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Motives for *Labeobarbus* Fish Species Migration to Gumara River, Lake Tana, Ethiopia

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Abstract
The flocks of endemic fish species in Lake Tana, i.e., *Labeobarbus* species (*L. intermiduis, L. tsanansis, L. brevicifaleus, L. acutirostris* and others) migrate for spawning during the rainy season (peak from August to September) to the rivers that flow into Lake Tana. These migrations make them vulnerable for aggregated fishery. The Gumara River is one of the tributaries that flow into Lake Tana where the *Labeobarbus* fish species migration is predominant. A study was conducted to determine the factors that trigger *Labeobarbus* migration to Gumara River from January 2001 to November 2001. The objectives of the study were: to determine the factors that stimulate the migration of the *Labeobarbus* fish species to the Gumara River mouth and upstream and based on that to recommend protective measures. Fish and environmental data were collected at two sites, i.e., at the River mouth and upstream of Gumara. Data were analyzed using simple statistical models. Amount of rainfall and level of the lake appeared to trigger upstream migration of *Labeobarbus*. To protect the breeding population of migrating *Labeobarbus*, fishing must be prohibited from July-October at the river mouths, rivers and their tributaries.

Keywords: *Labeobarbus* species; fish migration; spawning population; environmental factors, management

1. Introduction
Lake Tana, the source of the Blue Nile, is the largest lake in Ethiopia. It covers an area of over 3 thousand km^2 and has an average depth of 8 m, with a maximum of 14 m. It is situated at an altitude of 1830 m and can be characterized as an oligo-mesotrophic lake. The watershed of Lake Tana is about 17 thousand km^2. A major rainy season with heavy rains, during June to October and sometimes a minor rainy season during February to March characterize the climate of Lake Tana and its environs.

The Lake Tana ecosystem provides multiples of services. Electric power generation, water transportation, irrigation agriculture, sand mining, water for consumption, waste disposal, fisheries, ecotourism are a few of the services. The information on these activities is in scarce. Scientific information on the species composition, abundance, distribution and dynamics of the fish stocks in Lake Tana is not adequate.

Gilgel Abay, Rib, Gumara, Gelda, and others enter the lake, the Blue Nile River being the only outflow. Some 30 km downstream, the Blue Nile river plunges down 40-meter-high waterfalls, isolating Lake Tana and its tributaries from other Parts of the Nile basin. Four fish species dominate the commercial and traditional fishery. Tilapia (*Oreochromis niloticus*), Catfish (*Clarias gariepinus*), the various morpho-type *Labeobarbus* species flock (*L. intermiduis, L. tsanansis, L. brevicifaleus, L. acutirostris*) and other *Labeobarbus* fish species flock (Nagelkerke, 1997) and to some extent *Varicorhinus beso*. Small barbus fish is a key species in the Lake Tana food web, supporting that the most important flow of energy and mass to the *Labeobarbus* biomass production that leads from phytoplankton via zooplankton (Dejen et al., 2004).

The cyprinids are the major component of the fish fauna. The *Labeobarbus* fish species have migration behavior for reproduction. Recent studies revealed that the different species of *Labeobarbus* fish species migrate at different times and space (Nagelkerke, 1997; de Graaf, 2003; Wassie, 2005). Gumara River was identified as a major breeding ground of *Labeobarbus* fish species. The unique *Labeobarbus* fish species that are only found in Lake Tana are currently under high fishing pressure unlike other non-migrating species *Oreochromis niloticus* and *Clarias garipinus*.

The main problem of the high fishing pressure on the *Labeobarbus* fish species is related to migration into the inflowing river Gumara and its tributaries for reproduction. The intensity of fishing pressure on the *Labeobarbus* fish species on Gumara River is high because of the *open access* or unregulated situation. The fishing community use traditional fishing techniques such as poisoning fish by using powdered Birbira, *Milletia ferruginea* (Abebe Ameha, 2004). Recently, researchers suggested the need for working on the biology and management of fish stocks (Nagelkerke, 1997; Tesfaye Wudneh, 1998; de Graaf 2003; Dejen et al., 2004). Generally development of commercial fishery has been intensified over the last decade in Lake Tana (Tesfaye Wudneh, 1998).

To promote Sustainable spawning Stock Biomass (SSB) of the *Labeobarbus* fish species and to develop appropriate management strategy/tool, information is required on where, when and why the *Labeobarbus* fish species migrate. De Graaf (2003) has addressed the where and when issue of the migration. However, specific factors that trigger spawning migration are not clearly identified. Thus, the objectives of this research paper were to identify what environmental factors trigger upstream migration of *Labeobarbus* fish species and then to recommend some management techniques so that the Sustainable Spawning Biomass (SSB) of the *Labeobarbus* fishes species will be protected.

2. Materials and Methods

Study Area

The Gumara River is one of the tributaries that flow into Lake Tana. A number of small streams/rivers feed the Gumara River. The tributaries contribute water and enrich the ecology of the Gumara River. In the upstream, near *Wanzaye hot spring*, a natural waterfall hinders the upstream movement of fish. The water volume of Gumara significantly fluctuates with season (high during the rainy season and low during dry season). The riparian system also varies. The upstream is covered with natural shrubs; the lower stream is devoid of the natural vegetation because of heavy agricultural activities. Fig. 1 shows the traditional fishing practiced by farmers, which is typically unregulated. The sampling site is illustrated in Fig. 2.

Data Collection and analysis

Fish data was collected monthly from January 2001 to June 2001 (dry season) and from July 2001 to November 2001 (wet season) from the River mouth (*Megenagna*) and upstream of Gumara (*Wanzaye hot spring*) for about one year. The data collection continued for the whole year at the Gumara River mouth (*Megenagna*) and was interrupted during the wet season at the *Wanzaye* upstream because of difficulty of fishing with gillnets on the river.

Fig. 1. Open access fishing on migrating Labeobarbus fish species at Gumara River; Source: Amhara Region Bureau of Agriculture and Rural Development, Bahir Dar, Ethiopia**.**

For few occasions fish data were collected on tributaries (*Kizen* and *Dokalit*). Sampled fish were categorized in terms of species, sex, gonad maturity stage, body length and weight. The monthly average rainfall (1995 - 2004) and average monthly daily air temperature (1999-2003), data was purchased from the Ethiopian Meteorology Services Agency. The Lake Tana water level data was collected from the Bureau of the Amhara National Regional State Water Resources Development. Limnological data such as water temperatures, pH and oxygen were collected throughout the data collection period at the two sites. Different mesh size of gillnets (40 mm, 60 mm, 80 mm, 100 mm, 120 mm and 140 mm) were used to collect fish. Measuring boards and balances were also used in data collection. A pH meter, model 3050 ELE, Electric Products (China) and oxygen meter, Oxy guard International A/S (Denmark) were used to measure the limnological parameters. At Megenagna site, water level change of the lake was observed on monthly basis. The Gumara River water flow was also observed during the data collection period. Descriptive statistics was used for data analysis.

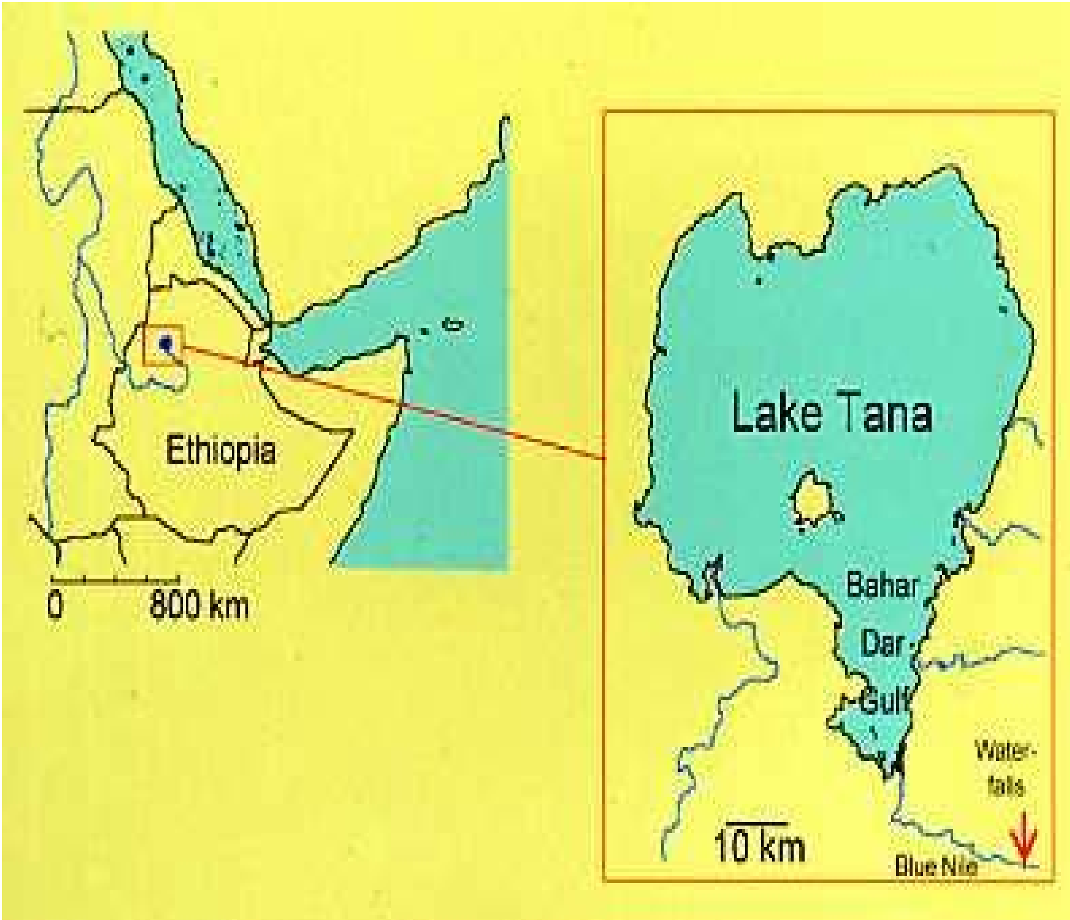

Fig. 2. Map of Ethiopia, Lake Tana and Gumara River; **Source**: Bahir Dar Fish and Aquatic Life Research Center

3. Results

Environmental Parameters

Environmental parameters are shown in Figs. 3, 4, 5 and 6. Having a look at a four year data (1999-2003), the average daily air temperature in the sampling site at Gumara River mouth (*Megenagna*) peaked in April to May (dry season) and at the end of the wet season including the sampling year 2001 (Fig. 3). The average monthly rainfall of Lake Tana was higher from June to August in the sampling period.

The water temperatures showed two peaks at the Gumara River mouth. The first peak occurred during dry season in May and the second peak occurred in November at the end of wet season (Fig. 5). The pH and oxygen data did not show significant variation during the sampling period. The water level of Lake Tana increased at the end of the wet season (August to November) (Fig. 6). The water level increased because of the influx of water from the different inflowing rivers one of which is the Gumara River.

Fish Abundance and Species Composition

A total of 2567 fish was sampled during the study period. The sample consists of 89% *Labeobarbus* fish species and 11% non-labeobarbus fish species in both sampling sites. The total number of sampled fish, the *Labeobarbus* and non-Labeobarbus species composition during the wet season is higher than the number caught during the dry season. A total of 2013 fish were sampled at the Gumara River mouth and 554 at Wanzaye upstream. At the Gumara River mouth, some 63.1% of the fish were sampled during the wet season and 36.9% during the dry season.

At Megenagna sampling site, 75.6% of the fish sampled belonged to the dominant Labeobarbus fish species comprising 52.6% *L. intermiduis*, 9% *L. tsanansis*, 7% *L. brevicifaleus*, 7% L. acutirostris and 13.4% other Labeobarbus fish species (Table 1). *L. intermiduis* and *L. tsanansis* were the dominant species. At Wanzaye, no sampling was conducted because of difficulty of net setting in the river during the wet season. Some fish were collected from a few tributary rivers (Table 2). Labeobarbus species were also more abundant and had more species composition during the wet season (Table 2).

4. Discussion

The Environmental Parameters

Having a look at a four year data (1999-2003), the average daily air temperature in the sampling site at Gumara River mouth (*Megenagna*) peaked in April to May (dry season) and at the end of the wet season including the sampling year 2001 (Fig. 3). The average monthly rainfall of Lake Tana was higher from June to August in the sampling period. This corroborates data for the longer term period (1995 - 2004) confirming the rainfall for the above stated months (Fig. 4). The water volume increment of both the Gumara river and Lake Tana increases vertically and longitudinally during the rainy season facilitating the migration of the *Labeobarbus* fish species to the river mouth and upstream.

Table 1. Fish Species Sampled at Gumara River Mouth (Megenagna) from January 2001 to November 2001

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
B. acutirostris	25	4	16	2	12	3	4	3	11	14	25	
B. brevicephalis	20	0	0	0	18	4	3	10	5	15	20	
B. dainellii	5	0	0	7	0	2	0		0	0	0	
B. intermidius	30	58	150	25	26	54	83	76	104	180	284	
B. tsanensis	1	0	49	0	5	0	25	19	47	66	7	
B. truttiformis	1	6	2	8	2	1	1	1	6	7	0	
B. platydorusus	0	0	0	0	0	0	2	1	5	6	6	
B. crassibarbus	0	0	0	0	0	0	3	3	6	9	2	
B. megastoma	0	0	0	0	0	0	1	1	3	4	0	
B. macrophtalmus	0	0	0	0	0	0	0	0	6	6	6	
V. beso	0	0	0	8	0	6	0	0	1	0	1	
C. gariepinus	32	4	28	29	8	0	1	8	1	9	1	
O. niloticus	41	9	36	1	6	0	2	0	0	0	1	
Total # species	8	5	6	6	7	6	10	9	11	10	10	
Total # fish	153	81	81	80	77	70	125	122	195	317	512	

Table 2. Fish Species Sampled at Gumara Upstream (Wanzaye) from January 2001 to November 2001

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
L. acutirostris	2	6	1	-	22	4	11	7	3	-	1	-
L. brevicephalis	5	4	4	-	15	6	1	.-	7	-	39	-
L. dainellii	3	2	.-	-	.-	2	-	.-	. .-	-	.-	-
L. intermidius	10	50	8	-	18	8	32	6	62	-	29	-
L. tsanensis	1	5		-	-	4	-	-	-	-	.-	-
L. truttiformis	-	-	3	-	-	-	-	-	-	-	6	-
L. platydorusus	-	-	-	-	-	-	-	-	-	4	-	-
L. crassibarbus	-	-	-	-	-	-	-	-	-	-	-	-
L. megastoma	-	-	-	-	-	-	-	1	8	1	8	-
L. macrophtalmus		-	-	-	-	-	-	-	-	-	-	.-
V. beso	2	-	4	8	6	-	-	-	-	-	-	-
C. gariepinus	-	-	-	10	9	-	-	-	-	-	-	-
O. niloticus	-	9	-	-	2	-	-	-	-	-	-	-

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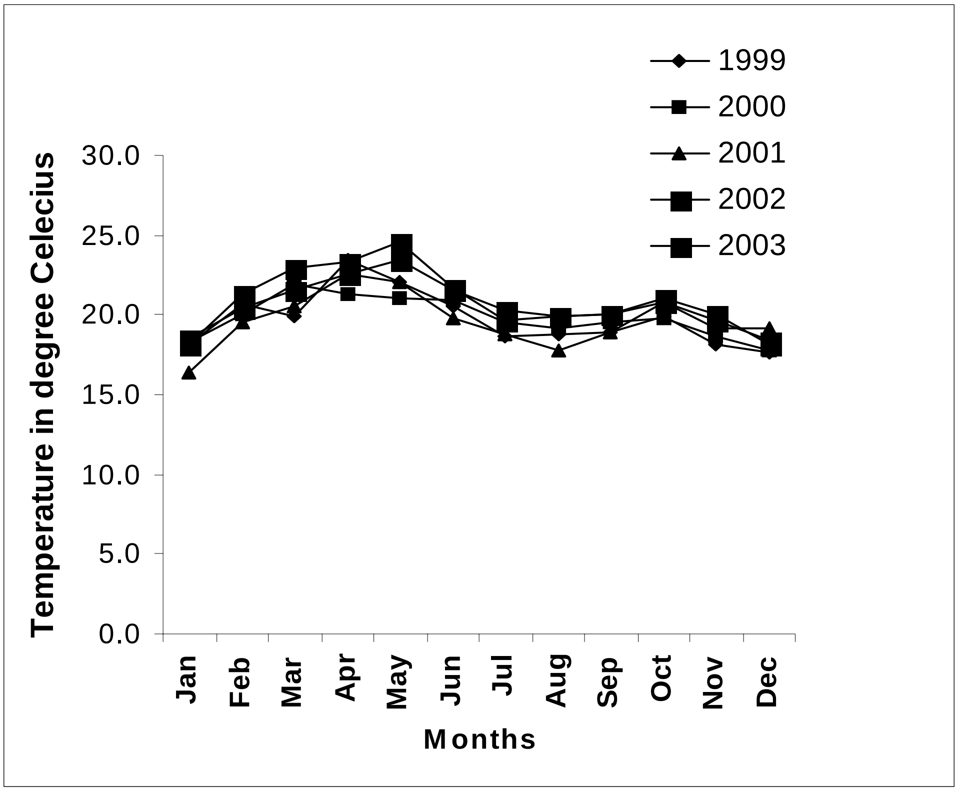

Fig. 3. Average daily air temperature of Lake Tana from 1999 to 2003.

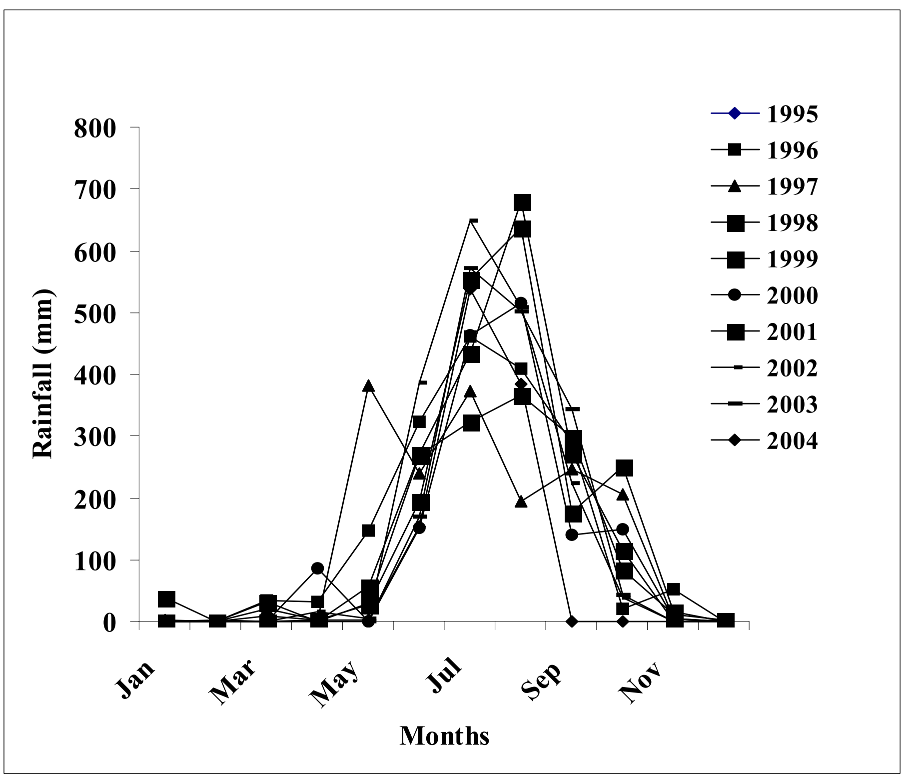

Fig. 4. Average Monthly Rainfall on Lake Tana from 1995 - 2004.

The water level always peaked in September to October as confirmed from the previous (Fig. 6) and observed during the study period (personal observation). The rainfall facilitates stimulating factors such as increment of longitudinal water volume connectivity of the Gumara River creating suitable and favorable condition such as pool and rifle water current that facilitate migration and spawning.

As indicated in the result the seasonal increment of *Labeobarbus* fish migration in terms of species and total number indicates that wet season environmental parameters particularly rainfall and water level have triggering mechanism for upstream migrations of the *Labeobarbus* fish species. The wet season rainfall associated factors externally influenced by influx of water from the tributary rivers creating pool and rifle condition in Gumara and nutrients that could be stimulant to the migration of the spawning population of the *Labeobarbus* fish species are considered to be the important factor that could have played great role in stimulating the migration. This does not rule out further investigation on other environmental and physiological factors that could have the triggery mechanism for spawning migration of *Labeobarbus* fish species of Lake Tana. The other environmental factors of Lake Tana considered and observed during the sampling period are almost similar as stated by previous studies (Tesfay Wudneh, 1998; de Graaf et al., 2003; Dejen et al., 2004).

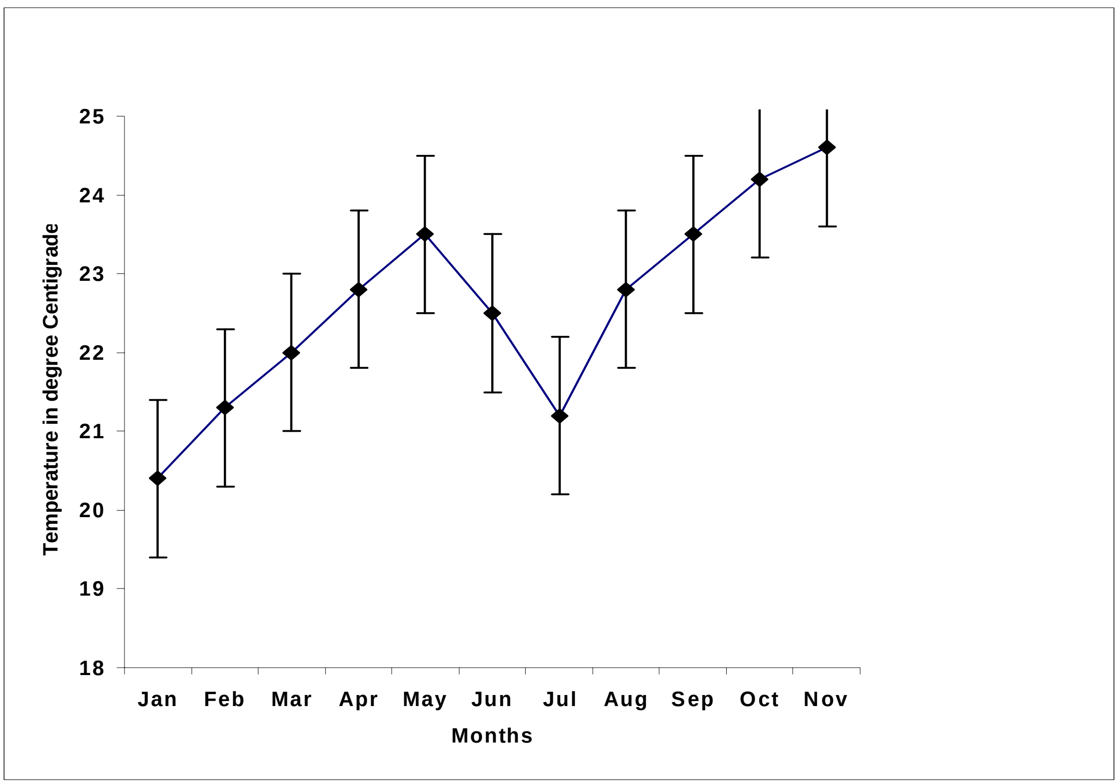

Fig. 5. Monthly Water Temperature at Gumara River Mouth (Megenagna) from January 2001 to November 2001

De Graaf et al. (2003) stated that most migratory fish species in the inter-tropical regions including African Barbus at large make their upstream migration during the rainy season accompanied with high flow of water. Banks (1969) also stated that an increase in river flows stimulates Atlantic salmon to enter fresh water. River flow is the variable most frequently mentioned as controlling the rate of upstream migration of Atlantic salmon (Banks, 1969; Alabaster, 1970). It is generally assumed that increases in river flow stimulate Atlantic salmon to ascend a river (Jensen et al., 1986; Laughton, 1991).

The present study of Lake Tana *Labeobarbus* fish species migration towards the Gumara River mouth and upstream of Gumara River with water flow increment associated with rainfall as stimulating factor for migration has a conformity with previous studies that have been done by different authors in different parts of the world.

Fish Abundance and Species Composition

The seasonal variation of the *Labeobarbus* fish species aggregation in number and species composition during the sampling period in the Gumara River mouth and upstream migration indicated the coherence with the influx of nutrients and other rainfall associated factors during the wet season within Gumara River and its tributary rivers.

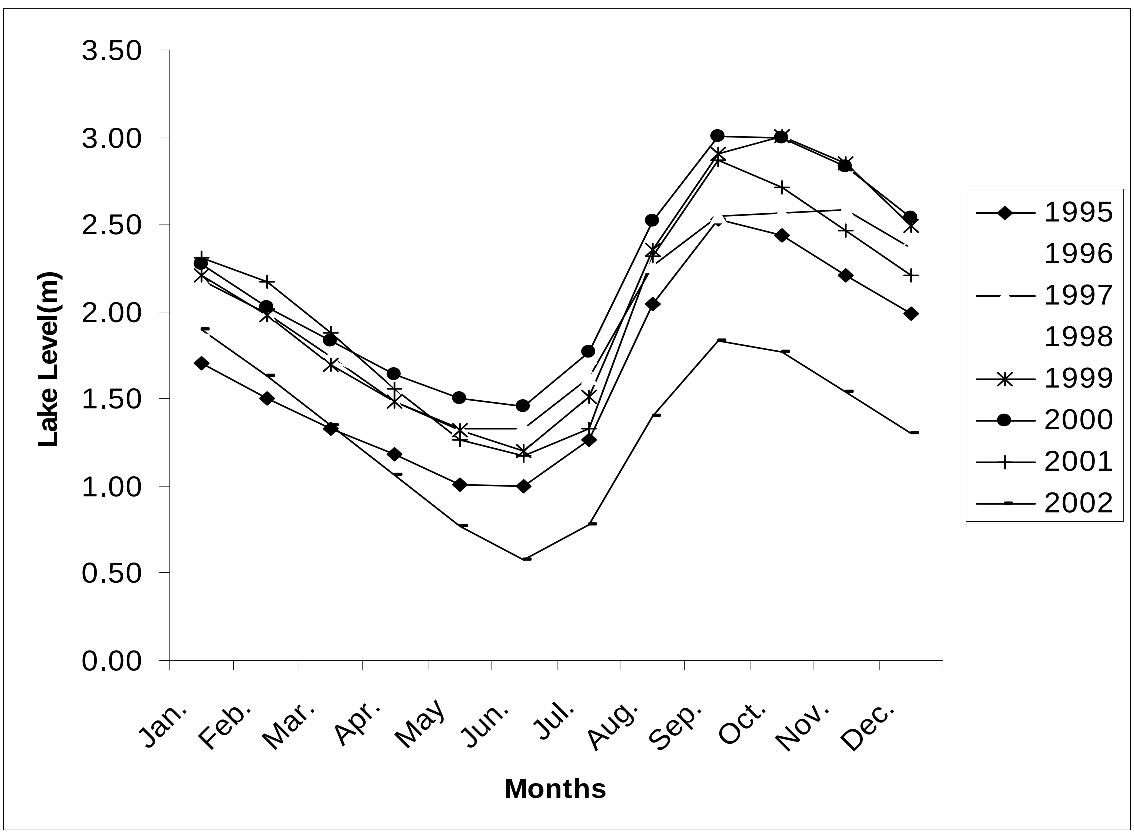

Fig. 6. Lake Tana water level from 1995 – 2002

These results indicated that *Labeobarbus* fish species migration during the wet season for reproduction exposes for fishing pressure at their way and requires protection through well established management strategy that enable to take measures that sustain the biodiversity of the Lake Tana and its surroundings.

De Graaf et al. (2004) stated that the Catch per Unit Effort of Labeobarbus fish species in July to October is three times higher in the river mouth of Gumara when compared with the mean Catch per Unit Effort of the lake on other occasions. This confirms that the abundance of migrating of *Labeobarbus* fish species is associated with the wet season particularly associated with rainfall and lake and river water level increment. The use of motorized commercial gillnet fisheries targeting the spawning aggregations in the Gumara River mouth and other inflowing rivers seems to be the main cause of observed dramatic decline of Lake Tana's Labeobarbus fish species stock (de Graaf et al., 2003).

To mitigate this declining situation of the migrating *Labeobarbus* fish species, the Lake Tana fisheries resource calls for Appropriate Management Plan for the targeted *Labeobarbus* fish species in particular and for the fisheries resources of the lake in general. The Appropriate Management Plan objective of fisheries management of Lake Tana must ensure the sustainable use of Lake Tana fisheries resources by the fisheries communities of the Lake. Four basic ideas to be considered in fisheries resource management and development of Lake Tana include:

i. The management of the fisheries resource of Lake Tana should incorporate social and political considerations.
ii. The management strategies and tools used efficiently from the fishery's biology point of view should be socially and politically accepted to the parties involved in fisheries particularly whose livelihood is affected by the management implementation.
iii. The stated reference points (Maximum Sustainable Yield/MSY) for the management of the fisheries of Lake Tana or targets to be achieved should not be reached.
iv. The control mechanism (closed area and closed season) is effective to sustain the fisheries resources in terms of cost, beneficiaries, with clearly defined procedures and responsibilities of all parties involved.

These basic concepts are considered as the springboard for fisheries resources management of Lake Tana *Labeobarbus* fish species that is considered as declining species. Appropriate management strategies/tools that can be applied on Lake Tana fisheries resources could be many but the urgent situation calls to implement the closed area and closed season management strategies/tools to sustain fisheries of Lake Tana, particularly for *Labeobarbus* fish species that are at potential risk of declining.

5. Conclusion and recommendation

The fishers community harvest *Labeobarbus* fish species on Gumara River mouth and upstream spawning grounds using a variety of fishing techniques such as gillnetting, barriers / fences, basket traps, hooks, scoop nets and poisoning with dried and crushed seeds of birbira tree (*Milletia ferruginae, Leguminosae*).

The research data showed that the Lake Tana *Labeobarbus* fish species in Gumara River mouth and upstream spawn during high flow of water volume consistent with other inter-tropical species. Workable management strategies that limit the motorized gillnet fishery at all feeder streams of the lake during and at the conclusion of the rainy season is vital. Considering Gumara River as an aquatic park may also be justified to maintain the appropriate spawning biomass. A vigorous public education campaign is essential for conveying the need to preserve the *Labeobarbus* fish species for the present and the next generations. To mitigate and ameliorate the open access system, of fisheries during the wet season, the Federal Democratic Republic of Ethiopia (2003) Proclamation No 315/2003 and Amhara National Regional State (2003) Proclamation No. 92/2003 of Fisheries Legislation at Federal and Regional levels have to be implemented before the resources become depleted resulting in inefficient biological, economic and social effect in the long-term situation of the fisheries resource in particular and the biodiversity in general.

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