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THE LACUSTRINE SPECIES OF *LABEOBARBUS* OF LAKE TANA (ETHIOPIA) SPAWNING AT MEGECH AND DIRMA TRIBUTARY RIVERS

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ABSTRACT: The spawning habits of the endemic *Labeobarbus* species were studied in the upstream reaches of Dirma and Megech affluent rivers of Lake Tana. Fish and other environmental parameters were sampled from February to October 2004 using various fishing gears. Collected specimens were identified, dissected and sexed. Five lacustrine species of Lake Tana (*L. brevicephalus, L. intermedius, L. megastoma, L. tsanensis* and *L. truttiformis*) migrate to upstream reaches of Dirma and Megech Rivers for spawning from August to October. Neither macro (between rivers) nor micro (within the rivers) spatial segregation among the migrating species was observed. However, the overall comparisons of the spawning run showed temporal patterns of segregation among these migrating species. *Labeobarbus truttiformis* and *L. tsanensis* were the first to migrate up rivers and *L. megastoma* just follows and then *L. brevicephalus* was the last to migrate. Running *L. intermedius* were most abundant starting from the middle of September to end of October. Although *L. nedgia* was collected in Megech and its tributary Dimaza, it was considered as a riverine dwelling fish. Four species (*L. crassibarbis, L. macrophthalmus, L. longissimus* and *L. surkis*) were rarely caught. However, five species (*L. acutirostris, L. dainellii, L. gorgorensis, L. gorguari* and *L. platydorsus*) were missing. To sustain the riverine *Labeobarbus* spawners, closing the gillnet fishery from August to October at Dirma and Megech River mouths is strongly recommended. Degradation of the breeding grounds (rivers) by agricultural and construction activities should be urgently halted by applying proper land-use management system in the area.

Key words/phrases: Endemic, management, migration, peak breeding, segregation

INTRODUCTION

Although many cyprinids are riverine in their origin, they secondarily adapted to live in lakes or lacustrine environments. Nevertheless, most of these species still migrate upstream to spawn in tributary rivers (Skelton *et al.*, 1991). This indicates that they are not still fully adapted to the lake environment. Various studies (Nagelkerke and Sibbing, 1996; Palstra *et al.*, 2004; De Graaf *et al.*, 2005) conducted in some tributary rivers such as Gelgel Abbay, Gelda and Gumara in the southern Gulf of Lake Tana indicated the upstream spawning migration of the lacustrine *Labeobarbus* species. Previous works in the above tributaries showed that the ancestral (riverine) reproductive strategy is found to be a characteristic for at least seven (*L. acutirostris, L. brevicephalus, L. macrophthalmus, L. megastoma, L. platydorsus, L. truttiformis,* and *L. tsanensis*) of the 15 endemic *Labeobarbus* species of Lake Tana. The riverine spawners of *Labeobarbus* species ascend 30 to 40 km upstream Gumara River from August to October (Palstra *et al.*, 2004). They spawn in fast flowing, shallow, and well-oxygenated gravel beds of small tributaries of the Gumara River and possibly in the main channel.

Most African large lake-adapted cyprinids congregate in the river mouths during spawning. This makes them highly vulnerable for modern fisheries (Ogutu-Ohwayo, 1990). Unregulated modern fishing has proven to have severe impact on the stocks of lake-dwelling riverine spawning cyprinids. Gill nets are set near the river mouths and effectively block upstream migrations. The most plausible explanation for the decline of the *Labeobarbus* stock in Lake Tana is attributed to recruitment overfishing by the commercial gill net fishery (De Graaf *et al.*, 2004) since seven of the 15 endemic *Labeobarbus* aggregate in these river mouths.

The remaining eight 'missing' *Labeobarbus* species (*L. dainellii, L. surkis, L. gorgorensis, L. crassibarbis, L. gorguari, L. nedgia, L. longissimus, L. intermedius*) have been hypothesized to migrate and spawn in other inflowing rivers such as Dirma, Megech, and Arno-Garno (Fig. 1) or maybe even within the lake itself (lacustrine spawning) (Nagelkerke and Sibbing, 1996; Palstra *et al.*, 2004; De Graaf *et al.*, 2005). Problems in logistics and transportation in accessing the Dirma and Megech tributary rivers of Lake Tana located in the northern part of the lake (far from Bahir Dar) prevented extensive sampling in time and space important in studying reproductive segregation of fishes in the field. However, scientific data about fish spawning migration to the rivers on this larger part of the lake in general and in Dirma and Megech Rivers in particular are extremely important to the sustainable utilization of the declining fishery resources of the endemic *Labeobarbus* species of Lake Tana. Therefore, the aim of this paper is to unveil the spawning habits of *Labeobarbus* species in Dirma and Megech Rivers.

MATERIALS AND METHODS

Study area

Lake Tana, the headwater of the Blue Nile River, is located in the northwestern highlands of Ethiopia (at an elevation of 1830 m). The lake has an area of about 3200 km^2 and it is the largest water body in the country. It is an oligo-mesotrophic shallow lake (Eshete Dejen *et al.*, 2004) with an average depth of 8 m and maximum depth of 14 m. Seven big perennial rivers flow into Lake Tana: Gelgel Abbay, Gelda, Gumara, Rib, Arno-Garno, Megech and Dirma (Fig. 1). However, the lake has only one outflowing river, the Blue Nile. Although the lake is the source of the Blue Nile, the lake's ichthyofauna is completely isolated from the lower Nile basin by 40 m high waterfalls, down 30 km from the Blue Nile outflow (Fig.1).

During the rainy season, Megech is on average about 10-15 m wide and 1.5-2.50 m deep in the upstream sampling sites (MUPS1 and MUPS2). The bed of the main channel of the river in the lotic habitat is characterized by bedrock, boulders, pebbles and gravel beds. About 30 km, the river flows through the alluvial and lacustrine Dembia plain deposits until it joins Lake Tana in a muddy mouth. About 3 km upstream from the bridge (main asphalt road from Bahir Dar to Gondar town), a small seasonal river, Dimaza, joins Megech (Fig. 1). Dimaza River, starting from its mouth to Azezo (Gondar) town, flows over pebble and gravel beds. The stream has a waterfall (3 m high) about 2 km upstream, which completely blocks *Labeobarbus* migration further upstream.

Dirma River in the rainy season, has a width of about 8-10 m and a depth of about 0.5-1.5 m at the sampling site (Fig. 1). Starting from the bridge at Kola Diba town, the river upstream, like Megech, is covered with boulders, pebbles and gravel beds. However, downstream from Kola Diba town, the river runs slowly through the alluvial Dembia plain deposit until it joins Lake Tana.

During the dry season (from February to the first week of June 2004), both rivers completely dried at their mouths most probably due to excess water extraction for irrigation by the local farmers. Nearly all stretches of the river banks of both rivers are subjected to crop farming. This problem is particularly severe in Dirma River, as it was almost completely dry or reduced to pockets of pools for extended periods of time. During the spawning season, both rivers recovered in volume due to the heavy rains in the area.

Sampling frequency and fish collection

Sampling sites were selected based on the suitability of the river bed type for *Labeobarbus* spawning ground. At the selected sampling sites the oxygen content (mgl^{-1}), water temperature (°C) (using Oxyguard portable probe) and pH (using pH meter) were measured depending on the availability of enough volume of water in the river main stream to take the measurements. Fish samples were taken monthly from February to May 2004 at Megech River (MUPS1) by setting 6, 8, 10, and 12 cm stretched mesh size gillnets. However, samples were taken bimonthly in June and July and weekly from August to October at all selected sites of Dirma and Megech Rivers (Fig. 1) using 6, 8, 10, and 12 cm stretched mesh size gillnets, fykes (polyfilament twine, bar mesh 5 mm, length 4 m, 8 compartments) and locally-made basket traps ('keffo') of average bar mesh of 30 mm. These fishing gears were set in the rivers for an over night sampling. At MUPS1 fish were also purchased from local fishermen who used hooks and lines (Table 1).

Table 1. Sampling sites estimated distance from the mouth, fishing gears used and coordinates. Here onwards, DUPS, MUPS1 and MUPS2 refer to the sampling site codes unless stated otherwise.

Site	Code	Distance	Gear used	Coordinate (GPS)
Dirma upstream	DUPS	25km	Local traps, Fyke, Gill net	12° 26′ 26.1″N; 37° 20′ 13.9″E
Megech upstream	MUPS1	28km	Local traps, Fyke, Gill net, Hook and line	12° 29′ 11.4″N; 37° 26′ 49.9″E
	MUPS2	32km	Local traps, Fyke, Gill net	12° 29′ 48.3″N; 37° 27′ 19.3″E
Dimaza	DZ	30km	Local traps, Fyke, Gill net	12° 29′ 24″N; 37° 26′ 53.3″E

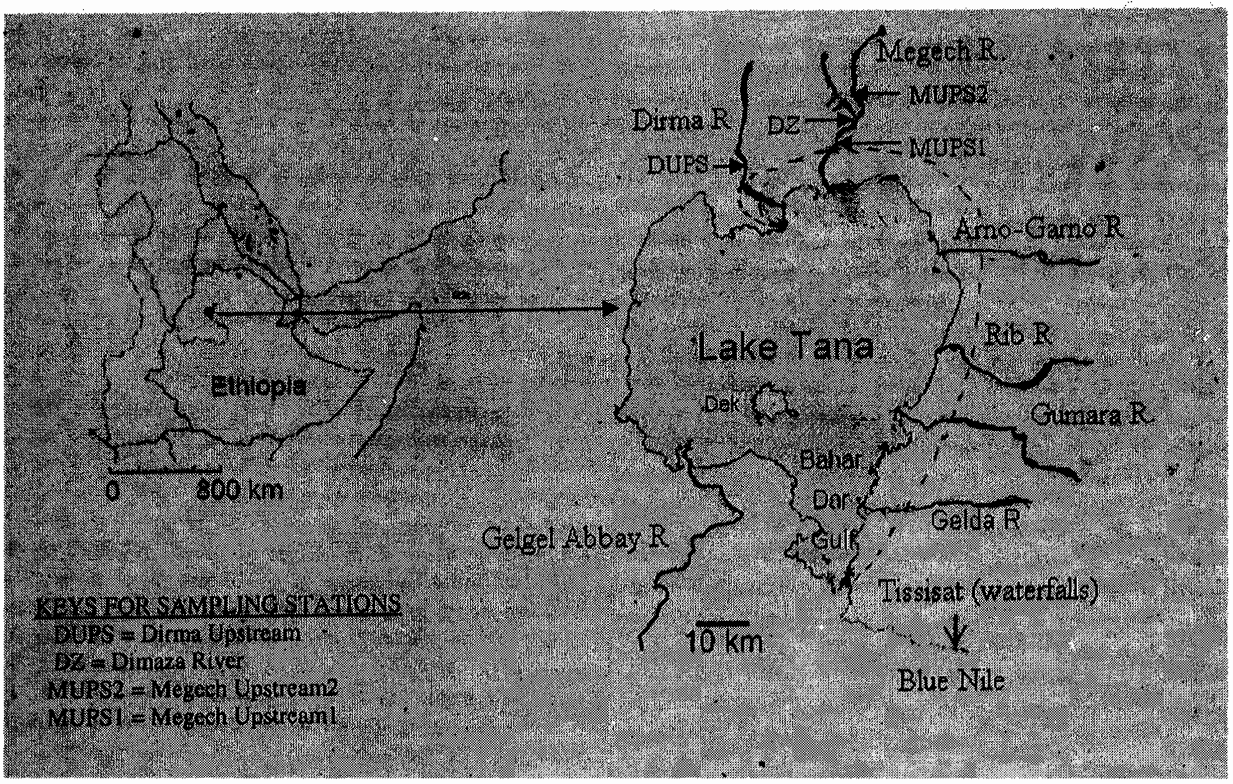

Fig.1. Lake Tana, inflowing and out flowing rivers and the sampling stations. (Reproduced from De Graaf, 2003).

Fish specimens collected in the sampling areas were transported fresh to the laboratory of Gorgora Fish and Other Aquatic Life Research Sub Centre and classified to species level with the help of an identification key developed by Nagelkerke and Sibbing (2000). In the laboratory each specimen of *Labeobarbus* species was identified to the species level, dissected, the gonads were examined visually and sexed. The gonad maturity stages of specimens of each species of *Labeobarbus* were determined according to Pet *et al.* (1996).

Abundance of fish in the sampling sites

Overall temporal and spatial segregation among *Labeobarbus* species in the upstream sites of the rivers were made using one-way analysis of variance (ANOVA) after the catch data were checked for the assumptions of ANOVA using Kolmogorov-Smirnov (K-S) test. If significant variance was observed, Bonferroni's post hoc tests for multiple comparisons were carried out. Those *Labeobarbus* species which were fewer than 10 specimens (total) in all sampling sites (pooled) were considered as rare and left out of analysis of spatial and temporal spawning segregations. For spatial and temporal data analysis, only the catches of August, September and October were used. For statistical data analysis SPSS for windows software (Version 10) was used.

RESULTS

Abiotic parameters

Mean dissolved oxygen, temperature and pH were compared among the sampling sites. There was no significant difference in the means of temperature and pH across the sampling sites. Mean temperature was relatively highest at Dimaza (24.63 ± 2.5 SE) as it had smaller volume of water during the sampling period, whereas, the mean dissolved oxygen was significantly higher ($p<0.05$) in Megech and Dimaza ((7.52±0.73 SE, 7.51±0.44 SE, respectively) than in Dirma (6.87±0.40) (Table 2).

Table 2. Abiotic parameters (oxygen, temperature and pH) at the sampling sites with their means± E.

Site	Oxygen (mgl^{-1})	Temperature (°C)	pH
	Mean ± SE	Mean ± SE	Mean ± SE
Dirma (10)	6.87 ± 0.40	21.18 ± 0.9	7.82 ± 0.2
Megech (16)	7.52 ± 0.73	22.29 ± 0.4	7.87 ± 0.3
Dimaza (11)	7.51 ± 0.44	24.63 ± 2.5	7.65 ± 0.2

Note: SE stands for standard error of the mean. Numbers between parentheses indicate the number of samplings.

Species composition

A total of 703 fish specimens of *Labeobarbus* were collected from the sampling sites. Six species (Table 3) contributed about 98.5% of the total *Labeobarbus* catch. The incidentally collected *Labeobarbus* species from the rivers include: *L. crassibarbis* (0.43%), *L. longissimus* (0.58%), *L. surkis* (0.7%) and *L. macrophtalmus* (0.01%). Five species (*L. acutirostris, L. dainellii, L. gorgorensis, L. gorguari* and *L. platydorsus*) were completely missing in the upstream areas.

Gonad maturity stages

For all of the *Labeobarbus* species caught at Dirma and Megech Rivers, the gonad proportion of mature (gonad stages IV, V), running (gonad stage VI), and spent (gonad stage VII) on average was higher (about 90%) than the immature gonads (gonad stages I-III). Except in *L. nedgia*, more than 80% of the specimens in each species were running (gonad stage VI) (Fig. 2A). A total of 92 *Labeobarbus* specimens (13 %) were spent. For most species spent fish were relatively numerous at the end of October (Fig. 2b). Fish with immature gonads were relatively common for *L. nedgia* (Fig. 2a). Gonad stages IV and V were absent in the catch (Fig. 2a).

Spatial segregation

The differences in mean abundance (in number) among the six migrating *Labeobarbus* species between the two rivers and within a river were compared. The overall and pair wise comparisons among the six migrating *Labeobarbus* species revealed poor spatial segregation (p>0.05) in Dirma and Megech Rivers. Those *Labeobarbus* species which spawn in Megech River also spawn in Dirma River (Fig. 3). Significant difference was not observed (p>0.05) when the catches of the three sampling sites in Megech River were compared.

Table 3. Composition of the most abundant *Labeobarbus* species (temporally and spatially) in the upstream of Megech and Dirma Rivers. Data represent absolute number of specimens.

Species	Temporal variation				Spatial variation			
	Feb-Jul	Aug	Sep	Oct	DUPS	MUPS1	MUPS2	DZ
L. brevicephalus	0	33	45	65	28	26	49	40
L. intermedius	20	58	78	108	71	57	110	26
L. megastoma	0	2	12	0	6	3	5	0
L. nedgia	1	2	3	20	0	6	14	6
L. truttiformis	0	74	54	2	10	33	23	64
L. tsanensis	0	50	58	5	9	32	13	59

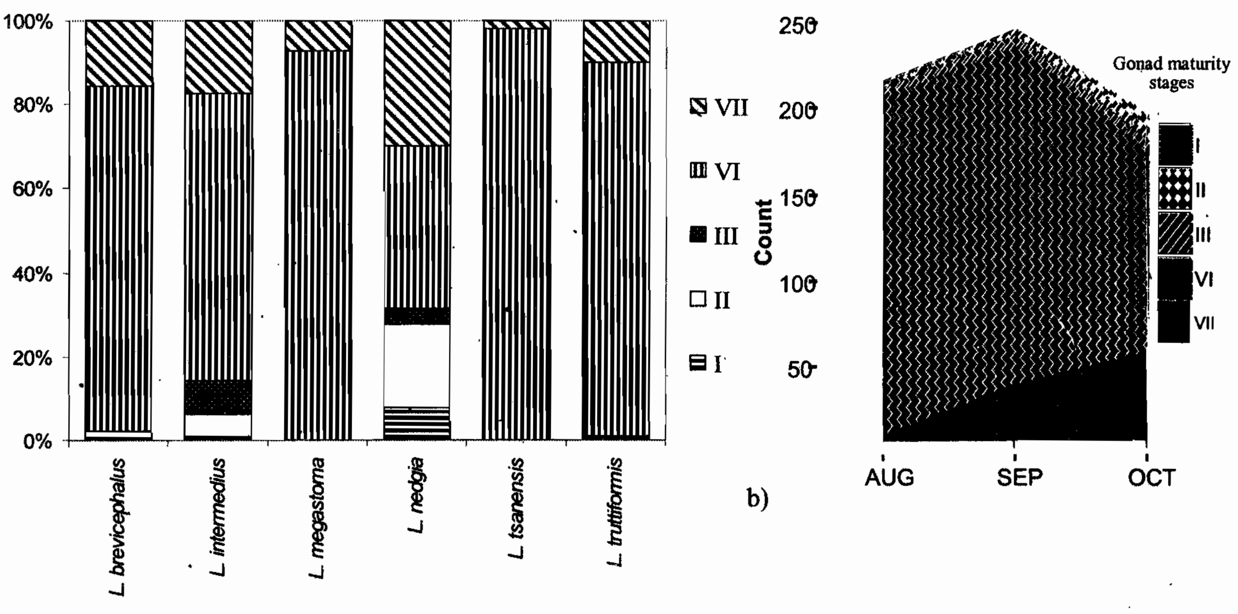

Fig. 2. Proportion (%) of different gonad maturity stages (I to VII) (A) and temporal variations of the different gonad stages (B) of *Labeobarbus* species during the spawning months (August to October) in Dirma and Megech Rivers.

Temporal segregation

Migration patterns in the upstream areas on weekly basis are given in Figure 4. Although there is some overlap, overall significant ($p<0.05$) temporal segregation was observed among the six migrating species of *Labeobarbus* of Lake Tana. The pair wise comparison also showed significant ($p<0.05$) variation in temporal segregation, except in *L. tsanensis* and *L. truttiformis* (Table 4). The first migrants to upstream rivers were *L. tsanensis* and *L. truttiformis*. They started to ascend at the middle of August, but migrate in mass at the end of August and beginning of September in Megech (MUPS1) and Dimaza stream (Fig. 3). *L. megastoma* was common starting from end of August to the middle of September. Catches of *L. nedgia* and *L. brevicephalus* reached their peak at the end of October. *L. intermedius,* although common in samplings of all weeks (Fig. 4), it was caught in mass starting from the middle of September to end of October.

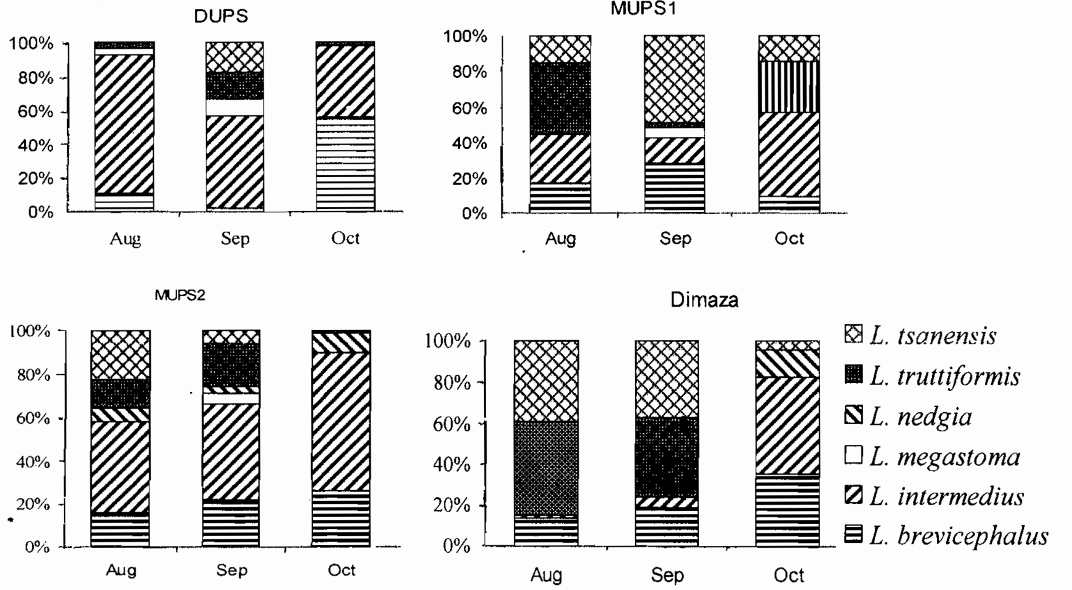

Fig. 3. Relative proportions (percentage compositions) of *Labeobarbus* species represented as a function of time. Refer Table 3 for the absolute number of specimens in each month and site.

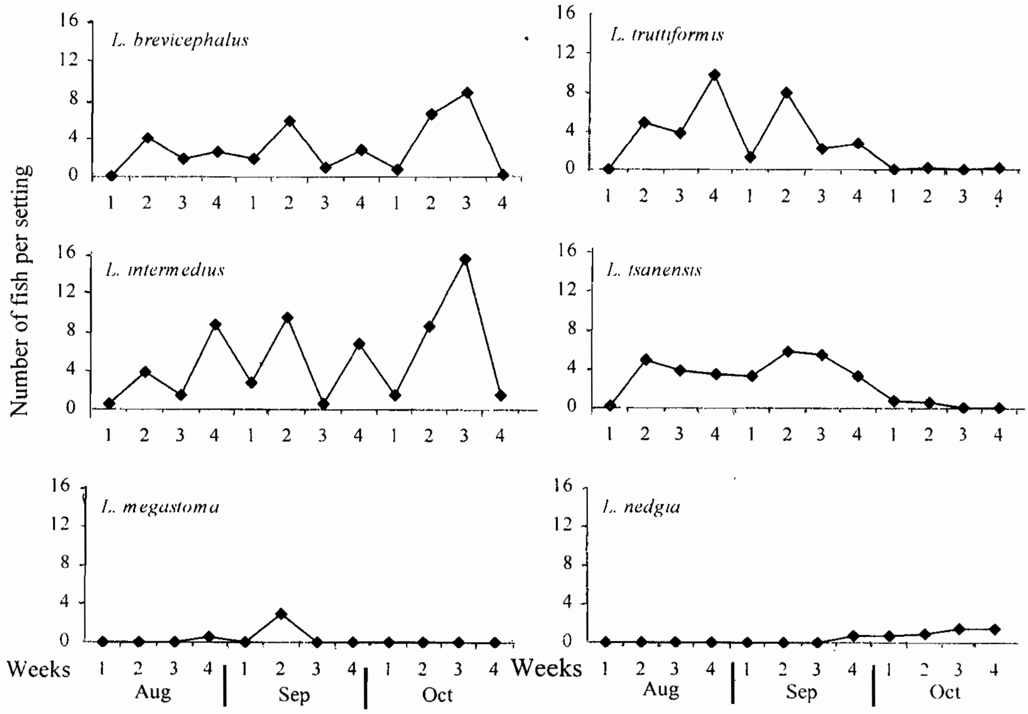

Fig. 4. Temporal variation in abundance (pooled data of all upstream sites) on weekly basis during the peak breeding season (August to September).

Table 4. Pair wise comparisons of temporal segregation of the six *Labeobarbus* species over the three spawning months (Aug-Oct) in the river upstream reaches.

	L. brevicephalus	*L. intermedius*	*L. megastoma*	*L. nedgia*	*L. tsanensis*	*L. truttiformis*
L. brevicephalus	X					
L. intermedius	*	X				
L. megastoma	*	*	X			
L. nedgia	*	**	**	X		
L. tsanensis	***	***	*	***	X	
L. truttiformis	***	****	*	***	ns	X

* = P<0.05, ** = P<0.01, *** = P<0.01, ns = not signifiant (P>0.05)

DISCUSSION

Spawning grounds

Fast flowing, clear, highly oxygenated water, and gravel-bed streams or rivers are preferred places for *Labeobarbus* spawning. These conditions are important for hatching and growth of 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 facilitates diffusion of oxygen (Lowe-McConnell, 1975). Although Dirma and Megech tributary rivers flow about 25 to 30 km in the muddy Dembia plain (lentic habitat), the upper stretches (lotic habitat) of both rivers fulfill the conditions stated above for spawning ground of *Labeobarbus* species. Megech River has higher oxygen (Table 2), water volume and many tributary streams, such as Dimaza, Keha, and Angereb, which have gravel beds at their mouths. This is most probably the reason for the relatively more abundant specimens of *Labeobarbus* available in Megech River compared to Dirma. Megech and its tributary Dimaza stream have rapids and small waterfalls, which may cause for the significantly higher oxygenation (Table 2). Relatively, the higher abundance of specimens in Dimaza stream, like in the small seasonal tributaries of Gumara (Kizen, Dukolit, Wanzuma; Palstra *et al.*, 2004), indicates that most of the riverine spawners of *Labeobarbus* of Lake Tana prefer side streams to the main channels of the rivers for spawning. In Dimaza the breeding stretch is short as fish migration is blocked by about 3 m waterfalls about two kilometers from its mouth.

Migrating species of Labeobarbus

When the catches of August to October are considered, more than 90% of the specimens in each species of *Labeobarbus* migrating to the upstream areas, except *L. intermedius*, were either running (gonad stage VI) or spent (gonad stage VII). No *Labeobarbus* fish with gonad stages IV or V was caught (Fig. 2a). This indicates that they migrate for spawning. Nagelkerke and Sibbing (1996), Dgebuadze *et al.* (1999) and Palstra *et al.* (2004) after studying *Labeobarbus* migration at Gumara River (in the southern Gulf of Lake Tana), reported that *L. acutirostris, L. brevicephalus, L. macrophtalmus, L. megastoma, L. tsanensis* and *L. truttiformis* were riverine spawners. However, the absence of *L. acutirostris* and *L. macrophtalmus* in the distant Megech and Dirma Rivers (in the northern part of Lake Tana, which is about 60 km far from Gumara River) calls for the need to study the ecological distribution of the genus in this relatively larger lake.

L. nedgia was totally absent in the upstream areas of Dirma and Gumara Rivers but found only in Megech and its tributary, Dimaza. The most probable explanation is that *L. nedgia* may be spending its entire life in Megech River basin. In May 2004 samples, an immature *L. nedgia* was captured in upstream pools of Megech River when it was completely dry at its mouth and totally disconnected from the lake. About 30% of the catch was immature in the upstream of this river during the spawning season (Fig. 2a). This species did not form any spawning aggregation at the river mouths of Dirma and Megech during the sampling period (Wassie Anteneh, 2005); neither did at other rivers (De Graaf *et al.*, 2005). This evidence supports the idea that this species is dwelling in Megech River and that the lake's population never migrate to the rivers in mass (Wassie Anteneh, 2005). However, whether this riverine *L. nedgia* is different from the Lake's population of *L. nedgia* needs detailed biological investigation. The other species which was very common in our upstream samples but absent in Gumara River (Palstra *et al.*, 2004) was *L. intermedius*.

The highest proportion of the catch in the upstream reaches of Dirma and Megech was contributed by the 'shore complex' called *L.*

intermedius. Fish with mature and immature gonads of this species was common even when the rivers were dry at their mouths. This implies that like *L. nedgia*, population of this species is also river dwelling, but unlike *L. nedgia*, it migrated to rivers. Its migration is deduced from the aggregation at the river mouths of both rivers in this sampling season (Wassie Anteneh, 2005). But, the question as to why the species was absent totally from Gumara River (Palstra *et al*., 2004) was not explained. It is suspected that this species might be lumped with *L. tsanensis* due to identification problem. Moreover, it was commonly caught in Gumara River by Bahir Dar Fish and other Aquatic Life Research Center (unpublished data). Abebe Ameha (2004) had also caught 44 specimens of this species in Gumara River upstream areas.

Overall and pairwise comparisons of the six migrating species did not indicate significant ($p>0.05$) spatial segregation. All *Labeobarbus* species those migrate to spawn in Dirma River also migrate to Megech River. Absence of macro spatial segregation was also reported in the previous studies conducted in Gumara, Rib, Gelgel Abbay and Gelda tributary rivers of Lake Tana (De Graaf *et al*., 2005). Unlike the present result, in the study conducted in Gumara and its small tributary rivers micro spatial segregation was evident (Palstra *et al*., 2004) for some of the *Labeobarbus* species migrating to this river, although strong overlap was observed. But the study did not clearly show as to which physical (such as water depth, velocity, temperature and bottom type), chemical, biological and homing factor (s) segregate spawning sites in Gumara and its tributaries.

Temporal variation (overall) in upstream migration in Dirma and Megech Rivers was also evident among the six (Table 3) most abundant species (Fig. 4). Pairwise comparison among these species indicated that no two species migrate together except *L. tsanensis* and *L. truttiformis* ($p<0.05$; Table 4). These two species were segregated neither spatially nor temporally. If assortative mating occurs in these two species there must be another mechanism. Pre-mating mechanisms that minimize hybridization and facilitate assortative mating in the *Labeobarbus* species of Lake Tana are poorly known (Dgebuadze *et al*., 1999). The sequence of the migration pattern to the upstream reaches of Dirma and Megech Rivers was determined based on weekly catches on the four upstream sampling sites (pooled) (Fig. 4). The first species to run in the rivers were *L. truttiformis* and *L. tsanensis*, starting from the second week of August, with most running fish in the last week of August and the first half of September (Fig. 4). The second migrating river spawner was *L. megastoma*, the highest number of running specimens were collected in the second week of September. The last spawners were *L. brevicephalus* and *L. nedgia*, with the highest number of running fish observed in the third week of October. In Gumara River, *L. megastoma* was the first to migrate in Gumara upstream (Palstra *et al*., 2004), the second species to migrate up were *L. acutirostris* and *L. tsanensis*, *L. truttiformis* followed them, and then *L. brevicephalus* comes next to it. The last river spawner in this river was *L. macrophtalmus*. This spawning sequence virtually looks like river specific however, whether this pattern of migration in these rivers remains the same every year or it changes, should be further investigated.

Fisheries management

The single annual upstream migration reproductive strategy of African *Labeobarbus*, *Barbus*, and *Labeo* species make them highly vulnerable as fishermen target the spawning aggregations (Skelton *et al*., 1991). Dramatic reduction (75%) in total abundance, both in number and biomass of *Labeobarbus* adults and (90%) in the number of juveniles was observed in Lake Tana within ten years (1991-2001) (De Graaf *et al*., 2004). The most likely explanation for such drastic reduction is recruitment overfishing.

In the upstream spawning areas in Dirma and Megech Rivers, fishing activity currently is quite limited. Only a few people are used to fish mostly using hook-and-line fishing gears for subsistence purposes. Gill net fishery is common at the river mouths of both rivers (Wassie Anteneh, 2005). Nevertheless, the potential problem is the environmental degradation of the spawning rivers. Diversion of the rivers for irrigation by local farmers and sand extraction for construction in Megech River has altered the rivers' natural flows. Juvenile fish were observed usually stranded in the irrigated farmlands when the rivers are completely diverted (pers. comm. with local people). At some stretches of Dimaza and Megech, the rivers' natural channels are changed due to intensive digging for sand (Pers. Obs.).

The application of land-use classification system in the area is a corner stone in order to keep the natural ecosystem intact. Agricultural activities in the banks of all breeding tributary streams must be immediately banned. Total diversion of tributary rivers for irrigation should be minimized, at least there must be some water in the rivers channel for the juveniles to return to the lake through out the year. Sand digging activities in the river channels need to be carried out safely without damaging the rivers' natural flow.

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REFERENCES

1. Abebe Ameha (2004). The effect of birbira, *Milletia ferruginea* (Hochst.) Baker on some *Barbus* spp. (Cyprinidae, Teleostei) in Gumara River (Lake Tana), Ethiopia. MSc thesis, Addis Ababa University.
2. De Graaf, M. (2003). Lake Tana's piscivorous *Barbus* (Cyprinidae, Ethiopia) Ecology, evolution. exploitation. PhD thesis, Wageningen Agricultural University, The Netherlands.
3. De Graaf, M., Machiels, M.A.M., Tesfaye Wudneh and Sibbing, F.A. (2004). Declining stocks of Lake Tana's endemic *Barbus* species flock (Pisces: Cyprinidae): natural variation or human impact? *Biol Cons.* **116**:277–287.
4. De Graaf, M., Nentwich, D., Osse, J.W.M. and Sibbing, F.A. (2005). Lacustrine spawning: is this a new reproductive strategy among 'Large' African Cyprinid fishes? *J. Fish. Biol.* **66**:1214–1236.
5. Dgebuadze, Y.Y., Mina, M.V., Alekseyev, S.S. and Golubtsov, A.S. (1999). Observations on reproduction of the Lake Tana barbs. *J. Fish. Biol.* **54**:417–423.
6. Eshete Dejen, Vijverberg, J., Nagekerke, L.A.J. and Sibbing, F.A. (2004). Temporal and spatial distribution of microcrustacean zooplankton in relation to turbidity and other environmental factors in large tropical lake (L. Tana, Ethiopia). *Hydrobiologia* **513**:39–49.
7. Lowe-McConnell, R. (1975). *Fish Communities in Tropical Freshwaters: their Distribution, Ecology, and Evolution.* Longman, London, 337 pp.
8. Nagelkerke, L.A.J. and Sibbing, F.A. (1996). Reproductive segregation among the large barbs (*Barbus intermedius* complex) of Lake Tana, Ethiopia. An example of intralacustrine speciation? *J. Fish. Biol.* **49**:1244–1266.
9. Nagekerke, L.A.J. and Sibbing, F.A. (2000). The large barbs (*Barbus* spp., Cyprinidae, Teleostei) of Lake Tana (Ethiopia), with a description of a new species, *Barbus ossensis*. *Neth J. Zool.* **2**:179–214.
10. Ogutu-Ohwayo, R. (1990). The decline of the native fishes of Lakes Victoria and Kyoga (East Africa) and the impact of introduced species, especially the Nile Perch, *Lates niloticus* and the Nile tilapia, *Oreochromis niloticus*. *Envi Biol Fish* **27**:81–96.
11. Palstra, A., De Graaf, M. and Sibbing, F.A. (2004). Riverine spawning and reproductive segregation in lacustrine cyprinid species flock, facilitated by homing? *Anim B iol.* **54(4)**:393–415.
12. Pet, J.S., Gevers, G.J.M., van Densen, W.L.T., Vijverberg, J. (1996). Management options for a more complete utilization of the biological fish production in Srilankan reservoirs. *Ecol. Fresh. Fish.* **5**:1–14.
13. Skelton, P.H., Tweddle, D. and Jackson, P. (1991). Cyprinids of Africa. **In**: *Cyprinid Fishes, Systematics, Biology and Exploitation*, pp. 211–233, (Winfield, I.J. and Nelson, J.S., eds), Chapman & Hall, London.
14. Tómasson, T., Cambray, J.A. and Jackson, P.B.N. (1984). Reproductive biology of four large riverine fishes (*Cyprinidae*) in a man-made lake, Orange River, South Africa. *Hydrobiologia.* **112**:179–195
15. Wassie Anteneh (2005). Spawning migration and reproductive biology of *Labeobarbus* (Cyprinidae: Teleostei) of Lake Tana to Dirma and Megech Rivers, Ethiopia M.Sc thesis, Addis Ababa University, Ethiopia.