) *V. beso*, (b) *L. nedgia*, (c) L. *intermedius* and (d) *L. forsakalii* in both seasons and *L. intermedius* were also found at breeding condition during wet season than dry season. *Labeo forskalii* did not seem to reproduce in both seasons during the sampling time. From a large number of juveniles collected during the wet season it seemed that these fishes might be breading in the early rainy season. During dry season, except few individuals of *L. nedgia* and *L. intermedius*, most of the fishes were at stage II. That means they were at off breeding season. To confirm the peak breeding season, year-round sampling is needed.

Fecundity: Absolute fecundities (AF) of *V. beso* was determined based on number of eggs per gram egg or gonad weight (Fig. 4). Sixty five specimens of *V. beso* with fork length ranging from 17 to 36.5 cm, mean and standard error of 22.48 and 0.42; had mean Absolute Fecundity (AF) of 3705 and it ranged from 576 to 19352 eggs (Fig. 4). From the present study it seemed that a large flock beso species are typically adapted in the river with good condition as the condition of the fish was good and most of them were in breeding condition during the wet season sampling.

The relationship between Absolute Fecundity (AF) with Fork Length for *V. beso* was curvilinear (Fig. 5), whereas, the relationship between AF with total weight and Gonad Weight for *V. beso* was linear. In general, AF of *V. beso* was strongly positively correlated with Fork Length, total weight and gonad weight. There was significant relation of AF with Fork Length, total weight and gonad weight for *V. beso*, ANOVA ($p<0.05$).

DISCUSSION

Abiotic parameters and some biological aspects of fishes at Aveya river: Aquatic organisms like terrestrials are highly dependent upon abiotic factors or characteristics of the aquatic habitat which support all their biological functions (reproduction, growth, feeding and sexual maturation). Thus, these factors are controlling the aquatic life as they shape most the biological functions of aquatic life (Murdoch and Martha, 1999). Cyprinids species 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 important in the development of eggs and larvae (Tomasson *et al*., 1984). Deposition of eggs in the gravel or pebble beds protect them from being washed away by riffle and clear water do not cover them with affirm of obstructing the diffusion of oxygen (Lowe-McConnell, 1975). Hence, the Aveya River is full of sand, gravel bed and it has

Fig. 4: Matured (VI) gonad with yelow colored eggs of female *V. beso* at Aveya River

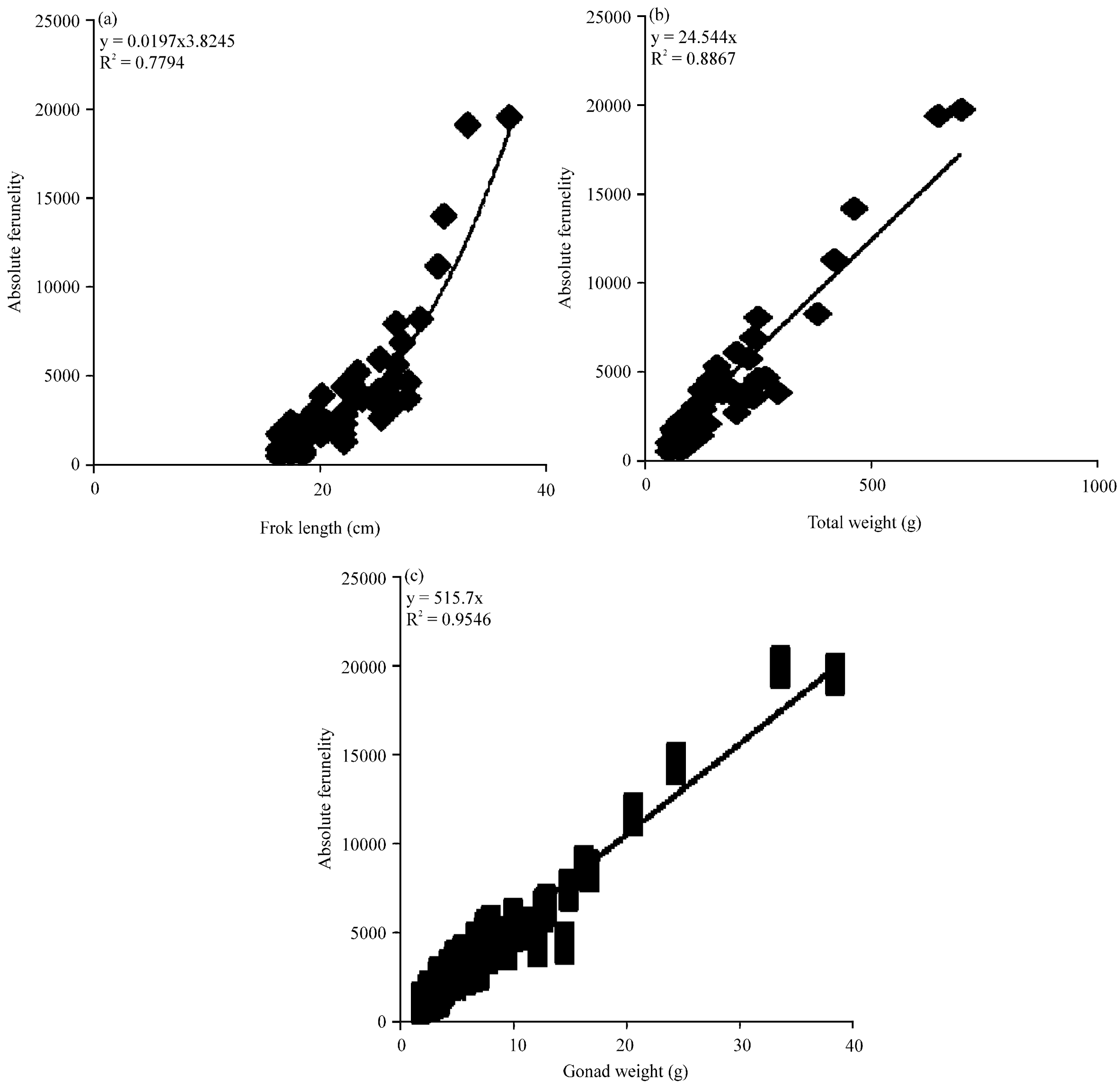

Fig. 5(a-c): Relationship between absolute fecundity with (a) Fork length, (b) total weight and (c) Gonad weight for *V. beso* (n = 65; p<0.001)

very clean, well oxygenated and fast flowing water. That's why it is dominated by cyprinid family. The physico-chemical parameters of the river didn't show significant difference among sampling sites. However, conductivity and total dissolved solids showed significance difference in the study area during the sampling season. The higher conductivity and total dissolved solids in dry season may be because of the higher concentration of ions in the pools of sampling sites due to less speed and volume of water in dry season. The little rain in the dry season did not seem to affect these parameters.

Length weight relationship: In fishes, if the regression coefficient (b) is about 3 it indicates isometric growth. When this value becomes exactly 3, fishes retain the same shape and their specific gravity remains unchanged during their life time (Ricker, 1975). If the weight increased according to the fish length it is said to be isometric growth (Mansor *et al*., 2001). However, fishes may have 'b' value greater or less than 3, a condition of allometric growth (Bagenal and Tesch, 1978). A value less than 3 shows that the fish becomes lighter (-ve allometric) or greater than 3 indicates that the fish become heavier (+ve allometric) for a particular length as it increases in size (Wootton, 1998; Zafar *et al*., 2003). The 'b' values for all fish specimens examined was about 3. That means *V. beso*, *L. nedgia*, *L. intermedius* and *L. forskalii* in Aveya Rivers was nearly isometric growth which means the weight of these fishes increases as the cube of length because the b value is nearly 3 for these fish species in the river systems. This value is close to the values reported for some freshwater fish species by Wassie (2005) in Dirma and Megech Rivers, (Tewabe, 2008) in Gendewuha, Guang, Shinfa and Ayima Rivers, (Tesfaye, 2006) in Angereb and Sanja Rivers, (Abebe *et al*., 2008) in Ribb River, (Berie, 2007) from Gelegel Beles River, (Tessema *et al*., 2012) in Borkena and Mille Rivers and Omer (2010) in head of Blue Nile River and Awoke (2011) in Blue Nile River below the Fall.

The measurement of fish condition can be linked to the general health, fat and lipid content prey or food availability, reproductive potential, environmental condition and water level fluctuation. In general, higher condition is associated with higher energy (fat) content, increasing food base, reproduction potential or more favorable environmental condition (Pauker and Rogers, 2004). The mean Fulton condition factor value obtained in the present study for *L. intermedius* in Aveya River was greater than the values reported by Awoke (2011) from Blue Nile River with a value of 0.99, by Omer (2010) with value of 0.87 in a head of Blue Nile River, by Tesfaye (2006) from Angereb and Sanja Rivers with a value of 1.06, by Tewabe (2008) from Gendwuha, Guang and Shinfa Rivers with a value of 1.12, by Beletew (2007) from Gelegel Beles River but it was less than from those values reported by Tessema *et al*., (2012) with a values of 1.23 and 1.31 in Borkena and Mille Rivers. The difference might be due to the difference in river system, catchment areas, size of river and level of disturbance by different developmental or human activities. The results for L. *forskalii* were not also in line with Awoke (2011) in Blue Nile River and Tesfaye, (2006) Sanja and Angereb Rivers during the dry and wet seasons.

For all sampled specimens, females had better FCF values as compared to males. This is probably due to egg production by female consumes much energy than sperm preparation by male fishes. The higher and better values of FCF were observed in Aveya River as compared to the main Blue Nile River reported by Awokek (2011). Generally, there was better FCF values of all specimens examined in the studied rivers probably due to food availability in quantity and quality, better hiding places, good water levels and good flow rate and water temperature conditions.

The sex ratio deviates from unity. This variation might be probably related to different biological mechanisms such as differential maturity rates, mortality rates and migratory rates between the males and females (Sadovy and Shapiro, 1987; Matsuyama *et al*., 1988). This kind of phenomena is also common in other cyprinids. The sex ratio results in this study are in agreement with the reports by Awoke (2011) from the main Blue Nile River below the TissIsat Fall. However, there should be further study on the potential effects of one sex dominance in the whole population.

Estimation of the absolute fecundity will help us to know the potential productive and reproductive capacity of a given stock. The information on fecundity of large *Barbus* fish species in Africa is scarce (Marshall, 1995). There was few data on the fecundity of Ethiopian large *Barbus*. Alekseyev *et al*. (1996), Wassie (2005) and Gebremedhin (2011) studied fecundity of large *Barbus* in Lake Tana and its tributaries. Compared to Lake Tana *Labeobarbus* species a similar sized female *L. intermedius* in Aveya River had higher number of eggs. The absolute fecundity of L.*intermedius* reported by Tewabe (2008) in Gendewuha, Guang, Shinfa and Ayima Rivers ranged from 542 to13769 and in Borkena and Mille Rivers The absolute fecundity of *L. intermedius* ranged rom 2736-12124 (Tessema *et al*., 2012). In the present study, the absolute fecundity in the respective species seemed higher and in good status. This is probably due to the suitability of the environment or else fishes became more fecund to increase their survival in harsh conditions.

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